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A SIMULATION OF VISUAL PROGRAMMING OF A BATCH REACTOR

CEKMAS CEKDIN[1]*, FADILAH[2], SITI SAILAH[3] and ARMIN SOFIJAN[4]

[1,2]Electrical Engineering Study Program, Faculty of Engineering, Muhammadiyah University of Palembang.
[3]Physics Study Program, Faculty of Mathematical and Natural Sciences, University of Sriwijaya.
[4]Electrical Engineering Study Program, Faculty of Engineering, University of Sriwijaya.

Abstract

This paper discusses the working process of a batch reactor for chemical processing in industry which is simulated using a personal computer. The simulations are made manually and automatically with Visual programming techniques so that they can represent the real working conditions in the field. The simulations on the working process of this batch reactor can be grouped into two groups, namely the process simulation section and the controller simulation section. The object that will be simulated in the process section consists of the level simulation inside the reactor, the simulation of batch reaction process and the simulation of disturbance/damage. The objects that will be simulated in the controller section consist of the simulation of power ON/OFF control, the simulation of manual/automatic system control, the simulation of temperature control set point, the simulation of control of alarm panels and the simulation of control of emergency stop panels. Both groups of these sections can be simulated Visually in the form of display designs and operator panels.

Keywords: Batch Reactor, Visual Programming, Process Simulation, Controller Simulation.

1. INTRODUCTION

The rapid growth of industry in Indonesia in recent years, has increased competition among industries, and to be able to remain competitive well, an industry needs to improve efficiency in various fields, especially in the production system of the industry. In addition, the difficulty of getting experienced operators in the field of work offered, makes industrialists feel the need to provide adequate training for their employees who will be placed as operators in the factory [1].

As the need of industries for a facility that can be used to train operators in the factory, it should be supported by researchers that are able to make a simulator that is highly efficient, inexpensive, with exactly the same visualization as the control panel for the process in the factory. This can be realized by utilizing personal computers and good simulation software [2].

In line with the development of computer software technology, it can be realized by utilizing personal computers and creating process simulations using the Visual Basic programming language, object-oriented visual programming techniques with complete control and timer facilities to support the simulation needs of these industrial processes with all required controls provided in the form of push-buttons around the process [3]. The industrial processes can be described in terms of their physical forms with their state of reality that can be programmed in such a way that they seem

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dynamic (moving) according to the dynamics of the process. The simulation of the batch reactor work process in industry is designed for the appearance to create a simulation using a personal computer with the Visual Basic programming language so that all required controls are provided in the form of push buttons or initialization around the batch reactor process [4]. This paper is more focused on making simulations which consist of two groups of parts, namely the process simulation section and the controller simulation section. The objects that will be simulated in the process section consist of the level simulation in the reactor, the simulation of batch reaction process and the simulation of disturbance/damage. The objects that will be simulated in the controller section consist of the simulation of power ON/OFF control, the simulation of manual/automatic system control, the simulation of temperature control set point, the simulation of control of alarm panels and the simulation of control of emergency stop panels.

2. LITERATURE STUDY

2.1. Batch Reactor

Batch reactor is a reactor that is used to produce a material/a product within a certain time cycle that does not occur continuously. The walls of the batch reactor are enclosed by an envelope chamber which contains a steam spiral pipe. The use of the steam spiral pipe is for the purpose of flowing heating steam, while the cooling water is flowed into the casing. In Figure 1, a configuration of a batch reactor [5] is shown, consisting of a process for introducing reactants into the reactor, a process for introducing heating steam into a spiral tube of steam inside the casing, and a process for introducing cooling water into the casing.

The reactants (raw materials A and B) are fed through the valve opening V1 into the reactor, until the reactor is fully filled, then valve V_1 is closed again. The reactants will be processed to produce the desired product, and a certain working temperature is required. For this purpose, the heating steam is introduced into the steam spiral pipe in the reactor casing, through the valve opening V_2. Heating steam heats the reactor walls to a temperature of T_J. The reactor wall will conduct heat at a temperature of T_M, then the heat conducted by the reactor wall will be transferred to the reactants, so that the temperature of the reactant T will increase until it reaches the working temperature.

After the working temperature is reached, the reactants will react and the reaction is exothermic, causing the temperature in the reactor tank to increase. Therefore the heating steam must be reduced to an appropriate amount. If the temperature of the reactants continues to rise, cooling needs to be carried out, for that the valve of V_2 must be closed, while the valve of V_3 must be opened to let the required cooling water enter the reactor envelope, then the cooling water will exit through the valve opening of V_4. The amount of cooling water introduced into the reactor envelope must be adjusted so that the temperature of the reactants in the reactor still reaches the working temperature (T^{set}).

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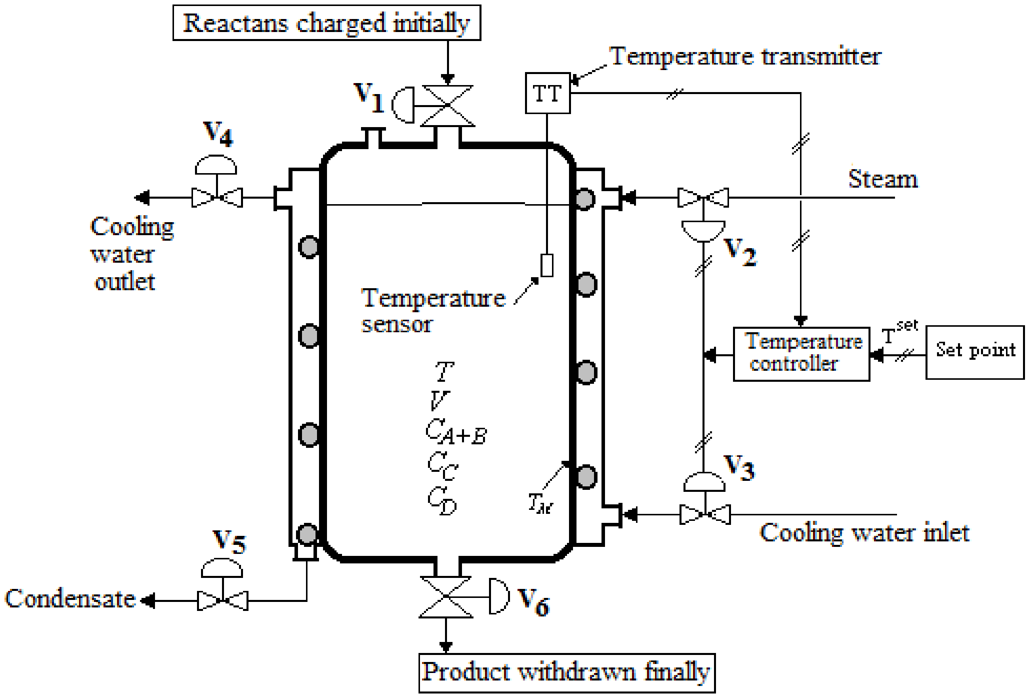

Figure 1: Typical batch reactor [5]

After the temperature of the reactants reaches the working temperature, the following sequential reactions will occur: [6],

$$A + B \xrightarrow{k_1} C \xrightarrow{k_2} D$$

The desired product is component C. If the reaction lasts too long, a further reaction will occur which decomposes component C to become component D, so that if the reaction is left too long, component C will react too much to form an unwanted component D. If the reaction is stopped too quickly, the components A and B react too little and too little of the resulting component C is formed. Therefore there is an optimum time at which the reaction should be stopped. The selection of the length of the batch reaction process can be determined graphically as shown in Figure 2. In the figure the concentrations of components A and B are getting smaller and smaller, so that the concentration of component C produced is getting bigger and bigger, but after reaching a certain time (t_b) the concentration of component C is reduced due to a further reaction that changes the concentration of component C to become a concentration of component D, so that the concentration of component D is getting bigger and bigger. This is not desirable. The desired result is the largest concentration of component C. Based on Figure 2, it can be determined that at time $t = t_b$, component C has the highest concentration, while the concentration of component D is relatively moderate and the concentrations of components A and B are relatively small, so the batch time is determined at t_b.

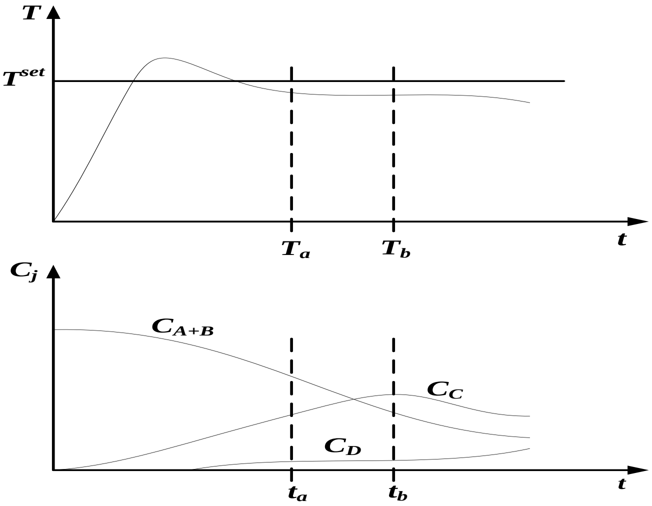

Figure 2: Sketch of reactant temperature and results of batch concentration

For the reactant temperature T to follow the working temperature (set point temperature T^{set}), it is necessary to control, namely controlling the temperature. Controlling the temperature is done by setting the steam valve of the V_2 heater to open and the valve of V_3 to remain closed during heating. The valve of V_4 where the cooling water exits and the valve of V_5 where the condensate exits are left open. The temperature of the reactant T will be detected by a temperature sensor mounted at the end of the temperature transmitter. The temperature transmitter will send a signal to the temperature controller. When the reactant temperature T exceeds the set point temperature T^{set}, the temperature controller sends a signal to the heating steam valve of V_2 to command the valve to close and open the cooling water valve of V_3. The opening of the V_3 valve is to let the cooling water enter the reactor casing. The introduction of cooling water into the reactor envelope is used to reduce the reactant temperature T so that it can follow the set point temperature T^{set}. This temperature control system is called a split control system.

