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STUDENT HANDBOOK

Distributed Control System Operation (DCS)

INCT 2430

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Prepared by

Industrial Instrumentation & Control Skills Team

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INCT 2430

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Preface

The purpose of this workbook is to train the plant operator how they can use DCS to control and monitor the whole plant process.

With the help of various simulated processes, the student would be able to understand what they have to do in case of any fault, how they can change the set point/parameter of any controller, and how they can analyze the causes of plant trip.

For example, the tank level in the process plant is high, with the help of DCS one can monitor and control all the parameters in a single control room.

1. Distributed Control System (DCS)

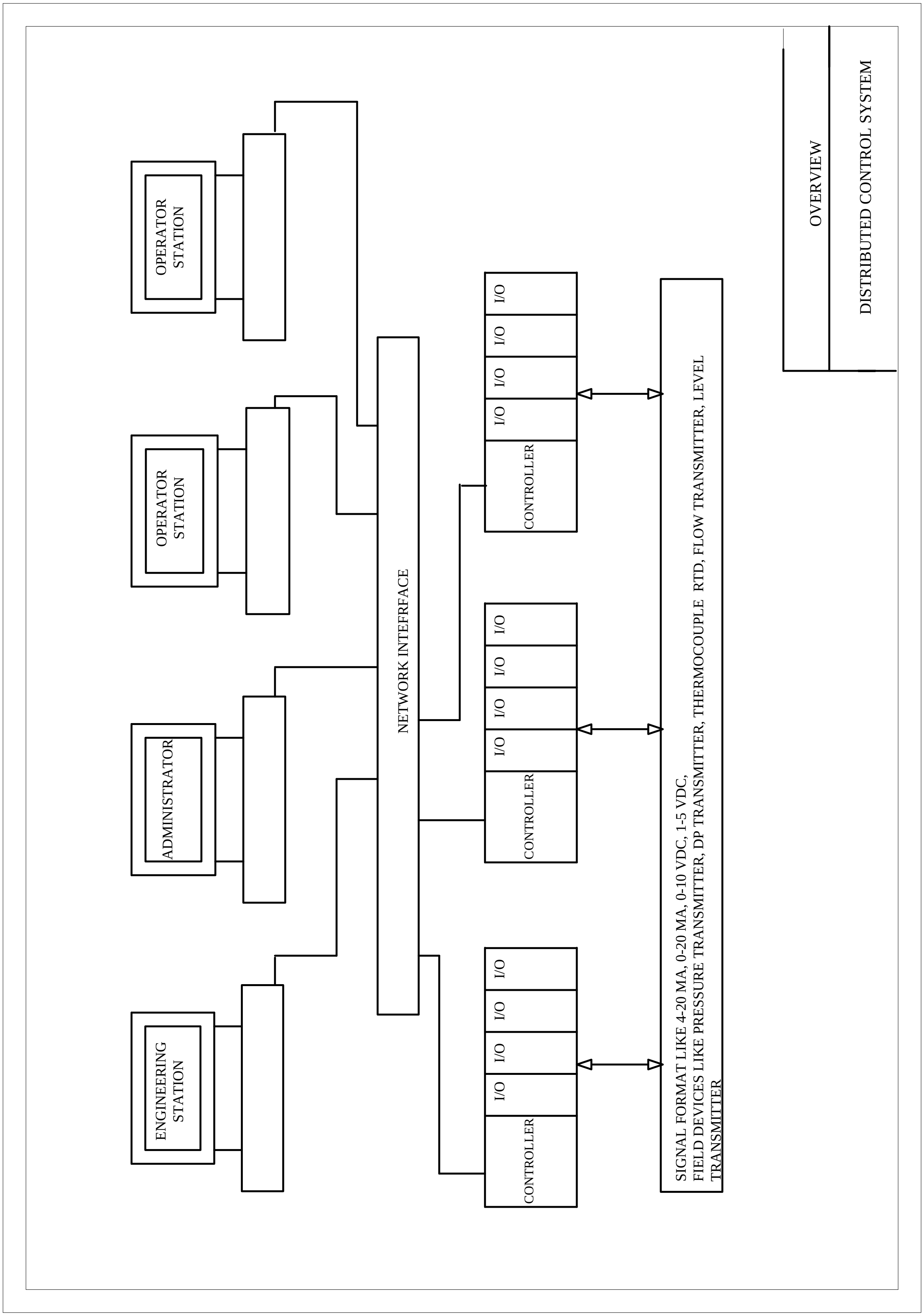
DCS stands for Distributed Control System. DCS is mostly used in large process plants where there is a need to control and monitor the whole process from a single control room.

A large process can be distributed to many sub processes. These sub processes can be handled locally by a controller and an I/O module. All these controllers are connected to the system through a common data bus. Due to this feature, the whole system is called a Distributed Control System. The DCS is also used as a data acquisition system whenever there is a need to study the system and know its history.

Different manufacturers of DCS's are available in the market, such as Fisher, ABB, Siemens, Honeywell, and Yokogawa. The DCS system used in our workshop is Honeywell TDC3000. Each manufacturer designs different system architecture with different characteristics. Also, different operating systems are used in different DCS terminals, like Windows, Unix and Solaris.

1.1 Important Characteristics of Distributed Control Systems:

- Single window to process with common screens and tools
- Data acquisition (Data can be access from any terminal, view plant status and troubleshoot from virtually anywhere via remote communications)
- Incremental level of control
- History collection (Journals, logs, alarm, trends, printing, statistics, reports)
- Third party device connection
- Continuous growth & updating
- Easy to train operator
- Less operator error due to friendly, intuitive screens
- Expandable capabilities
- Real time trending
- Alarm management
- Multi-tasking and security features all incorporated into HMI
- Exceptional graphic display
- Easily generate and modify screens.


DISTRIBUTED CONTROL SYSTEM
OVERVIEW
OPERATOR STATION
OPERATOR STATION
ADMINISTRATOR
ENGINEERING STATION
NETWORK INTEFRFACE
CONTROLLER
I/O
I/O
I/O
I/O
CONTROLLER
I/O
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I/O
I/O
CONTROLLER
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SIGNAL FORMAT LIKE 4-20 MA, 0-20 MA, 0-10 VDC, 1-5 VDC,
FIELD DEVICES LIKE PRESSURE TRANSMITTER, DP TRANSMITTER, THERMOCOUPLE RTD, FLOW TRANSMITTER, LEVEL TRANSMITTER

2. DCS Architecture

- Engineering Station
- Administrator Station
- Operator Station
- Controller
- Network Interface
- Online Printers

2.1 Engineering Station

Engineering stations are used to develop control logic and graphic screens.

Standard graphic screens can be developed as per process requirement and can be modified during plant operation.

Control logic and graphic screens can be downloaded to operator stations and controllers.

Only an authorized person can use engineering stations.

2.2 Administrator Station

The administrator station controls all the data transfer activities between different stations. Operating system instructions can be used depending on which operating system is used on the station.

Only authorized personnel can use administrator station.

2.3 Operator Station

Operator stations are used to control and monitor the whole process. The operator can energize different devices like pumps, motors and switchgears. Set point/parameter values of different controllers can also be changed during operation as per the requirements.

Alarms and events can be seen on different graphic screens, which provide a lot of help to control the process. If required signal logging can be performed for a defined period of time and interval.

Trend curves of different process variable can be seen which provide help to analyze the different process.

2.4 Controller

Controllers are used to read signals from different transmitters, calculating output to be sent to field devices according to algorithms selected by the user and determining whether alarm trip points have been exceeded.

2.5 Network Interface

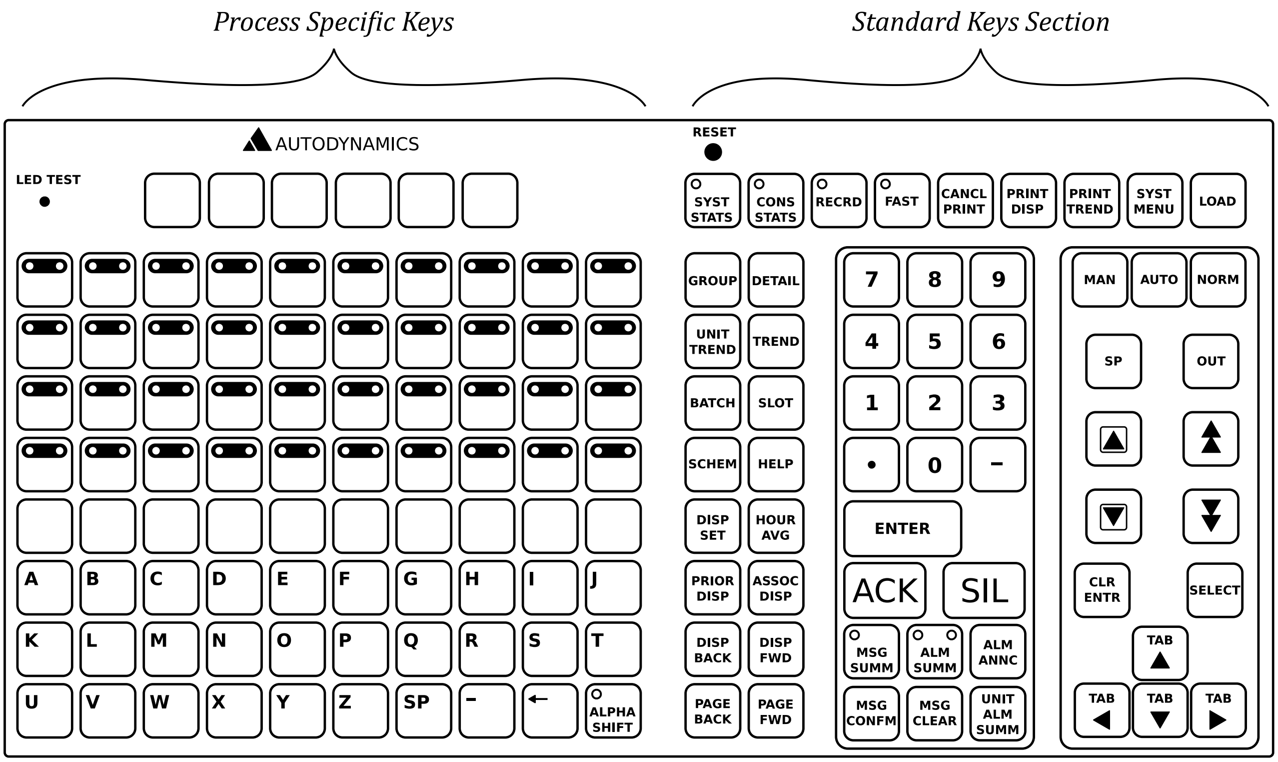
Network interface is used to interconnect the network.

2.6 Comparison between PLC & DCS

PLC (Programmable logic controller) is a controller that is a standalone and performs a specific task. PLC mostly used to control small individual process. Whereas DCS is a network of PLCs that communicate in some fashion to control and monitor large plant.

3. How to use Emulated Operator Keyboard

Using this operator keyboard (Emulated as TDC3000), the operator can control what is displayed on the screen.

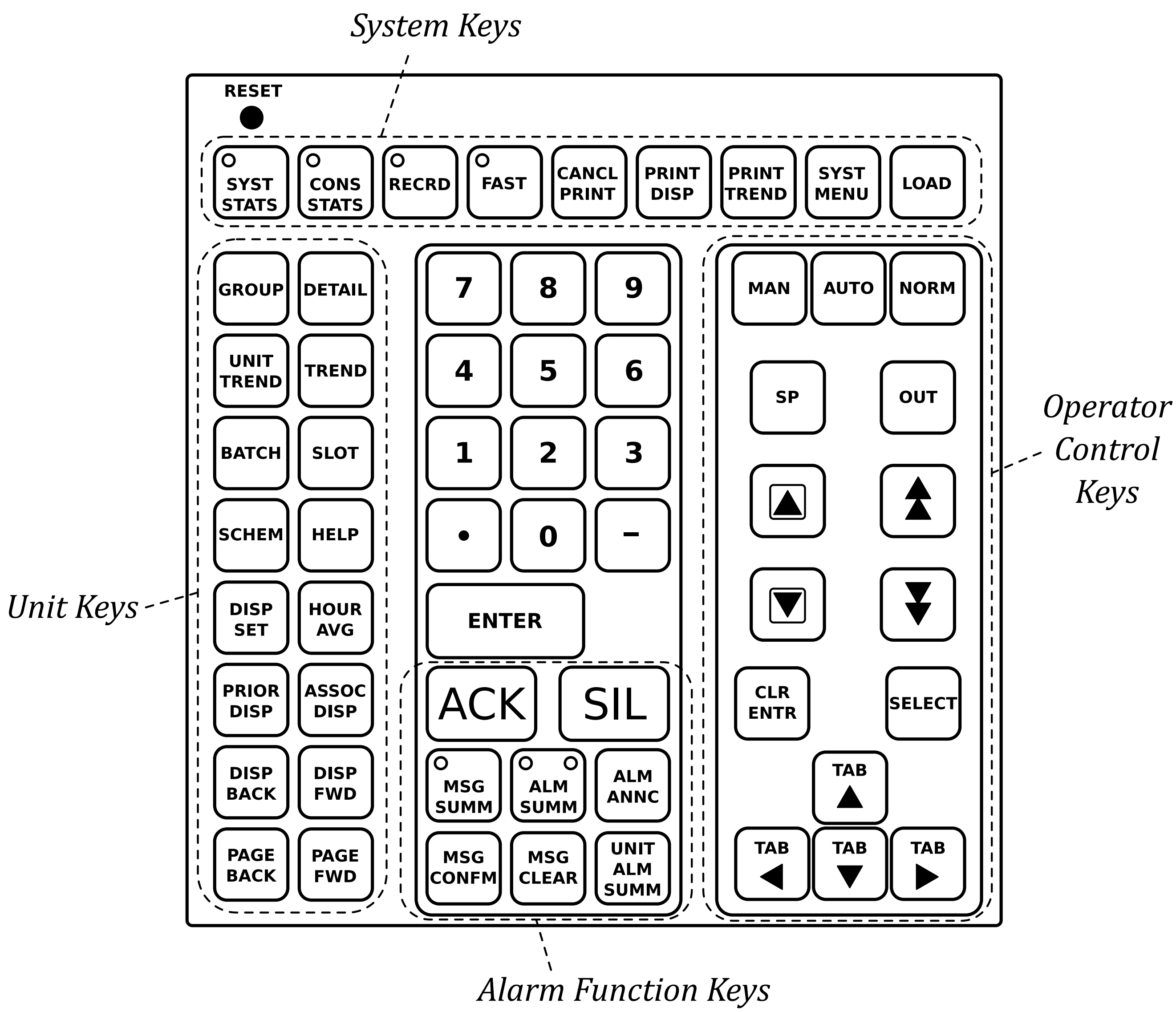


The Keyboard is divided into two major sections,

- Standard Keys Section
- Process Specific Keys

Standard Keys

The Standard Keys Section, located on the right hand side of the keyboard, consist of predefined keys used to perform specific functions. Refer to Figure for an illustration of the Standard Keys Section of the emulated TDC-3000 keyboard.

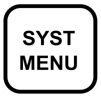


The function of these keys will be the same regardless of the process being controlled. Some of the keys are backlit with red LEDs to annunciate certain process events or to indicate specific states. One key, the alarm summary key, ALM SUMM, is backlit with both a red LED and a yellow LED. These LEDs indicate alarm statuses and can be configured to represent both critical and non-critical alarms.

System Keys

The first set of keys that will be discussed is the nine keys which run along the top of the Standard Key Section and are called the System Keys. Of these nine keys, only one key is operable on the emulation keyboard. This will be discussed now.

System Menu Key



The System Menu key, SYST MENU, calls up the System Menu Display. This menu contains lists of items that show the configuration and organizational set-up of the system. From this menu, the operator can access the Organizational Summary Menu, configure up to ten new groups, and clear the screen.

The Organizational Summary Menu supports the following summaries:

- Point Attribute Summary
- Area Titles
- Unit Titles
- Group Titles
- Unit Trend Titles
- Schematic Titles

To access a summary, the operator should highlight the box in front of the desired summary by using the TAB keys or mouse, and then press the SELECT key. The desired summary will then be highlighted. Next, the operator should move the cursor to the DISPLAY box and press the SELECT key once again. The summary selected will then be displayed.

The Point Attribute Summary allows the operator to view lists of instruments that have been set up for the following configurable parameters:

- Alarm inhibit
- Alarm disable
- Manual mode

The Area Titles, Unit Titles, Group Titles, Unit Trend Titles, and Schematic Titles Summaries contain lists of designations which have been pre-configured for the plant area, unit, groups, unit trends and plant schematics. These titles can be accessed by the operator as a reference guide for quick direction to access more detailed information regarding plant operations.

The remaining keys on the top row of the keyboard are not emulated on the Operator Station keyboard. These keys include the System Status key [SYS STATS], the Record key [RECRD], the Cancel Print key [CANCL PRINT], the Print Display key [PRINT D/SP], the Print Trend key [PRINT TREND] and the Data Load key [LOAD]. Pressing any one of these above mentioned keys will have no effect on the simulator.

Unit Keys

The next section of keys that will be discussed are the two vertical columns of keys located on the left hand side of the standard key section. These keys are referred to as the Unit keys. All of these keys will be discussed here, except three, which are not supported by the emulation. These keys are the Hourly Average key [HOURAVG], the Batch key [BATCH], and the Display Set key [DISP SET]. The discussion of the keys in this section will begin with the top left hand most key, the Group key.

Group Key

The Group key [GROUP] is used to call up a Group Display and requires entry of a group number. Once the group number has been entered using the numeric keypad, use the [ENTER] key in order to display the desired group. Another way to reach the group display is to assign a user defined key to each group and use the key to switch between groups.

Detail Key

To the right of the [GROUP] key is the Detail key [DETAIL], which calls up the detail display for an instrument point. If an instrument has already been selected in a Group or Schematic Display, the details for that instrument will be immediately displayed once the [DETAIL] key is pressed. If a point has not been selected, entry of a tag name [Point ID] by the operator will be requested. After the tag name has been typed in, the [ENTER] key must be used in order to display the detail.

Unit Trend Key

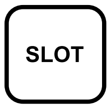
The Unit Trend key, located directly below the GROUP key, calls up the Unit Trend Display. But before the trend can be displayed, the operator must input a two (2) digit alphanumeric unit ID number. Once this number has been entered, the ENTER key must be used in order to display the desired Unit Trend. These trends groups can have from one to twenty-four (24) instruments present.

These unit trends have been pre-configured during the development of the program and are not accessible to the operator.

Trend Key

Located directly below the DETAIL key is the Trend key, TREND. This key is used to call up a Trend Display of an individual analog point (controller or indicator) that has been selected in a Group Display. If no instrument has been selected, the trend will display all the instruments in that group that have been configured as trend able instruments.

Slot Key



Located directly below the TREND key is the Slot key, SLOT. This key is used to call up a point from the Group Display and requires the entry of a slot number (1-8). Once the slot number has been entered, use the ENTER key in order to select the instrument in that slot.

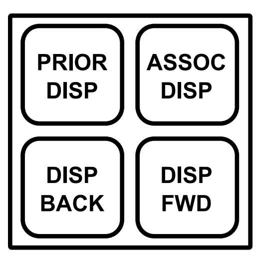
Schematic Key

Located directly below the BATCH key is the Schematic key, SCHEM. This key is used to call up a Schematic Display and requires the name of the Schematic to be inputted prior to displaying the schematic. These schematics or graphics usually have operator accessible points used in the operation of the plant. These graphics are developed and by technicians prior to operation of the plant and have specific names attributed to them. For example, G5020S1M could be the schematic title for schematic #1 of the metric version of program 5020. This is the schematic name that must be entered after the SCHEM key has been used in order to display the desired schematic.

Another way to call up a schematic to use user defined keys on the keyboard.

Display Keys

The display keys are used to switch between different types of related or adjacent displays. These keys include the following: PRIOR DISP, ASSOC DISP, DISP BACK, and DISP FWD. Refer to the figure below for an illustration of the display keys.

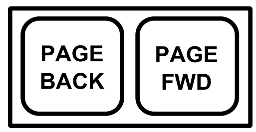


The Prior Display key, PRIOR DISP, calls up the display that was on the Operator Station CRT immediately before the current display. If pressed during a Group Trend, the screen will return to the group display. The Associated Display key, ASSOC DISP, calls up the configured display associated with an item chosen from the current display.

The Display Back and Display Forward keys, DISP BACK and DISP FWD, are used to toggle between adjacent displays of the same type. For example, if Group #05 is displayed and the DISP BACK key was pressed, Group #04 would be displayed. If the DISP FWD key were then pressed, the Group #05 would again be displayed on the screen.

Page Keys

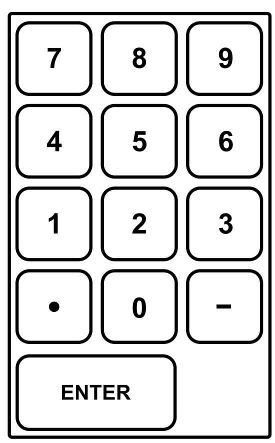
The final two keys in the Unit Keys section are the Page keys, PAGE BACK and PAGE FWD. These keys are used to toggle between pages of multiple-page displays. Refer to Figure for an example of the page keys.



Both keys have a wrap around feature so that when the PAGE FWD key is pressed when the last page is displayed on the Operator Station CRT, the first page will be displayed. Similarly, when the PAGE BACK key is pressed while the first page is displayed, the last page will be displayed. A good example of where these keys might be used is when the Operator is viewing the Alarm Summary and there is more than one page of alarms present.

Standard Numeric Touch Pad Keys

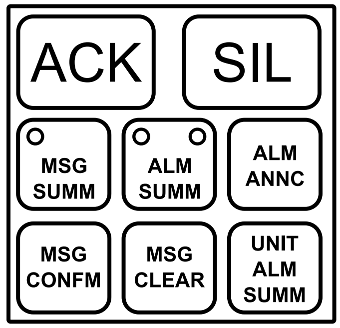
The Standard Numeric Touch Pad section keys are used to enter numeric data onto the screen. This group of keys is located in the middle of the Standard Key Section of the keyboard. Refer to Figure for an illustration of the standard numeric touch pad keys.



This section of the keyboard includes all numbers as well as the Decimal key, •, the Hyphen key, -, and the Enter key, ENTER. Numbers will be required in such situations such as to change an analog input, a controller setpoint or output; enter a specific group number, enter a slot number, enter a schematic name; or for entering a numeric character of an instrument tag name. Numeric values are displayed on the screen in the data-entry field character-by-character as they are entered. The ENTER key is pressed after the desired number(s) have been entered in order to complete the data entry.

Alarm Function Keys

Alarm function keys used to check different alarm of a particular process.



Most of the alarms that occur at the Operator Station are associated with the process being operated. Some of the alarms could be associated with the system or the Hi way - Gateway (data cables) which carry the data to/from the operator console to/from the plant.

The Silence key, S/L, silences all audible alarms on the console whether they are plant related or distributed control system related.

The Acknowledge key, ACK, acknowledges all process status alarms that are currently displayed on the screen of the Alarm Display page. The audible alarm will also be silenced if not already silenced. ACK only acknowledges the alarm and stop blinking but alarm will be displayed until the condition return to normal.

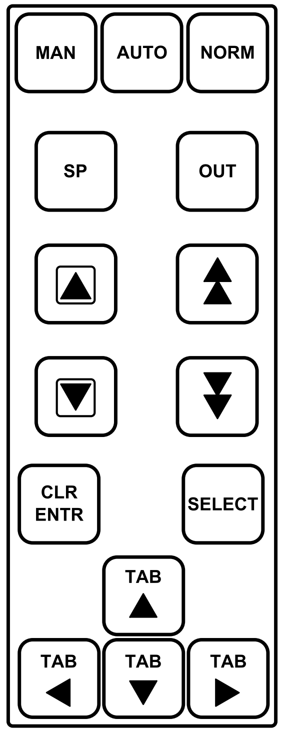
The Alarm Summary key, ALM SUMM, calls up the Area Alarm Summary Display. The backlit red or yellow LED for the Alarm Summary key lights whenever an alarm event exists in the area. The color of the LED that is illuminated depends on the severity of the alarm based on how the alarm was configured. The red LED indicates a critical alarm and the yellow LED indicates a non-critical alarm. When either one of the LEDs is flashing, it indicates an unacknowledged alarm of that type. If either one of the LEDs is lit but not flashing, it indicates that an alarm of that type is present, but has been acknowledged. The alarm status LED will go out when all alarms of that type have returned to normal.

The Alarm Annunciator key, ALMANNC, calls up the Alarm Annunciator Display.

The Unit Alarm Summary key, UNIT ALM SL/MM, calls up the Unit Alarm Summary Display and requires a Unit I.D.

3.1 Operator Control Keys

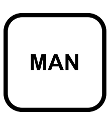
Operator control keys used to change different settings of a process controller.



Some of the operations that can be performed using these keys include:

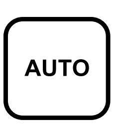
- change control statuses of the controller (manual, automatic, etc.)
- change output and set point values
- cursor movements within a graphic or group via the Tab keys.

Manual Mode Key



The Manual Mode key, MAN, places a selected controller in manual mode operation. While a controller is in MANUAL mode, the output for that controller is under direct control of the operator. In addition, depending on the configuration of the controller, it may not be possible to manipulate the set point of the instrument while it is in MANUAL.

Automatic Mode Key



The Automatic Mode key, AUTO, places a selected controller in the AUTOMATIC mode, if it has been configured for that mode. While in this mode of operation, the operator can adjust the set point of the particular controller, but cannot adjust the output of the controller. The output of the controller is calculated by a pre-configured algorithm, located internally within the controller. This pre-configured algorithm uses an operator entered set point for calculating the correct output for the controller.

Normal Mode Key

NORM

The Normal Mode key, NORM, places the selected controller in its normally configured mode of operation. This normally configured mode of operation has been predefined and configured by a technician. Under most circumstances, this mode is for an instrument that can be placed in the CASCADE mode of operation. When a controller is set to CASCADE, its set point is being calculated and altered by a different controller which is called the master controller. The instrument that receives its remote set point signal from a master controller is commonly referred to as a slave controller. When a controller is in the CASCADE mode of operation, the operator is not allowed to alter either the controller's output or its set point.

