CHAPTER 5

DCS: DISTILLATION CONTROL SIMULATION

DCS, developed in this research work, is a simulator for chemical engineering students to study important aspects of distillation dynamics and control without spending hours or days in the laboratory and without obscurity with would otherwise result for any real equipment, if it is used and does not work quite properly.

DCS is built by using the theories described in the previous chapters. Students can use DCS with ease without many commands to remember. The program provides a menu-driven interface. The results are printed in colorful graphics that let students follows distillation column dynamics as the results of their inputs unfold. In this chapter the menu-driven interface, the scope of the program and the program illustration are presented.

5.1 Menu-driven Interfaces

When the program is executed, the first menu will appear as show in Figure 5.1. From this menu, students can specify a distillation COLUMN, input FEED condition, set CONTROL PARAMETER, and select control STRUCTURE by moving the arrow to the appropriate icons and click the right mouse. Then the corresponding submenu will show up.

5.1.1 COLUMN data

The distillation COLUMN is a binary distillation column. The column dynamics are simulted using models published by Luyben (1990) and Grassi II (1992). Students can specify the numbe of trays (not include condenser and reboiler) and the feed tray. The tray at the bottom is tray 1 and the top is tray NT.

5.1.2 FEED condition

There are 10 components in the program that students can select two of them to be a feed. Students input the FEED condition by selecting FEED. Flow rate (lbmole/hr), composition (mole fraction), feed temperature (^{o}F) and feed components (i-Butane, n-Butane, i-Pentane, n-Pentane, n-Hexane, Benzene, i-Heptane, n-Heptane, Toluene, n-Octane) see figure 5.2. At this menu students may specify the heat duty of a reboiler (Btu $x10^6$/hr) and the reflux rate (lbmole/hr).

Fig. 5.1 Menu-driven Interface

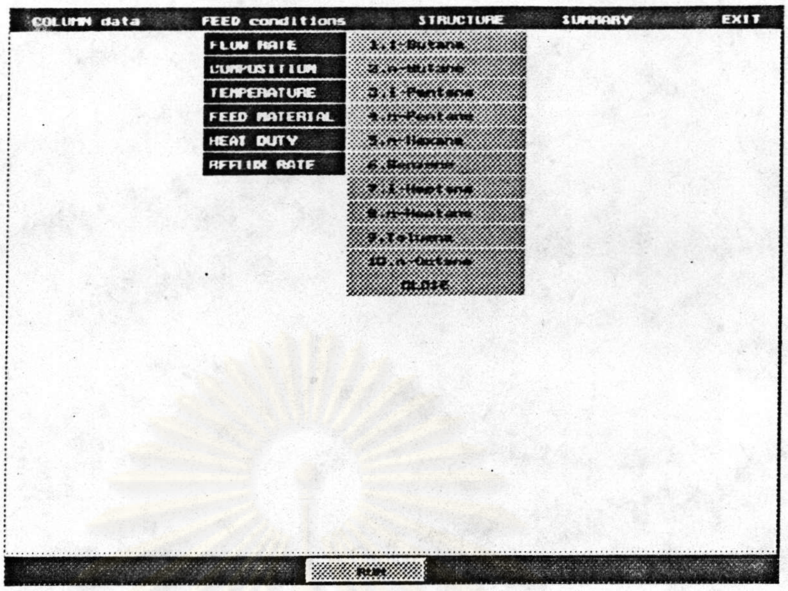

Fig.5.2 FEED conditions menu

5.1.3 Control STRUCTURE

Figure 5.3 show the basic distillation column which has five control valves, one on each the following streams: distillate, reflux, coolant, bottom, and heating medium. It is assumed that the feed stream is set by the upstream unit. So this simple column has five degrees of freedom. Then, there are five control loops possible. Two types of control are inventory and quality controls. The inventory controls are the liquid level in the reflux drum, the liquid level in the base of the column, and the column pressure, i.e. the vapor content in the column. The quality loops are the composition of distillate and the composition of the bottoms. The combination of controlled variables and manipulated variables results in 120 possible control structures to be considered. Fortunately, most of them are eliminated by realising that a control loop involving variables across the column would give a poor performance. Typically, only one product composition (temperature) is controlled, while the other is in manual.