When the reaction is stopped, the component products must be removed from the reactor through the valve opening of V_6. After all of the component products are removed from the reactor through the valve opening of V_6, the valve opening must be closed again and the batch reactor is ready to be used again for the next production.

2.2. Batch reactor modeling

The modeling of the batch reactor discussed in this paper consists of modeling of the height of the reactants in the reactor and modeling of the changes in the quantity of the batch reaction process.

2.2.1. Modeling of the height of the reactants in the reactor

The volume of reactant (v) that is fed into the reactor depends on the opening of the valve V_1 with the symbol K_1, the flow rate of the reactants entering the reactor (Qin) through the valve

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opening of V_1 and the length of time for filling (t) so that the volume of reactant (v) that is fed into the reactor can be written as the following equation [7]

$$v = K_1.Q_{in} . t \tag{1}$$

in which v is the volume of reactant that is fed into the reactor with unit of ft^3, K_1 is the size of the valve opening of V_1 in percent (%), Q_{in} is the flow rate of reactants entering the reactor through the valve opening of V_1 with units of ft^3/sec and t is the length of time the reactant enters the reactor in unit of sec. If the flow rate of reactants entering the reactor through the valve opening of V_1 in a 100% open state is Q_{inmax}, then Equation (1) becomes

$$v = K_1.Q_{inmaks}.t \tag{2}$$

The volume of reactants (v) in the reactor can also be determined directly proportional to the height of the reactants (h) in the reactor and the cross-sectional area of the bottom of the reactor (A), so that the volume of reactants (v) in the reactor is determined by the following equation

$$V = h. A \tag{3}$$

in which h is the height of the reactants in the reactor in unit of ft and A is the cross-sectional area of the inside of the reactor in unit of ft^2. By equating Equations (2) and (3), it is obtained that the height of the reactants in the reactor every time for entry is as the following equation:

$$h = \frac{K_1.Q_{inmaks}.t}{A} \tag{4}$$

If the height of the reactants h entering the reactor is maximum and the value is supposed to be x ft, while the percentage of the height of reactant L_{in} in the reactor at that maximum height is expressed as 100%, then the height of the reactants in the reactor is obtained every time in percent. In general it can be written as follows

$$L_{in} = \frac{100.h}{x} \tag{5}$$

with the substitution of Equation (4) it is obtained

$$L_{in} = \frac{100.K_1.Q_{inmaks}.t}{x.A} \tag{6}$$

from Equation (6) above x.A is the maximum reactant volume (v) that is fed into the reactor, so Equation (6) can be written as the following equation

$$L_{in} = \frac{100.K_1.Q_{inmaks}.t}{V} \tag{7}$$

in which the unit of L_{in} is percent (%).

Likewise for the modeling of the release of reactants from the reactor, if the valve opening of V_6 is (K_6). The flow rate of the reactants leaving the reactor through the valve opening of V_6, in the state of V_6 valve opening which is 100% open or Q_{outmax}. the height of reactant h that is

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removed from the reactor is x ft and the length of time the reactant is released from the reactor is t, then the value of the height of the reactants is obtained each time in percent. In general it can be written as follows

$$L_{out} = \frac{100.K_6.Q_{outmaks}.t}{x.A} \tag{8}$$

from Equation (8) above x.A is the maximum reactant volume (v) removed from the reactor, so Equation (8) can be written as follows

$$L_{out} = \frac{100.K_6.Q_{outmaks}.t}{v} \tag{9}$$

in which K_6 is the valve opening of V_6 with unit of percent (%), Q_{outmax} is the flow rate of reactants coming out of the reactor through the valve opening V_6 in the V_6 valve opening state of 100% with unit of ft^3/sec and t is the length of time the reactants are removed from the reactor with unit of sec.

If the rate of change of altitude per second for the introduction of reactants into the reactor is expressed by $\frac{dL_{in}}{dt}$, so that Equation (7) can be written as follows

$$\frac{dL_{in}}{dt} = \frac{100.K_1.Q_{inmaks}}{v} \tag{10}$$

in which $\frac{dL_{in}}{dt}$ is in unit of (%)/sec.

Likewise, if the rate of change of altitude per second for the release of reactants from the reactor is expressed by $\frac{dL_{out}}{dt}$, so that Equation (9) can be written as follows:

$$\frac{dL_{out}}{dt} = \frac{100.K_6.Q_{outmaks}}{v} \tag{11}$$

Based on Equations (10) and (11) the equation for the height of the reactants in the reactor will be obtained numerically that can be written as follows

$$L_t = L_{t-1} + \frac{100.K_1.Q_{inmaks}}{v} - \frac{100.K_6.Q_{outmaks}}{v} \tag{12}$$

in which L_t is the height of the reactants in the current reactor and L_{t-1} is the height of the reactants in the previous reactor.

If the magnitude of the reactant flow rate into the reactor for various values of valve opening V_1 can be written into the following equation

$$Q_{in} = K_1.Q_{inmaks} \tag{13}$$

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Likewise, if the flow rate of reactants leaving the reactor for various values of valve opening K_6 can be written into the following equation

$$Q_{out} = K_6 . Q_{outmaks} \tag{14}$$

Based on Equations (13) and (14) the equation for the height of the reactants in the reactor can be obtained and in Equation (12) it can be simplified into the following equation

$$L_t = L_{t-1} + \frac{100}{v}(Q_{in} - Q_{out}) \tag{15}$$

2.2.2. Modeling changes in magnitude of batch reaction process

Changes in the magnitude of the batch reaction process consist of [5][8][9], changes in the concentrations of components A and B to become concentrations of component C, changes in concentration of component C to become concentrations of component D, changes in reactant temperature and changes in energy.

The rate of change in the concentration of components A and B to become the concentration of component C is expressed in proportion to the decrease in the concentrations of components A and B to become the concentration of component C with a specific reaction rate constant of k_1 that can be written as follows

$$\frac{dC_{A+B}}{dt} = - k_1 C_{A+B} \tag{16}$$

in which $\frac{dC_{A+B}}{dt}$ is the rate of change of concentration of components A and B to become the concentration of component C with unit of lb.mol.A/ft^3 per minute, C_{A+B} is the concentration of components A and B with unit of lb.mol.A/ft^3, k_1 is the reaction rate constant specific of components A and B to become component C with unit of minute-^{1}.

Whereas the rate of change in the concentration of component C to become the concentration of component D is also proportional to the concentration of component A and B to become the concentration of component C with a specific reaction rate constant of k_1, reduced by the concentration of component C to become a concentration of component D with a specific reaction rate constant of k_2

$$\frac{dC_C}{dt} = k_1 C_{A+B} - k_2 C_C \tag{17}$$

in which $\frac{dC_C}{dt}$ is the rate of change of the concentration of component C to become the concentration of component D in unit of lb.mol.A/ft^3 per minute, C_C is the concentration of component C in unit of lb.mol.A/ft^3, and k_2 is the specific reaction rate constant of component C to become component D with unit of minute$^{-1.}$

The specific reaction rate constants for these two reactions can be expressed as follows

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$$k_1 = \alpha_1 e^{\square E_1/RT} \qquad (18)$$

$$k_2 = \alpha_2 e^{\square E_2/RT}$$

in which α_1 is the preexponential factor on k_1 with units of minute^{-1}, α_2 is the preexponential factor on k_2 with units of minute^{-1}, E_1 is the activation energy of components A and B to become component C with units of Btu/lb.mol, E_2 is the activation energy of component C to become component D with units of Btu/lb.mol, R is the ideal gas constant (1.99 cal/g. mol. °K or 1545 lb_f ft/lb.mol ^oR) and T is the reactant temperature with units of ^oF.

Equation (18) states that the magnitude of the specific reaction rate constant (k_1 and k_2) of each component depends on the temperature of the reactants (T). As long as the reactants in the reactor are reacted, the amount of heat energy due to changes in the temperature of the reactants is proportional to the amount of heat energy required for the change from components A and B to become components C, plus the heat energy required to change component C to become component D and the heat energy conducted by the surface area on the inside of the reactor wall that can be written as the following equation

$$\rho V C_\rho \frac{dT}{dt} = -\lambda_1 V k_1 C_{A+B} - \lambda_2 V k_2 C_C - h_i A_i (T - T_M) \qquad (19)$$

in which ρ is the density of the reactants with units of lb_m/ft^3, V is the volume of reactants in the reactor with units of ft^3, C_ρ is the heat capacity of the reactants in units of $Btu/lb_m.^oF$, $\frac{dT}{dt}$ is the rate of change of the temperature of the reactants in units of ^oF/minute, λ_1 and λ_2 are the respective latent heats of vaporization from the reaction of components A and B to become component C and from the reaction of component C to become component D with units of Btu/lb.mol, V is the volume of reactants in the reactor in units of ft^3, ρ is the density of the reactants in unit of lb/ft^3, C_ρ is the heat capacity of the reactants in units of Btu/lb.mol, h_i is the heat transfer coefficient on the inside of the reactor wall in units of Btu/h ^oF ft^2, A_i is the surface area on the inside of the reactor wall in units ft^2, T is the temperature of the reactants in the reactor in units of ^oF and T_M is the temperature of the reactor walls in units of ^oF.