Set point Key

SP

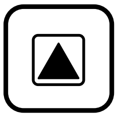
The Set point key, SP, permits set point values to be entered using the numeric keys or modified by the raise/lower keys for a selected point. If the controller is configured for set point initialization (tracking), the set point value can only be altered while the controller is in the AUTOMATIC mode of operation. This is because when a controller with set point initialization (PV tracking) is in the MANUAL mode of operation, the controller allows the set point value to "track" or follow the process variable (PV) value. With set point initialization, a controller will always switch smoothly from the MANUAL mode of operation to the AUTOMATIC mode of operation. If the controller does not have set point initialization (PV tracking), the set point can be altered while the controller is in either the AUTOMATIC or MANUAL mode of operation.

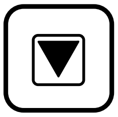
Output Key

OUT

The Output key, OUT, allows output values to be entered using the numeric keys or the raise/lower keys for a selected controller. Normally, the output of an instrument can only be altered while that controller is in the MANUAL mode of operation. With cascade control loops, if a slave controller is configured for output initialization, the output value of the master controller will "track" or follow the process variable signal of the slave controller (when the slave controller is in MANUAL or AUTOMATIC mode). With output initialization, a controller will always switch smoothly into and out of the AUTOMATIC and CASCADE modes of operation.

Digital Output and Slew Slow Keys

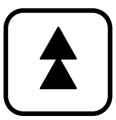


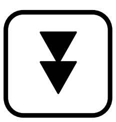


These two keys can be used in two different ways. When used with digital instruments, they act as Digital State Change keys. When used with analog instruments, they act as slow-speed raise/lower or "slew" keys. When a digital point has been selected such as a pump start/stop switch or a valve open/close switch, these up and down arrow keys correspond as ON and OFF switch. For a latching switch, the ENTER key must be pressed in order to effect the change of state. For a momentary switch, the ENTER key is not required.

When these keys are used with an analog instrument, they raise or lower the output or set point value of the selected controller/instrument by smaller increments than with the fast raise/lower keys described below. The predetermined rate of change for the slew slow keys is usually 0.1% of the instrument's range.

Slew Fast Keys



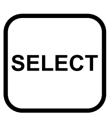


Pressing the one of the Fast Raise/Lower "Slew" keys causes the selected output or set point value of that controller/instrument to be increased or decreased at a pre-configured fast rate. If either of the keys is held down, the selected value continues to be changed at the pre-configured rate of change. The predetermined rate of change is usually defined as 1.0% of the instrument's range.

Clear Entry Key

This key is used to clear an incorrect character or unwanted entry in an entry box at any time before the ENTER key is pressed, thus removing the incorrect character or undesired change.

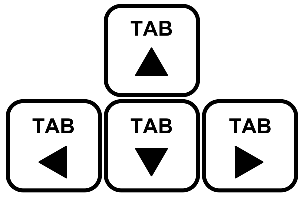
Select Key



This key is used to select an item where the cursor currently appears. If the cursor is positioned on a graphic at an instrument tag name, that instrument will appear in the instrument pad located at the bottom of the graphic. If the cursor is at an instrument set point value for a controller, a box will appear above the set point where the new value can be entered.

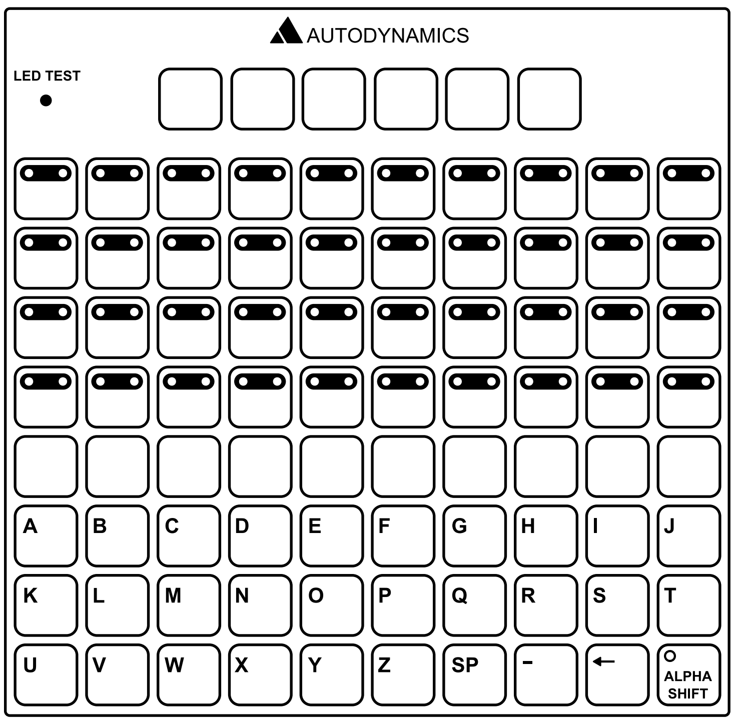
Tab Keys

These keys are used to position the cursor vertically or horizontally to any point on the display.



3.2 Process Specific Keys

These keys are used to call different graphics on the screen. There are user defined function keys in this section. If in fact, the desired schematic has been configured for one of the keys.in this case, pressing the key will call up the display immediately.

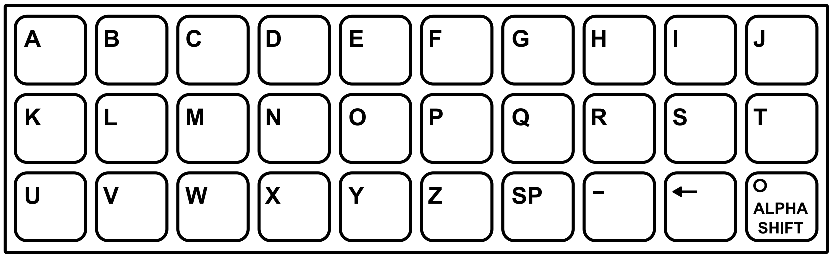


Led Test Key

This key is used to test all LED’s on the keyboard.

Alphabet Key Set Keys

These keys used to enter alphabetical letter

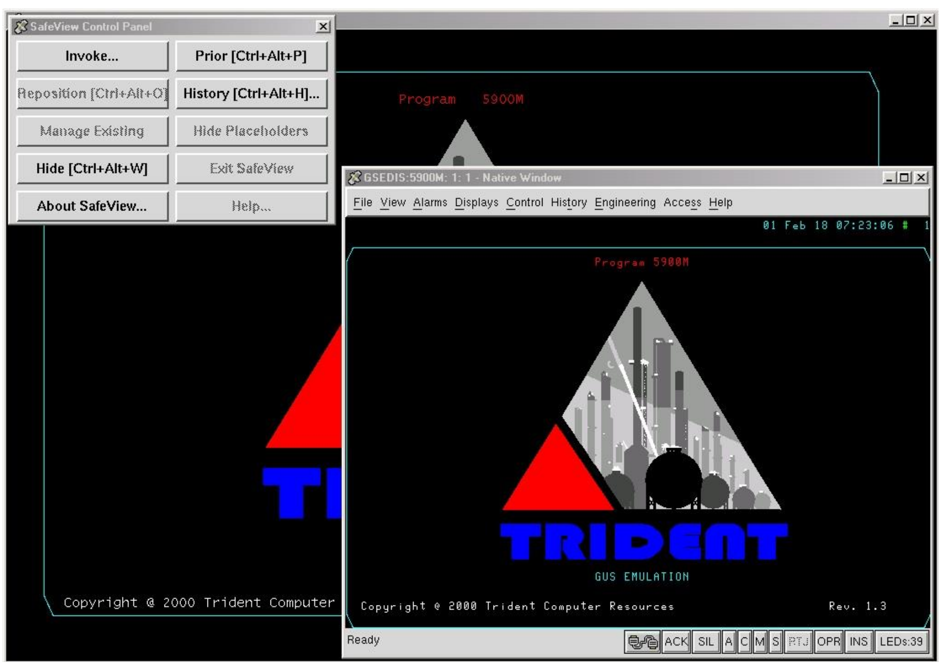


4. How to use Operator Display

When a simulation program is first started on the emulated GUS Operator Station, three (3) windows will appear on the Operator Station Screen. They are

- **Safe View Control Panel window**
- **GUS Native Window**
- **GUS Graphic window**

Refer to Figure for an illustration of the three above mentioned windows as they appear upon first starting up a simulation program.



The GUS Graphic window will always come up in the background with the Safe View Control Panel window and the GUS Native Window on top of it. Normally, the Safe View Control Panel window will appear in the upper left hand corner of the Operator Station screen and the GUS Native Window located below and to the right of the Safe View Control Panel window.

4.1 Safe View Control Panel Window

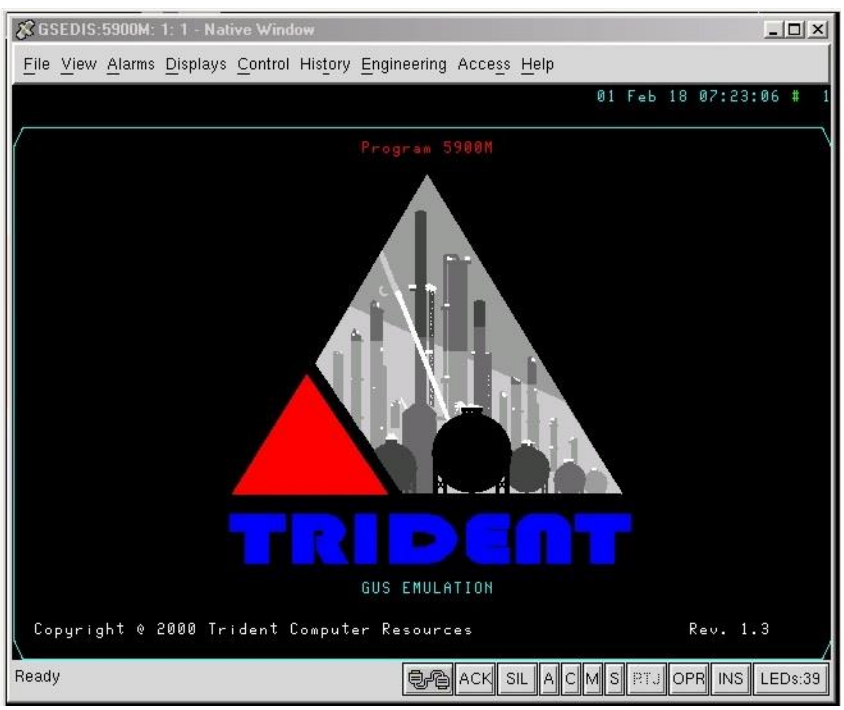
The Safe View Control Panel Window is created as a sub-window of the GUS Native Window, and by default, appears initially in the top left hand corner of the CRT screen. It can be relocated on the CRT screen separately from the GUS Native Window, but is minimized when the GUS Native Window is minimized. The Safe View Control Panel window contains ten (10) targets that provide various display call up mechanisms, which can be useful to the Operator in the manipulation of the simulated program. Refer to Figure on the next page for an illustration of the Safe View Control Panel Window.

Basically, the Safe View Control Panel Window allows for easy access for all customized graphics (schematics) that have been developed for your simulation program. In this manner, all program graphics can be easily accessed, even when they have not been configured using one of the configurable keys on the emulated GUS Operator Station keyboard.

4.2 GUS Native Window

This window contains Group display, Detail display, Alarm Summary display, etc.

Using the GUS Native Window, all operator functions can be performed on the simulated process. Refer to Figure for an illustration of the GUS Native Window as it first appears upon the initial startup of a simulation program.



The GUS Native Window can be divided into four distinct parts. These parts are

- title bar and window border
- menu bar
- display area
- status bar

Each part will be discussed in the following sections.

4.2.1 Title bar and window border

The window border is a colored rectangle outline around the outside of the window. It changes color to indicate input focus, meaning that it is now possible to make changes within this window.

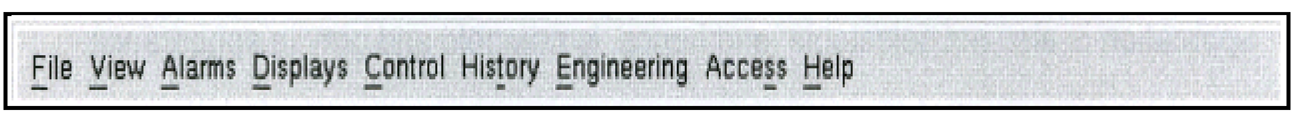
The Title Bar is a colored bar along the top of the GUS Native Window, and stretches the full length of the window. Refer to Figure for an example of the GUS Native Window title bar.

WARNING!!!

Do not attempt to close this window. If it is closed, all operations from the GUS Native Window will be lost. The only way to restart the GUS Native Window is to reboot the computer running the Operator Station. In order to do this with no upset to the simulator system, the program running must be terminated and then restarted once the Operator Station reboot is complete.

4.2.2 Menu bar

Located directly below the title bar of the GUS Native Window is the Menu Bar. The pull-down menus are: File, View, Alarm, Display, Control, History, Access, and Help.



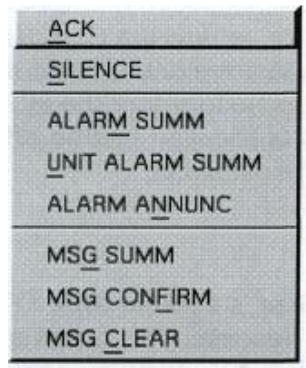
Those which are configured will be discussed

To the right of the View pull-down menu on the Menu Bar is the Alarm pull-down menu. From this menu, the following applications can be accessed:

- ACK
- SILENCE
- ALARM SUMM
- UNIT ALARM SUMM

- ALARM ANNUNC
- MSG SUMM
- MSG CONFIRM
- MSG CLEAR

Refer to Figure for an illustration of the Alarm pull-down menu.



4.2.3 Acknowledge

The first application in the alarms pull-down menu is the ACKNOWLEDGE application. This application is used to acknowledge Operator Station (console) alarms. Once used, the alarms that are showing on the screen will be acknowledged, meaning that they will no longer blink. This application works just like the ACKNOWLEDGE key on the Operator Station keyboard.

4.2.4 Silence

The next application in the Alarms pull-down menu is SILENCE. This application is used to silence the audible alarm from the Operator Station. This application works just like the SILENCE key on the Operator Station keyboard.

4.2.5 Alarm Summary

The application after SILENCE is ALARM SUMMARY. This application is used to bring up the Area Alarm Summary display. This application works just like the ALARM SUMMARY key on the Operator Station keyboard.

4.2.6 Unit Alarm Summary

The next application, UNIT ALARM SUMMARY, calls up the specified unit alarm display. Not only does this application need to be selected, but the unit number also has to be entered in order to display the unit alarm summary. This application works just like the UN IT ALARM SUMMARY key on the Operator Station keyboard.

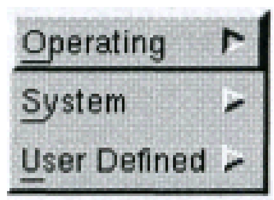
4.2.7 Alarm Annunciator

Below the UNIT ALARM SUMMARY application is the ALARM ANNUNCIATOR application. This application is used to call up the Alarm Annunciator display. This application works just like the Unit Alarm Summary key on the keyboard.

The next pull-down menu is Displays, which has three applications, all with sub menus. These applications are

- Operating
- System
- User Defined

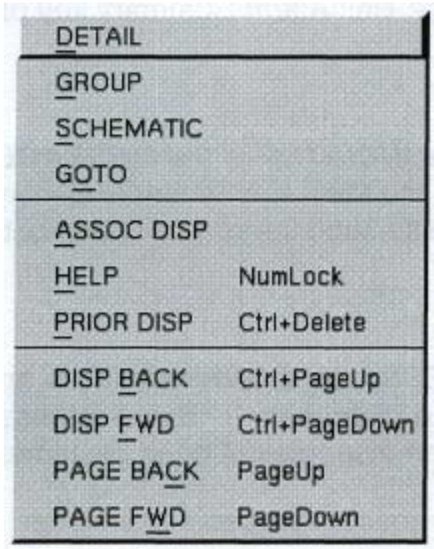
Refer to Figure for an illustration of the Displays pull-down menu.



The first application, Operating, has a sub menu attached to it. Selecting the Operating application will bring up the Operating sub menu. This sub menu has the following applications associated with it:

- DETAIL
- GROUP
- SCHEMATIC
- GOTO
- ASSOCIATED DISPLAY
- HELP
- PRIOR DISPLAY
- DISPLAY BACK
- DISPLAY FORWARD
- PAGE BACK
- PAGE FORWARD

Refer to Figure for an illustration of the Operating sub menu.



The first application in the Operating sub menu is DETAIL. This application is used to call up the detail of an instrument that has been selected. If no instrument has been selected, a prompt will appear asking for the instrument tag name. Once the instrument tag name has been inputted and the ENTER key used, the instrument's detail will be displayed. This application works just like the DETAIL key on the Operator Station keyboard.

The next application, GROUP, displays the requested group. In order to display a group, use the GROUP application, enter the group number, and then use the ENTER key. The desired group will be displayed. This application works just like the GROUP key on the Operator Station keyboard.

The next application, SCHEMATIC, displays the requested schematic. In order to display a schematic, use the SCHEMATIC application, enter the schematic name, and then use the ENTER key. The desired schematic will be displayed. This application works just like the SCHEMATIC key on the Operator Station keyboard.

The next application in the Operating sub menu is GOTO. This application allows the Operator to go to select a particular point or slot in a group. To select the slot, use the GOTO application, enter the slot number, and then use the ENTER key. The desired slot will be highlighted (selected). This application works just like the SLOT key on the Operator Station keyboard.

Following the GOTO application is the ASSOCIATED DISPLAY application. If a display has been configured with an Associated Display, using the ASSOCIATED DISPLAY application will bring up that display. If no associated display has been configured, using this application will have no effect on the simulator. This application works just like the ASSOCIATED DISPLAY key on the Operator Station keyboard.

When PRIOR DISPLAY is pressed this will bring up the last display viewed prior to the present display. This application works just like the PRIOR DISPLAY key on the Operator Station keyboard.

Following the PRIOR DISPLAY application is the DISPLAY BACK application. This application is used to display the next lower-numbered display of the same display type, such as groups or schematics. When the lowest numbered display appears and this application is used again, the highest numbered display will appear. This application works exactly like the DISPLAY BACK key on the Operator Station Keyboard.

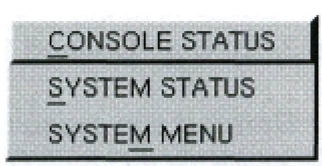
Following the DISPLAY BACK application is the DISPLAY FORWARD application. This application is used to display the next higher-numbered display of the same display type, such as groups or schematics. When the highest numbered display appears and this application is used again, the lowest numbered display will appear. This application works exactly like the DISPLAY FORWARD key on the Operator Station Keyboard.

The next application is PAGE BACK. This application is used to display the next lower-numbered page of the same type, such as alarm pages. When the first alarm page appears and this application is used, the highest numbered alarm page will appear. If there is only one alarm page, using this application will have no effect on the simulator. This application works exactly like the PAGE BACK key on the Operator Station Keyboard.

The final application in the Operating sub menu is PAGE FORWARD. This application is used to display the next higher-numbered page of the same page type, such as alarm pages. When the last alarm page appears and this application is used, the first alarm page will appear. If there is only one alarm page, using this application will have no effect on the simulator.

This application works exactly like the PAGE FORWARD key on the Operator Station Keyboard.

The next application in the Displays pull down menu is System, which also has a sub menu attached to it. When this application is selected, the System sub menu appears. The following applications can be accessed from the System sub menu: CONSOLE STATUS, SYSTEM STATUS, and SYSTEM MENU. Refer to Figure for an illustration of the System sub menu.

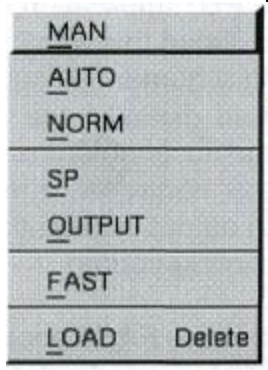


The last application in the System sub menu is SYSTEM MENU. When this application is used, the System Status display appears. This application works exactly like the SYSTEM MENU key on the Operator Station keyboard.

The next pull down menu available from the Menu bar is Control. Selecting this application reveals a pull down menu with the following applications:

- MAN
- AUTO
- NORM
- SP
- OUTPUT
- FAST
- LOAD

Refer to Figure for an illustration of the Control pull down menu.



The first application in the Control pull down menu is MAN. Selecting this application allows the operator to place the selected point in the GUS Native Window in the MANUAL mode of operation. This application works exactly like the MAN key on the Operator Station keyboard.

The next application in the Control pull down menu is AUTO. Selecting this application allows the operator to place the selected point in the GUS Native Window in the AUTOMATIC mode of operation. This application works exactly like the AUTO key on the Operator Station keyboard.

Following the AUTO application is the NORMAL application. This application is used to place the selected point in the GUS Native Window in the NORMAL mode of operation. This is the mode of operation that the instrument normally resides in. For slave controllers, the normal mode of operation is CASCADE. This application works exactly like the NORM key on the Operator Station keyboard.

The next application in the Control pull down menu is SP. This application is used to adjust the set point of a controller. Once this application has been selected, the set point needs to be adjusted, either by entering a numerical value for the set point, or by using one of the ramp keys. If the new set point is being entered digitally, the ENTER key must be used from the Operator Station keyboard in order to enable the change to the controller's set point. Also not that if the controller is configured with PV tracking and the controller is in MANUAL, it is not possible to alter the controllers set point as it has been configured to automatically track the controller's PV while in MANUAL. This application works exactly like the SP key on the Operator Station keyboard.

After the SP application is the OUTPUT application. Using this application allows changes to analog or digital output values. Once this application is used, the instrument's output can be changed either by entering a numerical value, or by using one of the ramp keys. If the new output is being entered digitally, the ENTER key must be used from the Operator Station keyboard in order to enable the output change. Also note that if the controller is configured as a master controller, it may not be possible to alter its output value if it has been configured with output initialization. This application works exactly like the OUT key on the Operator Station keyboard.

4.3 Gus native window display area

All the process schematics/graphics will be displayed on this window.

4.3.1 Status bar

The message area on the left side of the status bar shows Ready when the GUS Native Window is ready for user input. When an item is selected from one of the menu pull down menus, a description of the selected menu item is shown in this area.
The targets located on the right half of the Status Bar contains the following applications: Connect/Disconnect, ACK, S/L, A, C, M, S, R7J, OPR, INS, and LEDs:39. These pushbuttons will be discussed in the following paragraphs.

The first target on the right hand side of the GUS Native Window Status Bar is a symbol representing Connect/Disconnect This target disconnect is used to either connect or disconnect the GUS Native Window from the Universal Station (US). The target, as displayed on the GUS Native Window Status Bar indicates Connect. This Connect icon will always be present as the Disconnect action has not been implemented on the emulated GUS Operator Station. Therefore, selecting this target will have no effect on the operation of the GUS Native Window or the Operator Station.

The next target on the GUS Native Window Status Bar is ACK. This target is used to acknowledge all console alarms and messages. This target works exactly like the ACK key found on the emulated Operator Station keyboard.

The target following ACK is S/L. This target is used to silence all audible alarms on the console. This target works exactly like the S/L key on the emulated Operator Station keyboard.

Following the S/L target is the A target. Using this target calls up the Area Alarm Summary display on the GUS Native Window. This target works exactly like the ALM SUMM key on the emulated Operator Station keyboard.

4.3.2 Operations

This chapter deals with the operations that are possible from the displays in both the GUS Native Window Displays and the GUS Graphical Displays. Not much time will be spent with the operations from the GUS Graphical Displays as they are completely dependent on how the graphics were built and what features were incorporated in them. Since the majority of the operational windows are accessed from the GUS Native Window, these will be discussed first. Where possible, illustrations have been provided to aid in the discussion of these operations.

At the top of every display on the GUS Native Window are two lines that serve the same purpose no matter what display is in the GUS Native Window. In the upper left hand corner of the display is the prompt line, which is used to request the operator to perform some action. Immediately below the prompt line is the place where operator error messages can be displayed. In the upper right hand corner is the logical display number. This number refers to the display to which the keyboard that called up the display is attached. There are two ways to select targets on a display:

- Using a key assigned on the emulated GUS Operator Station keyboard (see keyboard description).

- Via a mouse,

A mouse/trackball can also be used to select an item by positioning the pointer to the desired preconfigured target and pressing the left button to select it.

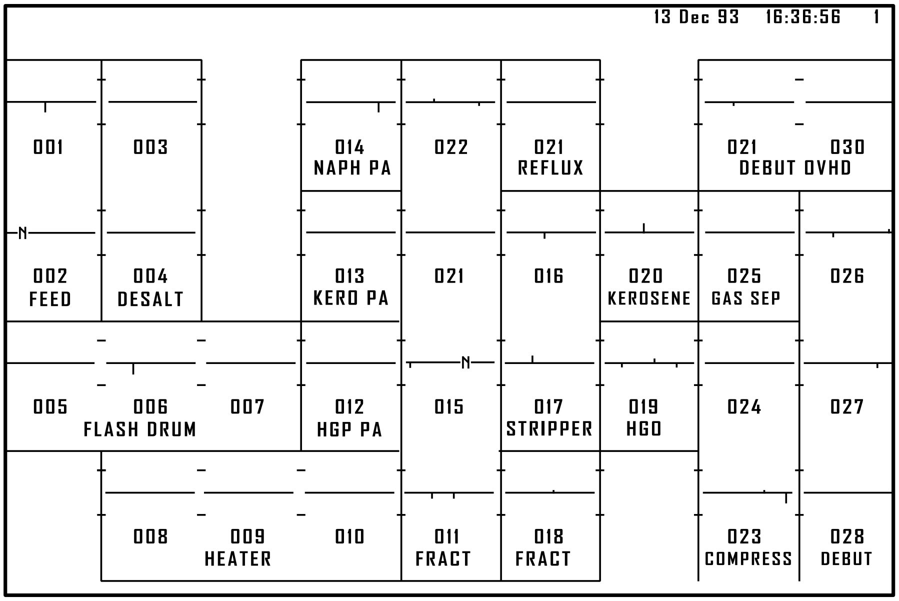
4.3.3 Overview Display

The purpose of the Overview Display is to:

- Show a deviation (PV from SP) bar-graph of all points in up to thirty-six (36) process groups,
- Indicate points in alarm in up to thirty-six (36) process groups.