Students select a control STRUCTURE by click at the STUCTURE button. There are four common control structures, shown as figure 5.4-5.7, available for studying.

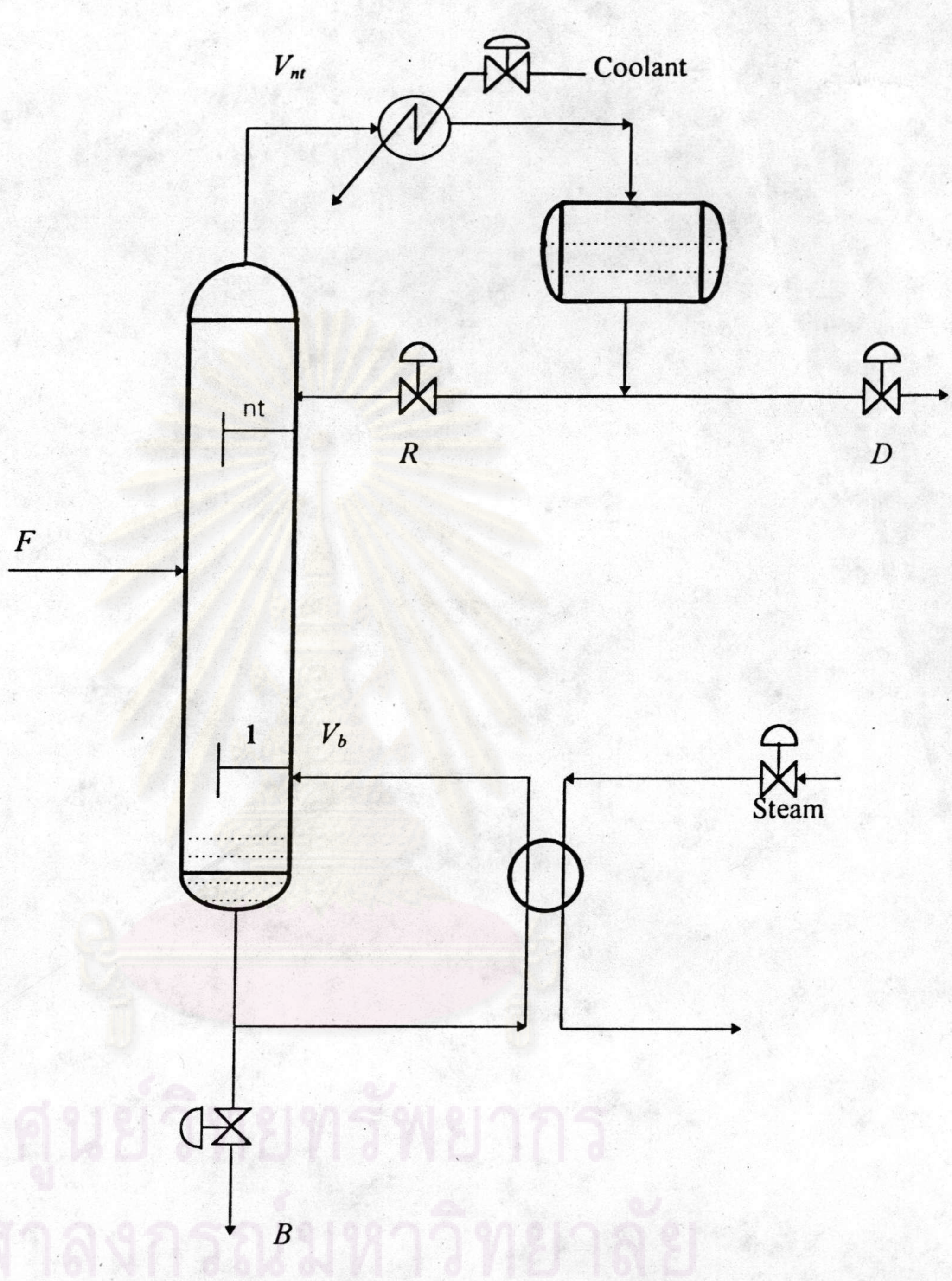

Fig.5.3 The basic distillation column with fives control valves.