Equation (19) can be simplified into

$$\frac{dT}{dt} = \frac{}{} [h_i A_i (T_J - T_M) - \lambda_1 V k_1 C_{A+B} - \lambda_2 V k_2 C_C] \qquad (20)$$

Equation (20) states the magnitude of the change in temperature of the reactants with time. The magnitude of the change in temperature of these reactants is proportional to the amount of energy in the form of heat that is conducted by the surface area on the inside of the reactor wall, minus the amount of heat energy from the reaction of components A and B to become component C, and reduced again by the amount of heat energy from the reaction of component C to become component D, then the result is divided by the heat capacity of the reactants mass.

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The amount of heat energy conducted by the reactor wall due to changes in the temperature of the reactor wall itself is proportional to the amount of heat energy conducted by the surface area on the outside of the reactor wall minus the amount of heat energy conducted by the surface area on the inside of the reactor wall that can be written as the following equation

$$\text{——} = h_o\ A_o\ (T_J - T_M) - \ h_i\ A_i\ (T_M - T) \qquad (21)$$

in which ρ_M is the reactor wall density in units of lb_m/ft^3, V_M is the reactor wall volume in units of ft^3, C_M is the heat capacity of the reactor walls in units of $Btu/lb_m.^oF$, $\frac{dT_M}{dt}$ is the rate of change of reactor wall temperature in units of ^oF/minute, h_o is heat transfer coefficient on the outside of the reactor wall in units of Btu/h ^oF ft^2, A_o is the surface area on the outside of the reactor wall in units of ft^2 and T_J is the temperature inside the reactor envelope in units of ^oF.

The heat energy conducted by the reactor walls is dependent on the amount of heating steam flowing through the spiral pipe in unit time. The amount of heating steam flowing through the spiral pipe in unit time is proportional to the amount of heating steam flow rate entering the spiral pipe minus the amount of condensate flow rate coming out of the spiral pipe that can be written as the following equation

$$\text{——} = \qquad (22)$$

in which V_J is the volume of the reactor envelope in units of ft^3, —— is the rate of change of the density of heating steam in the spiral pipe in units of lb_m/ft^3 per minute, F_s is the flow rate of heating steam that will enter the spiral pipe in units of ft^3/minute, is the density of heating steam which will enter the spiral pipe in units of lb_m/ft^3 and W_c is the rate of condensate flow out of the spiral pipe in units of lb/minute.

The amount of density of the heating steam in the spiral pipe can be counted as follows

$$= \text{——} \quad \text{——} + \qquad (23)$$

in which M is the molecular weight of the heating steam = 18 lb/mol, Avp and Bvp are the water vapor pressure constants of -8744.4 ^oR and 15.70.

The amount of energy in the reactor envelope due to heat from heating steam flowing through the spiral pipe is proportional to the amount of energy flow rate of heating steam that will enter the spiral pipe minus the amount of energy conducted by the surface area on the outside of the reactor wall and reduced again by the amount the energy of the condensate flow rate that comes out of the spiral pipe that can be written as the following equation

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———— = (24)

in which ———— is the rate of change of energy of heating steam in a spiral pipe in units of Btu/lb per minute, H_s is the enthalpy of heating steam in units of Btu/lb_m and h_c is the enthalpy of condensate in units of Btu/lb_m.

If the energy change in the reactor envelope due to heat from the heating steam flowing through the spiral pipe is negligible and the condensate flow rate out of the spiral pipe is assumed to be equal to the flow rate of the heating steam entering the spiral pipe, then from Equation (24) the following equation will be obtained

$$W_c = \frac{h_o A_o (T_J \square T_M)}{H_s \square h_c} \tag{25}$$

The equation (25) above states that the rate of flow of condensate out of the spiral pipe is proportional to the amount of energy conducted by the surface area on the outside of the reactor wall and divided by the difference between the enthalpy of the heating steam and the enthalpy of the condensate.

In order that the heat of the reactants in the reactor is not excessive, cooling is needed, for this purpose cooling water is inserted into the reactor envelope. The amount of energy contained in the cooling water in the reactor envelope is proportional to the amount of energy flow rate of cooling water plus the amount of energy that is conducted by the surface area on the outside of the reactor wall that can be written as the following equation

—— = + (26)

in which C_J is the heat capacity of the cooling water in the reactor enclosure in units of Btu/lb_m ^oF, ρ_{Jo} is the density of cooling water that will enter the reactor envelope in units of lb_m/ft^3, F_{wo} is the flow rate of cooling water that will enter the reactor envelope in unit ft^3/minute and T_{jo} is the initial temperature inside the reactor envelope in units of ^oF.

The parameters of the batch reactor as contained in the Equations (16) up to (26) can be seen in Table 1 below

Table 1: Parameters for batch reactor[5]

Symbol	Value
α_1	729,55 min^{-1}
α_2	6567,6 min^{-1}
E_1	15.000 Btu/lb.mol
E_2	20.000 Btu/lb.mol
C_{AB0}	0 - 1.0 lb.mol.A/ft^3
T_{J0}	80^{0}F
T_{M0}	80^{0}F
T_0	80^{0}F
A_i	56,5 ft^3
λ_1	-40.000 Btu/lb.mol
λ_2	-50.000 Btu/lb.mol
C_J	1 Btu/lb$_m$.^{0}F
C_M	0,12 Btu/lb$_m$.^{o}F
C_ρ	1 Btu/lb$_m$.^{0}F
V_J	18,83 ft^3
V_M	9,42 ft^3
V	42,5 ft^3
ρ_J	62,3 lb$_m$/ft^3
ρ_M	512 lb$_m$/ft^3
ρ	50 lb$_m$/ft^3
H_s - h_c	939 Btu/lb$_m$
h_{os}	1000 Btu/h ^{o}F ft^2
h_{ow}	400 Btu/h ^{o}F ft^2
h_i	160 Btu/h ^{o}F ft^2
C_{vs}	120 lb$_m$/min psi$^{0.5}$
C_{vw}	100 gpm/psi$^{0.5}$

2.3. Controlling with split control system

Controlling with a split control system is a controlling system to control two mutually coordinated valves [10][11][12]. In this context it is to control two valves, namely the heating steam valve V_2 and the cooling water valve V_3. The two valves are specially adjusted wherein, the heating steam valve V_2 is set to operate on a control signal from 9 psi to 15 psi, while the cooling water valve V_3 is set to operate on a control signal from 3 psi to 9 psi. So that the working characteristics of the two valves are as shown in Figure 3. If the control signal supplied to the two valves is 3 psi, then the heating steam valve V_2 is closed and the cooling water valve V_3 is 100% open, and when the control signal supplied to the two valves is 4.5 psi, the heating steam valve V_2 is still closed and the cooling water valve V_3 is 75% open.

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Figure 3 shows that the relationship between the control signal and valve opening is linear with the equation

$$K_2 = \frac{100.CS}{6} - 150 \quad ; \quad 9 \text{ psi} \subseteq \text{CS} \subseteq 15 \text{ psi} \tag{27}$$

$$K_3 = 150 - \frac{100.CS}{6} \quad ; \quad 3 \text{ psi} \subseteq \text{CS} \subseteq 9 \text{ psi} \tag{28}$$

in which CS is the control signal which is sent to the heating steam valve V_2 and cooling water valve V_3 in units of psi, K_2 and K_3 are the openings of the heating steam valve V_2 and cooling water valve V_3 in units of percent (%).

The way to control it is that the temperature of the reactant T is detected by a temperature sensor mounted at the end of the temperature transmitter. From the temperature transmitter it will send a signal to the temperature controller and if the temperature of the reactant T exceeds the set point temperature T^{set}, the temperature controller sends a signal to the heating steam valve V_2 to command it to close the opening. valve and open the cooling water valve V_3. The opening of the V_3 valve is to allow the cooling water enter the reactor casing. The introduction of cooling water into the reactor envelope is used to reduce the reactant temperature T so that it can follow the set point temperature T^{set}.

The temperature transmitter measurement range has a value from 50 ^oF on a 3 psi signal to 250 ^oF on a 15 psi signal, then the magnitude of the P_{TT} output signal from the temperature transmitter against the temperature measured in the reactor can be determined as the following equation [5]

$$P_{TT} = 3 + (12T - 600)/(200) \tag{29}$$

The equation (29) above when written for the desired working temperature (set point temperature) becomes

$$P_{TT} = 3 + (12T - 600)/T^{set} \tag{30}$$

in which P_{TT} is the output signal from the temperature transmitter against the temperature measured in the reactor in psi units. T is the reactant temperature in the reactor in ^oF units and T^{set} is the desired working temperature (set point temperature) in ^oF units. The output signal from this temperature transmitter is fed to the temperature controller, and to determine the magnitude of the output signal from the temperature controller which is channeled to the heating steam valve of V_2 and the cooling water valve V_3 can be determined from the following equation [5]

$$CS = bias + K_c(P^{set} - P_{TT}) \tag{31}$$

in which CS is the output signal from the temperature controller which is channeled to the heating steam valve V_2 and the cooling water valve V_3 in psi units, bias is the output signal constant from the temperature controller if there is no error in psi units (the value is 7 psi), K_c is the amplification of the temperature controller (magnitude 2), P^{set} is the set point signal on the temperature controller in units of psi (in this simulation the magnitude is 12.6 psi).

When the reactant temperature approaches the working temperature (set point temperature), then P^{set} set point signal on the temperature controller will decrease slowly and can be determined as the following equation

$$P_t^{set} = P_{t-1}^{set} - Delta\,.\,RAMP \qquad (32)$$

in which P_t^{set} is the set point signal on the current temperature controller in psi units. P_{t-1}^{set} is the set point signal on the previous temperature controller in psi units. Delta is the difference in the length of the current iteration calculation with the previous iteration P_{t-1}^{set} calculation in minutes and RAMP is the rate of change from P^{set} set point signal on the temperature controller in units of psi/minute.