The method of calling up the Overview Display is to press the user-defined function key preconfigured for that purpose.

Normally, one of the six (6) configurable keys in the top row on the left hand side of the keyboard is used. Refer to Figure for an example of a typical Overview Display.



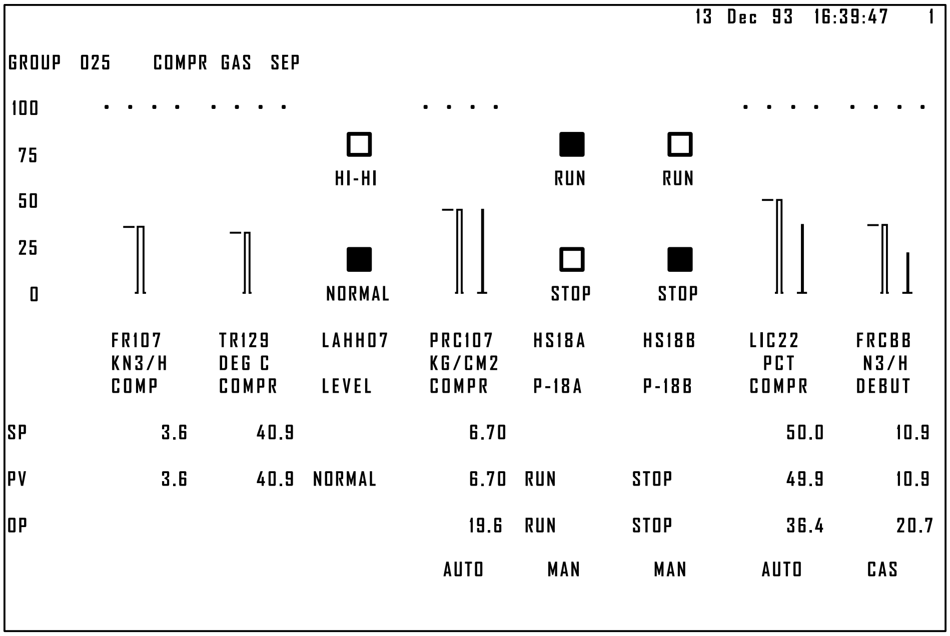
Any deviation from set point for an analog instrument is displayed as a vertical line propagating above or below the horizontal line for each group. The further above or below the horizontal line the vertical line is, the greater the deviation from set point. An M in the horizontal line indicates that a digital instrument is in MANUAL, and an A indicates that an instrument is in alarm.

4.3.4 Group Display

The primary purpose of the Group Display is to:

1) monitor and manipulate the primary operating parameters (such as SP, PV, and MODE) of up to 8 points (tags or loops),
2) call up trends,
3) show bar-graphs of analog SP, PV, and OP; and show status lamps (filled/empty boxes) for digitals, flags, lights, and switch points.

A Group Display can be called up using the emulated GUS Operator Station keyboard by pressing the Group key or to press a preconfigured key for the group. If the GROUP key is used to access a group, the operator will be prompted to enter the number of the desired group which can be entered using the numeric keys to enter the group number and then pressing the ENTER key. Refer to Figure for an example of a typical Group Display.



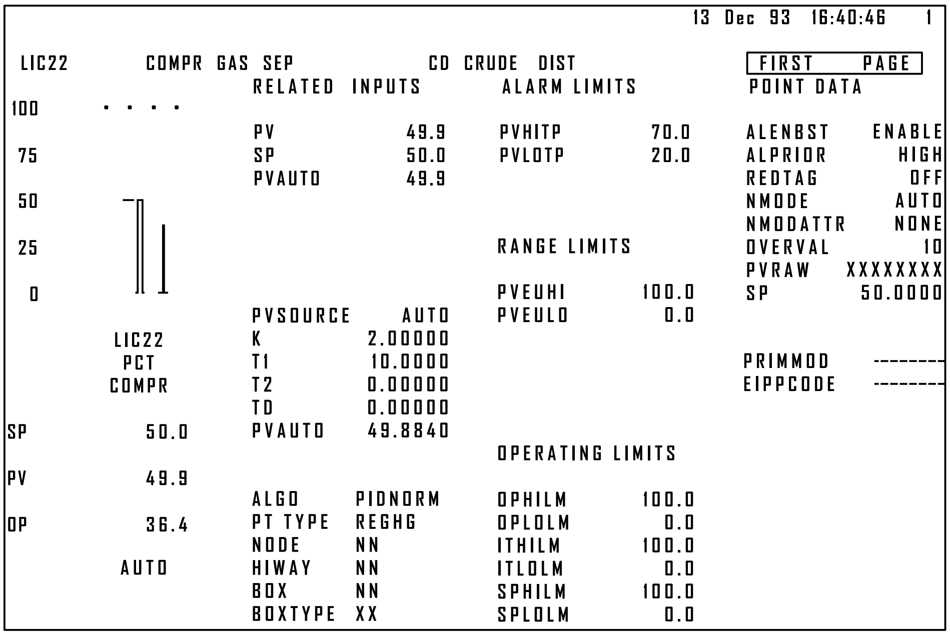
One other way to access a Group Display is to touch the baseline (horizontal line) of the requested group from the Overview Display. Generally, a User-defined Function key will be assigned to each group. In this case, pressing the appropriate key will call up the display immediately. Using this method does not require the use of the ENTER key.

To make a change to a controller's set point or output, first select the desired instrument. Then either use the desired key, SP or OUT, where upon a rectangular box will appear above the desired item to be changed. Finally change the value either by using the ramp keys or by entering the new value using the numerical keypad and then using the ENTER key. The desired change will take effect. Another method of changing a controller/instrument's SP or PV is to select the data value to be changed. The change box will appear above the item to be changed.

To make a change to a digital instrument such as a switch, first select the name of the desired instrument in order to "focus" on it. Next, use the OUT key and either the “A “or the” T “for the desired change. Finally, use the ENTER key in order to affect the change. All of the above mentioned keys can be found on the emulated GUS Operator Station keyboard.

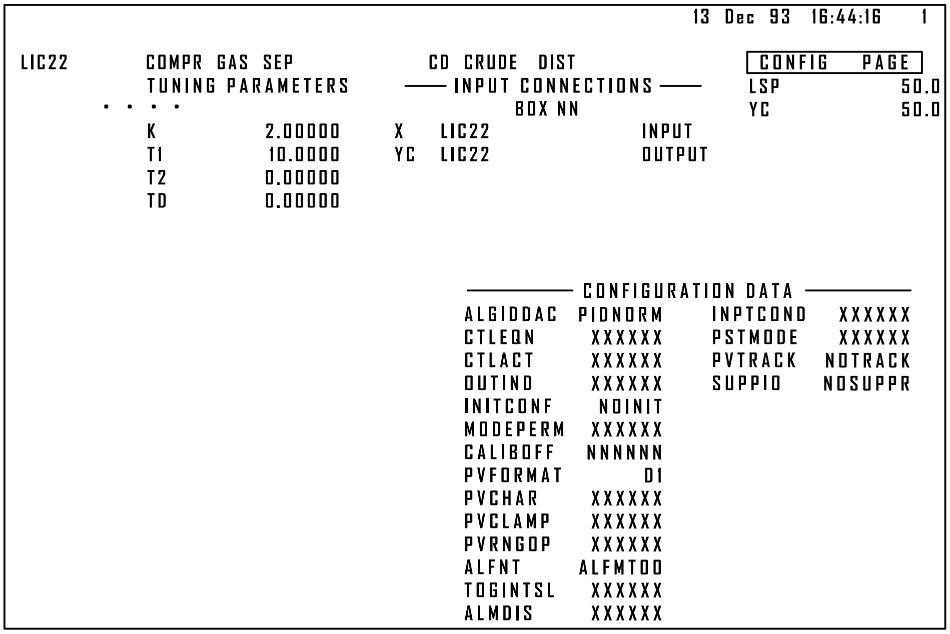
4.3.5 Detail Display

The Detail Display is a multi-page display that allows the operator to monitor and manipulate parameters of a single point. Depending on the instrument type, this display may contain more than one page. Refer to Figure for an example of the first page of a Detail Display for an analog instrument.



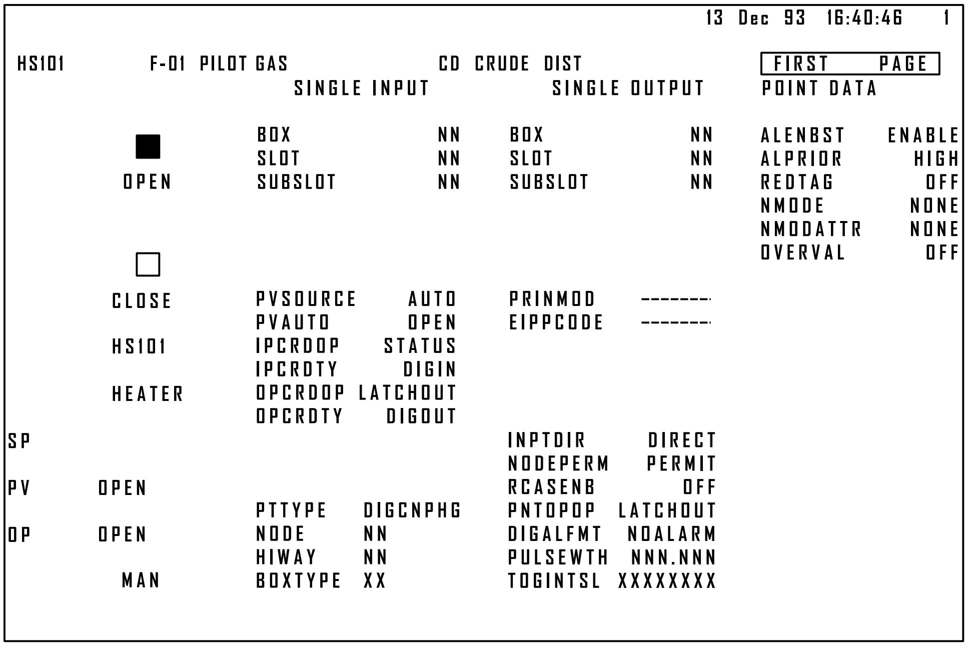
To call up a Detail Display for a point that has been selected from a group display, press the DETAIL key. If the desired point has not been selected, go to the Group Display containing the point, press the SLOT key, enter the slot number (position) of the point using the numerical key pad and press the ENTER key. The instrument can also be selected using the touch screen (if one has been provided) or the mouse and the left mouse button.

Once the desired instrument has been selected, access the detailed information for this point by pressing the DETAIL key. Refer to for an example of the second page of an analog detail display.



A Detail Display for an instrument can also be called up from any display by pressing the DETAIL key. At this point, a data entry box will appear prompting the operator to enter the desired instrument's tag name. Once the instruments tag name has been properly entered, use the ENTER key in order to display the instruments Detail Display. If an instrument has been configured with more than one Detail Display page (such as controllers), the other page(s) can be viewed by using either the PAGE BACK or the PAGE FORWARD keys on the emulated GUS Operator Station keyboard.

There is some information on the instrument's Detail Display page(s) that can be accessed. Specifically, for controllers, the instrument's tuning parameters, setpoint, and output can be accessed. For both indicators and controllers, their alarm settings can be altered. For digital instruments, alarm settings can also be altered. It is also possible to change the position of switches from the instrument's Detail Page. For an example of a Detail Display Page, refer to Figure the next page.

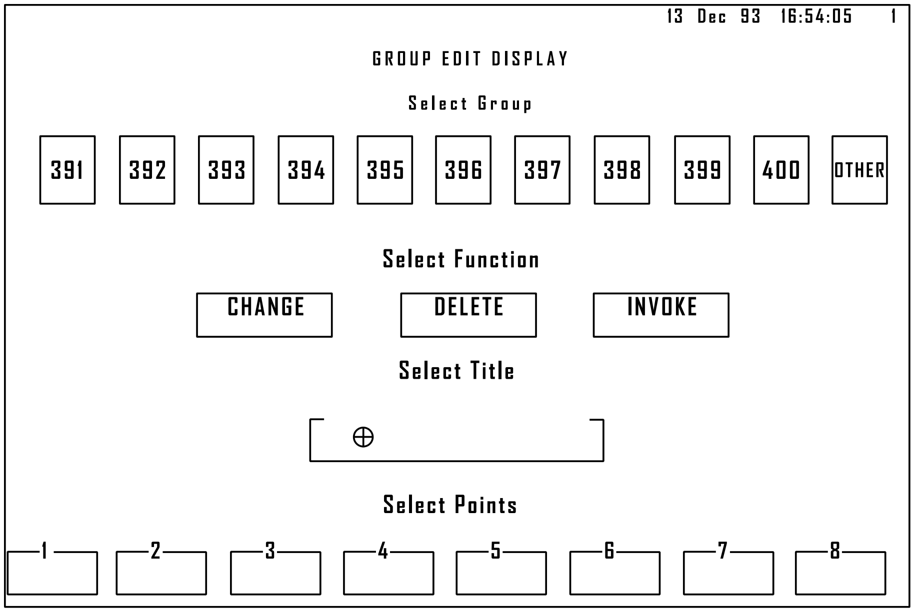


4.3.6 Group Edit Display

The Group Edit Display can be used by the operator to configure up to ten groups of instruments in addition to the groups preconfigured with the simulator. Refer to Figure for an example of the Group Edit Display page. This feature is handy when the operator wishes to have certain instruments that were originally configured in separate groups to be on the screen at the same time.

The Group Edit Display is accessed by pressing the SYST MENU key (System Menu) on the emulated GUS Operator Station keyboard. The System Menu page will appear. Next, using the mouse, or tab keys, select the small box to the left of the menu item GROUP EDIT DISPLAY.

To add or change a group, select a group number box using the mouse, or keyboard tab keys. Three boxes will appear; CHANGE, DELETE, and INVOKE. A group name and eight slot boxes will also appear. Select the CHANGE box. If this is a new group or the name of the group is to change, select the group name box and enter the group name using the keyboard.

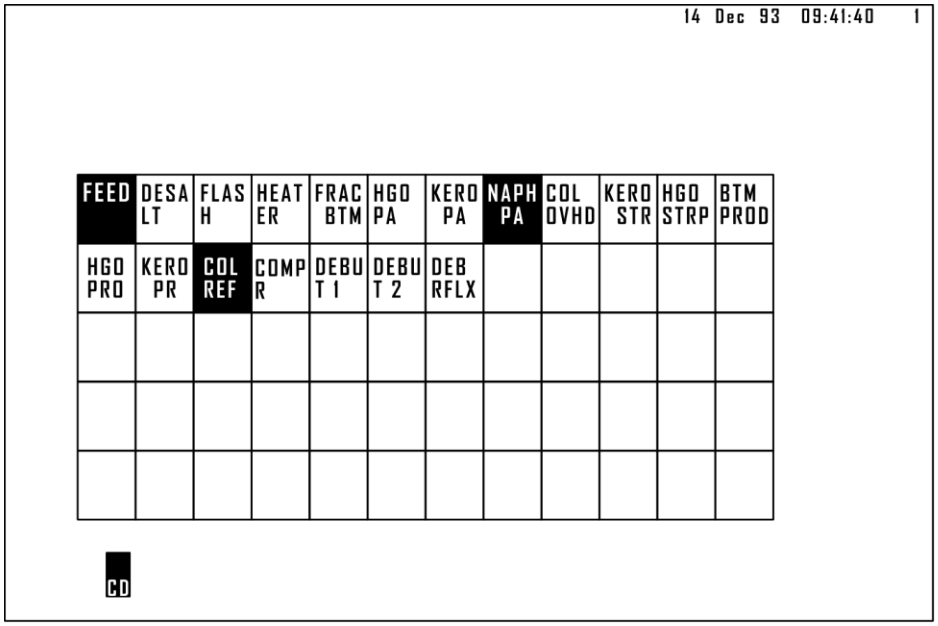


Then configure each slot in the group by selecting the slot and entering the tag name of the instrument to be displayed in that position in the group.

To delete a group (from 391 to 400 only) go to the Group Edit Display page, select the group number box, select the DELETE box. To call up a new group display (from 391 to 400 only) go to the Group Edit Display, select the new group number box and select the INVOKE box. Once a new group has been configured, it can also be called up using the GROUP key on the emulated GUS Operator Station keyboard, entering the group number, and then using the ENTER key. The desired group will be displayed.
The OTHER box in the Group Edit Display is not supported.

4.3.7 Alarm Annunciator Display

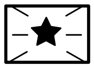
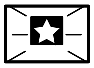
The Alarm Annunciator Display simulates an alarm annunciator panel on a one page display and annunciates point alarms for up to 600 points in the area. The Point Alarm Annunciator Box can also be configured with an associated display. Refer to Figure for an example of an Alarm Annunciator Display.



This display is called up by pressing the ALM ANNC (Alarm Annunciator) key, located on the emulated GUS Operator Station keyboard. Each alarm box represents alarms for up to 10 points.

Box Title Behavior	**Background Behavior**	**Alarm Priority**	**Acknowledgement State**	**Unit Status**
YELLOW	STEADY BLACK	-	-	INHIBITED or DISABLED
RED (reverse video)	BLINKING RED	EMERGENCY	UNACKNOWLEDGED	ASSIGNED & ENABLED
YELLOW (reverse video)	BLINKING YELLOW	HIGH	UNACKNOWLEDGED	ASSIGNED & ENABLED
RED (reverse video)	RED	EMERGENCY	ACKNOWLEDGED	ASSIGNED & ENABLED
YELLOW (reverse video)	YELLOW	HIGH	ACKNOWLEDGED	ASSIGNED & ENABLED
GREEN	STEADY BLACK	-	-	ASSIGNED & ENABLED: NO ALARMS

Annunciator Box Behavior

INDICATOR	MEANING
 (Blinking)	Unacknowledged Alarm
 (Reverse-Video Blinking)	Condition causing alarm returned to normal before acknowledgement (See Note)
BLANK (No Asterisk)	Acknowledged alarm (alarm condition HAS NOT returned to normal) (See Note)
Note: Acknowledged alarm line disappears and remaining alarm lines move up when condition causing alarm returns to normal	

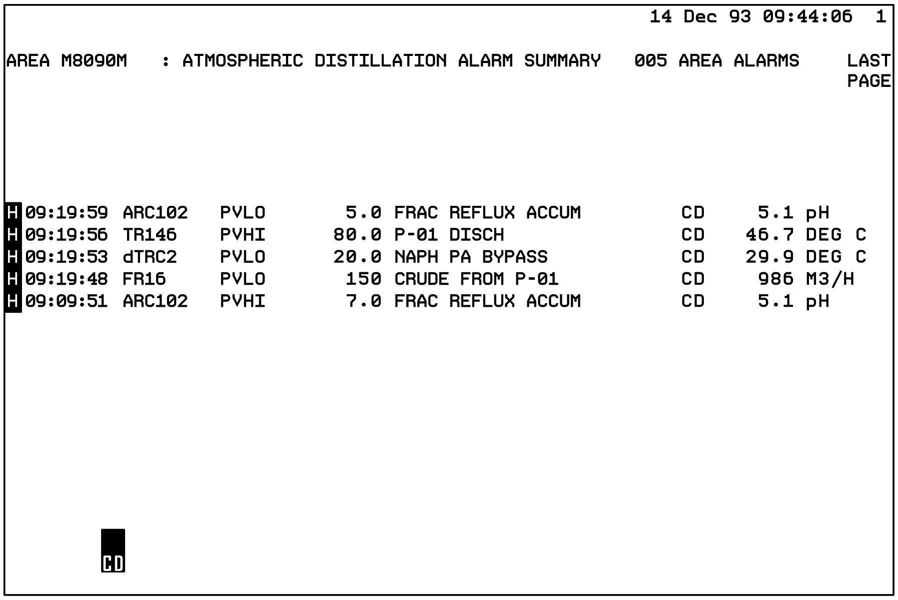
Acknowledgement State Indicators

INDICATOR	MEANING
PVHI	Process Variable Greater Than High PV Trip Point
PVHH	Process Variable High Alarm
PVLO	Process Variable Less Than Low PV Trip Point
PVLL	Process Variable Low Alarm
DEVHI	Setpoint Greater Than High Deviation Trip Point
DVHH	Setpoint High Deviation
DEVLO	Setpoint Less Than Low Deviation Trip Point
DVLL	Setpoint Low Deviation
FLAG	BC Flag Change Alarm
CHGOFST	Digital Change of State
Digital State Descriptors	Digital States

Alarm Indicators

4.3.8 Area Alarm Summary Display

The five (5) page Area Summary display shows up to one hundred (100) of the most recent Emergency and High-Priority alarms in the area, twenty (20) alarms on each page. New alarms appear on the top of Page 1, pushing older alarms further downward. If the number of alarms exceeds twenty (20) alarms, the older alarm will move to the next page. Below the alarms list are Unit Annunciator Boxes showing alarm status of all Units in the Area. The boxes also act as targets to allow the operator to call up the Unit Alarm Summary Displays. Refer to Table 1 in Appendix A for meaning of the box indications. Refer to Figure for an example of an Area Alarm Summary Display.



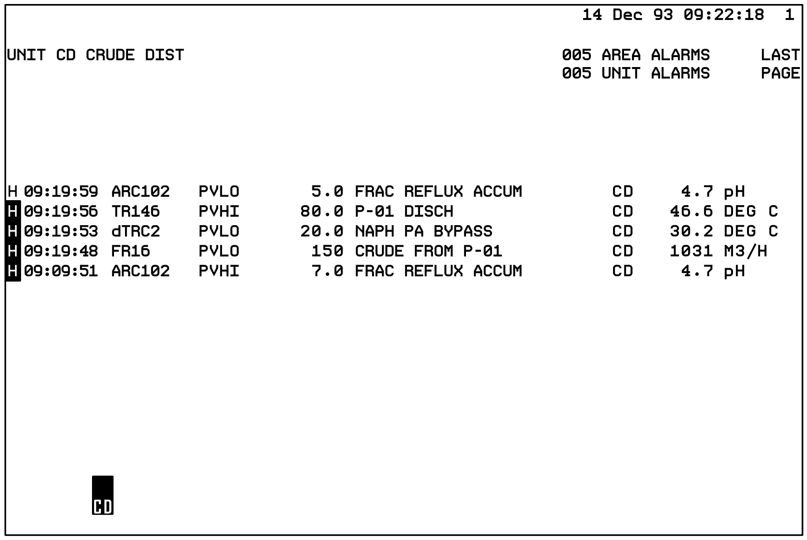
The Area Alarm Summary Display is called up by pressing the ALM SUMM (Alarm Summary) key from the emulated GUS Operator Station keyboard. The first page of alarms contains the TWENTY (20) most recent alarms. Each alarm contains the following information from left to right: the alarm priority and acknowledgement state, the time of the alarm; the tag name; the alarm indicator the alarm point value; the instrument description; the unit ID; and the current process variable value with engineering units.

The number of alarm pages is displayed in the upper left hand corner. If there are more than one alarm page, the other alarm pages can be accessed using either the PAGE FORWARD or the PAGE BACK keys on the emulated GUS Operator Station keyboard until the desired alarm page is displayed.

4.3.9 Unit Alarm Summary Display

This five (5) page display shows up to one hundred (100) of the most recent High and Low Priority alarms in the specified unit. As with the Area Alarm Summary Display pages, The Unit Alarm Summary Display also has twenty (20) alarms to a page. This display is very similar to the Area Alarm Summary Display except that it focuses in on one unit in the area, not the entire area.

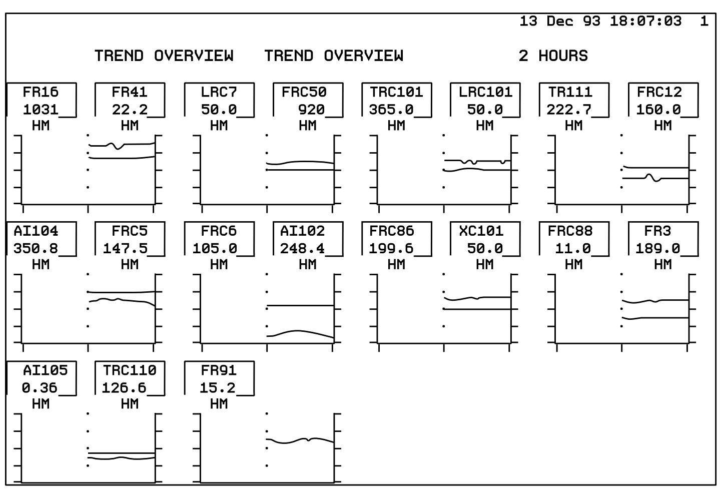
As new alarms occur, they appear on the top of alarm page #1, and the older alarms are pushed downward. If more than twenty (20) alarms are on a page, the oldest alarm is pushed to the next page. Below the alarms list are Unit Annunciator Boxes showing alarm status of all Units in the Area. The boxes also act as targets to allow the operator to call up the other Unit Alarm Summary Displays. At the upper right hand side of the screen is displayed the total number of alarms in the unit. Refer to Figure for an example of a Unit Alarm Summary Display.



The Unit Alarm Summary Display is called up by pressing the UNIT ALM SUMM (Unit Alarm Summary) key located on the emulated GUS Operator Station keyboard. The first page of alarms will contain the twenty (20) most recent alarms. Each alarm contains the following information from left to right: the alarm priority and acknowledgement state the time of the alarm; the tag name for the instrument in alarm; the alarm indicator the alarm value; the instrument descriptor; the unit ID; and the current process variable value with engineering units.

4.3.10 Area Trend Display

The Area Trend Display is a function that if so preconfigured, can trend up to twenty-four (24) analog points in an area for the last two (2) to eight (8) hours. The display contains up to twelve (12) graphs with each graph having one (1) or two (2) Process Variable traces. A user defined function button is used to call up the Area Trend Display. Refer to Figure for an example of an Area Trend Display.