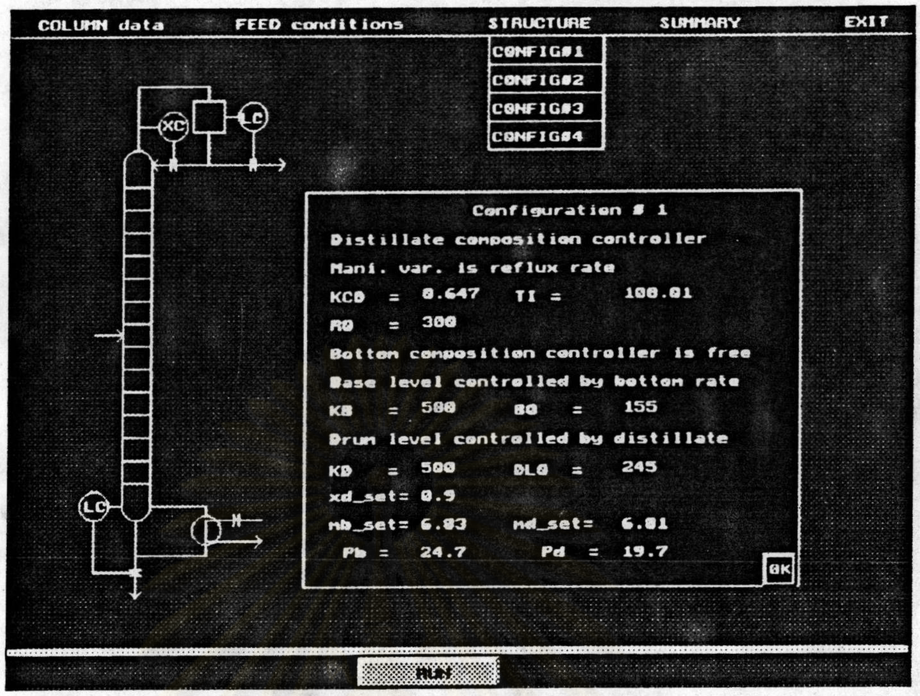

Fig. 5.4 Control Structure 1

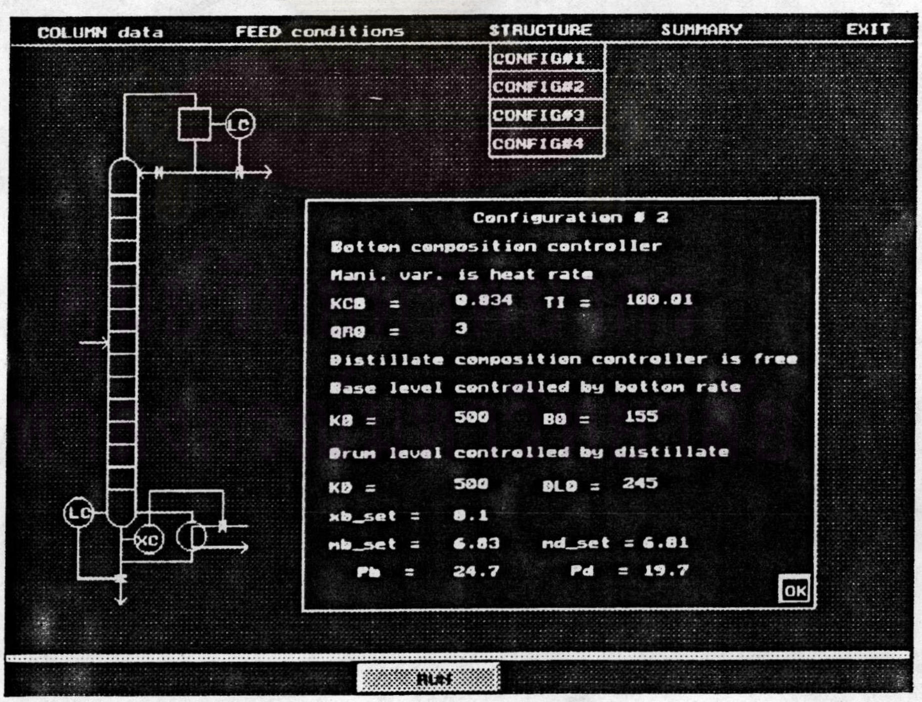

Fig. 5.5 Control Structure 2

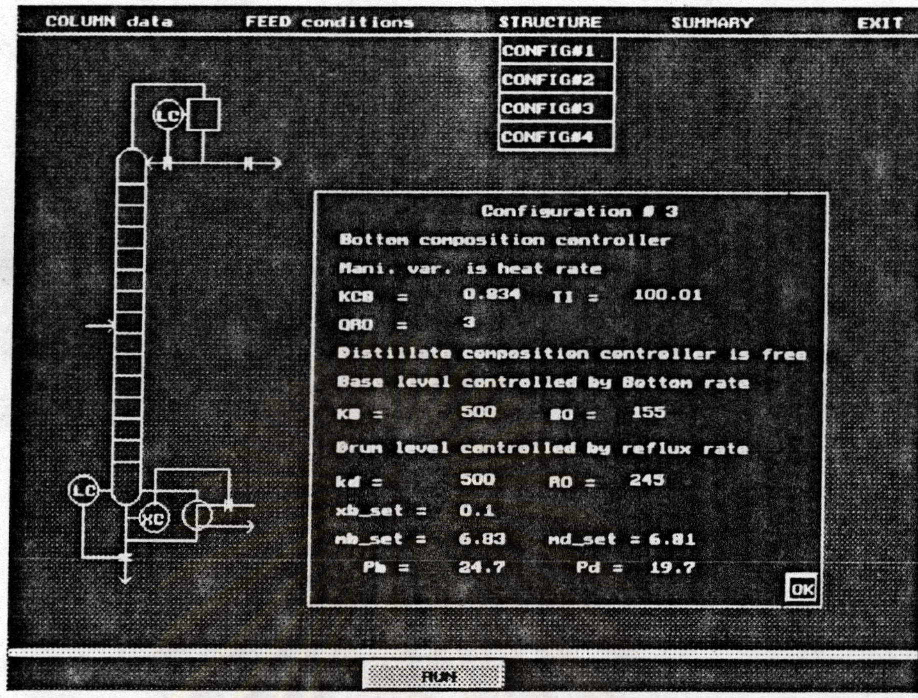

Fig. 5.6 Control Structure 3

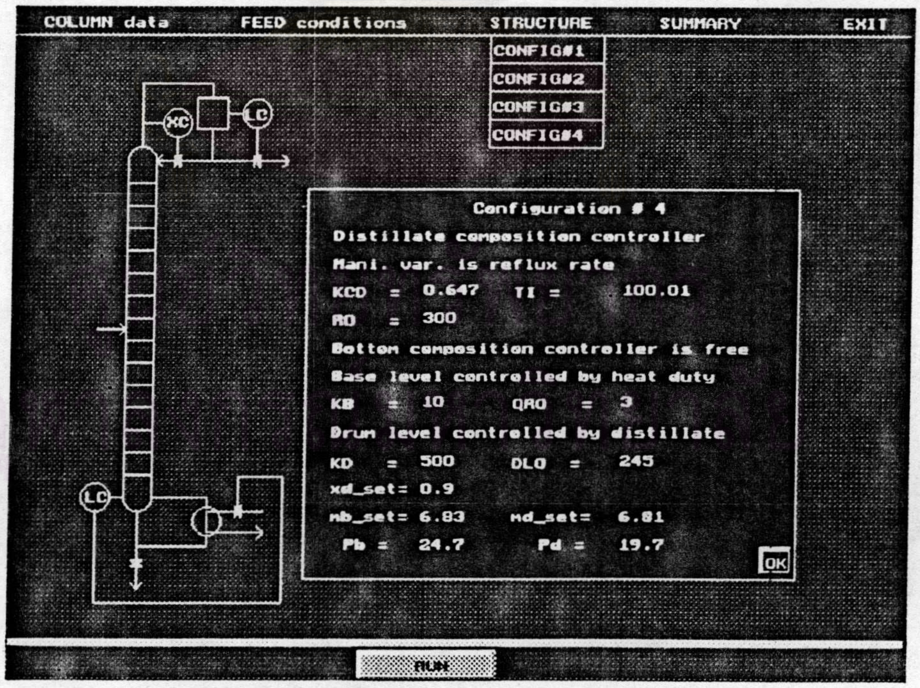

Fig. 5.7 Control Structure 4

When a control structure is selected, the structure is displayed. Students can set the control loops of the selected structure. The control parameters are controller gain (*KC*), reset rate (*R*), derivative time constant (*TD*) and bias term (*BO*).