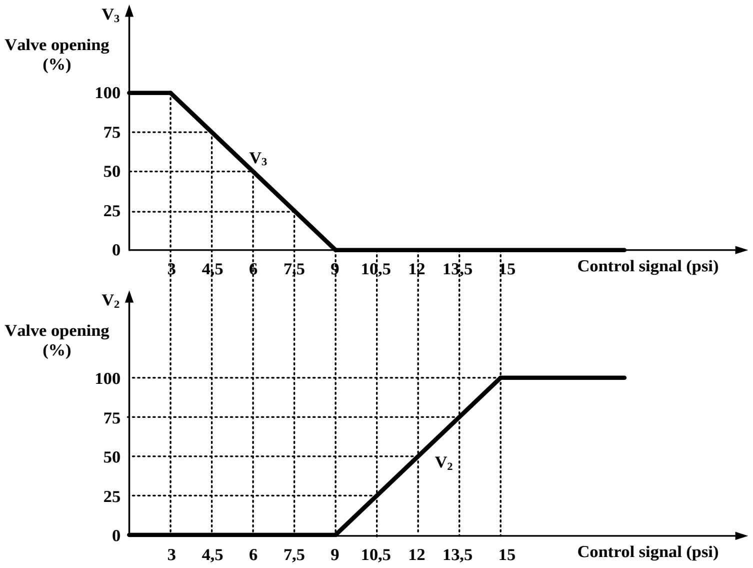

Figure 3: Characteristics of valve V$_2$ and valve V$_3$.

The relationship between the control signal and valve opening can be shown as in Table 2.

Table 2: Relationship between control signal and valve opening

Control signal (psi)		Valve opening	
		V$_2$ (%)	V$_3$ (%)
	3	Closed	100
	4,5	Closed	75
	6	Closed	50
	7,5	Closed	25
	9	Closed	Closed
	10,5	25	Closed
	12	50	Closed
	13,5	75	Closed
	15	100	Closed

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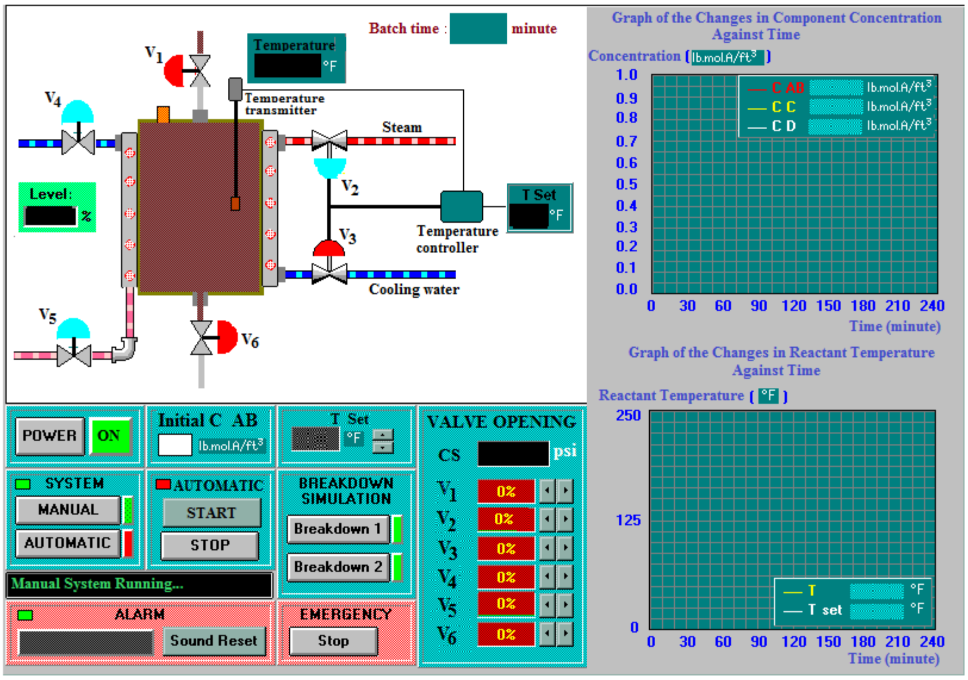
3. RESULTS OF SIMULATION AND ANALYSIS

3.1. Display Design

The results of the display design of the process simulation section and the controller simulation section can be seen in Figure 4. These two sections are placed in one place, namely on the computer monitor screen. To display images the Visual Basic programming language is used [13][14].



Manual System Running...

Figure 4: The display design of the simulation of batch reactor working process

Figure 4 above shows a power ON/OFF panel, a manual/automatic system panel, a set point temperature panel, an initial selection panel for the concentrations of components A and B, a level panel, a graph display of changes in reactant temperature, a graph display of changes in component concentrations, a breakdown simulation panel, alarm panels and emergency stop panels.

3.2. Simulation of power ON/OFF

To activate the works of the whole system press the power button "ON" on the power ON/OFF panel, to stop it press the power button "OFF" on the power ON/OFF panel. The simulation flow diagram for activating and stopping the entire system can be seen as shown in Figure 5.

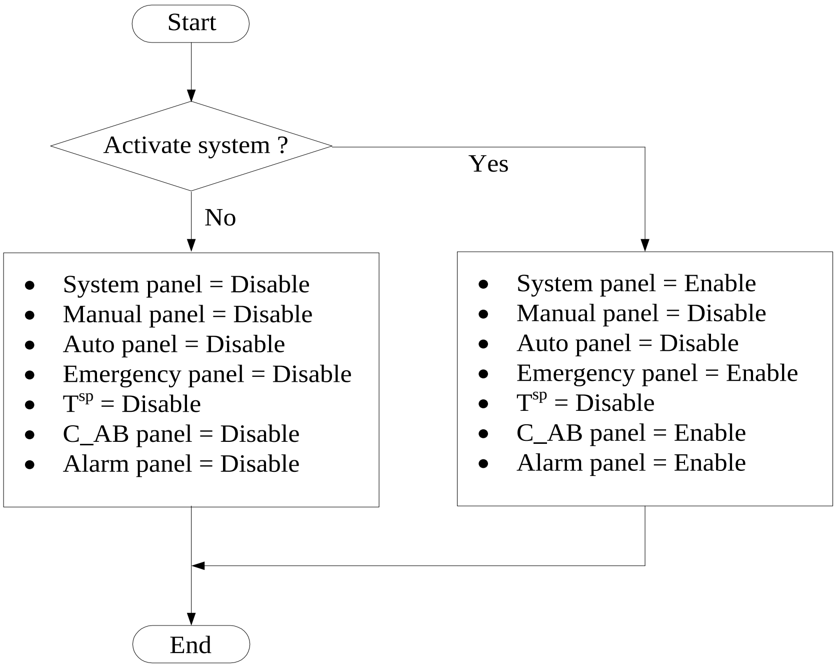


Figure 5: Simulation flowchart to activate and stop the work of the whole system.

The display for activating/stopping the work of the entire system is made into the power panel ON/OFF as shown in Figure 6.

` (a) (b)

Figure 6: Panel power: (a) Button ON, (b) Button OFF

The ON button is active with a green indicator light on the power ON/OFF panel, indicating the state of the system is ready to work, the ON button is activated by pressing the "POWER" button. When the system is not desired to be active, press the “POWER” button which is indicated by the OFF button, the indicator light is red.

3.2.1. Simulation of manual/automatic system

To start the system working can be done with manual / automatic facilities. The manual system is a system that works when it is directly operated by humans as operators. The automatic system works without being operated by humans but directly controlled by the controller.

The manual system is used to regulate the opening and closing of the valves V_1, V_4, V_5 and V_6. The opening and closing movements of the valves are controlled by the operator.

The use of a special automatic system is carried out to regulate the opening and closing of the V_2 and V_3 valves. The opening and closing movements of the two valves are regulated by the controller, in this case the temperature controller. The simulation flow diagram for controlling the choice of system to work manually/automatically can be seen in Figure 8.

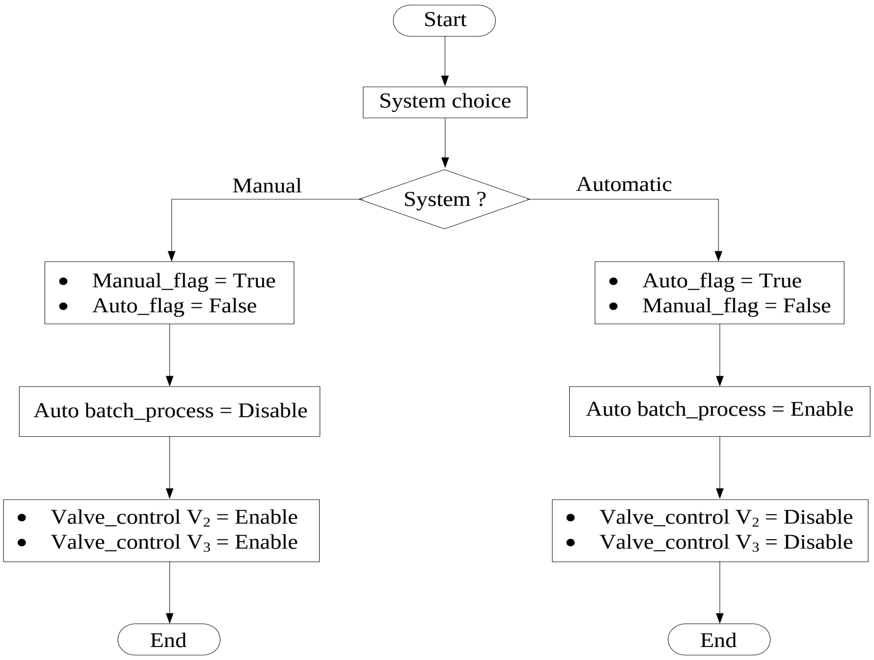
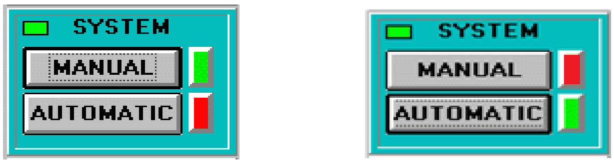


Figure 8: Flowchart diagram of simulation of control system choice to work manually/automatically.