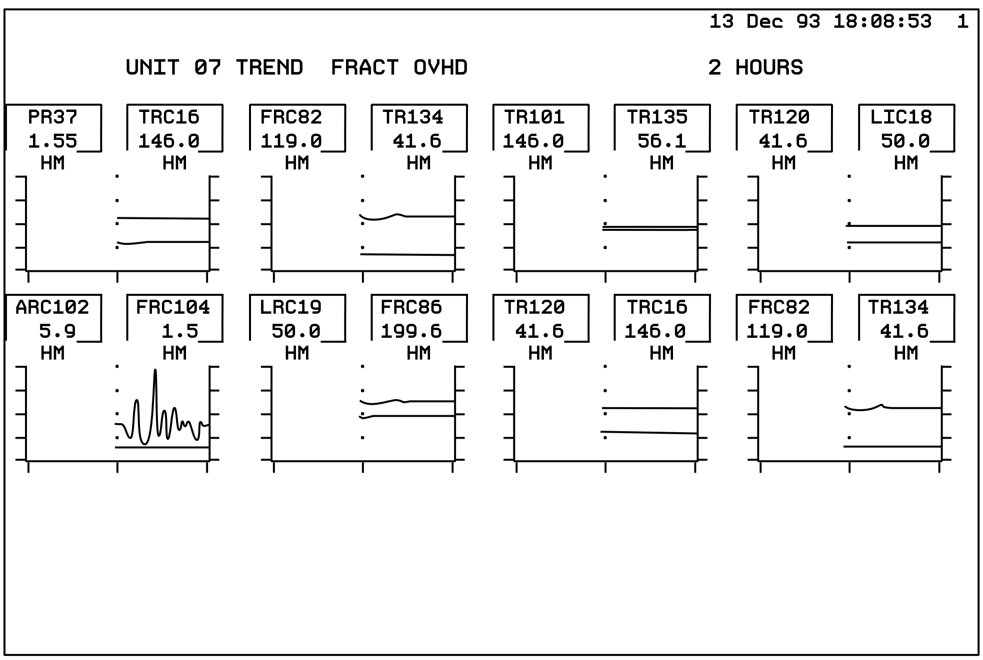


The first line of the display contains the area title and the time base for the trends. Each graph shows the trend of the Process Variable(s) in 0-100% of scale for the duration of the time base. Above each graph are one or two boxes that will display the tag name and current value of each process variable displayed on the graph.

4.3.11 Unit Trend Display

The Unit Trend Display is a function that if so preconfigured, can trend up to twenty-four (24) analog points in a specified unit for the last two (2) to eight (8) hours. The display contains up to twelve (12) graphs with each graph having one or two Process Variable traces.

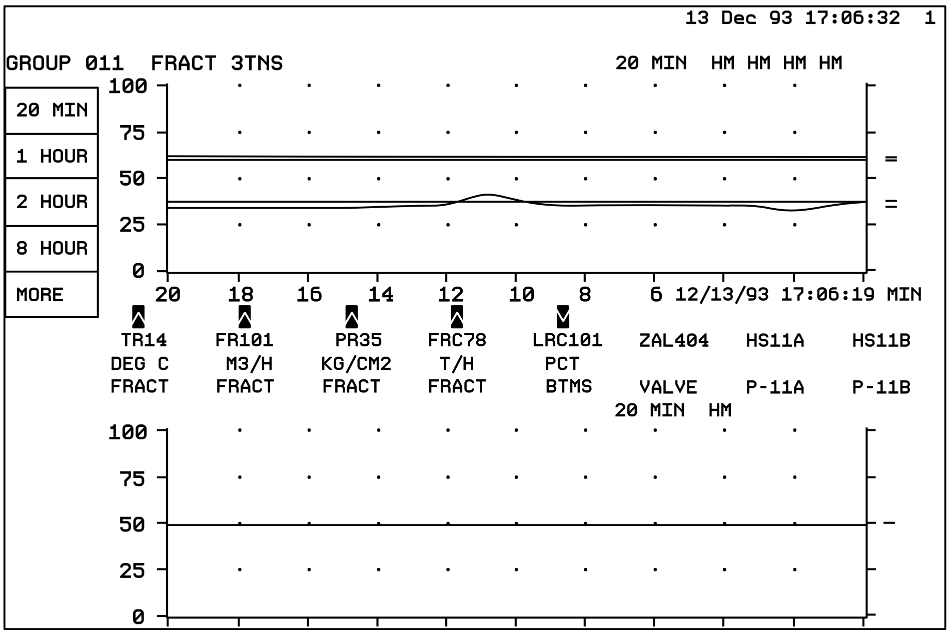
The Unit Trend Display is called up using the emulated GUS Operator Station keyboard by pressing the UNIT TREND key, entering the Unit ID, and then pressing the ENTER key. Refer to for an example of a Unit Trend Display.



The first line of the display contains the Unit ID and title as well as the time base for the trends. Each graph shows the trend of the Process Variable(s) in 0-100% of scale for the duration of the time base. Above each graph are one or two boxes that will display the tag name and current value of each process variable displayed on the graph.

4.3.12 Group Trend Display

The Group Display is used to show trend graphics for up to eight (8) process variables in the Group Display that is displayed on the GUS Native Window screen. Points can be selected for trending on the group display or a trend can be preconfigured to be displayed whenever the TREND key is pressed on the emulated GUS Operator Station keyboard with no tag selected. To display a Group Trend, call up the group containing the analog point (instrument) to be trended, select the point (instrument), and then press the TREND key. Refer to Figure for an example of a typical Group Trend Display.

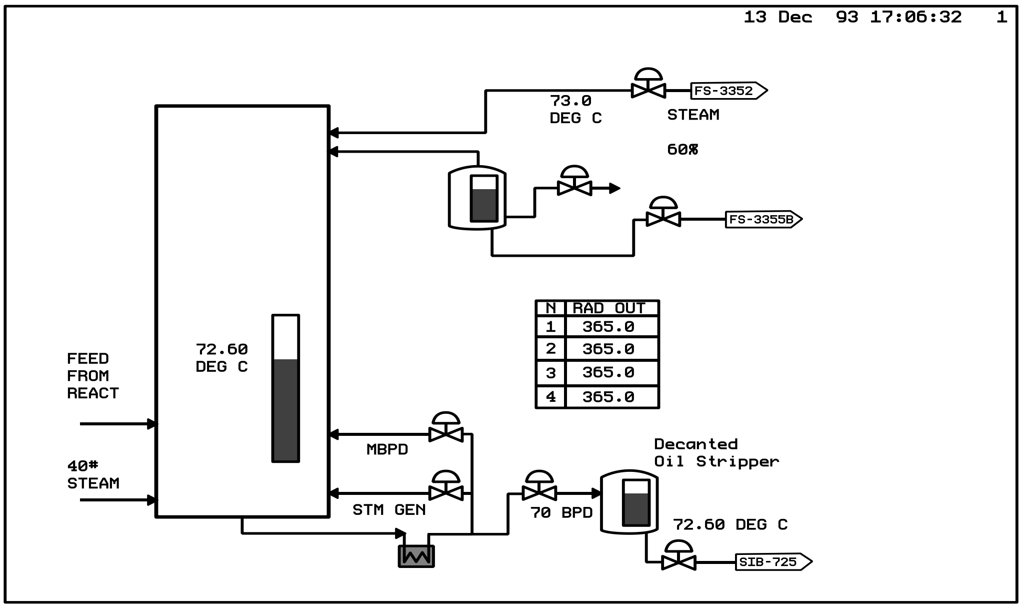


The trend for that point will be displayed on the top half of the screen. Repeating this procedure will display on the lower part of the screen the 5th through 8th points in the group.

To the left of the graph are four targets for the purpose of changing the time base of the trend. To change the trend time scale, select the target that represents the desired new time base. In order to display the Y-axis scale for a specific point in engineering units, select the point (instrument) while the point is trending. The engineering units for that point will appear to the left of the normal 0 to 100% scale. To return to the group display, press the PRIOR DISP (Prior Display) key from the emulated GUS Operator Station keyboard once if only one trend graph is displayed or twice if two trend graphs are displayed.

4.4 GUS Graphic Window Display

The purpose of the GUS Graphic Window Display is to show the process information in custom graphic format. Schematics, bar-graphs, pie-charts, and operating instructions are typical of this display. This display allows process parameters to be changed and start-up of preconfigured action procedures (through targets). Refer to Figure for an example of a typical GUS Graphic Window display.



A Schematic Display can be called up in the GUS Graphic window using several different methods. First, the operator can press the SCHEM (Schematic) key from the emulated GUS Operator Station keyboard. The operator will then be prompted to enter the name of the schematic. The schematic name can be entered using the alphabetic keys and the numerical key pad and then pressing the ENTER key. Another method is using a user-defined function key from the emulated GUS Operator Station keyboard if in fact, the desired schematic has been configured for one of the keys. In this case, pressing the appropriate preconfigured key will call up the display immediately. In this case, the use of the ENTER key is not required. Finally, the desired schematic can be called up by using the Invoke target from the Safe View Control Panel window. This opens the Available GUS Graphics pop-up window. From this window, select the desired schematic name and then use the Invoke target at the bottom of the pop-up window in order to display the desired schematic.

The Schematic Display can be configured with targets that call up specific instrumentation for manipulation or which call up associated displays. Normally, this information for instrument manipulation comes up in a change zone that is most likely configured along the bottom of the schematic. However, depending on how the schematic was configured, the change zone can appear anywhere within the graphic display.

5. Process Fundamentals

5.1 Process Variable

An actual process input is called a Process Variable (PV). Some operators call the PV the "present value."

5.2 Set point

The set point (SP) of a controller is the desired value for the PV. When the PV is equal to the set point, no further corrections are made by the controller until either the PV deviates from the set point or the operator changes the set point.

5.3 Output

The output (OP) of a controller is the signal that goes to the final control element. Mostly the final control element is a valve. It is also shown as output percentage.

6. Control Modes

6.1 Manual Control Mode

Manual mode stops the control action. The output is held at its current position. In Manual mode, the operator is in direct control of the output.

6.2 Automatic Control Mode

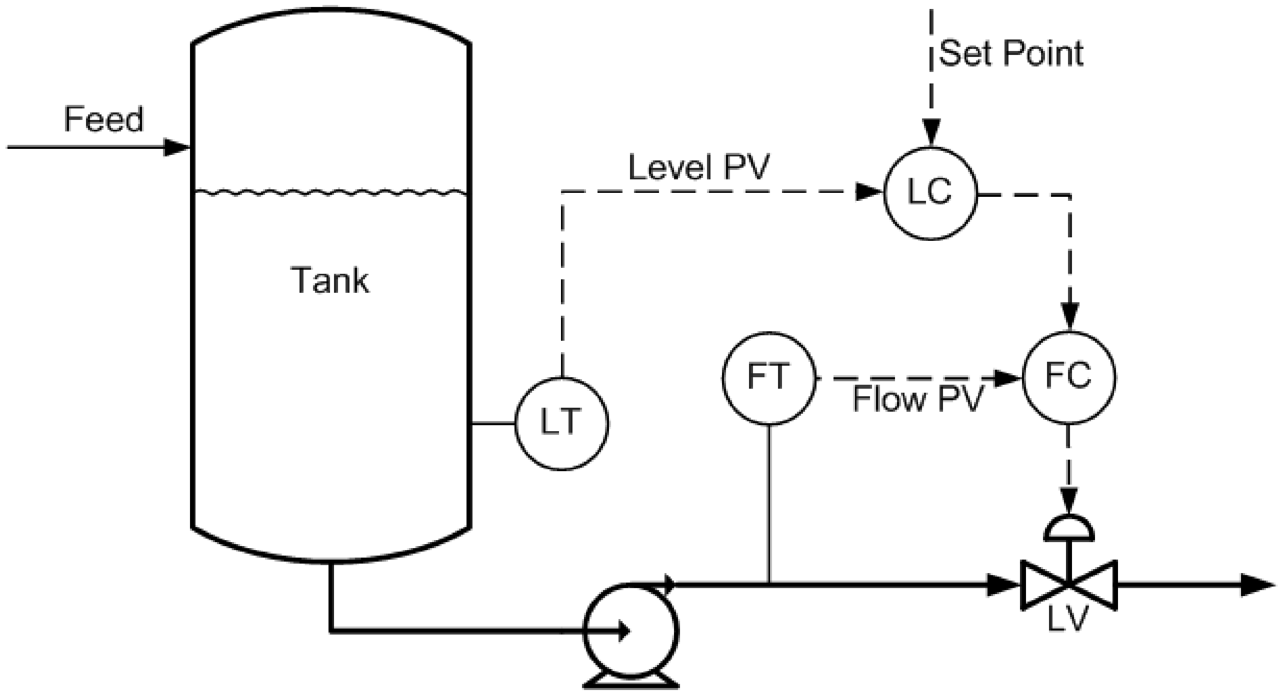
In Automatic mode, the controller automatically adjusts the output to keep the PV on set point.

In Automatic mode, the operator controls the set point.

6.3 Cascade Control Mode

In Cascade mode, the output of one controller drives the set point of another controller. The controllers are “cascaded” together. The “driver” is called the primary or master. The controller that follows the primary is called the secondary or slave. The secondary normally operates in Cascade control mode. The primary normally operates in Automatic.

If a computer controls the set point or output of a secondary controller, the secondary normally operates in Cascade mode also.



Digital Type Displays

Conventional running lamps that indicate the current state of field equipment, such as motors, pumps, and fans are seen on the operator display as colored boxes, which act like lamps.

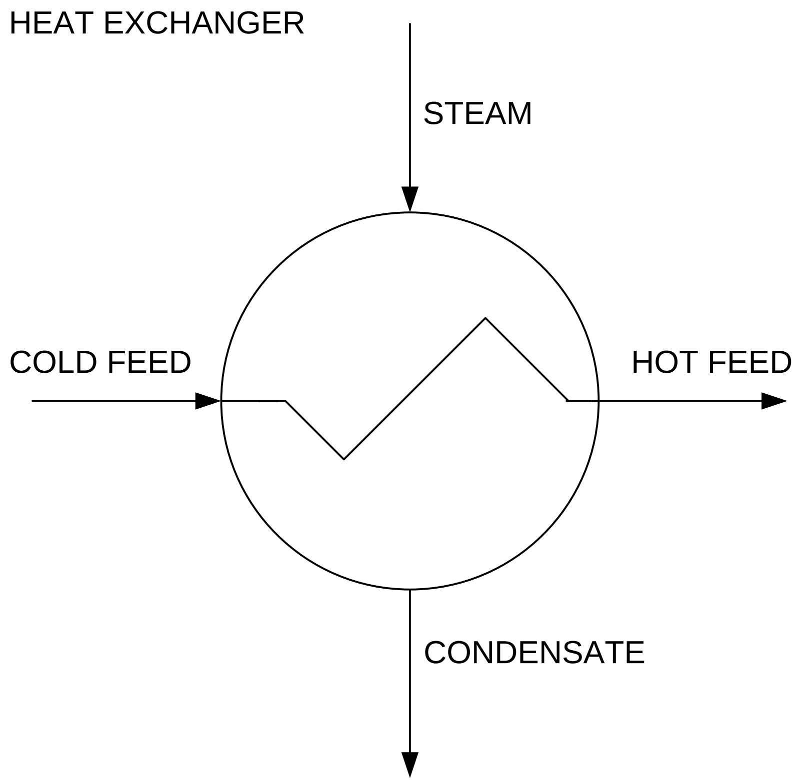
If the operator is to be allowed to turn a device ON and OFF, then a digital I/O point (also called a composite point) will be seen in the display.

7. Process 1 (Heat Exchanger)

5020M

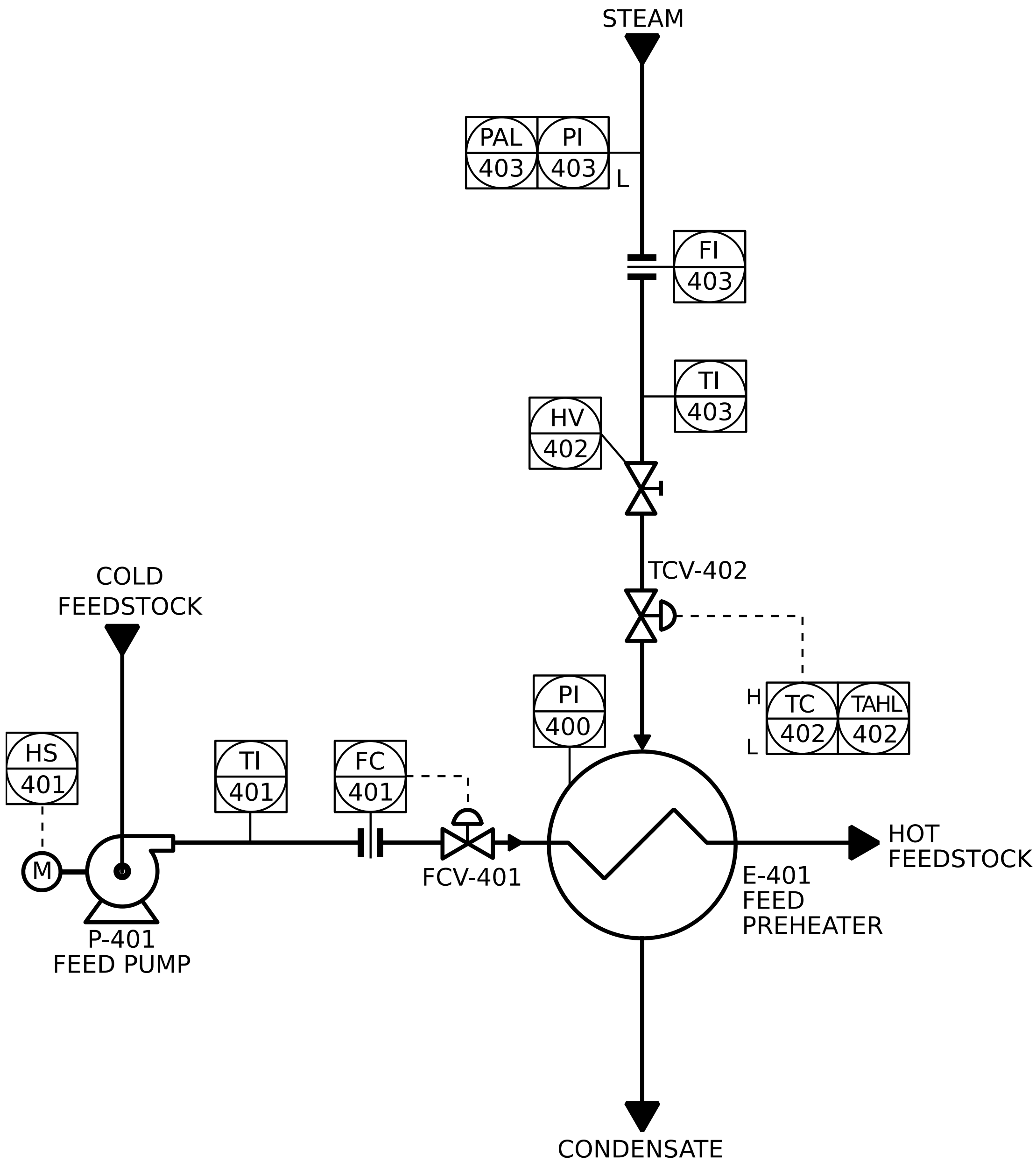
7.1 Basic Unit operation & Instrumentation

Heat exchanger transfer heat energy from hot medium to the cold feed. Ordinary heat exchanger constitute of a shell and tubes inside the shell.



Normally steam is used as heating medium. Steam from steam header enter into the shell and cold feed (which is to be hot) flow in the tubes inside the shell. Steam transfers its heat energy to the cold feed which is flowing in the tube and in result cold feed temperature increases. As the steam lost its heat energy some percentage of steam converted into water called as condensate.

The purpose of this process is to increase the temperature of cold feed stock as desired. To get this purpose instrumentation is used to control the whole process.



7.2 Heat Exchanger Process

FC-401 EXCHANGER FEEDSTOCK FLOW, 0 to 33.33 m3/h

This instrument controls the flow of cold feedstock entering the tube side of the heat exchanger E-401 by positioning a valve in the cold feedstock line.

FI-403 EXCHANGER STEAM FLOW, 0 to 10 t/h

This instrument indicates the flow of steam to the heat exchanger E-401.

HS-401 FEED PUMP, ON/OFF

This switch operates the cold feedstock pump P-401. The pump sends cold feedstock through the heat exchanger E-401.

HV-402 EXCHANGER STEAM VALVE, OPEN/CLOSED

This switch operates the block valve on the steam line through which steam is routed from the header to the shell side of the heat exchanger E-101. This > valve is located upstream of the exchanger.

PAL-403 STEAM SUPPLY PRESSURE, NORMAL/LOW

This alarm fires when the steam supply pressure for the heat exchanger E-101 falls below 6.0 Barg.

PI-400 EXCHANGER STEAM PRESSURE, 0 to 15 Barg

This instrument indicates the pressure of the steam in the shell side of the heat exchanger E-401.

PI-403 STEAM SUPPLY PRESSURE, 0 to 15 Barg

This instrument indicates the steam supply pressure to the heat exchanger E-401.

TAHL-402 EXCHANGER EFFLUENT FEED TEMPERATURE, HIGH/LOW

This alarm fires should the temperature of the feedstock at the outlet of the exchanger E-101 rise above 85.0 °C or fall below 71.0 °C.

TC-402 EXCHANGER EFFLUENT FEED TEMPERATURE, 0 to 200 °C

This instrument controls the temperature of the feedstock at the exchanger outlet by regulating the steam flow to the shell side of the heat exchanger E-401.

TI-401 FEEDSTOCK SUPPLY TEMPERATURE, 0 to 200 °C

This instrument indicates the temperature of the feedstock entering the heat exchanger E-401.

TI-403 STEAM SUPPLY TEMPERATURE, 0 to 200 °C

This instrument indicates the temperature of the steam entering the shell side of the heat exchanger E-401.

7.3 Startup & Shutdown Procedure

Startup means to energize the process. There could be two possibilities before startup

- Plant was not running before startup. This type of startup called as cold start
- Plant was running before startup. This type of startup called as warm start

Cold start means all the equipment must be in their initial condition (cold state) prior to startup. Warm start means plant was running but due to some reason plant tripped or shutdown it means all the equipment must be in warm state.

Start-up Procedure

The procedures listed below represent typical start-ups of basic units.
The instrument readings for the Cold Start are these

Instrument	Description	Process Variable
Module1: Heat Exchanger		
FC-401	EXCHANGER FEEDSTOCK FLOW	0.0 m^3/h
FI-403	EXCHANGER STEAM FLOW	0.0 t/h
HS-401	FEED PUMP	OFF
HV-402	EXCHANGER STEAM VALVE	CLOSED
PAL-403	STEAM SUPPLY PRESSURE	NORMAL
PI-400	EXCHANGER STEAM PRESSURE	0.00 Barg
PI-403	STEAM SUPPLY PRESSURE	10.35 Barg
TAHL-402	EXCHANGER EFFLUENT FEED TEMP	LOW
TC-402	EXCHANGER EFFLUENT FEED TEMP	24.0 °C
TI-401	FEEDSTOCK SUPPLY TEMPERATURE	24.0 °C
TI-403	STEAM SUPPLY TEMPERATURE	186.0 °C

Cold Start Instrument Reading

Instrument	Description	Process Variable
Module1: Heat Exchanger		
FC-401	EXCHANGER FEEDSTOCK FLOW	20.0 m^3/h
FI-403	EXCHANGER STEAM FLOW	2.14 t/h
HS-401	FEED PUMP	ON
HV-402	EXCHANGER STEAM VALVE	OPEN
PAL-403	STEAM SUPPLY PRESSURE	NORMAL
PI-400	EXCHANGER STEAM PRESSURE	3.12 Barg
PI-403	STEAM SUPPLY PRESSURE	10.35 Barg
TAHL-402	EXCHANGER EFFLUENT FEED TEMP	NORMAL
TC-402	EXCHANGER EFFLUENT FEED TEMP	80.0 °C
TI-401	FEEDSTOCK SUPPLY TEMPERATURE	38.0 °C
TI-403	STEAM SUPPLY TEMPERATURE	186.0 °C

Warm Start (Design Start) Instrument Reading

Shutdown Procedures

The shutdown procedures are gradual steps for decreasing key variables. The procedures listed below are typical. If your practice differs from the procedures outlined here, changes or substitutions should be made.

Exercise 1: Heat Exchanger Shutdown

1) Place both TC-402 and FC-401 in **MANUAL** and slowly decrease their outputs to 0.0%.

   NOTE: Decrease the outputs gradually to avoid bumping the heat exchanger outlet temperature. Monitor this temperature at TC-402. The steam flow at FI-403 decreases as does the exchanger shell pressure at PI-400.

2) When the output of FC-101 is down to 0%, stop the main feed pump P-401 by setting HS-401 **to OFF.**

3) **CLOSE** the steam supply block valve using HV-402.

4) Click ALARM SUMMARY key, click ACK and SIL, and note down the alarm summary that exist in the native window display during the plant shutdown.

Exercise 2: Heat Exchanger Start-Up

1) Turn ON HS-401 to start the feed pump P-401.

2) Adjust the output of FC-401 in manual mode to 10.0% to allow a flow of cold feed through the heat exchanger tubes.

3) **OPEN** the main steam block valve HV-402.

4) Adjust the output of TC-402 in manual mode to 5.0% to start the steam flow through the exchanger. Notice the heat exchanger shell pressure change at PI-400.

5) Place FC-401 in **AUTOMATIC** at its present value.

6) Place TC-402 in AUTOMATIC at its present value.

7) Set the set point of FC-401 to 4.0 m^3/h.

8) Slowly increase the set point of TC-402 to 80.0 °C in 5.0 °C increments. Wait 2-3 minutes on each increment for temperature to stabilize around set point.

9) When the temperature of the hot feed stock reaches to 80.0 °C, increase the set point of the flow of cold feed stock (FC401) to 24.0 m3/h in 3.0 m^3/h increments. Wait 2-3 minutes on each increment for flow to stabilize around set point.

10) Notice the change at PI-400 due to the rate of condensation within the shell of the heat exchanger, which affects the heat transfer within the exchanger.

11) Note the Process value of PI400________BarG at stable reading.

12) Click the TREND key and type PI400 and click enter.

13) Describe the trend of PI400.

____

____

Exercise 3: Test Your Knowledge

After successful startup please observe carefully and if there is an alarm read it and then analyzes what you have to do in this condition.