The manipulated and controlled variables of the inventory loops and the composition loop of each structure is presented in Table 5.1

Table 5.1 Control Structures in this work.

Structure	Inventory		Composition	
	Reflux drum	Column base	Distillate	Bottom
1	Distillate	Bottom	Reflux	on Manual
2	Distillate	Bottom	on Manual	Heat duty
3	Reflux	Bottom	on Manual	Heat duty
4	Distillate	Heat duty	Reflux	on Manual

In each control structure there are a number of parameter to be specified, They are set points and pressures.

XB_SET = set point of the bottom composition loop (light component)

XD_SET = set point of the top composition loop (light component)

MB_SET = set point of the bottom inventory loop

MD_SET = set oint of the top inventory loop

PB = pressure at colum base

PD = pressure at reflux accummulator

5.1.4 Entry SUMMARY

This menu will display all the data input, i.e. column data, control structure, and controller settings at a glance.

5.2 Simulation

After all data are entered, the program will be ready to run a simulation by pushing the RUN button and new interface will appear (See Figure 5.8).

The window in the first quater of the screen is the plot of the column base level and time. The second window shows the plot of the reflux drum level and time. The third window displays the plot of the distillate composition and time. The fourth window is the plot of the bottom composition and time.

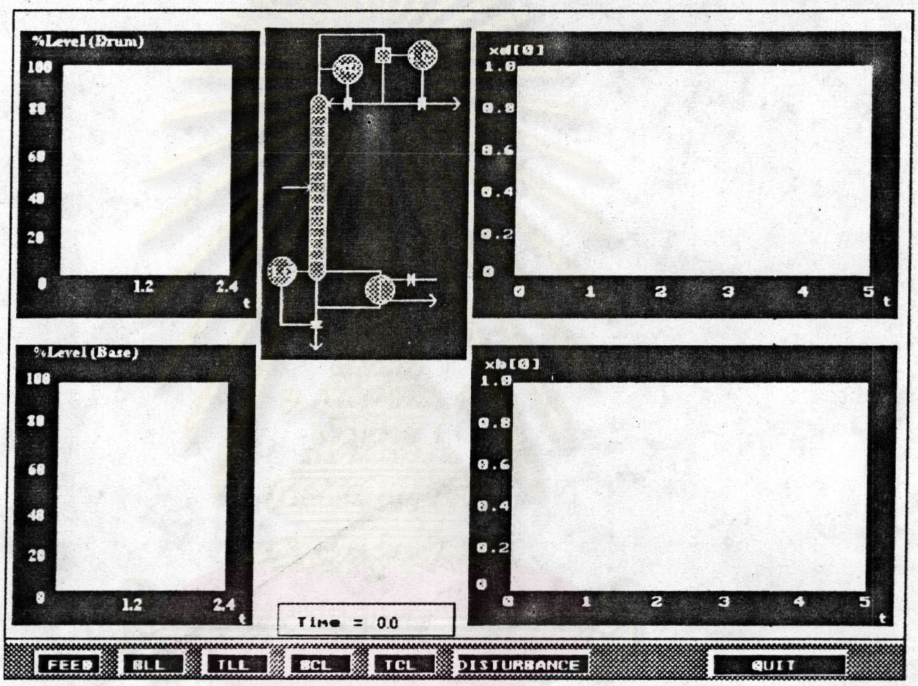

Fig. 5.8 Window screen of simulation

Also in this menu a user can change some of the column and control data by selecting the buttons appeared between the right and the left window.

- TCL (Top Composition Loop)
- BCL (Bottom Composition Loop)
- TLL (Top Level Loop)
- BLL (Bottom Level Loop)

The composition loop which is in manual will display the manipulated variable and students can change its value.