The display of the manual system panel and the automatic system panel can be seen as shown in Figure 9.



(a) (b)

Figure 9. System panel in active state: (a) Manual system,(b) Automated systems.

The system is ready to be operated manually or automatically. If it is desired to operate manually press the "MANUAL" button with a green indicator color. When it is red it indicates that the system is not manually activated. If it is to be operated automatically, press the "AUTOMATIC" button with a green indicator color

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indicating the system is active automaticallyl. If it is red it means the system is not active automatically.

3.2.2. Level simulation inside the reactor

The reactants (raw materials A and B) will be processed and fed into the reactor through the valve opening of V_1, until the reactor is fully filled with the indication on the panel level showing 100%. After the reactor is fully stuffed, the valve of V_1 is closed. The desirable values of the valve opening of V_1 for introducing the reactants into the reactor is from 0 to 100%. The reactants are processed to produce a specific product. The product is removed from the reactor through the valve opening of V_6. When all products come out of the reactor, the valve of V_6 is closed. The desirable values of the valve opening of V_6 for removing the product from the reactor is from 0 to 100 %. During the processing of the reactants, the height of the reactants in the reactor is considered to be unchanged. At the time to remove the product from the reactor, the indication of the number on the level panel still shows 100%. The height of the reactants in the reactor can be calculated by using Equation (15). In this simulation where the maximum reactant flow rate (Q_{inmax}) that enters the reactor through the valve opening of V_1 at the 100% open is 0.773 ft^3/sec, and for the maximum product flow rate (Q_{outmax}) that comes out of the reactor through the valve opening of V_6 at 100% open is 0.758 ft^3/sec, while the reactant volume (V) in the fully stuffed reactor is 42.5 ft^3. The simulation of the flow diagram of the level inside the reactor can be seen as shown in Figure 10.

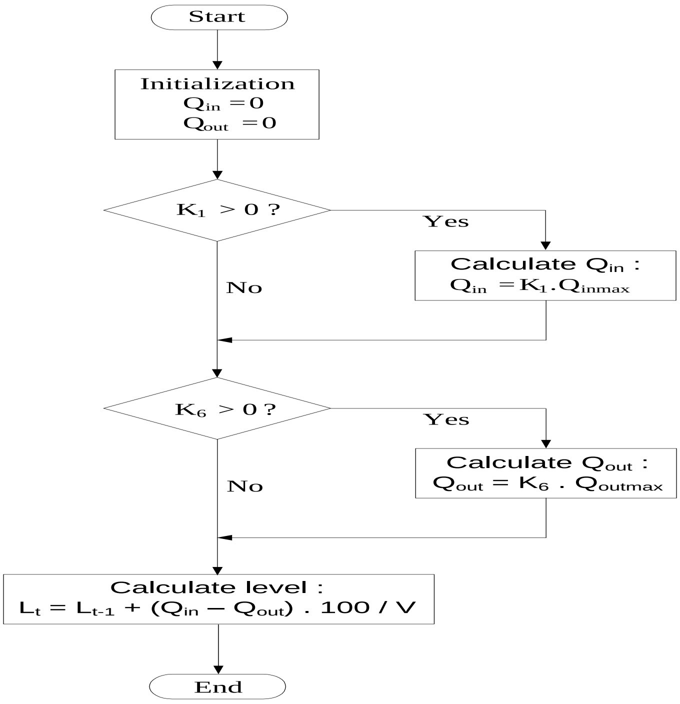

Figure 10: Flowchart of level simulation inside the reactor

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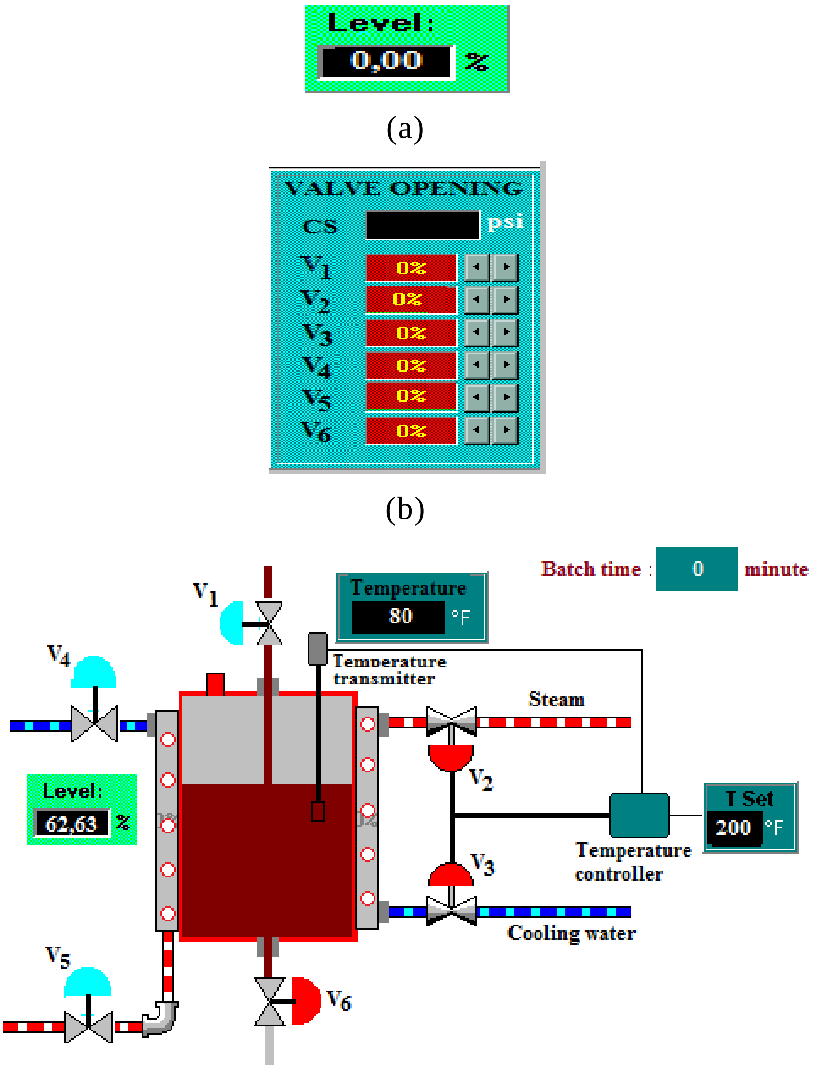
The level panel display, valve opening/closing panel, the process of stuffing reactants into the reactor and the process of removing products from the reactor can be seen as in Figure 11.



(a)

(b)

(c)

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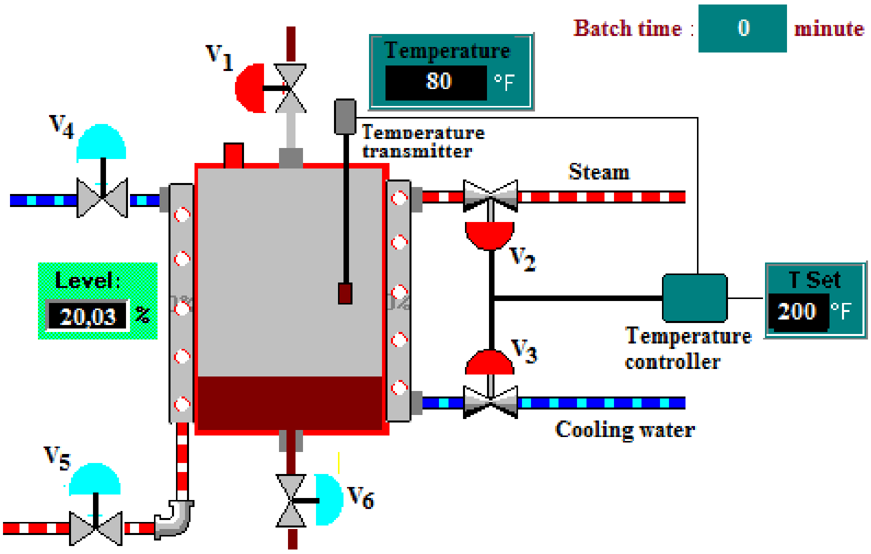

(d)

Figure 11: (a) Level panel, (b) Valve opening/closing panel, (c) The process of stuffing reactants into the reactor, and (d) The process of removing products from the reactor.

The flow of reactants entering the reactor and the flow of products leaving the reactor is colored red.

3.2.3. Simulation of Controlling

Simulation of controlling automatically is to open or close the valves of V_2 and V_3. The simulation starts by pressing the “Start” button on the automatic panel and stops it by pressing the “Stop” button on the automatic panel. Control of opening or closing valves V_2 and V_3. Automatic control to open or close the heating steam valve V_2 and cooling water valve V_3. To indicate that valves V_2 and V_3 are open, they are marked in green and when closed, they are marked in red. The amount of control signal that is transmitted to open and close valves V_2 and V_3 is from 3 psi to 15 psi. The heating steam valve V_2 is set to operate on a control signal from 9 psi to 15 psi, while the cooling water valve V_3 is set to operate on a control signal from 3 psi to 9 psi. If the control signal transmitted to the two valves is 3 psi, then the heating steam valve of V_2 is closed and the cooling water valve of V_3 is 100% open, and if the control signal transmitted to the two valves is 4.5 psi, the valve of the steam heater V_2 is still closed and the cooling water valve of V_3 is 75% open. To show the magnitude of the control signal for valve opening of V_2 and V_3 can be seen on the panel opening and closing valves of V_2 and V_3. Opening and closing of valves of V_2 and V_3 can also be done manually. The simulation flow diagram to open both valves of V_2 and V_3 automatically can be seen in Figure 12.