If there is an alarm of heat exchanger feedstock high temperature then how we have to react

- First of all pay attention to this alarm.
- Press the silence button to switch off sound.
- Open the alarm summary window Check which alarm it is.
- If required you can change the mode of controller from auto to manual.
- Now analyze, feed stock temperature is high what could be the possible causes

    - Valve is not working properly that’s why too much steam entered in the heat exchanger causing high temperature of feed.

    - Actual temperature is not high may be alarm is fake due to some instrument error. Just call field operator to check actual output feed temperature.

    - May be there is some loose connection in the field.

    - May be controller is not working properly.

- After troubleshooting, the mode of the controller can be change from manual to auto.

8. Process 2 (Three Element Boiler Control)

5020M

Boiler is an essential part of almost every plant. Boiler converts water into high pressure and high temperature steam. A typical circulation boiler uses the principle of convection to transfer heat to water to produce steam.

Here we will discuss three element boiler. Furnace burner and fuel supply system is not included.

8.1 Feed water

Boiler feed water is pumped from a de-aerator (used to separate air from condensed water) to the boiler drum by centrifugal pumps. Treated water is used for this purpose. Feed water flow rate is controlled by a three element system involving

- Output of Drum Level Controller
- Steam Flow Rate from the Drum
- Water Flow rate to the Drum

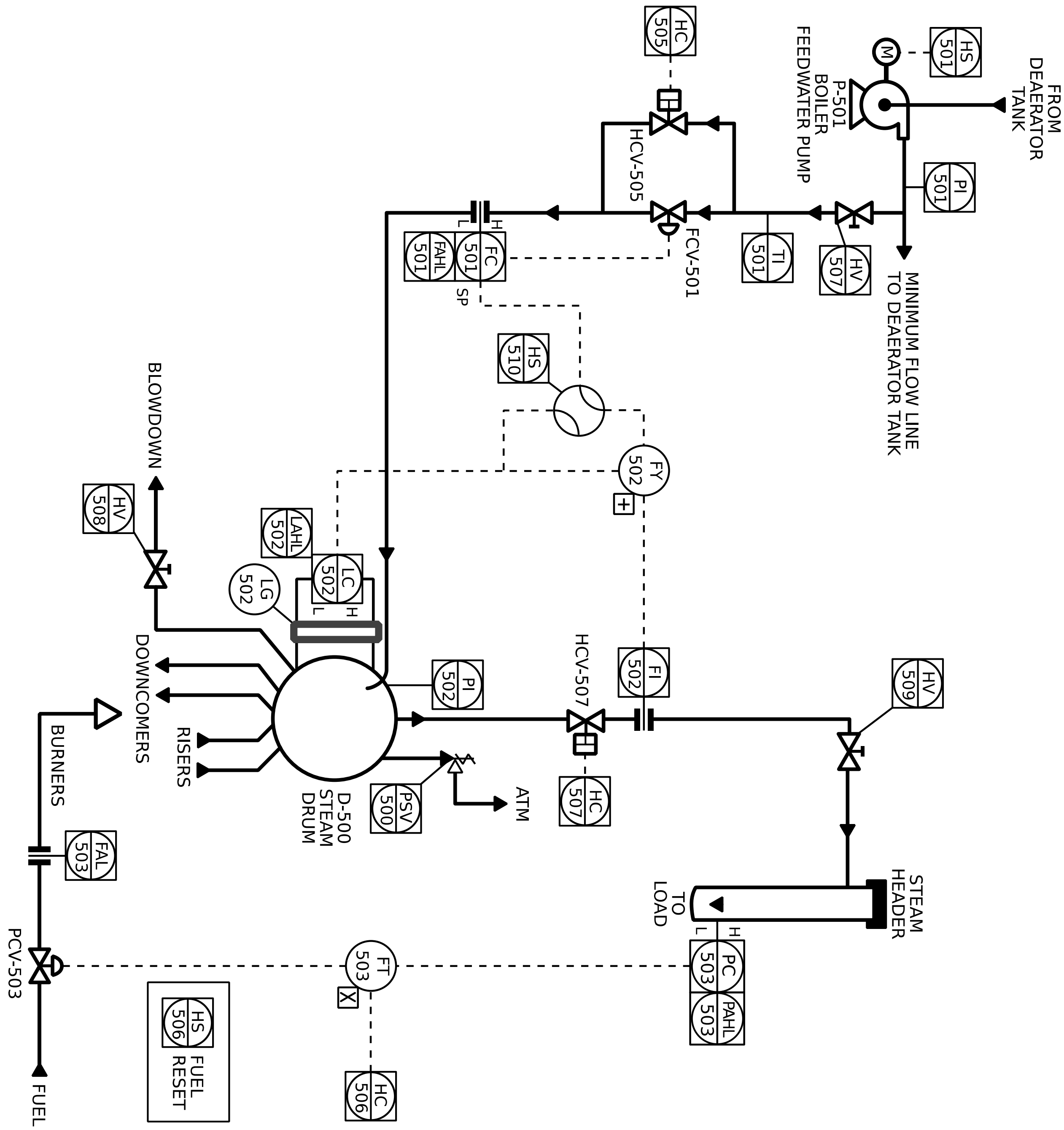
8.2 Boiler Drum

Water from the drum flows by natural circulation through down comers tubes. These tube banks are exposed to burner flames gets heat energy and convert water into saturated steam. The effect of shrink and swell phenomenon can be seen by monitoring the steam drum level during the transient stages of operation.

8.3 Steam Header

Steams exit the boiler drum and flows to a generalized load. The load demand for the steam header is depend on the usage of steam in that particular plant.
The header pressure controller, therefore regulates the flow of fuel to the boiler.

8.4 Three Element Boiler Control sample schematic



8.4 Instrument Description

FAHL-501 BOILER FEEDWATER FLOW, HIGH/LOW

This alarm fires when the boiler feed water flow to the steam drum D-500 rises above 44.0 m^3/h or falls below 11.0 m^3/h.

FAL-503 BURNER FUEL FLOW, NORMAL/LOW

This alarm fires when the fuel flow to the burner decreases to zero.

FC-501 BOILER FEEDWATER FLOW, 0 to 50 m^3/h

This instrument controls the boiler feed water flow from the boiler feed water pump P-501 to the steam drum D-500. This controller can receive a remote set point signal from either the steam drum level controller LC-502 or the 3-element level control, depending on the position of HS-510.

FI-502 STEAM DRUM STEAM FLOW, 0 to 50 t/h

This instrument indicates the flow of steam from the steam drum D-500 to the steam header. HC-507 controls this flow.

HC-505 FC-501 BYPASS VALVE, 0 to 100 PCT

This manual control station operates the valve on the bypass line around the boiler feed water flow controller FC-501. This valve is used in the event that the feed water flow controller is inoperative in order to control the boiler feed water flow to the steam drum.

HC-506 BURNER FUEL BIAS, 0.5 to 2.0

This instrument controls the amount of bias added to the output signal from the steam header pressure controller PC-503 to the burner fuel flow valve PCV-503. The output of HC-506 is sent to multiplier FY-503 where it is multiplied with the output of the steam header pressure controller PC-503. The resultant signal is converted to a burner fuel flow requirement signal and is used to position the valve on the burner fuel flow line.

HC-507 STEAM DRUM OUTLET STEAM VALVE, 0 to 100 PCT

This manual control station operates the steam valve on the line from the steam drum D-500 to the steam header. This valve can be used to control the steam flow from the steam drum to the steam header.

HS-501 BOILER FEEDWATER PUMP, ON/OFF

This switch operates the boiler feed water pump P-501. This pump draws boiler feed water from the de-aerator and sends it to the steam drum D-500.

HS-506 BURNER FUEL RESET, ON/OFF

This switch resets the logic associated with the burners in the event that the fuel flow to the burners has tripped. The fuel flow to the burners can be tripped due to an extremely low or high level in the steam drum D-500 as read at LC-502. This switch is a momentary switch and will turn OFF after about ten (10) seconds. If the steam drum level has not been brought back to within non-trip limits, the fuel flow will be tripped again.

HS-510 BOILER FEEDWATER FLOW CONTROL SELECTOR, LC502/FY502

This switch selects the control scheme for regulating which remote set point signal is sent to the boiler feed water flow controller FC-501. When the switch is set to FY-502, FC-501 receives a remote set point signal from the 3-element controller FY-502. When the switch is set to LC-502, FC-501 receives a remote set point signal from the drum level controller LC-502.

HV-507 BOILER FEEDWATER BLOCK VALVE, OPEN/CLOSED

This switch operates the block valve at the discharge of the boiler feed water pump P-501. This valve is located downstream of the pump minimum flow recycle line so it is possible for the pump to be in operation even though the block valve is closed.

HV-508 STEAM DRUM SLOWDOWN VALVE, OPEN/CLOSED

This switch operates the block valve in the blow down line from the steam drum D-500 to the drain header.

HV-509 STEAM HEADER INLET VALVE, OPEN/CLOSED

This switch operates the block valve on the steam line at the inlet to the steam header. This valve is located downstream of steam line throttle valve HC-207 and the steam flow indicator FI-502.

LAHL-502 STEAM DRUM LEVEL, HIGH/LOW

This alarm fires when the boiler feed water (BFW) level in the steam drum D-500 rises above 75.0% or falls below 30.0%.

LC-502 STEAM DRUM LEVEL, 0 to 100 PCT

This instrument controls the boiler feed water level in the steam drum D-500 by sending a remote set point signal either to the boiler feed water flow controller FC-501 or the 3-element controller FY-502. HS-510 determines the destination of the signal.

PAHL-503 STEAM HEADER PRESSURE, HIGH/LOW

This alarm fires when the steam pressure in the steam header rises above 76.0 Barg or falls below 52.0 Barg.

PC-503 STEAM HEADER PRESSURE, 0 to 85 Barg

This instrument controls the steam pressure in the steam header by regulating the flow of fuel gas to the burner. The output of PC-503 is multiplied by a bias factor set at the fuel bias controller HC-506. FY-503 multiplies the values, then transforms the product to a fuel flow requirement value that positions the burner fuel flow valve to maintain the desired steam header pressure. For more information regarding this control loop, refer to the COMPLEX PROCESS CONTROL INSTRUMENTS section located at the end of this chapter.

PI-501 BOILER FEEDWATER PUMP DISCHARGE PRESSURE, 0 to 100 Barg

This instrument indicates the pressure at the discharge of the boiler feed water pump P-501. This reading is taken upstream of the boiler feed water supply block valve HV-507.

PI-502 STEAM DRUM PRESSURE, 0 to 85 Barg

This instrument indicates the steam pressure in the steam drum D-502.

PSV-500 STEAM DRUM PRESSURE RELIEF VALVE, OPEN/CLOSED

This instrument indicates the status of the steam drum safety valve PSV-500. This valve automatically opens when the pressure in the steam drum rises above 80.0 Barg as read at PI-502. The valve closes when the pressure in the steam drum falls below 80.0 Barg.

TI-501 BOILER FEEDWATER SUPPLY TEMPERATURE, 0 to 200 °C

This instrument indicates the temperature of the boiler feed water supply to the steam drum D-500. This reading is taken downstream of the boiler feed water pump P-501.

8.5 Boiler Feed water Flow Control Loop

FC-501 controls the boiler feed water flow via remote set point. A selector switch HS-510 is provided for selecting one (1) of two (2) available control schemes - the FY-502 adder scheme or the LC-502 scheme.

When HS-510 is set to the FY-502, the remote set point signal sent to the boiler feed water flow controller FC-501 is determined by FY-502 using the boiler drum level, LC-502, and the steam flow FI-502 signals. The steam flow signal is sent to FY-502 where it is adjusted based on a change in the drum level. That is, if the drum level is steady (not changing), the steam flow signal will be the remote set point signal for the boiler feed water flow controller. However, if the steam drum level is in transition (changing), the steam flow signal is adjusted by FY-502, upwards in the event that the drum level is decreasing or is adjusted downwards in the event that the drum level is increasing. This is done in order to maintain more stable steam drum levels when the unit is in transition.

When HS-510 is set to LC-502, FC-501 receives a remote setpoint signal directly from the level controller LC-502. In this mode of operation, the flow adder FY-502 is not functional.

8.6 Steam Header Pressure

PC-503 controls the steam header pressure by regulating the flow of fuel gas to the burner. The output signal from PC-503 is multiplied by a factor between 0.5 and 2.0, as set at the burner fuel bias controller HC-506. This is accomplished by multiplier FY-503. The signal is then converted to a fuel flow requirement and used to position the valve on the burner fuel flow line.

The output signal of HC-506 is sent to a multiplier, FY-503, which multiplies the output from PC-503 by the output from HC-506 in order to determine the burner fuel flow requirement. FY-503 uses this signal to position the burner fuel flow valve. Increasing the setting of HC-506 increases the multiplication factor. Conversely, decreasing the setting reduces the multiplication factor. When the ratio is increased, the output of PC-503 is multiplied by a larger factor, resulting in a greater increase in the fuel flow to the burner. This, in turn, increases the steam production rate faster. The steam header pressure increases temporarily until the PC-503 output decreases to compensate for the larger bias setting. If, on the other hand, the setting at HC-506 is decreased, the output signal of PC-503 must increase to correct any negative set point deviation.

8.7 Logic

Module 2 includes an automatic logic action for safe operation of the boiler drum. If, at any time, the pressure in the drum exceeds 80.0 Kg/cm^2, pressure safety valve PSV-500 automatically opens to vent the excess steam to the atmosphere. PSV-500 is a field-mounted valve. It cannot be manipulated at the operator station. There is a status light for PSV-500 displayed at the operator station which illuminates the OPEN position when the valve opens. The light returns to the CLOSED position when the valve closes.

Additional logic action trips the fuel valve when the boiler level LC-502 falls below 10.0% or rises above 90.0%. Any trip or failure of the fuel valve requires a reset of switch HS-506 before fuel can be brought back to the burners. The reset switch is a momentary type switch and automatically turns OFF after about ten (10) seconds.

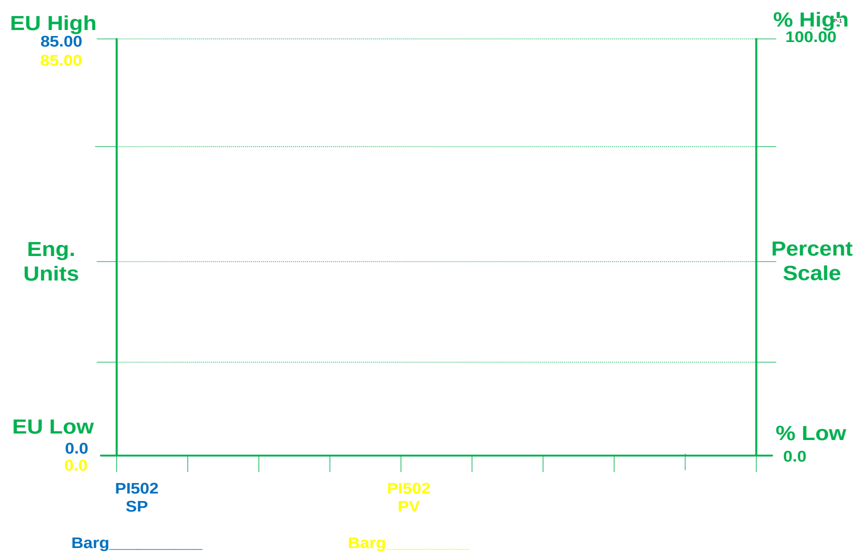
Exercise 4: Logic action of PSV500

ACTION:

1. Have the instructor reset the system.
2. Increase the set point of PCV503 to 80 and wait until PSV500 opens.
3. Note the pressure reading of PI502 = ______barg at the time PSV500 opens.
4. Decrease the set point of PCV503 to 75 and wait until PSV500 closes.
5. Monitor the process and note the pressure reading of PI502 = ______barg at the time PSV500 turn to close position.
6. Draw the trend of PI502 showing the set point (SP) and process variable (PV).

Trend: PI502

Time base: _________



TEST YOUR KNOWLEDGE:

10. Describe the basic operation of PSV500 for the “Three Element Boiler Control”.

____

____

____

____

Exercise 5: Logic action of LC502

ACTION:

1. Put FC501 into manual mode and slowly reduce its output to zero. Wait and observe until the fuel valve PCV503 goes to 100%.
2. In what percent level as seen on LC502 ______%, the fuel valve PCV503 trips?
3. Monitor the steam drum pressure PI502 ______bar G; the steam header pressure PC503_____bar G, and the steam demand flow FI502_____t/h.
4. Click the ALARM SUM key and note the alarm summary in the Native window screen.
5. Ask the instructor to reset the system.
6. Put back FC501 and LC502 in manual mode and slowly increase the output FC501 to 100%, wait and observe until the fuel valve PCV503 goes to 100%.
7. In what percent level as seen on LC502_____%, the fuel valve PCV503 trips?
8. Click the ALARM SUM key and note down the alarm summary in the Native window screen.

TEST YOUR KNOWLEDGE:

1. Describe the logic action of boiler drum level as seen on LC 502.

   ____

   ____

2. Click the TREND key and type LC502, hit enter. Analyze the trend. If necessary expand the time base to show the trend starting point and end points.

Boiler trips condition:

1. Fuel valve PCV503 opens 100% maximum.
2. Steam drum pressure PI502, header pressure PC503 drops to min.______barG.
3. Steam demand flow FI502 drops to 0.0 t/h.

Exercise 6: Logic action of Fuel Reset Switch HS506

ACTION:

1. Have the instructor reset the system.

2. Click HS506 fuel reset button and click OP to ON position. Wait and observe the automatic logic action of HS506.

TEST YOUR KNOWLEDGE:

1. Describe the logic action of HS506 based on your observation.

   ____

   ____

8.8 Three-Element Boiler Control Shutdown Procedure

Exercise 7: Three –Element Boiler Shutdown Procedure.

The shutdown procedure is gradually decreasing the important variables.

1. Put PC-503 in manual mode and slowly decrease its output to 30%.

2. Tell the steam consumers (Instructor) that slowly decrease the steam demand to 2.0t/h at a ramp time of 5.0 minutes. Observe the reading on FI502___________?

3. As the steam demand is slowly decreased, continue to decrease the output of PC-503 to 15%.

   Note: The steam demand should not be decreased below 2.0t/h.

4. Gradually decrease the steam header pressure PC-503 to 0.0 BarG by closing the fuel valve to 0.00%. Observe the steam drum pressure, PI-202____________?

5. Stop the feed water pump P-501 by HS-201.

6. Place the steam drum level controller LC-502 and the boiler feed water flow controller FC-501 in manual. Decrease the output of FC-501 to 0.0%. Set HS-510 to LC-502.

7. Close feed water block valve using HV-507.

8. Wait until steam drum pressure as read on PI502 reads less than 3.5 BarG.

9. Slowly decrease the output of HC507 to 0.0%, close HV509.

10. Click the ALARM SUMMARY key and write the alarm summary in the table below for the three element boiler during plant shutdown condition.

Alarm Summary:

Time:	Tag no.	Status	Description	Process Value(PV)

8.9 Three-Element Boiler Control Start-Up

Exercise 8: Three –Element Boiler Startup Procedure.

<u>WARM START INSTRUMENT READING</u>

FAHL-501	BOILER FEEDWATER FLOW	NORMAL
FAL-503	BURNER FUEL FLOW	NORMAL
FC-501	BOILER FEEDWATER FLOW	29.48 m^3/h
FI-502	STEAM DRUM STEAM FLOW	29.50 t/h
HC-505	FC-201 BYPASS VALVE	0.0 PCT
HC-506	BURNER FUEL BIAS	33.3 PCT
HC-507	STEAM DRUM OUTLET STEAM VALVE	100.0 PCT
HS-501	BOILER FEEDWATER TEMP	ON
HS-506	BURNER FUEL RESET	OFF
HS-510	BFW FLOW CONTROL SELECTOR	FY202
HV-507	BOILER FEEDWATER BLOCK VALVE	OPEN
HV-508	STEAM DRUM BLOWDOWN VALVE	CLOSED
HV-509	STEAM HEADER INLET VALVE	OPEN
LAHL-502	STEAM DRUM LEVEL	NORMAL
LC-502	STEAM DRUM LEVEL	50.0 PCT
PAHL-503	STEAM HEADER PRESSURE	NORMAL
PC-503	STEAM HEADER PRESSURE	62.8 Barg
PI-501	BFW PUMP DISCHARGE PRESSURE	86.13 Barg
PI-502	STEAM DRUM PRESSURE	66.2 Barg
PSV-500	STEAM DRUM PRESSURE RELIEF VALVE	CLOSED
TI-501	BOILER FEEDWATER SUPPLY TEMP	121.1 °C

<u>COLD START INSTRUMENT READING</u>

FAHL-501	BOILER FEEDWATER FLOW	LOW
FAL-503	BURNER FUEL FLOW	LOW
FC-501	BOILER FEEDWATER FLOW	0.0 m^3/h
FI-502	STEAM DRUM STEAM FLOW	0.0 t/h
HC-505	FC-201 BYPASS VALVE	0.0 PCT
HC-506	BURNER FUEL BIAS	33.3 PCT
HC-507	STEAM DRUM OUTLET STEAM VALVE	0.0 PCT
HS-501	BOILER FEEDWATER TEMP	OFF
HS-506	BURNER FUEL RESET	OFF
HS-510	BFW FLOW CONTROL SELECTOR	LC202
HV-507	BOILER FEEDWATER BLOCK VALVE	CLOSED
HV-508	STEAM DRUM BLOWDOWN VALVE	CLOSED
HV-509	STEAM HEADER INLET VALVE	CLOSED
LAHL-202	STEAM DRUM LEVEL	LOW
LC-202	STEAM DRUM LEVEL	0.1 PCT
PAHL-503	STEAM HEADER PRESSURE	LOW
PC-503	STEAM HEADER PRESSURE	2.1 Barg
PI-501	BFW PUMP DISCHARGE PRESSURE	2.10 Barg
PI-502	STEAM DRUM PRESSURE	2.1 Barg
PSV-500	STEAM DRUM PRESSURE RELIEF VALVE	CLOSED
TI-501	BOILER FEEDWATER SUPPLY TEMP	23.9 °C

Establish Boiler Drum Level

1. **OPEN** the feed water block valve HV-507.

2. **START** the feed water pump P501 using hand switch HS-501.

3. Put FC 501 in manual and set the output to 5% and wait until the drum level reach 50% as read at LC502.

4. When the boiler drum level reaches 50.0% as read at LC-502, decrease the output of FC-501 to 0.0%. **Result:** The feed water circulates to the de-aerator and back through the boiler feed water pump P-501.

Supply Heat for the Boiler

1. Put FC501 back in cascade mode and put LC502 on auto and adjust the set point of LC502 to 30%.

2. Adjust the output of the burner fuel load bias station HC506 to 25%.

3. Open the steam block valve HV509, increase the output of the steam non-return valve HC507 to 100%. Result: This allows the steam flow to the steam header and increases the steam header pressure as read at PC503.

4. Start the flow of fuel gas to the burners by increasing the output of PC503 to 10%.

5. Reset the fuel trip by setting HS506 to ON. This is a momentary switch, meaning it will turn off automatically after about ten seconds. Note: Gradual swelling of the water level occurs and the drum pressure begins to increase as read at PI502 and LC502 respectively.

6. Have the instructor set the steam demand to 5.0 t/h using IV (2,5).

7. Continue to gradually increase the output of PC503 to 25% slowly, until the pressure reading at PC503 reaches to approximately 62.8 barG, place PC503 in automatic and adjust the set point to 62.8 barG.

8. Maintain the drum level LC502 with the set point at 30%.

9. Have the instructor continue to gradually increase the steam demand until it reaches its design value of 29.5 t/h.

10. Observe and wait until the process stabilizes. Note the following process variables: Steam drum level as read on **LC502**_____%, Steam drum pressure as read on **PI-502**______BarG, Steam header pressure as read on **PC503**_____BarG, Steam demand as read on **FI502**______t/h, feed water flow as read on **FC501**_____m^3/h.

Line out the system

1. Adjust the set point of LC502 to 50%.

2. Next, set the HS510 to FY502 for 3-element operation of the level control scheme. At this point the output from the level controller LC502 is biased by a change in the steam flow in order to “anticipate” any sudden change in the steam flow and hence, the steam drum level.

3. Verify the set point of LC502 at 50% to maintain the steam drum level at safe side.

4. Click the alarm summary, press the ACK and SIL. **Note:** There should be no alarm in the native window screen.

5. Click the TREND key and type LC502 and click enter. If necessary adjust the time base: ______, to show the trend starting point and the end point of the process.

6. Describe the trend of LC502.

   ____

   ____

8.10 Common Possible Faults

Boiler Feed water valve Fail in closed position

Boiler feed water valve fail in closed position resulting in a loss of feed water flow to the boiler. Feed water flow low alarm will generate when the flow fall below 11.0 m^3/h.

In this condition operate the feed water bypass valve HC-205 to restore the supply of feed water. A technician should be sent to check the valve and repair if required.

If the repair/troubleshooting is not possible in the field then valve should be send to workshop for repairing. To dismantle the valve shutdown is require so inform the area engineer about this condition.

Fuel Valve Closed

This fault causes the fuel supply to the burner to fail. Due to this fault the output of PC-503 increases to 100%, the steam flow at FI-502 drops, and LC-502 increases slightly.

A technician should be sent to check the status of fuel valve. Because due to criticality of this valve there is no bypass arrangement available.

After repairing/troubleshooting of fuel valve, HS506 must be switched ON to reset PCV-503 after it is tripped.

Boiler Feed Pump Cavities

Sometime boiler feed pump cavities from inside resulting in a sharp fluctuation in the discharge pressure. Due to this feed water pump open and close.

Check the pump and repair.

Exercise 1

Start the three element boiler from its initial condition as per startup procedure. Run the process for 20minutes then shut down the plant as per shutdown procedure. Note down the alarm summary.

Exercise 2

Load demand on plant decreases from 29.5t/h to 15t/h due to tripping of any consumer unit. Now observe what changes take place due to decrease in steam demand. Is there anything?

INSTRUMENTATION TRAINING PROGRAM

PROGRAM MANUAL

FOR THE AUDY 5900M

CHAPTER 1

9. PROGRAM OVERVIEW

9.1 INTRODUCTION

Audy's 5900M Instrumentation Training Program is a comprehensive dynamic simulation of modules that teach typical control concepts. Combined with the most up-to-date training features, Program 5900M is an effective tool to teach operators, instrument mechanics and engineers the procedures to tune, troubleshoot and understand controls and control loops.