- FEED
- DISTURBANCE

FEED menu includes three submenus: feed flow, feed composition, feed temperature. A student can change these variables at the feed stream by selecting this menu (Figure 5.9).

By selecting DISTURBANCE, a student can simulate the occurance of the disturbance at the feed stream. First a student must choose among three variables: feed, composition (light component) or temperature. Figure 5.10 shows this submenu. After the disturbance is selected, new submenu showed in Figure 5.11, appears. Four types of input disturbance signal can be introduced to the column. They are step, pulse, sinusoidal, and random (pure white noise) signals. A student, then, can observed the response of the column in the windows.

A student may restart the program by selecting QUIT. Selecting EXIT means leaving the program.

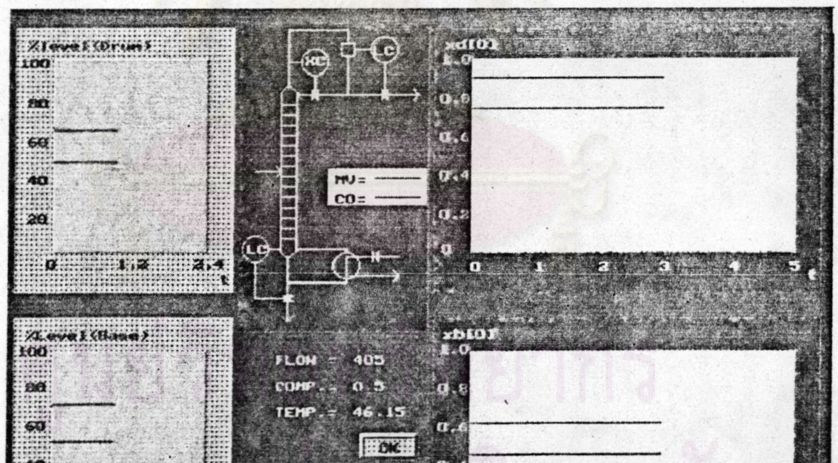