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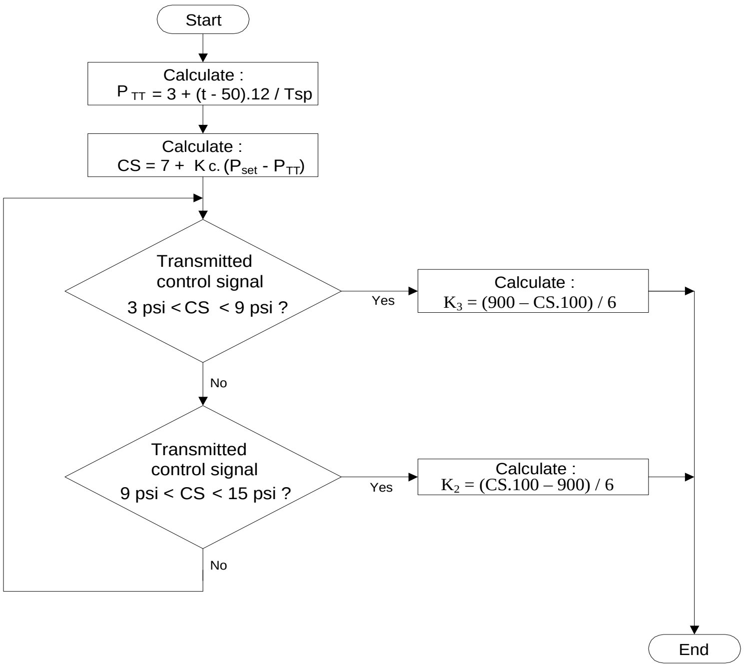
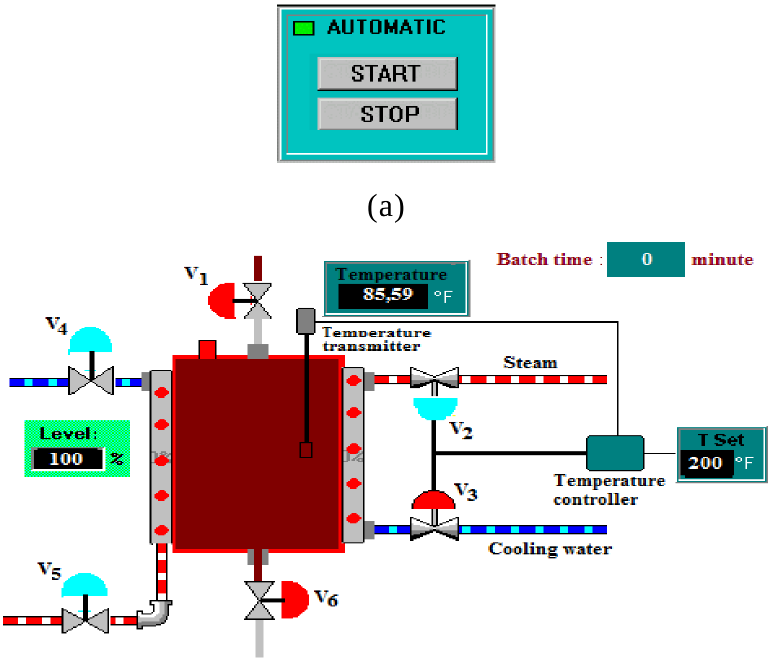


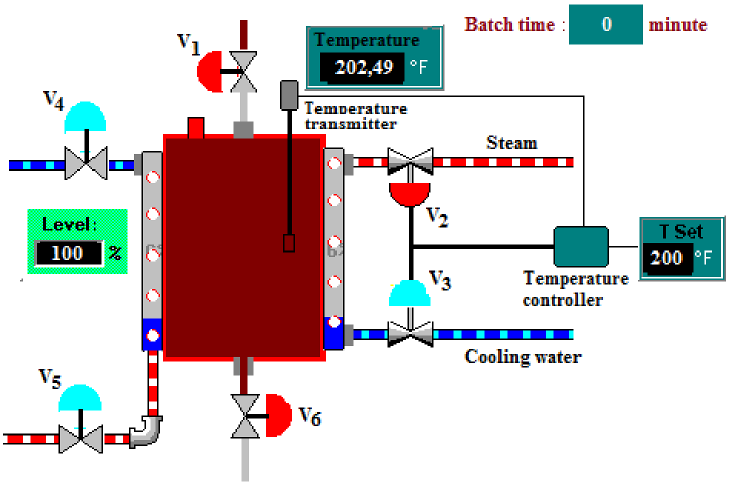
Figure 12: Simulation flowchart for opening both valves of V_2 and V_3 automatically.

The automatic panel display, the process of introducing heating steam and cooling water can be seen as shown in Figure 13.



(a)

(b)



(c)

Figure 13: (a) Automatic panel, (b) The process of introducing heating steam into the spiral, and (c) The process of introducing cooling water into the reactor envelope.

The heating steam inlet stream into the spiral is colored red, and the cooling water inlet stream into the reactor shell is colored blue.

3.2.4. Simulation of batch process

Before starting the calculation of the batch process simulation, first read the initial value and then do the calculation. The flow chart of the batch process simulation can be seen in Figure 14.

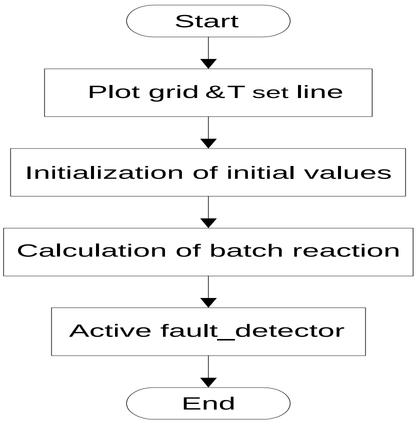


Figure 14: Flowchart of the batch process simulation.

The reactants in the reactor will react to produce the desired product. It is necessary to have a certain working temperature. The reactants must be heated by heating steam which is introduced into the spiral pipe through the valve opening of V_2. The temperature of the reactants will change from the initial temperature to the working temperature (set point temperature). The magnitude of the desired T^{set} set point temperature in the simulation is from 100 °F to 220 °F. The flow chart of the simulation for the desired T^{set} set point temperature can be seen as shown in Figure 15.

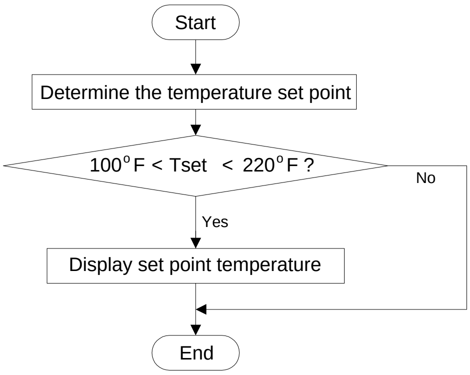


Figure 15: The flowchart of the simulation for selection of the desired temperature set point.

The panel display for selecting the desired set point temperature of 160°F can be seen as shown in Figure 16.

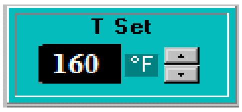


Figure 16: The panel display for selecting the desired set point temperature of 160°F.

If the temperature of the reactants continues to rise above the working temperature, it is necessary to cool it down with cooling water which is introduced into the reactor casing through the valve opening V_3, and the heating steam valve of V_2 must be closed. The entry of cooling water into the reactor envelope for cooling so that the temperature of the reactants in the reactor can be adjusted to the working temperature (set point temperature). When components A and B begin to be heated to the working temperature, the concentrations of components A and B will react. The reaction that occurs is that the concentration of components A and B changes into the concentration of component C, and the concentration of component C changes to the concentration of component D. The calculation of the process of changing the reactant temperature and component concentration can be simulated using Equation (16) to Equation (26), as well as using existing batch reactor parameters. The display of the reactant temperature panel and the graph of the changes in temperature of the reactants can be seen in Figure 17.

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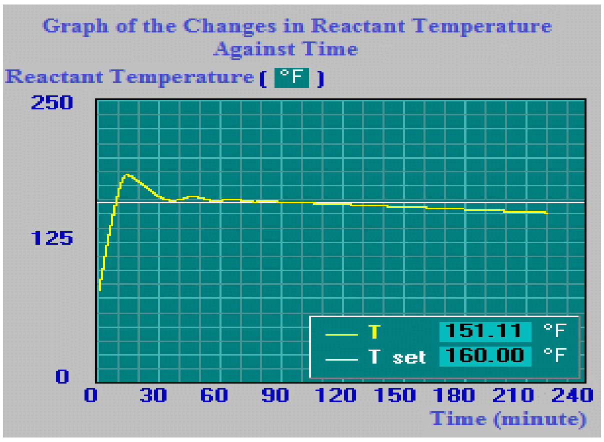
(a)



(b)

Figure 17: (a) Panel of reactant temperatures, and (b) Graph of changes in reactant temperature.

2.5. Simulation of changes in component concentration

The choice of the desired concentration value of components A and B in the simulation before heating is from 0 to 1.0 lb.mol A/ft^3, after being heated to the desired working temperature, the concentration of these components will change. The changes in the concentration of these components can be seen as in the graph of changes in the concentration of components. The graph of the changes in the concentration of this component serves to show the changes in the concentration of components A and B to become the concentration of component C and from the concentration of component C to the concentration of component D. The initial choice of concentration of components A and B is 0.8 lb.mol A/ft^3. The flow chart of the simulation for calculating component concentration changes in a batch reactor can be seen in Figure 17 above. The panel display of the initial value options for the concentrations of components A and B and a graph of changes in component concentrations can be seen in Figure 18.