9.2 PROGRAM CAPABILITIES

Program 5900M has multiple capabilities. When initialized in the IC1: DESIGN START mode, the simulated process begins operating at plant design conditions. All of the controllers are tuned for steady state operating conditions.

Included in the program is the capability to modify the simulated process at the instructor station by changing the value of thirty-one (31) instructor variables, thirty-eight (38) instructor faults and eleven (11) field operated devices (FOD's). Instructor variables enable the instructor to set plant conditions by adjusting operating parameters that are not accessible to the student. Instructor faults inject into the process the failure or malfunction of specific equipment and instrumentation. Field operated devices represent equipment that can only be exercised by plant engineers not in the control room.

9.3 UNIT DESCRIPTION

The Instrumentation Training Program is divided into six (6) modules:

- Module 1: Self-Regulating Process - Gravity Drained Holding Tank
- Module 2: Non-Self-Regulating Process - Pumped Holding Tank
- Module 3: Non-Linear Process - PH-Mixing Tank
- Module 4: Heat Exchanger
- Module 5: Three Element Control - Boiler
- Module 6: Process Interaction Effects – Distillation Column

The modules can be run separately or simultaneously. Note that the modules are not connected and operate independently.

9.4 CONTROL SCHEME

The process control scheme consists of thirty (30) controllers, forty-eight (48) indicators, thirty-four hand switches, and seven (7) manual control stations. These instruments control and/or monitor all key operating variables important to the operation of the simulated processes.

CHAPTER 2

10. PROCESS DESCRIPTION

10.1 INTRODUCTION

Each of the six (6) modules of the 5900M Instrumentation Training Program is described below.

10.2 MODULE 1, SELF-REGULATING PROCESS - GRAVITY DRAINED HOLDING TANK

This module demonstrates a process with a natural tendency to move towards an equilibrium point. In this self-regulating process, approximately 500 kg/min of water enters a hold-up tank and drains from the bottom by gravity.

The water enters the holding tank V-101 through flow control valve FC-101. The water drains from the tank by gravity through level control valve LC-102. Both valves have linear flow characteristics.

The holding tank simulated in this module has the following physical characteristics:

- Height 3.5 m
- Diameter 1.1 m
- Volume 3.0 cu. M

The vessel has approximately a 2.5-minute residence time when the vessel is maintaining a 50.0% level. All valves and piping have been designed to process a maximum of 1000 kg/min of water.

10.3 MODULE 2, NON-SELF REGULATING PROCESS-PUMPED HOLDING TANK

The module demonstrates a process with natural tendency to move away from equilibrium in a linear fashion. In this non-self-regulating process, approximately 500kg/min of water enters a hold-up tank and is pumped from the bottom of the tank by pump P-201.

The water enters the holding tank V-201 through a flow control valve FC-201. The water is pumped from the bottom of the tank by centrifugal pump P-201 through level control valve LC-203. The valve again has linear flow characteristics.

The holding tank simulated in this module has the following physical characteristics:

- Height 3.5 m
- Diameter 1.1 m
- Volume 3.0 m^3

The vessel has approximately a 2.5-minute residence time when the vessel is maintaining a 50.0% level. All valves and piping have been designed to process a maximum of 1000 kg/min of water.

10.4 MODULE 3, NON-LINEAR PROCESS - PH MIXING TANK

This module demonstrates a non-linear process. A test stream is neutralized by either an acid or a base stream. The pH of all the stream can be adjusted by the instructor.

The test stream enters the mixing tank V-301 through a flow control valve FC-301 (with linear flow characteristics). Acid or base enters the mix tank through two (2) valves that are controlled by split range controller QC-304. The product streams drains from the tank by gravity through level control valve LC-304.

10.5 MODULE 4, HEAT EXCHANGER

The heat exchanger E-401 is an ordinary shell and tube exchanger that heats a cold feedstock from about 40 ˚C to about 80 ˚C at design conditions. The cold feedstock is pumped by centrifugal pumped P-401 into the tube side of E-401. Steam from a steam header is used as the heating medium.

The steam enters the shell side of E-401 at a pressure of approximately 10.5 Barg and the cold feedstock enters the tube side of E-401. As the tube pass through the shell of E-401, an “exchange” of heat occurs between the steam and the feedstock. As the steam gives up heat to the feedstock, it condenses on the tubes. As a result of this heat transfer, the feedstock stream temperature increases. The hot feedstock exits from the E-401 tube side and the warm condensate exits from the E-401 shell side.

The heat exchanger simulated in this module has the following characteristics:

- Tube side – Consist of 78 copper tubes, each with the nominal 1.9 cm in size. The inside diameter of the tube is 2.1 cm and the outside surface area of the tubes is approximately 11 square meter.

- Shell side – Approximately 6.8 m long.

10.6 MODULE 5, THREE ELEMENT CONTROL – BOILER

The boiler simulated in this program is a typical circulation boiler that uses the principles of conviction to transport heat to water and to produce steam.

For the purpose of this discussion, the unit is divided into three (3) sections.

Feedwater

Boiler feedwater (BFW) is pumped from a deaerator to the boiler drum by centrifugal pump P-501. The feedwater flow rate is controlled by a three-element control system involving the drum level, the steam flow rate from the drum, and the water flow rate to the drum. This type of control system is typical for boilers and is discussed in detail in chapter 3.

The furnace burners and fuel supply systems are not included in the simulation.

Boiler Drum

Saturated steam is generated in the riser tube banks. Water from the drum flows by natural circulation through these tubes. By monitoring the steam drum level during the transient stages of operation, one can see the effects of the shrink and swell phenomenon.

The saturated steam exits the drum on route to the steam header. A pressure safety valve automatically opens to relieve drum pressure in emergency situations.

The physical characteristics of the drum simulated in this program are:

- Height 2.4 m
- Outside diameter 2 m
- Total volume 7.6 m^3

Steam header

Steam exits the boiler drum and flows to a generalized load. (The instructor sets the load demand as an Instructor Variable.) The steam load (t/h) is produced by the simulated boiler with header pressure dependent upon the boiler's firing rate. As a result, the header pressure controller regulates the flow to fuel to the boiler. This control loop is detailed in Chapter 3.

10.7 MODULE 6, PROCESS INTERACTION EFFECTS – DISTILLATION COLUMN

The distillation column receives the natural gas liquids (NGL) and separates two (2) fractions – propane, (C3), and butane (C4) – from the heavier natural gas components by the process of distillation. The distillation process takes place in two (2) columns; the depropanizer column and the debutanizer column. Three columns operate in series. Each column is designed to separate one component from the feed stream.

For the purpose of discussion, this section is divided into two (2) main sections.

Process Flow

The raw NGL feed is transferred by pump to the inlet of the depropanizer column C-601 at tray 18. The feed enters the column and is distributed via a staggered lateral inlet. Heat of the distillation process is supplied by a stream of saturated steam circulating through the tube side of the kettle-type bottoms reboiler E-601. The liquid inlet to the reboiler is taken from a tray 1 of the column – a total draw off tray with two (2) nozzles.

The hot vapor from the reboiler returns to the column below tray 1 while the reboiled liquid flows by gravity directly to the base of the column.

The column temperature at tray 5 determines the amount of heat input that the reboiler adds. The temperature controller TC-604 located at tray 5 cascades a setpoint to the flow controller FC-603 to regulate the supply of saturated steam to the reboiler. The tray 5 temperature therefore controls the column bottoms product composition.

The bottoms column liquid is transferred without a pump under level control to the inlet of debutanizer column C-602. The pressure differential existing between the two (2) columns is the driving force for the flow.

The overhead vapor product of the depropanizer is cooled and partially condensed by passing all the vapor through the air fan condenser E-602, which consist of four (4) fin-fans. The degree of condensation is the function of the column pressure, which is controlled by split range controller PC-604.

This pressure is controlled at the tower top by adjusting the variable pitch of the cooler fans. If the air fans cannot provide sufficient cooling, the pressure controller acts to open a vent valve to the flare system. The condensed overhead product then enters the reflux drum V-601, where vapor/liquid gravity separation occurs.

The liquid phase from the reflux drum is returned to the column as reflux. The reflux is pump back to the column by reflux pump P-603 above the top tray 40 through a spray pipe distributor. The reflux returned to the column is flow controlled, which allows the reflux ratio to be altered so as to maintain the top product purity.

The control of the reflux drum is achieved by cascade control of the top product flow. The vapor phase of the drum is the overload product of the depropanizer-column.

Feed to depropanizer column C-602 is the bottoms liquid from the depropanizer column. The feed enters the column at tray 15 through a vane-type distributor. The feed transfers from the depropanizer to the debutanizer without a pump due to the pressure differential existing between the two (2) columns.

Heat for the distillation process is supplied by a stream of saturated steam circulating through the tube side of the kettle-type reboiler E-603. Reboiler inlet and return configuration is identical to the reboiler system of the depropanizer column.

The reboiler heat input is controlled by cascade temperature control of the saturated steam supply at tray 3. This temperature controls the column bottoms product purity. The bottoms product of the debutanizer column is transferred to storage from the column by the level control. The overhead vapor product of the debutanizer is cooled and condensed in the air fan condenser E-604, and then enters the reflux drum V-602. The degree of condensation is a function of the column pressure, which is controlled by PC-613 through split range in the same manner as the depropanizer. Between 0.0% to 50.0% outputs, the controller regulates the pitch of the fans. An output greater than 50.0% controls the position of the vent valve on the fire system. During normal operations, this valve is closed.

Liquid accumulated in the dubutanizer reflux drum provide both reflux to the column and liquid overhead product streams through pump P-605. Reflux returns to the column above tray 30 and is flow controlled to maintain the top product purity. Level control of the reflux drum is achieved through cascade control of the top product flow.

Process Equipment

10.7.1 Depropanizer Column

The depropanizer column separates the propane component from the feed. The propane vapor product leaves the column through a top axial nozzle and the residual hot natural gas liquid leaves through a bottom axial nozzle.

The simulated column has the following physical characteristics:

- Height 30.0 m
- Top section (outside diameter) 2.5 m
- Bottom section (outside diameter) 3.0 m

The internal column fittings include:

- 40 valve trays, with calming sections
- Reflux inlet distributor above tray 40
- Two-phase feed inlet distributor between trays 18 and 19
- Total draw off at tray 1
- Two-phase reboiler return distributor below tray 1.

The valve trays each cover the total cross-sectional area of the column. The valve trays inside the debutanizer column are identical.

10.7.2 Debutanizer Column

The debutanizer column operates the butane component from the bottoms liquid of the depropanizer column. The butane products exits column through a top axial nozzle and the residual hot natural gas stream leaves through a bottom axial nozzle.

The simulated column has the following physical characteristics:

• Height	23.0 m
• Top section (outside diameter)	1.9 m
• Bottom section (outside diameter)	1.9 m

The internal column fittings include:

- Thirty valve trays, with calming sections
- Reflux inlet distributor above tray 30
- Two-phase feed inlet distributor between trays 15 and 16
- Total draw off at tray 1
- Two-phase reboiler return distributor below tray 1.

The construction of the valve tray is identical to those in the depronizer column.

10.7.3 Reflux Drums

The reflux drums associated with the depropanizer and the debutanizer columns provide storage for the column reflux and act as separators to minimize the entrainment of liquid in the column product streams.

These vessels are designed to act as horizontal, gravity type vapor/liquid phase separators. They are sized to reduce the velocity of the incoming vapor/liquid stream and allow sufficient residence time for gravity separation to take place.

The reflux drums have the following dimensions:

	V-1	V-2
• Length	10.35 m	7.62 m
• Outside diameter	2.32 m	1.60 m
• Total volume	45.00 m^3	16.00 m^3

10.7.4 Reboilers

The column reboilers E-601 and E-603 provide the reboiler heating requirements of the depropanizer and debutanizer columns. The heating medium for these reboilers is a stream of saturated steam.

The saturated steam is passes through the tube of the reboiler and the bottoms from the depropanizer and debutanizer columns pass through the shell side. Steam condenses and exits through the reboiler tubes. Vaporization occurs in the shell side and the hot vapor/liquid mixture enters the columns just below tray 1.

10.7.5 Condensers

The overhead vapor from the depropanizer and debutanizer columns are cooled and condensed in the overhead condenses E-602 and E-604. The condensers are structurally identical. Each contains four (4) fin-fans for cooling the overhead product by heat exchanger with ambient air.

<u>Pumps</u>

The module employs six (6) different pumps. All pumps are fixed-speed, centrifugal pumps.

Feed pumps P-601 and P-602 are used for transferring NGL feed to the depropanizer column C-601. Pump P-601 functions as the main feed pump and P-602 serves as the spare.

Reflux pumps P-603 and P-604 are used for supplying the reflux liquid to the depronizer column. The main reflux pump P-603 is capable of meeting the total reflux demanded during normal operations, while the other pump P-604 serves as a spare. At maximum unit feed rates, both reflux pumps are required.

Reflux pumps P-605 and P-606 are used for supplying the reflex liquid to the debutanizer column. The main reflux pump P-605 is capable of meeting the total reflux demanded during normal operations, while pump P-606 serves as a spare. At maximum unit feed rates, both reflux pumps are required.

CHAPTER 3

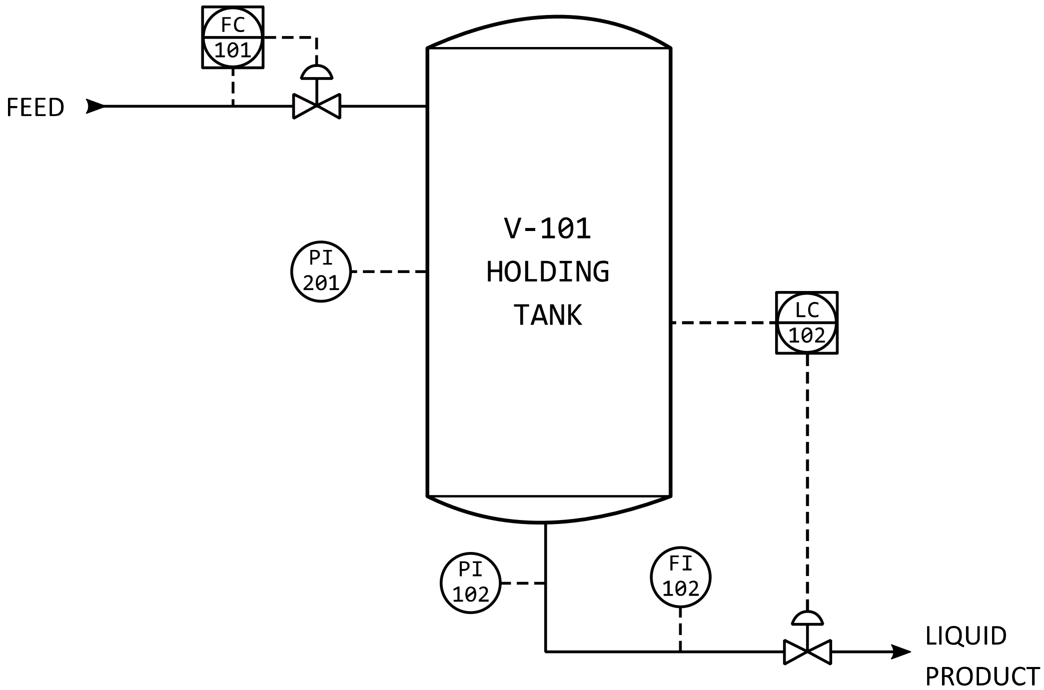
11. CONTROL SYSTEM

This chapter deals the function of each process control instrument included in the modules of the 5900M Instrumentation Training Program. The chapter accomplishes this in two (2) sections: the first section lists and describes the instruments of each module in alphanumeric order; the second section further details those instruments making up the complex or otherwise non-apparent control loops.

11.1 PROCESS CONTROL INSTRUMENTS

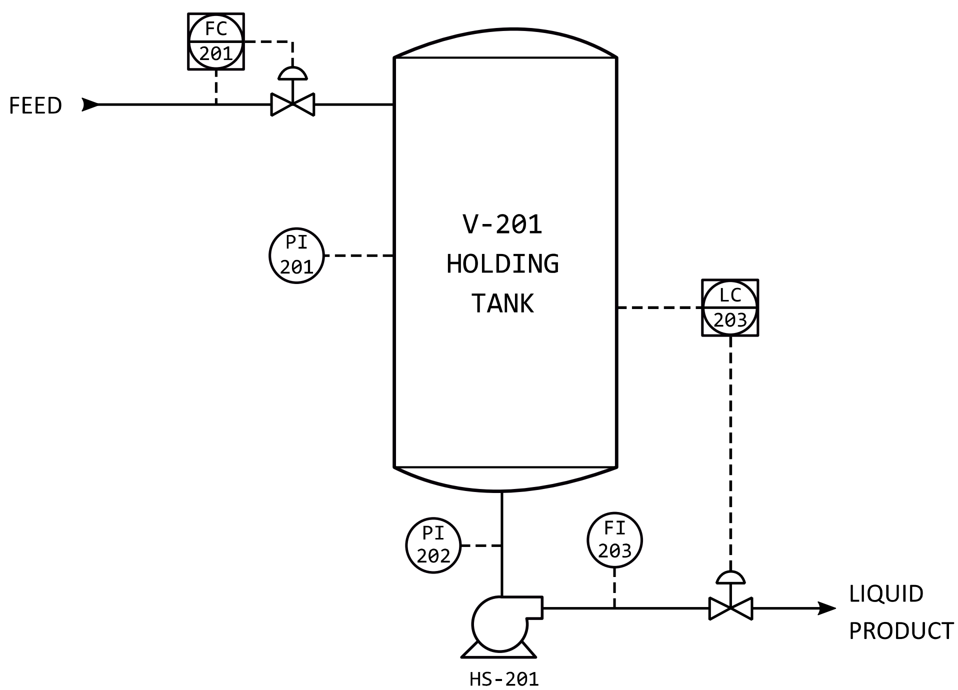
11.1.1 Module 1: Self-Regulating Holding Tank

Instrument	Description
FC-101	**HOLDING TANK INLET FLOW, 0 to 1000 kg/hr.** This instrument controls the flow of the feed entering the top of the holding tank V-101 by positioning a valve in the inlet feed line.
FI-101	**HOLDING TANK OUTLET FLOW, 0 to 1000 kg/hr.** This instrument indicates the outlet flow of material from the holding tank V-101.
LC-102	**HOLDING TANK LEVEL, 0 to 100 PCT.** This instrument controls the level in the holding tank v-101 by positioning a valve in the outlet flow line.
PI-101	**HOLDING TANK PRESSURE, 0 to 2 Barg** This instrument indicates the pressure at the top of the holding tank V-101.
PI-102	**OUTLET PRESSURE, 0 to 2 Barg** This instrument indicates the pressure of the outlet of the holding tank V-101.


FC
101
FEED
V-101
HOLDING
TANK
PI
201
LC
102
PI
102
FI
102
LIQUID
PRODUCT

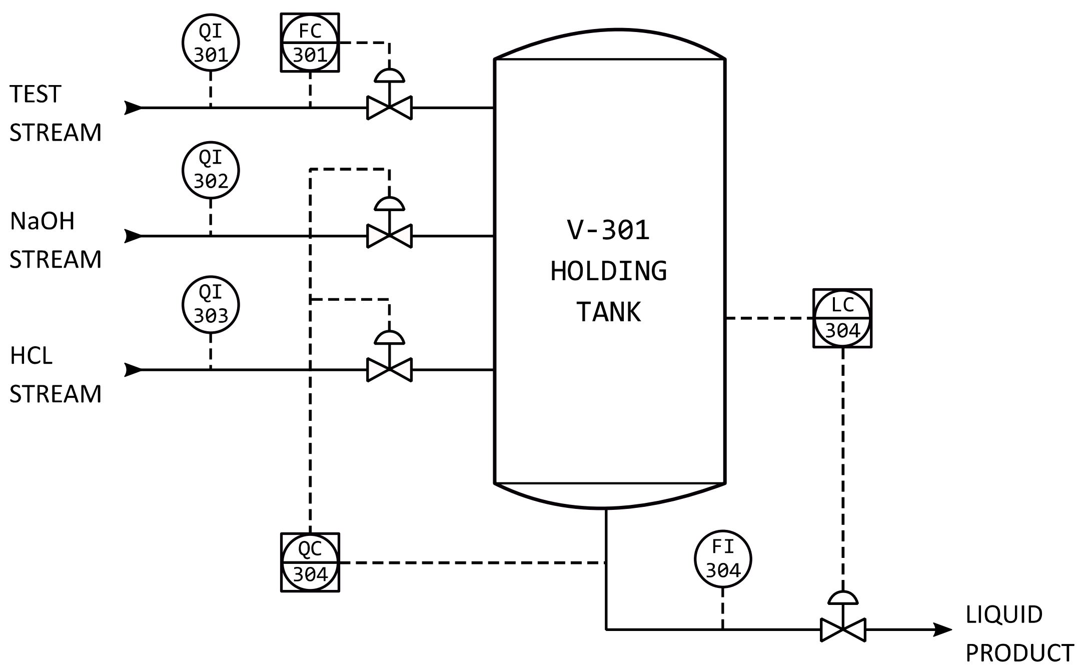
11.1.2 Module 2: Non-Self-Regulating Holding Tank

Instrument	Description
FC-201	**HOLDING TANK INLET FLOW, 0 to 1000 kg/hr.** This instrument controls the flow of the feed entering the top of the holding tank V-201 by positioning the valve in the inlet feed line.
FI-202	**HOLDING TANK OUTLET FLOW, 0 to 1000 kg/hr.** This instrument indicates the outlet flow of material from the holding tank V-201.
HS-201	**PRODUCT PUMP, ON/OFF** This switch operates the product pump P-201.
LC-202	**HOLDING TANK LEVEL, 0 to 100 Percent** This instrument controls the level in the holding tank V-201 by positioning a valve in the outlet flow line.
PI-201	**HOLDING TANK PRESSURE, 0 to 2 Barg** This instrument indicates the pressure at the top of the holding tank V-201.
PI-202	**OUTLET PRESSURE, 0 to 2 Barg** This instrument indicates the pressure of the outlet of the holding tank V-201.



11.1.3 Module 3: Non-Linear Control pH Mixing Tank

<u>Instrument</u>	<u>Description</u>
FC-301	**TEST STREAM INLET FLOW, 0 to 100 kg/hr** This instrument controls the flow of the test stream entering the top of the holding tank V-301 by positioning a valve in the inlet feed line.
FI-302	**NaOH STREAM INLET FLOW, 0 to 100 kg/hr** This instrument indicates the flow of the NaOH stream into mixing tank V-301.
FI- 303	**HOLDING TANK OUTLET FLOW, 0 to 100 kg/hr** This instrument indicates the flow of the NaOH stream into mixing tank V-301.



Module 3: Non-Linear Control pH Mixing Tank (continued)

Instrument	Description
FI-304	**HOLDING TANK OUTLET FLOW, 0 to 100 kg/hr** This instrument indicates the outlet flow of material from the mixing tank V-301.
LC-304	**MIXING TANK LEVEL, 0 to 100 PCT** This instrument controls the level in the mixing tank V-301 by positioning a valve in the outlet flow line.
QC-304	**PH OF THE OUTLET STREAM, 0 to 14 pH** This instrument controls the pH of the outlet stream, by a split range valve that controls the position of either the NaOh inlet valve or the HCL inlet valve.
QI-301	**PH OF THE TEST STREAM, 0 to 14 pH** This instrument indicates the pH of the test stream.
QI-303	**PH OF THE HCL STREAM, 0 to 14 pH** This instrument indicates the pH of the hydrochloric acid stream HCL.

11.1.4 Module 4: Heat Exchanger

Instrument	Description
FC-401	**EXCHANGER FEEDSTOCK FLOW, 0 to 50 t/h** This instrument controls the flow of cold feedstock entering the tube side of the heat exchanger E-101 by positioning a valve in the cold feedstock line.
FI-403	**EXCHANGER STEAM FLOW, 0 to 10 t/h** This instrument indicates the flow of steam to the heat exchanger E-101.
HS-401	**FEED PUMP, ON/OFF** This switch operates the cold feedstock pump P-101. The pump sends cold feedstock through the heat exchanger E-101.
HV-402	**EXCHANGER STEAM VALVE, OPEN/CLOSED** This switch operates the block valve on the stream line through which the steam is routed from the header to the shell side of the heat exchanger E-101. This valve is located upstream of the exchanger.
PI-400	**EXCHANGER STEAM PRESSURE, 0 to 15 Barg** This instrument indicates the pressure of the steam in the shell side of the heat exchanger E-101.
PI-403	**STEAM SUPPLY PRESSURE, 0 to 15 Barg** This instrument indicates the steam supply pressure to the heat exchanger E-101.
TC-402	**EXCHANGER EFFLUENT FEED TEMPERATURE, 0 to 200 ˚C** This instrument controls the temperature of the feedstock at the exchanger outlet by regulating the steam flow to the shell side of the heat exchanger E-101.
TI-401	**FEEDSTOCK SUPPLY TEMPERATURE, 0 to 200 ˚C** This instrument indicates the temperature of the feedstock entering the heat exchanger E-101.
TI-403	**STEAM SUPPLY TEMPERATURE, 0 to 200 ˚C** This instrument indicates the temperature of the steam entering the shell side of the heat exchanger E-101.

11.1.5 Module 5: Three Element Boiler Control

Instrument	Description
FC-501	**BOILER FEEDWATER FLOW, 0 to 50 t/h** This instrument controls the boiler flow from the boiler feedwater pump P-201 to the steam drum, D-200. This controller can receive a remote setpoint signal from either the steam drum level controller LC-202 or the 3-element level control, depending on the position of HS-210. For a detailed explanation of this instrument, refer to the COMPLEX PROCESS CONTROL INSTRUMENTS section located at the end of this chapter.
FI-502	**STEAM DRUM STEAM FLOW, 0 to 50 t/h** This instrument indicates the flow of steam from the steam drum D-200 to the steam header. HC-7 controls this flow.
HC-505	**FC-201 BYPASS VALVE, 0 to 100 PCT** This manual control station operates the valve on the bypass line around the boiler feedwater flow controller FC-201. This valve is used uin the event that the feedwater flow controller in inoperative in order to control the boiler feedwater flow to the steam drum.
HC-506	**BURNER FUEL BIAS, 0.5 to 2.0** This instrument controls the amount of bias added to the output signal from the steam header pressure controller PC-203 to the burner fuel flow valve PCV-203. The output of HC-206 is sent to multiplier FY-203 where it is multiplied with the output of the steam header pressure controller PC-203. The resultant signal is converted to a burner fuel flow requirement signal and is used to position the valve on the burner fuel flow line. For a detailed explanation of this instrument, refer to the COMPLEX PROCESS CONTROL INSTRUMENTS section at the end of this chapter.
HC-507	**STEAM DRUM OUTLET STEAM VALVE, 0 to 100 PCT** This manual control station operates the steam valve on the line from the steam drum D-200 to the steam header. This valve can be used to control the steam flow from the steam drum to the steam header.