Fig. 5.9 Submenu of FEED

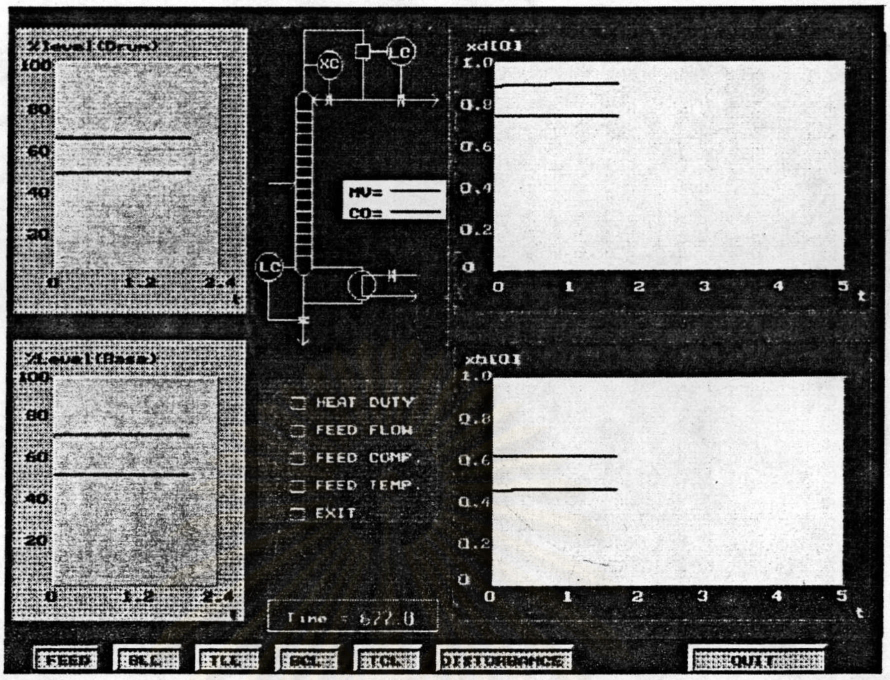

Fig. 5.10 Submenu of DISTURBANCE

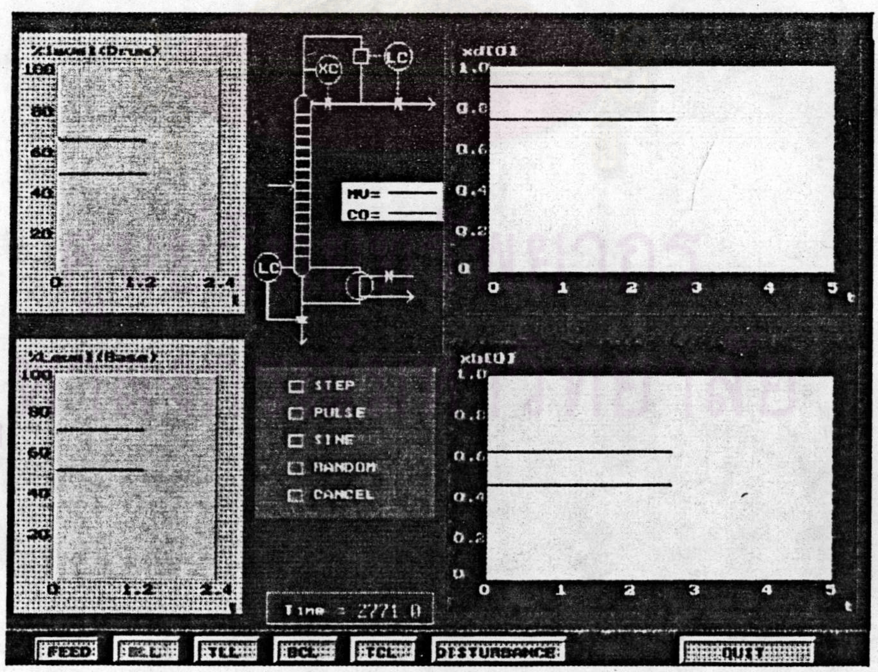

Fig.5.11 Four types of input disturbance

5.3 Sample Run

5.3.1 Case I

Data entry:

Feed: Components : 1. i-Butane

: 2. n-Butane

Flow rate = 405 lbmole/hr

Composition = .5 (of i-Butane)

Temperature = 46.15 ^{0}F

Heat Duty = 3 x 10^6 Btu/hr

COLUMN Design: No. of Trays = 15

Feed Tray = 9

Control STRUCTURE : 1

TCL : KC = 0.65

R = 1/100.01 1/hr.(Reset rate = 1/integral time)

RO = 300 lbmole/hr

TLL: KC = 500.00

DLO = 245.00 lbmole/hr

BLL : KC = 500.00

BO = 155.00 lbmole/hr

XD_SET = 0.90

MD_SET = 6.81 lbmole

MB_SET = 6.83 lbmole

PD = 19.7 psia.

PB = 24.7 psia.

The simulation result is shown in figure 5.12.

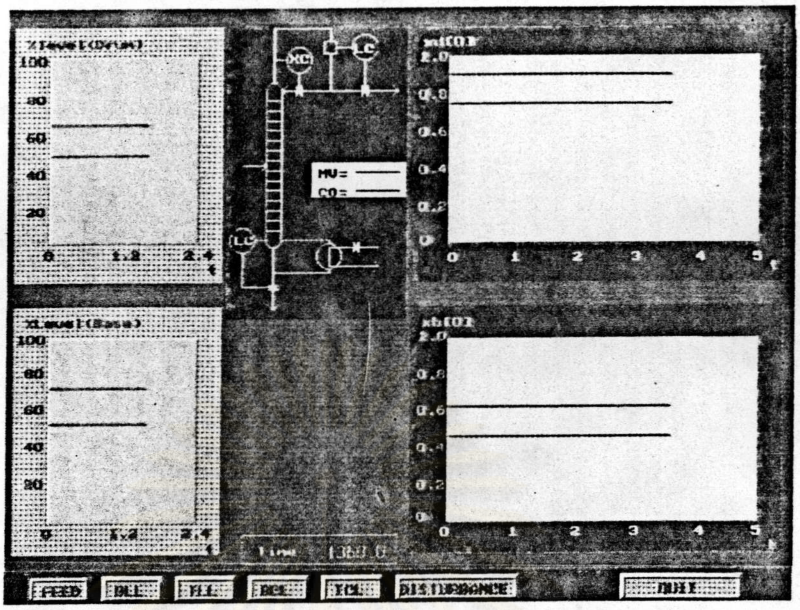

Fig.5.12 Case I results of simulation.