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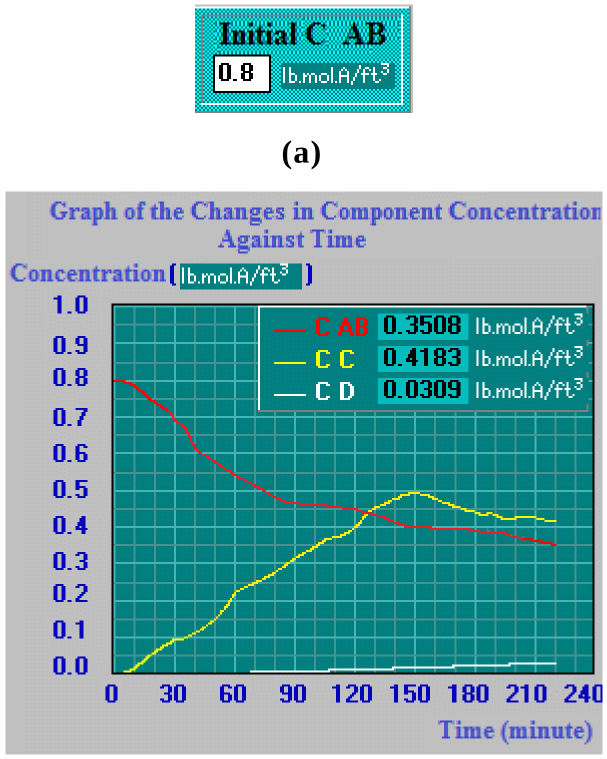

Initial C AB 0.8 lb.mol.A/ft3

(a)

Graph of the Changes in Component Concentration Against Time

C AB 0.3508 lb.mol.A/ft3
C C 0.4183 lb.mol.A/ft3
C D 0.0309 lb.mol.A/ft3

(b)

Figure 18: (a) Panel of initial value options for the concentrations of components A and B, (b) Graph of changes in component concentrations.

3.2.6. Simulation of disturbance

The disturbance given to the valve opening of V_4 is that the valve opening of V_4 is smaller than the valve opening of V_3. The disturbance given to the valve opening of V_5 is that the valve opening of V_5 is smaller than the valve opening of V_2 and the disturbance of the reactant level is when the reactants that are fed into the reactor do not reach 50%. If it is desired to simulate a disturbance in the valve of V_4, then the display screen will show a yellow circle representing the valve of V_4 experiencing disturbance. Likewise, if it is desired to simulate a disturbance on the valve of V_5, then the display screen will show a yellow circle representing the valve of V_3 experiencing disturbance. The flow chart of the simulation in case of equipment experiencing disturbances in the system can be seen as shown in Figure 19.

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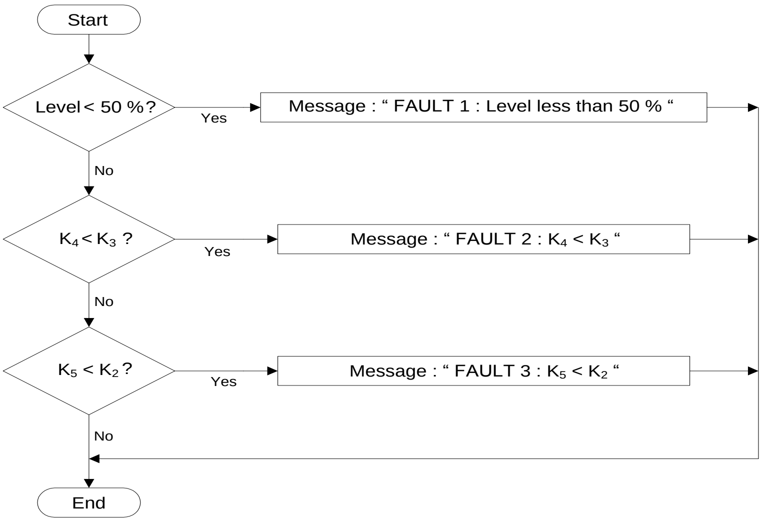
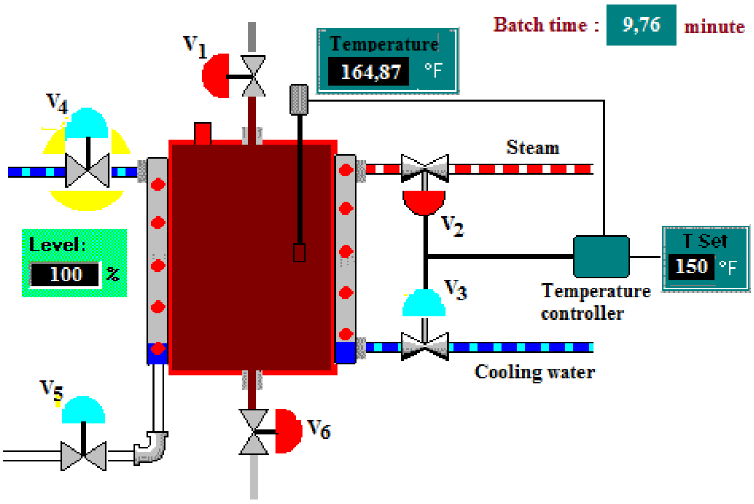


Figure 19: Flowchart of the simulation in case of equipment experiencing disturbance in the system.

The display when disturbances occur in the valves of V_4 and V_5 can be seen as shown in Figure 20.



(a)

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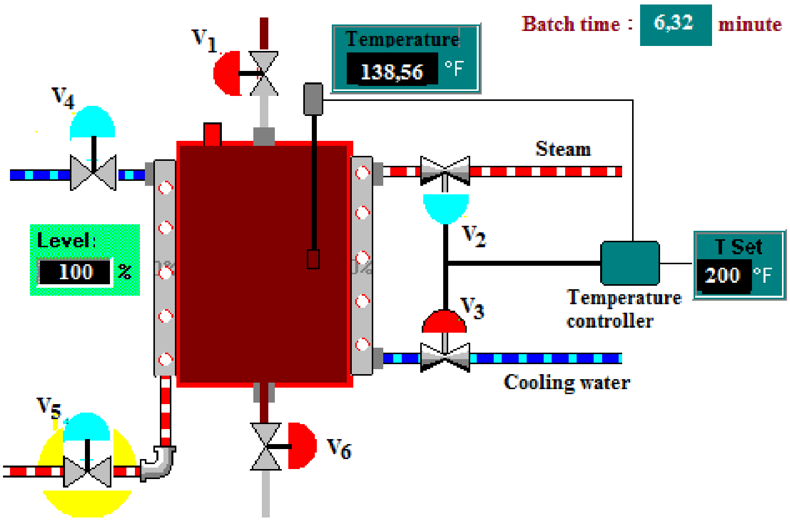

(b)

Figure 20: Simulation of disturbances on: (a) valve of V_4, (b) valve of V_5.

3.2.7. Simulation of damage

The simulation of equipment failure in the system is given to valves V_2 and V_3. The simulation of damage is given when the system equipment is active. The simulation of damage to the valve of V_2 is given when it is open, the valve of V_2 will close before the reactant temperature (T) reaches the set point temperature (T^{set}), so that the heating steam entering the spiral pipe stops flowing, resulting in a change in reactant temperature (T) to reach the set point temperature (T^{set}) which becomes relatively slow and takes a relatively longer time and is even difficult to achieve, and it also affects changes in reactions that occur due to changes in the concentrations of components A and B. The simulation of damage to the valve of V_3 is given when it is open and the valve of V_3 will close, so that cooling water entering the pipe spiral stops flowing, as a result the temperature of the reactants (T) will rise above the set point temperature (T^{set}). The temperature of the reactant T in the reactor is measured by a temperature transmitter measuring device through the detection of a temperature sensor mounted at the end of the temperature transmitter. The flow chart of the simulation in case of damage occurring to the valve of V_2 and the valve of V_3 can be seen as shown in Figure 21.