Module 5: Three Element Boiler Control (continued)

Instrument	Description
HS-501	**BOILER FEEDWATER PUMP ON/OFF** This switch operates the boiler feedwater pump P-201. This pump draws boiler feedwater from the deaerator and sends it to the steam drum D-200.
HS-506	**BURNER FUEL RESET, ON/OFF** This switch resets the logic associated with the burners in the event that the fuel flow to the burners has tripped. The fuel flow to the burners can be tripped due to an extremely low or high level in the steam drum D-200 as read at LC-202. This switch is a momentary switch and will turn OFF after about ten (10) seconds. If the steam drum level has not been brought back to within non-trip limits, the fuel flow will be tripped again.
HS-510	**BOILER FEED WATER FLOW CONTROL SELECTOR, LC202/FY202** This switch selects the control scheme for regulating which remote setpoint signal is sent to the boiler feedwater flow controller FC-201. When the switch is set to FY-202, FC-201 receives a remote setpoint signal from the 3-element controller FY-202. When the switch is set to LC-202, FC-201 receives a remote setpoint signal from the drum level controller LC-202. For a detailed explanation of this instrument, refer to the COMPLEX CONTROL INSTRUMENTS section located at the end of this chapter.
HV-507	**BOILER FEEDWATER BLOCK VALVE, OPEN/CLOSED** This switch operates the block valve at the distance of the boiler feedwater pump P-201. This valve is located downstream of the pump minimum flow recycle line, so it is possible for the pump to be in operation even though the block valve is closed.
HV-508	**STEAM DRUM BLOWDOWN VALVE, OPEN/CLOSED** This switch operates the block valve in the blowdown line from the steam drum D-200 to the drain header.
HV-509	**STEAM HEADER INLET VALVE, OPEN/CLOSED** This switch operates the block valve on the steam line at the inlet to the steam header. This valve is located downstream of steam line throttle valve HC-207 and the steam flow indicator FI-202.

Module 5: Three Element Boiler Control (continued)

Instrument	Description
LC-502	**STEAM DRUM LEVEL, 0 to 100 PCT** This instrument controls the boiler feedwater level in the steam drum D-200 by sending a remote setpoint signal either to the boiler feedwater flow controller FC-201 or the 3-element controller FY-202. HS-210 determines the destination of the signal. For more information regarding this control loop, refer to the COMPLEX PROCESS CONTROL INSTRUMENTS section located at the end of this chapter.
PC-503	**STEAM HEADER PRESSURE, 0 to 85 Barg** This instrument controls the steam pressure in the steam header by regulating the flow of fuel gas to the burner. The output of PC-203 is multiplied by a bias factor set at the fuel bias controller HC-206. FY-203 multiplies the values, and then transforms the product to a fuel flow requirement value that positions the burner fuel flow valve to maintain the desired steam header pressure. For more information regarding this control loop, refer to the COMPLEX PROCESS CONTROL INSTRUMENTS section located at the end of this chapter.
PI-501	**BOILER FEEDWATER PUMP DISCHARGE PRESSURE, 0 to 100Barg** This instrument indicates the pressure at the discharge of the boiler feedwater pump P-201. This reading is taken upstream of the boiler feedwater supply block valve HV-207.
PI-502	**STEAM DRUM PRESSURE, 0 to 85 Barg** This instrument indicates the steam pressure in the steam drum D-202.
PSV-500	**STEAM DRUM PRESSURE RELIEF VALVE, OPEN/CLOSED** This instrument indicates the status of the steam drum safety valve PSV-200. This valve automatically opens when the pressure in the steam drum rises above 80.0 Barg as read at PI-202. The valve closes when the pressure in the steam drum falls below 80.0 Barg.
TI-501	**BOILER FEEDWATER SUPPLY TEMPERATURE, 0 to 200 ˚C** This instrument indicates the temperature of the boiler feedwater supply to the steam drum D-200. This reading is taken downstream of the boiler feedwater pump P-201.

11.1.6 Module 6: Distillation Column

Instrument	Description
AI-602	**DEPROPANIZER BOTTOMS PCT LIGHTS, 0 to 5 PCT** This instrument indicates the mole percent of lights in the debutanizer bottoms liquid.
AI-605	**DEPROPANIZER FEED TRAY PCT LIGHTS, 80 to 100 PCT** This instrument indicates the mole percentage of lights in the vapor at the depropanizer column feed tray.
AI-606	**DEPROPANIZER OVERHEAD VAPORS PCT LIGHTS, 90 to 100PCT** This instrument indicates the mole percentage of lights in the depropanizer tower top.
AI-607	**DEPROPANIZER REFLUX DRUM PCT LIGHTS, 90 to 100PCT** This instrument indicates the mole percent of lights in the depropanizer top liquid.
AI-611	**DEPROPANIZER BOTTOMS PCT LIGHTS, 0 to 5 PCT** This instrument indicates the mole percent of lights in the debutanizer bottom liquid.
AI-614	**DEBUTANIZER FEED TRAY PCT LIGHTS, 80 to 100 PCT** This instrument indicates the mole percent of lights in the vapor at tray 15 of column debutanizer.
AI-615	**DWBOTANIZER OVERHEAD VAPOR PCT LIGHTS, 90 to 100 PCT** This instrument indicates the mole percent of lights in the debutanizer tower top flow. This same lights composition is displayed at the instructor station as a mole fraction with five digits.
AI-616	**DEBUTANIZER REFLUX DRUM PCT LIGHTS, 90 to 100 PCT** This instrument indicates the mole percent of lights in the liquid, leaving the debutanizer reflux drum. This same lights composition is displayed at the instructor station as a mole fraction with five digits.
FC-601	**DEPROPANIZER FEED FLOW, 0 to 300 m^3/h**

This instrument controls the flow of feed to tray 18 of the depropanizer column, C-601.

Module 6: Distillation Column (continued)

Instrument	Description
FC-603	**DEPROPANIZER REBOILER STEAM FLOW, 0 to 50 t/h** This instrument controls the flow of saturated steam to the reboiler E-601 through remote setpoint from TC-604. This instrument controls the depropanizer temperature at tray 5.
FC-606	**DEPROPANIZER REFLUX FLOW, 0 to 300 m^3/h** This instrument controls the flow of the reflux to the top of the depropanizer column from the reflux drum.
FC-607	**DEPROPANIZER TOP PRODUCT FLOW, 0 to 150 m^3/h** This instrument controls the depropanizer top product flow through a remote setpoint signal from LC-602, the depropanizer reflux drum level controller.
FC612	**DEBUTANIZER REBOILER STEAM FLOW, 0 to 20 t/h** This instrument controls the flow of saturated steam to the reboiler, E-603, trough remote setpoint from TC-613. This instrument controls the debutanizer temperature at tray 3.
FC-615	**DEBUTANIZER REFLUX FLOW, 0 to 150 m^3/h** This instrument controls the flow of reflux to the top of the debutanizer column from the reflux drum.
FC-616	**DEBUTANIZER TOP PRODUCT FLOW, 0 to 75 m^3/h** This instrument controls the debutanizer top product flow through a remote setpoint signal from LC-612, which controls the level in the debutanizer reflux drum.
FI-602	**DEPROPANIZER BOTTOMS PRODUCT FLOW, 0 to 150 m^3/h** This instrument indicates the depropanizer bottoms product flow rate.
FI-604	**DEPROPANIZER OVERHEAD VAPOR FLOW, 0 to 100 k Nm^3/h** This instrument indicates the depropanizer overhead vapor flow to the reflux drum.

FI-605 **DEPROPANIZER OVERHEAD FLARE FLOW, 0 to 100 k Nm^3/h**

This instrument indicates the depropanizer overhead vapor flow to flare.

Module 6: Distillation Column (continued)

Instrument	Description
FI-611	**DEBUTANIZER BOTTOMS PRODUCT FLOW, 0 to 75 m^3/h** This instrument indicates the debutanizer bottoms product flow rate.
FI-613	**DEBUTANIZER OVERHEAD VAPOR FLOW, 0 to 60 K Nm^3/h** This instrument indicates the depropanizer overhead vapor flow to the reflux drum.
FI-614	**DEBUTANIZER OVERHEAD FLARE FLOW, 0 to 60 K Nm^3/h** This instrument indicates the debutanizer overhead vapor flow to flare.
HC-601	**DEPROPANIZER REFLUX DRUM FLARE VALVE, 0 to 100 PCT** This manual control station regulates the valve on the depropanizer overhead flare line which vents vapor from the reflux drum. Increasing the setting increases the valve opening to allow more vapor from the depropanizer reflux drum to vent to flare.
HC-602	**DEPROPANIZER CONDENSER AIR LOUVER, 0 to 100 PCT** This manual control station regulates the position of the air louvers on the depropanizer overhead condenser e-602. Decreasing the setting decreases the louver opening.
HC-611	**DEPROPANIZER REFLUX DRUM FLARE VALVE, 0 to 100 PCT** This manual control station regulates the valve on the debutanizer overhead flare line. Increasing the setting increases the valve opening to allow more vapors from the debutanizer reflux drum to vent to flare.
HC-612	**DEPROPANIZER CONDENSER AIR LOUVER, 0 to 100 PCT** This manual control station regulates the valve on the debutanizer overhead condenser E-604. Decreasing the setting decreases the louver opening.
HS-601	**FEED PUMP, ON/OFF** This switch operates the main feed pump P-601. When the switch is in the ON position, the pump is running sending feed to tray 18 of the depropanizer column. When the switch is in the OFF position, the pump is not in operation.

Instrument	Description
HS-603	**DEPROPANIZER OVERHEAD CONDESER FAN A, ON/OFF** This switch operates the "A" fan in the depropanizer overhead condenser E-602. When the switch is in the ON position, the fan is running drawing cooler air across the tubes in the condenser. When the switch is in the OFF position, the fan is not in operation.
HS-604	**DEPROPANIZER OVERHEAD CONDESER FAN B, ON/OFF** This switch operates the "B" fan in the depropanizer overhead condenser E-602. When the switch is in the ON position, the fan is running drawing cooler air across the tubes in the condenser. When the switch is in the OFF position, the fan is not in operation.
HS-605	**DEPROPANIZER OVERHEAD CONDESER FAN C, ON/OFF** This switch operates the "C" fan in the depropanizer overhead condenser E-602. When the switch is in the ON position, the fan is running drawing cooler air across the tubes in the condenser. When the switch is in the OFF position, the fan is not in operation.
HS-606	**DEPROPANIZER OVERHEAD CONDESER FAN D, ON/OFF** This switch operates the "D" fan in the depropanizer overhead condenser E-602. When the switch is in the ON position, the fan is running drawing cooler air across the tubes in the condenser. When the switch is in the OFF position, the fan is not in operation.
HS-607	**DEPROPANIZER REFLUX PUMP, ON/OFF** This switch operates the main depropanizer reflux pump P-603. When the switch is in the ON position, the pump is running drawing liquid from the reflux drum and sending it either to storage as product or returning it to the top of the column as reflux. When the switch is in the OFF position, the pump is not in operation.
HS-609	**DEBUTANIZER OVERHEAD CONDESER FAN A, ON/OFF** This switch operates the "A" fan in the debutanizer overhead condenser E-604. When the switch is in the ON position, the fan is running drawing cooler air across the tubes in the condenser. When the switch is in the OFF position, the fan is not in operation.

Module 6: Distillation Column (continued)

Instrument	Description
HS-610	**DEBUTANIZER OVERHEAD CONDESER FAN B, ON/OFF** This switch operates the "B" fan in the debutanizer overhead condenser E-604. When the switch is in the ON position, the fan is running drawing cooler air across the tubes in the condenser. When the switch is in the OFF position, the fan is not in operation.
HS-611	**DEBUTANIZER OVERHEAD CONDESER FAN C, ON/OFF** This switch operates the "C" fan in the debutanizer overhead condenser E-604. When the switch is in the ON position, the fan is running drawing cooler air across the tubes in the condenser. When the switch is in the OFF position, the fan is not in operation.
HS-612	**DEBUTANIZER OVERHEAD CONDESER FAN D, ON/OFF** This switch operates the "D" fan in the debutanizer overhead condenser E-604. When the switch is in the ON position, the fan is running drawing cooler air across the tubes in the condenser. When the switch is in the OFF position, the fan is not in operation.
HS-613	**DEBUTANIZER REFLUX PUMP, ON/OFF** This switch operates the main debutanizer reflux pump P-605. When the switch is in the ON position, the pump is running drawing liquid from the reflux drum and sending it either to storage as product or returning it to the top of the column as reflux. When the switch is in the OFF position, the pump is not in operation.
HS-615	**DEPROPANIZER REFLUX DRUM TRIP RESET, ON/OFF** This switch is used for resetting the depropanizer reflux pump logic after a low-low level condition causes them to shut down. Refer to the logic discussion at the end of this chapter for a further explanation.
HS-616	**DEPROPANIZER REFLUX DRUM TRIP RESET, ON/OFF** This switch is used for restarting the depropanizer reflux pump logic after a low-low level condition causes them to shut down. Refer to the logic discussion at the end of this chapter for a further explanation.

Module 6: Distillation Column (continued)

Instrument	Description
HV-601	**FEED PUMP SUCTION VALVE, OPEN/CLOSED** This switch is used to operate the main feed pump P-601 suction block valve. When the switch is in the OPEN position, the block valve is open to allow feed to flow to the suction side of the main feed pump. When the switch is in the CLOSED position, the valve is closed.
HV-602	**FEED PUMP DISCHARGE VALVE, OPEN/CLOSED** This switch is used to operate the main feed pump P-601 discharge block valve. When the switch is in the OPEN position, the block valve is open to allow feed to flow to the depropanizer column. When the switch is in the CLOSED position, the valve is closed.
HV-606	**DEPROPANIZER BOILER STEAM VALVE, OPEN/CLOSED** This switch is used to operate the depropanizer reboiler steam block valve. When the switch is in the OPEN position, the block valve is open to allow feed to flow to the reboiler. When the switch is in the CLOSED position, the valve is closed.
HV-608	**DEPROPANIZER BOTTOMS VALVE, OPEN/CLOSED** This switch is used to operate the depropanizer bottoms product block valve. When the switch is in the OPEN position, the block valve is open to allow bottoms product to flow from the depropanizer to the debutanizer. When the switch is in the CLOSED position, the valve is closed.
HV-612	**DEPROPANIZER MAIN REFLUX PUMP SUCT VALVE, OPEN/CLOSED** This switch is used to operate the main depropanizer reflux pump P-603 suction block valve. When the switch is in the OPEN position, the block valve is open to allow overhead product to flow to the suction side of the main reflux pump. When the switch is in the CLOSED position, the valve is closed.
HV-613	**DEPROPANIZER MAIN REFLUX PUMP DISC VALVE, OPEN/CLOSED** This switch is used to operate the main depropanizer reflux pump P-603 discharge block valve. When the switch is in the OPEN position, the block valve is open to allow overhead product to flow back to the column as reflux or as top product. When the switch is in the CLOSED position, the valve is closed.

Module 6: Distillation Column (continued)

Instrument	Description
HV-618	**DEPROPANIZER OVERHEAD FLARE VALVE, OPEN/CLOSED** This switch is used to operate the depropanizer reflux drum flare line block valve. When the switch is in the OPEN position, the block valve is open to allow overhead vapors to the flare valve which is controlled by PC-604. When the switch is in the CLOSED position, the valve is closed.
HV-619	**DEBUTANIZER REBOILER STEAM VALVE, OPEN/CLOSED** This switch is used to operate the debutanizer reboiler steam block valve. When the switch is in the OPEN position, the block valve is open to allow steam to flow to the reboiler. When the switch is in the CLOSED position, the valve is closed.
HV-621	**DEBUTANIZER BOTTOMS VALVE, OPEN/CLOSED** This switch is used to operate the debutanizer bottoms product block valve. When the switch is in the OPEN position, the block valve is open to allow bottoms product from the debutanizer to flow to storage. When the switch is in the CLOSED position, the valve is closed.
HV-625	**DEBUTANIZER REFLUX PUMP SUCTION VALVE, OPEN/CLOSED** This switch is used to operate the main debutanizer reflux pump P-605 suction block valve. When the switch is in the OPEN position, the block valve is open to allow overhead product to flow to the suction side of the main reflux pump. When the switch is in the CLOSED position, the valve is closed.
HV-626	**DEBUTANIZER REFLUX PUMP DISCH VALVE, OPEN/CLOSED** This switch is used to operate the main debutanizer reflux pump P-605 discharge block valve. When the switch is in the OPEN position, the block valve is open to allow overhead product to flow back to the column as reflux or as top product. When the switch is in the CLOSED position, the valve is closed.
HV-631	**DEBUTANIZER OVERHEAD FLARE VALVE, OPEN/CLOSED** This switch is used to operate the debutanizer reflux drum flare line block valve. When the switch is in the OPEN position, the PCV-13 flare block valve is open to allow excess vapor from the debutanizer reflux drum to vent through PCV-13 to flare. When the switch is in the CLOSED condition, the valve is closed.

Module 6: Distillation Column (continued)

Instrument	Description
LC-601	**DEPROPANIZER BOTTOMS LEVEL, 0 to 100 PCT** This instrument controls the level in the bottom of the depropanizer column by regulating the flow of liquid exiting the bottom of the column.
LC-602	**DEPROPANIZER REFLUX DRUM LEVEL, 0 to 100 PCT** This instrument controls the level in the depropanizer reflux drum by regulating the flow of liquid exiting the reflux drum as top product. LC-602 supplies a remote setpoint to FC-607, the depropanizer top product flow controller.
LC-611	**DEBUTANIZER BOTTOMS LEVEL, 0 to 100 PCT** This instrument controls the level in the bottom of the debutanizer column by regulating the flow of liquid exiting the bottom of the column.
LC-612	**DEBUTANIZER REFLUX DRUM LEVEL, 0 to 100 PCT** This instrument controls the level in the debutanizer reflux drum by regulating the flow of liquid exiting the reflux drum as top product. LC-612 supplies a remote setpoint to FC-616, the debutanizer top product flow controller.
PC-604	**DEPROPANIZER PRESSURE, 0 to 20 Barg** This instrument controls the pressure in the depropanizer through split range control. When the controller output is 50.0% or below, the pressure is regulated by positioning the pitch of the air fans in the overhead condenser E-602. At outputs above 50.0%, the controller opens a vent valve on the flare line. This control loop is further discussed under the Complex Process Control Instruments section on previous page.
PC-613	**DEBUTANIZER PRESSURE, 0 to 10 Barg** This instrument controls the pressure in the debutanizer through split range control. When the controller output is 50.0% or below, the pressure is regulated by positioning the pitch of the air fans in the overhead condenser E-602. At outputs above 50.0%, the controller opens a vent valve on the flare line. This control loop is further discussed under the Complex Process Control Instruments section on previous page.

Module 6: Distillation Column (continued)

Instrument	Description
PDI-601	**DEPROPANIZER DIFFERENTIAL PRESSURE, 0 to 10 Bar** This instrument indicates the pressure differential across the depropanizer column.
PDI-611	**DEBUTANIZER DIFFERENTIAL PRESSURE, 0 to 5 Bar** This instrument indicates the pressure differential across the debutanizer column.
PI-603	**REBOILER SATURATED STEAM PRESSURE, 0 to 30 Bar** This instrument indicates the pressure of the steam flowing to both reboilers E-601 AND E-603.
TC-604	**DEPROPANIZER TRAY 5 TEMPERATURE, 0 to 200 ˚C** This instrument controls the temperature at tray 5 of the depropanizer column by sending a remote setpoint signal to FC-603. This instrument controls the flow of saturated steam to the reboiler.
TC-613	**DEBUTANIZER TRAY 3 TEMPERATURE, 0 to 200 ˚C** This instrument controls the temperature at tray 3 of the debutanizer column by sending a remote setpoint signal to FC-612. This instrument controls the flow of saturated steam to the reboiler.
TI-602	**DEPROPANIZER BOTTOMS PRODUCT TEMPERATURE, 0 to 200 ˚C** This instrument indicates the temperature of the depropanizer bottoms product.
TI-605	**DEPROPANIZER FEED TRAY TEMPERATURE, 0 to 200 ˚C** This instrument indicates the temperature at tray 18 of the depropanizer column.
TI-606	**DEPROPANIZER OVERHEAD TEMPERATURE, 0 to 100 ˚C** This instrument indicates the temperature of the vapors exiting the top of the depropanizer column.
TI-607	**DEPROPANIZER REFLUX DRUM TEMPERATURE, 0 to 100 ˚C** This instrument indicates the temperature of the liquid in the depropanizer reflux drum.

Module 6: Distillation Column (continued)

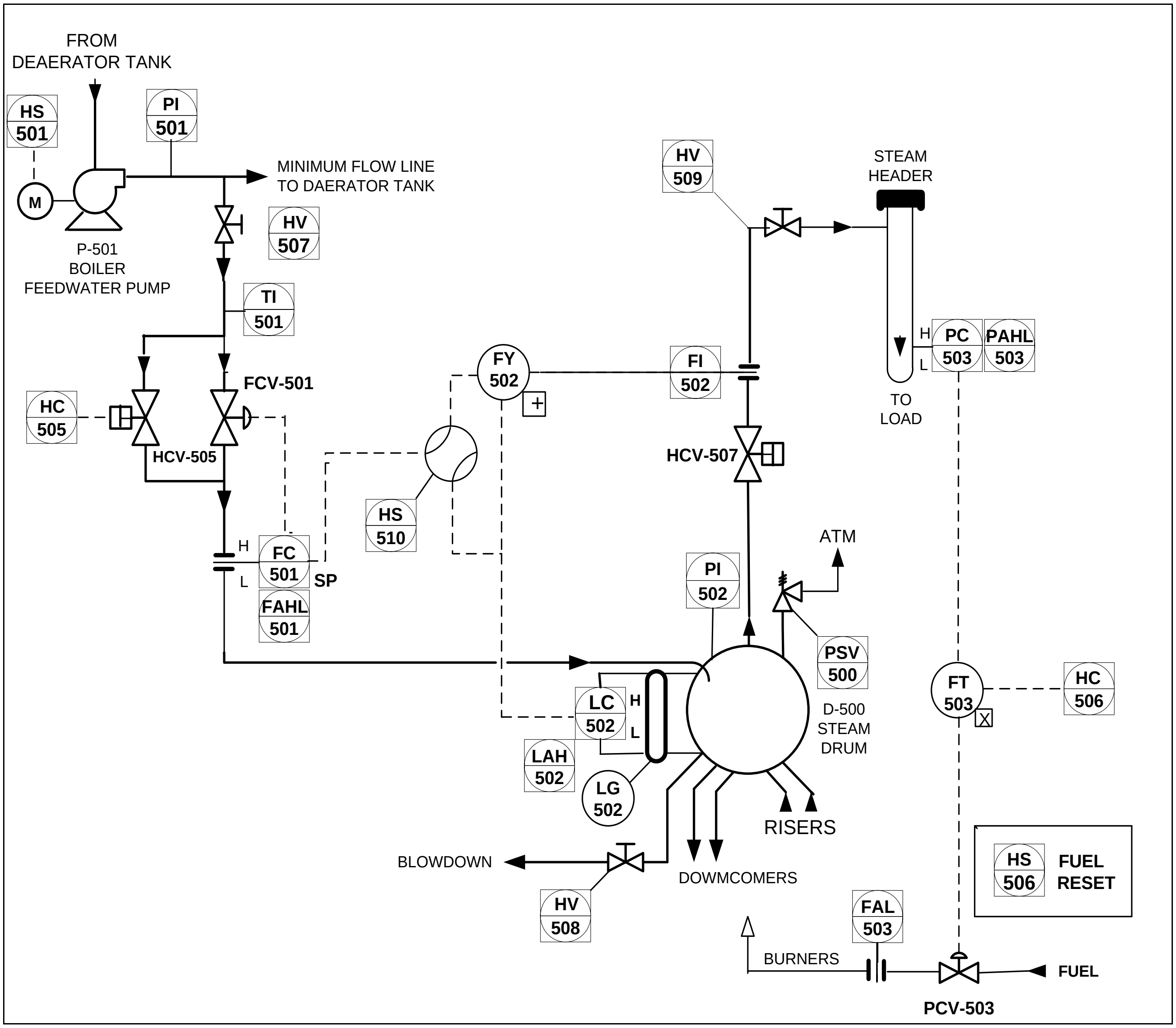
Instrument	Description
TI-611	**DEBUTANIZER TOWER BOTTOM PRODUCT TEMP, 0 to 200 ˚C** This instrument indicates the temperature of the debutaanizer bottoms product.
TI-614	**DEBUTANIZER FEED TRAY TEMPERATURE, 0 to 200 ˚C** This instrument indicates the temperature at tray 15 of the debutanizer column, which is also the feed tray.
TI-615	**DEBUTANIZER OVERHEAD TEMPERATURE, 0 to 100 ˚C** This instrument indicates the temperature of the vapors exiting the top of the debutanizer column.
TI-616	**DEBUTANIZER REFLUX DRUM TEMPERATURE, 0 to 100 ˚C** This instrument indicates the temperature of the liquid in the debutanizer reflux drum.

COMPLEX PROCESS CONTROL INSTRUMENTS

Module 5: Three-Element Boiler Control

Boiler Feedwater Flow Control Loop

FC-501 controls the boiler feedwater flow via remote setpoint. A selector switch HS-510 is provided for selecting one of two (2) available control schemes: the FY-502 adder scheme or the LC-502 scheme. Refer to Figure below.