5.3.2 Case II

When the results of Case I is at steady state operation, step input of feed temperature disturbance is entried by Amplitude at 40 °F.

The responses of simulation to step change in feed temperature is shown in figure 5.13.

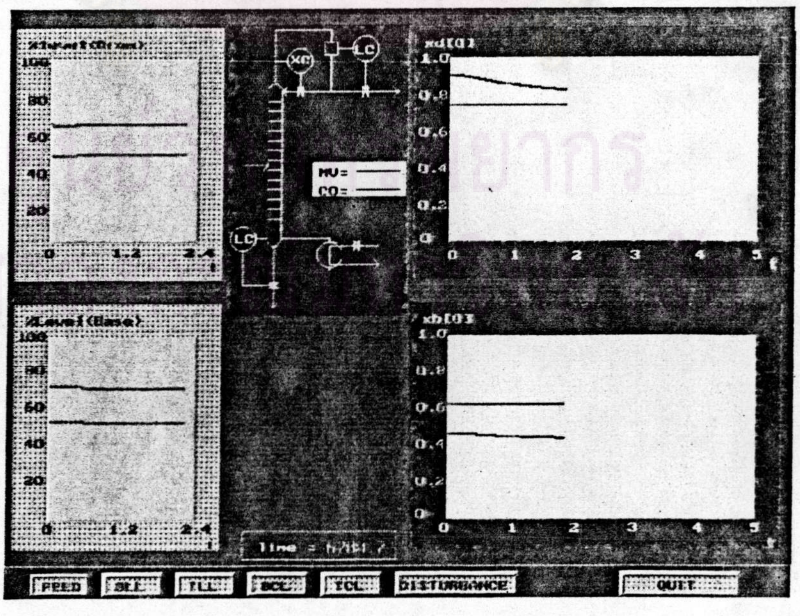

Fig.5.13 Case II results of simulation.

5.3.3 Case III

When the results of Case I is at steady state operation, sinusoidal input of feed temperature disturbance is entried by Amplitude at 40 °F and Period at 0.2 hr.

The responses of simulation to sinusoidal change in feed temperature is shown in figure 5.14.

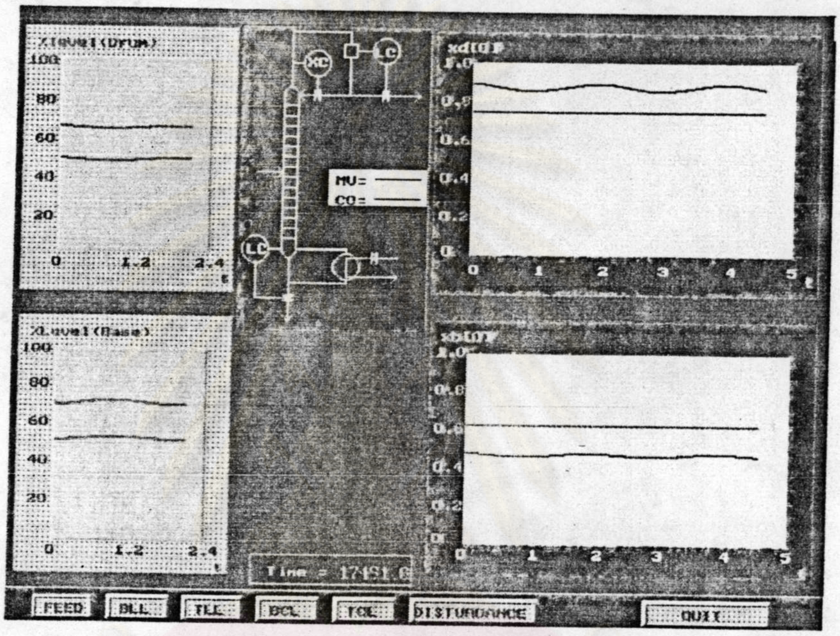

Fig.5.14 Case III results of simulation.