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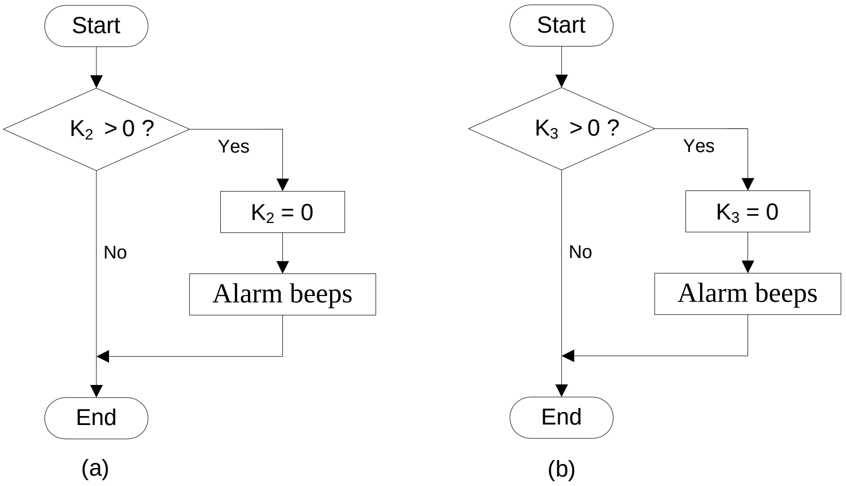
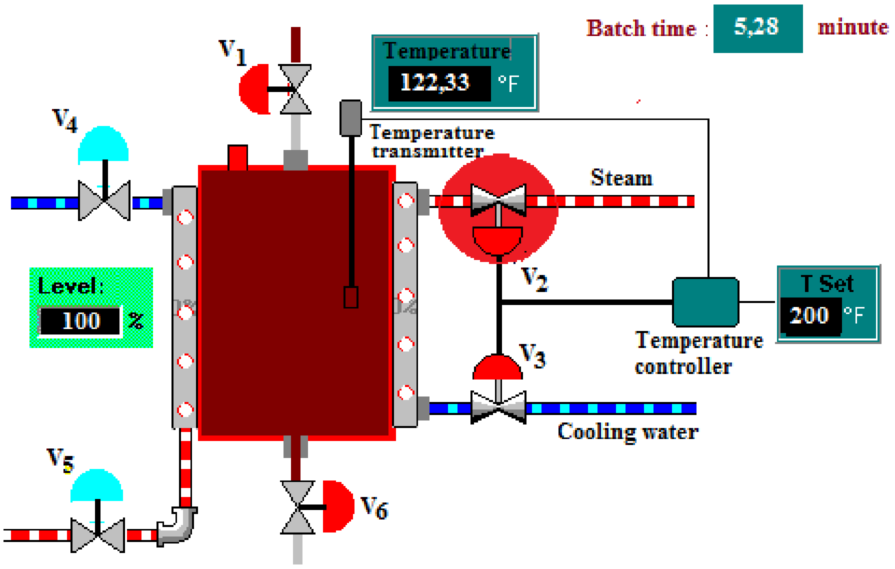
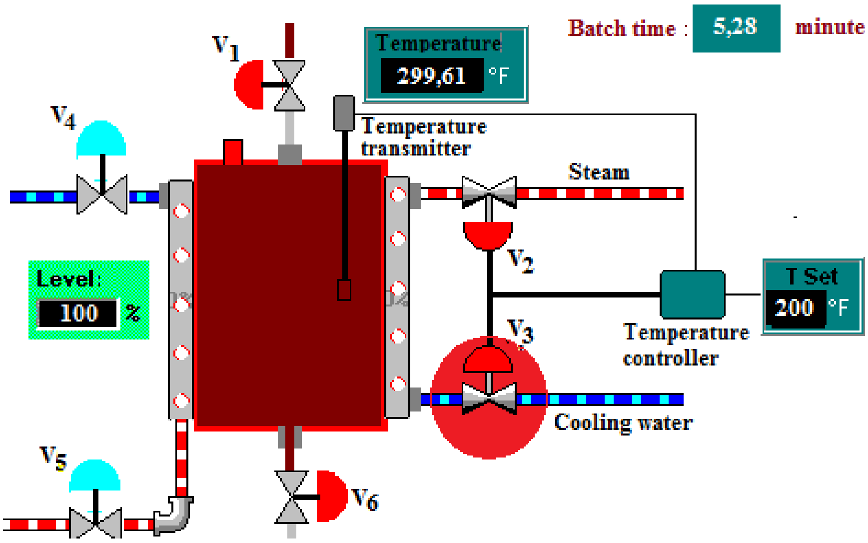


Figure 21: The flowchart of the simulation in case of damage occurring to: (a) the valve of V_2, (b) the valve of V_3.

The display when damages occur to the valves of V_2 and V_3 can be seen in Figure 22.



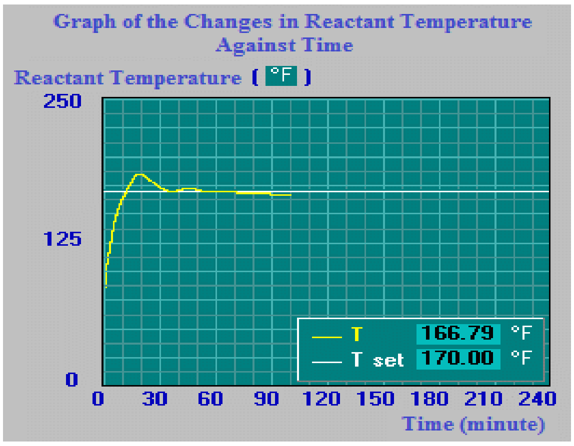
(a)



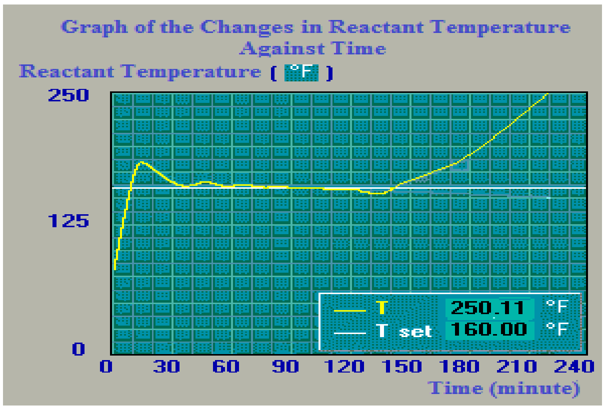
(b)

Figure 22: Simulation of damage occurring to : (a) the valve of V_2, (b) the valve of V_3.

The occurrence of damage to the valve V_2 causing the heating steam that enters the spiral pipe to stop flowing resulting in the change in reactant temperature (T) speed to reach the set point temperature (T^{set}) that becomes relatively slower and with a relatively longer time and even difficult to achieve. Similar occurence happens in providing a simulation of damage to the valve of V_3 as the cooling water entering the spiral pipe stops flowing resulting in the rise of the reactant temperature (T) above the set point temperature (T^{set}). The graphic display of the changes in reactant temperature when damage occurs to the valves of V_2 and V_3 can be seen as shown in Figure 23.



(a)



(b)

Figure 23: Graph of the changes in temperature of the reactants when damage occurs to: (a) the valve of V_2, (b) the valve of V_3.

3.2.8. Simulation panel breakdown.

The simulation of equipment breakdown on the system is started by pressing the button of "BREAKDOWN 1" or "BREAKDOWN 2" on the breakdown simulation panel. The result of pressing the button of "BREAKDOWN 1" or "BREAKDOWN 2" will display a choice of damage to the valve of V_2 or V_3. The simulation of equipment damage in this system is carried out when the system is in an active state. The display of the breakdown simulation panel can be seen in Figure 24.

(a) (b)

Figure 24: Display of simulation of panel breakdown on:

(a) Breakdown 1, (b) Breakdown 2.

The simulation of damage to the valve of V_2 is carried out when it is open, then valve of V_2 will close before the reactant temperature (T) reaches the set point temperature (T^{set}) resulting in the heating steam entering the spiral pipe to stop flowing. The simulation of damage to the valve of V_3 is carried out when it is open, then the valve of V_3 will close again resulting in the cooling water entering the spiral pipe to stop flowing. Performing a simulation of damage to the valve of V_2 is by pressing the button of "BREAKDOWN 1" on the breakdown simulation panel and on the right side of the "BREAKDOWN 1" button, a red color indicator will appear on the display screen and a red circle representing the damaged valve of V_2. Likewise, for performing the simulation of the damage to the valve of V_3 is by pressing the button of

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"BREAKDOWN 2" on the breakdown simulation panel and on the right side of the button of "BREAKDOWN 2", a red color indicator will appear on the display screen and a red circle representing the damaged valve of V_3 will appear.

3.2.9. Alarm panel

If there is a disturbance/damage to the parts of the equipment of the alarm system, it will beep and to stop this alarm's sound is by pressing the button of "Sound Reset" on the alarm panel so that the alarm sound will stop. The display of this alarm panel can be seen as shown in Figure 25.

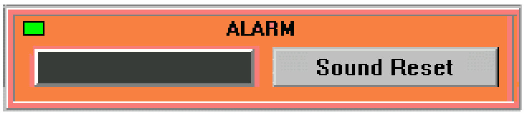

Figure 25: Display of alarm panel.

3.2.10. Panel of emergency stop

If there is a damage to the equipment in the system, the entire system must be stopped. To stop the entire work of this system is to press the "Stop" button on the emergency stop panel, so that the entire work of the system will stop. The emergency stop panel display can be seen as shown in Figure 26.

Figure 26: Display of emergency stop panel.

4. Analysis

Visual programming techniques have high graphic capabilities, and are object-oriented, with control and timer facilities that are quite complete to support the simulation needs of these industrial processes. The industrial processes can be described in terms of their physical form according to the state of reality, and can be programmed in such a way that they seem dynamic (moving) according to the dynamics of the process.

The initial concentration of components A and B is 0.8 lb.mol A/ft^3. The results of simulation calculation shown in Figure 19 that the optimum concentration of C component is 0.49 lb.mol A/ft^3 at 149.35 minutes, with a working temperature of 158.74 ^{o}F and a set point temperature of 160 ^{o}F. The system was stopped working at 220 minutes, because the concentration of component C tends to increase. At 220 minutes the concentration of components A and B is 0.3508 lb.mol A/ft^3, the concentration of component C is 0.4183 lb.mol A/ft^3, and the concentration of component D is 0.0309 lb.mol A/ft^3, with a working temperature of 151.11 ^{o}F and a set point temperature of 160 ^{o}F.

5. CONCLUSIONS

Object-oriented visual programming technique is provided with complete control and timer facilities to support the desired simulation needs of industrial processes. Industrial processes can be described in their shape according to the state of reality and can be programmed in such a way that they seem dynamic (moving) according to the dynamics of the process. All control facilities needed in the simulation can be provided in the form of push buttons around the batch reactor processes. The simulation made on the batch reactor work process consists of two parts, namely the process simulation section and the controller simulation section. The simulation in the process section consists of the level simulation in the reactor, the simulation of batch reaction process and the simulation of disturbance/damage. The simulations on the controller section consist of the simulation of power ON/OFF control, the simulation of manual/automatic system control, the simulation of set point temperature control, the simulation of control of alarm panels and the simulation of control of emergency stop panels.

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