Three Element Boiler Control sample graphics

When HS-510 is set to FY-502, the remote setpoint signal sent to the boiler feedwater flow controller FC-501 is determined by FY-502 using the boiler drum level LC-502 and the steam flow FI-502 signals. The steam flow signal is sent to FY-502, where it is adjusted based on a change in the drum level. That is, if the drum level is steady (not changing), the steam flow signal will be the remote setpoint signal for the boiler feedwater flow controller. However if the steam drum level is in transition (changing), the steam flow signal is adjusted by FY-502, upwards in the event that the drum level is decreasing or is adjusted downwards in the event that the drum level is increasing. This is done in order to maintain more stable steam drum levels when the unit is in transition.

When HS-510 is set to LC-502, FC-501 receives a remote setpoint signal directly from the level controller LC-502. In this mode of operation, the flow adder FY-502 is not functional.

Steam Header Pressure

PC-503 controls the steam header pressure by regulating the flow of fuel gas to the burner. Refer to the figure on the previous page. The output signal from PC-503 is multiplied by a factor between 0.5 and 2.0, as set at the burner fuel bias controller HC-506. Multiplier FY-503 accomplishes this. The signal is then converted to a fuel flow requirement and used to position the valve on the burner fuel flow line.

The output signal of HC-506 is sent to a multiplier FY-503, which multiplies the output from PC-503, by the output from HC-506 in order to determine the burner fuel flow requirement. FY-503 uses this signal to position the burner fuel flow value. Increasing the setting of HC-506 increases the multiplication factor. Conversely, decreasing the setting reduces the multiplication factor. When the ratio is increased, the output of PC-503 is multiplied by a larger factor, resulting in a greater increase in the fuel flow to the burner. This, in turn, increases the steam production rate faster. The steam header pressure increases temporarily until the PC-503 output decrease to compensate for the larger bias setting. If, on the other hand, the setting at HC-506 is decreased, the output signal of PC-503 must increase to correct any negative setpoint deviation.

Module 6: Distillation Column

Program 5900M Model 6 has two (2) control loops involving split-range control: depropanizer and debutanizer top column pressures. A description of tower top pressure control follows.

Tower Top Pressure Control

The pressure in the top of the depropanizer column is controlled by PC-604 and the pressure in the top of the debutanizer column is controlled by PC-613. The control schemes function identically so in this discussion we will use PC-604 for description purposes. Refer to the figure below for an illustration of the control scheme.

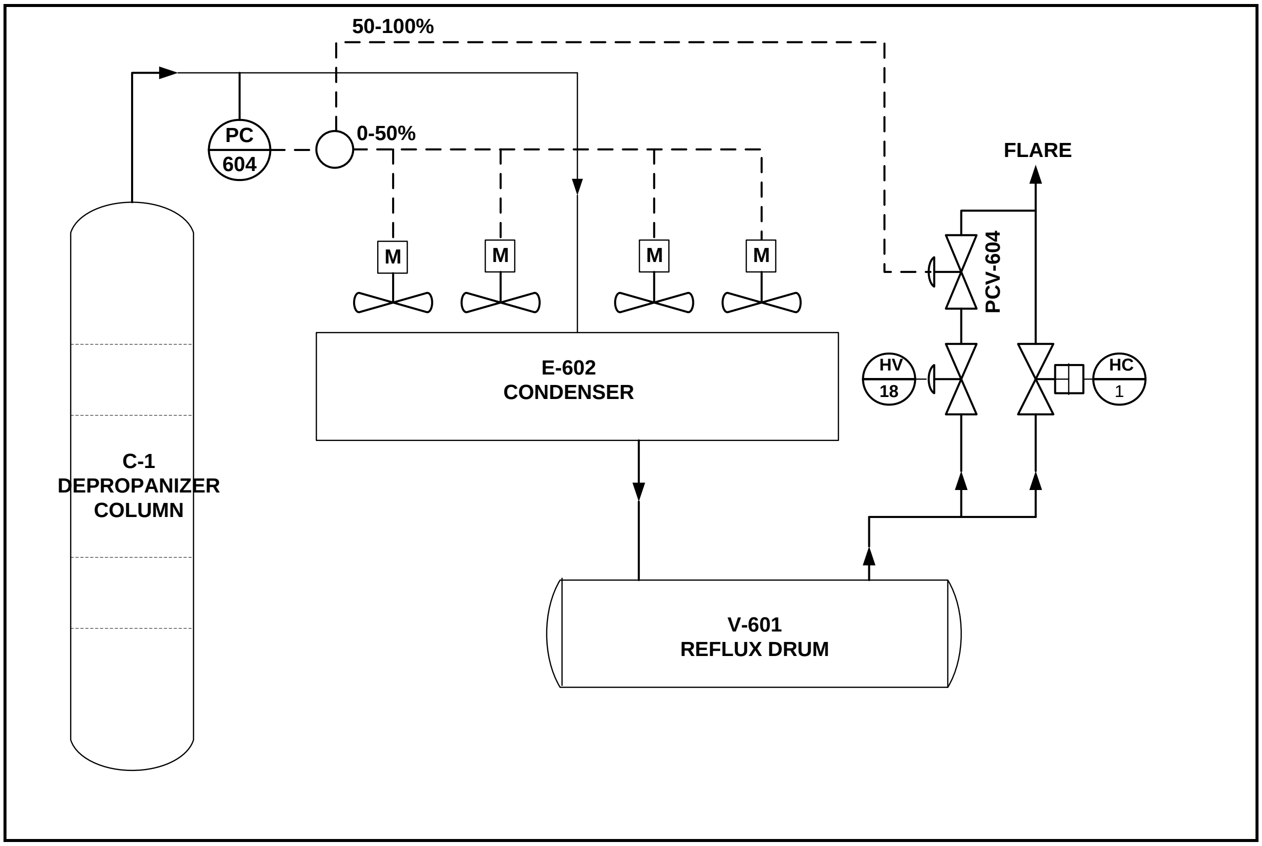


Figure 6-1, Depropanizer Tower Top Pressure Control

PC-604 maintains the depropanizer column pressure through split-range control. The controller output acts on the pitch of the fans in the column overhead condenser E-602 and also on a vent valve on the reflux drum V-601 overhead flare system.

When the controller output is between 0.0% and 50.0%, the column pressure is maintained by regulating the blade pitch on the fans in the overhead condenser. When the controller output is above 50.0%, the flare valve starts to open. During the course of normal operations, the column pressure is controlled by regulating the pitch of the condenser fan blades with the flare valve staying closed.

The debutanizer column top pressure is controlled by PC-613, which operates in the same manner as described for PC-604.

LOGIC CIRCUITS

Module 5: Three-Element Boiler Control

Module 5 includes an automatic logic action for safe operation of the boiler drum. If, at any time, the pressure in the drum exceeds 80.0 Barg, pressure safety valve PSV-500 automatically opens to vent the excess steam to the atmosphere. PSV-500 is a field mounted valve. It cannot be manipulated at the operator station. There is a status light for PSV-500 displayed at the operator station, which illuminates the open position when the valve is opens. The light return to the close position when the valve closes.

Additional logic action trips the fuel valve when the boiler level LC-502 falls below 10.0% or rises above 90.0%. Any trip or failure of the fuel valve requires a reset of switch HS-506 before fuel can be brought back to the burners. The reset switch is a momentary type switch and automatically turns OFF after about ten (10) seconds.

Module 6: Distillation Column

Module 6 is equipped with a logic system that safeguards again potential disasters. A variety of process conditions can initiate an automatic shutdown in the simulated plant.

Pump Logic

Pump suction valves must be open before starting the pump motors. Closing a pump suction valve while the pump is running causes the motor to automatically trip.

Reflux Drum Level

Both reflux drums V-601 and V-602 are equipped with logic circuits that protect them from a total loss of liquid level. When the level in either reflux drum falls below 5.0%, the reflux pumps automatically shut down to allow liquid to accumulate in the respective drum.

To reset the reflux pumps, perform the following steps:

1. Place the appropriate reset switch HS-615 or HS-616 in the RESET position.
2. Start the appropriate reflux pump by turning **ON** HS-607 or HS-613.

CHAPTER 4

12. List of Exercises for the 5900M Program

This chapter details various exercises that can be completed on the 5900M Instrumentation Training Program. Included here are various exercises for each of the different modules of the program. This section is designed to be completed from beginning to end. Based on individual knowledge it may be possible to start at various places in the text.

Prior to starting the exercises it is advisable to have read the Principles of Process Control included in the appendix.

NOTE:

The exercise below represents exercises that are geared to give a general understanding of control. If your practice differs from the exercises present here, changes, additions, or substitutions should be made.

12.1 Self-Regulating – Gravity Drained Tank

12.1.1 Section 1: Self Regulating Tank Characteristics

The objective of the first set of exercise is to determine how the self-regulating process behaves. This is demonstrated through the use of a gravity drained holding tank. These exercises should be completed with the controllers in manual.

Exercise 1: Vary the inlet flow

ACTION: Place the controllers FC101 and LC102 into manual. Increase the output of the inlet valve FC101 to 65% and allow the system to come to steady state. Next, decrease the output of the inlet valve FC101 to 35%, and allow the system to come to line out.

RESULT: The liquid level will respond to the new inlet flow rate and a new steady state level will be found. Eventually the inlet flow will equal the outlet flow. For the first case, above, the level should steady out around 65%, and for the second case the level should line out around 35%.

DISCUSSION: This exercise demonstrates that this process is self-regulating in nature; the liquid level was able to find a steady state value when the inlet (FC101) and the outlet flows (FI102) were out of balance. The fact that the process was able to reach a steady state without any action by a controller is what makes it a self-regulating process.

Exercise 2: Vary the outflow

ACTION: Controllers FC101 and LC102 remain in manual. Change the output of FC101 to 50%. Increase the output of the outlet valve LC102 to 100% and allow the system to come to steady state. Next, decrease the output of the outlet valve LC102 to 45% and allow the system to come to steady state.

RESULT: The liquid level responds to the new outlet flow rate and a new steady state level is found. Eventually the inlet flow equals the outlet flow. For the first case the level steadies out around 42%, and for the second case the level should steady out around 92%.

DISCUSSION: This exercise demonstrates that a self-regulating process has a steady-state relationship between the controlled variable and either the inflow or outflow or both. Typically, flow, pressure, composition and temperature are self-regulating process.

12.1.2 Section 2: Instrumentation and Control Hardware Exercises

The objective of this section is to introduce the student to the concept of control valve sizing and the differences in control valve types. The student will learn how the control valve size and type effects and influences a self-regulating process. These exercises should be performed with the controllers in manual.

Exercise 3: Vary the size of the inlet valve, FC101

ACTION: Place controllers FC101 and Lc102 in manual. On the instructor station change the valve size of FC101 to 1.3 times design and allow the system to come to steady state. Monitor the process during this time. Next, on the instructor change the FC101 valve size to 0.7 times design and allow the system to come to steady state. Again monitor the process and note the effects of the valve size change.

RESULT: In this exercise the output of the FC101 controller remained unchained. However, for a given controller output, the flow into vessel V-101 increased when the valve size was increased and decreases when the valve size was reduced. For the first case the level should “self-regulate” to approximately 65% and for the second case the level should “self-regulate” to approximately 35%.

DISCUSSION: The size of the valve determines the amount of material that passes through a valve and is inversely proportional to the pressure drop. Changing the valve size increases or decreases the flow of material at the expense of pressure drop. In this exercise it is possible to overflow the tank. This occurs when the valve size is increased beyond the capability of the outlet valve size.

Exercise 4: Change outlet valve size

ACTION: Place the controllers FC101 and LC102 into manual. On the instructor change the size of valve LC102 to 1.3 times design and allow the system to come too steady state. Next, on the instructor decrease the size of LC102 to 0.7 times design and allow the system to come to steady state.

RESULT: In this exercise the output of LC102 controller remained the same. However, for a given controller output the flow out of the system (FI102) increased with the valve size and decreases when the valve size was reduced. In both cases, a new "self-regulated" level was established. When the valve size was increased the level should "self-regulate" to approximately 39% and when the valve size was reduced the level should "self-regulate" to approximately 71%.

DISCUSSION: The size of the control valve determines the flow of material through it. When the valve size was changed the flow through the valve changed and the vessel V-101 "self-regulated" to a new level. In this exercise it is possible to overflow or empty the tank in the exercise. This occurs when the valve sixe is increased or decreased beyond the capability of the inlet valve. This will be performed in the next exercise.

Exercise 5: Overflowing the Tank

ACTION: Place controllers FC101 and LC 102 in manual. On the instructor change the size of LC102 to 0.7 times design and the size of FC101 to 1.3 times design. Next, change the output of FC101 and LC 102 to 50% and allow the system to come to steady state.

RESULT: In this case the process will attempt to "self-regulate" to a level that is above the top of the tank and the tank overflows. Eventually, the process has become a non-self-regulating process.

DISCUSSION: It was demonstrated in this exercise that self-regulating processes have useful ranges where the process is self-regulating. When the range is exceeded as in this case, the inflow flow rate exceeds the outflow flow rate and eventually the level increases beyond the tanks capacity, and overflows.

12.1.3 Section 3: Tuning Controller

In this section the student is introduced to one-technique for tuning controllers. ***As with all tuning correlations and techniques these methods provides initial tuning parameters only. Final tuning must occur on-line and be verified by trial and error using the actual process.***

Exercise 1: Tune FC101 controller using the Ziegler-Nichols Method

ACTION: Click on FC101 to display the trend of this point on the right hand side of the screen. Implement a P-Only controller by turning the integral portion of the control algorithm *off.* This is accomplished by increasing the integral term to 9999. This negates the 2nd term or the integral portion of the following ideal PID algorithm, equation 1.

$$CO = Kc\left[(E(t)) + \frac{1}{\tau 1}\int E(t)dt + \tau D\frac{dE}{dt}\right]$$

Equation 1: The ideal PID algorithm

Where:
- CO is the controller output
- Kc is the controller gain
- E(t) is the setpoint minus the process measurement
- t1 is the integral time or the reset time with units of minutes
- τD is the derivative time (minutes)

Next, increase the controller gain, Kc, on the controller to find the a) ultimate gain, and b) ultimate period. <u>The ultimate gain</u> can be determined by increasing the controller gain until you find the smallest value of the controller gain, Kc, which causes sustained oscillations in the measured process variable. The ultimate gain is reached when the oscillations neither grow nor die and the manipulated variable remain unconstrained. The period of the oscillations in the measured process variable at this condition is the ultimate period, Pu.

RESULT: The ultimate gain, Kc (approx. =1.43) and the ultimate period Pu (approx. = 0.2 min/repeat) are determined for the FC101 loop. These values can be used in the following correlations, determine by Ziegler's-Nichols in the 1040's, to determine the starting controller tuning constants.

Table 1: Ziegler – Nichols Tuning Relations

Controller	Kc	T1	TD
P-Only	0.50Ku	9999	0.00
PI	0.45Ku	Pu/1.2	0.00
PID	0.60Ku	Pu/2.0	Pu/8.0

DISCUSSION: The ultimate gain is the value of gain at which the loop is at the limit of stability with a proportional-only feedback controller. The period of oscillation is called the ultimate period. Typically, the Ziegler's-Nichols method gives a reasonable performance on some loops. However, there are many loops where the Ziegler's Nichols settings tend to be over dampened. Typically, The Ziegler's Nichols method gives a useful place to start the tuning process.

Exercise 2: Test a P-only controller for FC101

ACTION: Implement a P-only controller for FC101 as described above. Change the process gain, Kc, to the value determined in the previous exercise. Change the setpoint to 600 kg/hr and allow the system to stabilize.

RESULT: Confirm that the main advantage of this type is offset. The offset will become more apparent the further away from the design condition you become.

DISCUSSION: The P-only control law states, as controller gain increases the size of the offset decrease. Unfortunately, as controller gain increases, the oscillations in the controlled variable will also increase and eventually will go unstable.

Exercise 3: Test a PI Controller

ACTION: Implement FC101 as a PI controller with the tuning constants determined in exercise 1. Change the setpoint to 550 kg/hr. Allow the system to stabilize. It may be necessary to make additional changes to the tuning constants to get “good” response from the loop. After each tuning constant change, bump the process by changing the setpoint between 500 and 550 kg/hr.

RESULT: The offset that was present in the previous exercise has been eliminated.

DISCUSSION: The integral action of a controller addresses how long and how far the measured process variable has deviated from the set point. The big advantage of PI controller is that it eliminates offset present in a P-only control scheme. Offset is eliminated because as long as there is any error the integral term will shrink or grow in size and cause the controller output to change.

The big advantage of PI controller is that it eliminates the offset present in a P-only control scheme. Offset is eliminated because as long as there is any error in the integral term will shrink or grow in size and cause the controller output to change.

The main disadvantage of the PI controller is that it increases the oscillatory behavior of the measured process variable.

Exercise 4: Bad Level Control

ACTION: Tune the LC102 controller so that it reaches the setpoint as quickly as possible. Change the setpoint between 50% and 60% to determine the effect of your tuning constant changes.

RESULT: It is possible to tune the LC102 controller so that the setpoint is reach very quickly. When the LC102 controller is tuned using this method the valve rapidly opens and closes. This cause severe fluctuation of the flow out of the vessel.

DISSCUSSION: Many different factors need to be considered when a loop is tuned, including loop type, and the desired response. In this exercise tuning a level control loop for quick response seems like a good idea. However could drastically affect a downstream process. The goal of this exercise is to emphasis that it is important to consider the effected processes when tuning a controller.

Exercise 5: Good Level Control

ACTION: The goal of this exercise is to minimize the effects that a level controller passes on to subsequent units. The focus of this exercise is to tune the controller LC102 so that the level controller slowly varies the opening of the outlet valve. Thus the flow rate out of the vessel V-101, FI102, will vary slowly which minimizes the effect that it will have in other units.
RESULT: The controller will very slowly adjust the process variable so that the disturbances to downstream units are minimized.

DISSCUSSION: Typically this is the prepared method for tuning level controllers. In many cases, a level controller is used on a holding tank for storage or surge capacity and is used to eliminate disturbances from being passed to a downstream unit.

12.2 Non Self-Regulating-Pump Drained Tank

12.2.1 Section 1: Non-Self Regulating Tank Characteristic

The objective of this section is to determine how a non-self-regulating process behaves. This is demonstrated through the use of pump drained holding tank. These exercises should be completed with the controllers in manual. The model should be reset to the design condition between each of these exercises.

Exercise 1: Vary the inlet flow

ACTION: Place FC201 and LC203 into manual. Increase the output of FC201 to 60% and allow the trend to develop. Next, decrease the output of FC201 to 40% and allow the trend to develop. Monitor the level in V-201 by clicking on LC203.

RESULT: The level of vessel V-201, LC203 will begin to increase beyond the capacity of the tank. When the output is decreased the level of vessel V-201, LC203 will empty.

DISCUSSION: In this case the flow out of the vessel, FI-203 is independent of the level, LC203 and the flow into the vessel, FC201.

Exercise 2: Vary the outlet flow

ACTION: Place FC201 and LC203 into manual. Increase the output of LC203 to 60%.The flow rate measured at FI203 should increase to approximately 650 kg/hr, while the inlet flow rate measured at FC201 remains 500 kg/hr. Next, decrease the output of LC203 to 35%. The flow rate measured at FI203 should decrease to approximately 390 kg/hr, while the inlet flow rate will remains at 500 kg/hr. monitor the level in V-201 by clicking on LC203.

RESULT: When the output of LC203 is increased the level of the vessel V-201, LC203 will begin to empty. When the output is decreased the level of vessel 201, LC203 will fill beyond the capacity of the tank.

DISCUSSION: This exercise demonstrates that the flow out of the vessel, FC201 is independent of the level, LC203 or the suction head of the pump, P-201.

12.2.2 Section 2: Instrumentation and Control Hardware Exercises

The objective of this exercise is to teach the student the concept of pump head. The student will learn how these variables influence a non-self-regulating process. This exercise should be performed in manual. The model should be restored to the design condition between each exercise.

Exercise 3: Pump Head Effects

ACTION: Place FC201 and LC203 into manual. On the instructor reduce the available pump head of pump P-201 to 0.75 times design. The outlet flow rate measured at FI203 should decrease to approximately 450 kg/hr. Next increase the output of the inlet flow controller FC201 to 60%.

RESULT: The level in vessel V-201, LC203 will begin to increase when the available pump head is reduced. This is further emphasized in the second part of the exercise when the inlet flow is increased. In effect these two events together will cause the vessel level V-201 to increase much more rapidly than it did in exercise 1 of this section.

12.2.3 Section 3: Tuning Controllers

This section introduces the student to controller direction. The student should gain confidence as they tune simple flow and level controllers.

Exercise 4: Determining the controller action

ACTION: Place the controller FC201 into manual. Increase the output of FC201 to 60%. Monitor the effects. Next, decrease the output to 40%, and monitor the effects. Next, Change the output so that the PV of FC201 stabilizes around 50 kg/hr. Finally, put the controller into Automatic and increase the setpoint to 60 kg/hr.

RESULT: In this exercise a step change in the controller output or the manipulated variable, ΔU was performed. The result of this step change was that the process variable or measured variable, ΔY, changed.

$$\text{Process Gain, Kp} = \frac{\text{Total change in Measured Variable},\ \Delta Y}{\text{Total Change in Manipulated Variable},\ \Delta U}$$

Equation 2: Steady state Process Gain

The process gain, Kp and the sign associated with the process gain can be determined by plugging these values into equation 2. In the above exercise Kp has a positive sign associated with it.

DISCUSSION: If a decrease in the controller output causes the process measurement to decrease, the sign of the process gain is positive and the controller is considered to be a direct acting controller. On the other hand, if an increase in controller output causes the process variable to decrease, the sign on the process is negative and the controller is considered to be a reverse acting controller.

Exercise 5: The effect of wrong controller direction

ACTION: Change the direction of LC203 from DIRECT to REVERSE. Now change the setpoint of LC203 to 50%. Watch the output of the process measurement of LC203 to determine the trend. Next, reduce the setpoint of LC203 to 35% and determine the trend of both the output and the process measurement. At the end of the exercise, change the controller direction back to DIRECT, and change the setpoint to 50%.

RESULT: When the controller direction is reversed the LC203 controller begins to open the valve and the level begins to decrease. As the process variable of LC203 decreases the error between the setpoint and the process variable becomes increases and the controller responds by opening the valve more.

DISCUSSION: The controller direction depends on the action of the transmitter, the action of the valve (fail open, fail close), and the effect of the manipulated variable on the controlled variable.

12.3 Non-Linear Control – PH Mixing Tank

5900M

12.3.1 Section 1: Non – Linear Process PH Mixing Tank Characteristic

In this section the program is exploited in rather peculiar ways to illustrate the basic principles of acids, basis and pH scales.

Exercise 1: Split Range Control

ACTION: Place controller QC304 in manual, adjust output to 0%, 25%, 50%, 75% and 100%. Record the valve position for the HCL valve and NaOH valve in the space provided.

RESULT: When the output of the controller is at 0% the HCL valve is completely close. When the output is 50% both the HCL and the NaOH valves are closed, and when the output is 100% the NaOH valve is completely close.

DISCUSSION: QC304 is a split range controller that controls both the HCL stream and the NaOH stream. When the controller output of QC304 is at 50% both the HCL and NaOH valve are closed. The signal output of QC304 is split into two valves from (0% -50%) and from (50% – 100%).

Table 1: Split range control of QC304

QC304 output (%)	HCL Valve Position (%)	NaOH Valve Position (%)
0%		
25%		
50%		
75%		
100%		

Exercise 2: The pH of a strong acid

ACTION: Place FC301, QC304 and LC304 into manual. Set the output of FC301 to 50%, the output of QC304 to 50%, and the output of LC304 to 100%. This opens the test stream valve to 50%, note the pH, the flow of FC301 and the flow of FI302. On the instructor (IV 3, 1) increase the LC304 valve size to 1.5 times design. Allow the system to stabilize. The pH of the test stream starts out at 4.0. Now slowly decrease the output of QC304 from 50% to 25%. Note the pH and the flow rate of the FI302, after each change. Allow the system to stabilize.
RESULTS: A pH titration curve can be generated from the gathered data. This is accomplished by plotting the pH versus the flow rate of NaOH.

TREND: QC304 Time base: ________

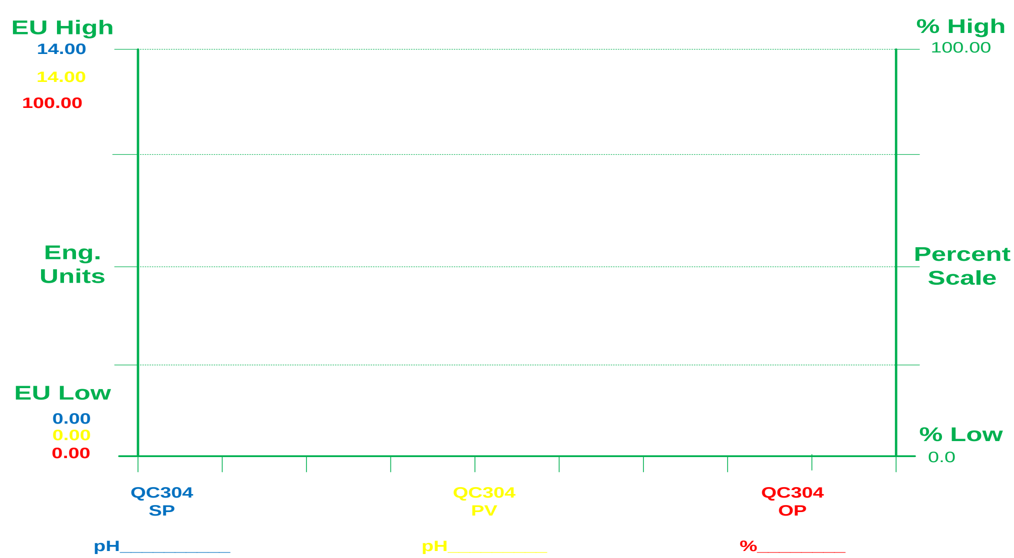


Figure 1: pH of a strong acid

Exercise 3: The pH of a strong Base

ACTION: This exercise is a continuation of the previous exercise. Begin by slowly decreasing the output of QC304 from 25% to 0%. At the beginning the steps should be very small. Note the pH, and the flow rate of FI302 after each change. Allow the system to stabilize before proceeding to the next change.

RESULT: A pH titration curve can be generated from the gathered data. This is accomplished by plotting the pH versus the flow rate of NaOH.

TREND: QC304 Time base: ________

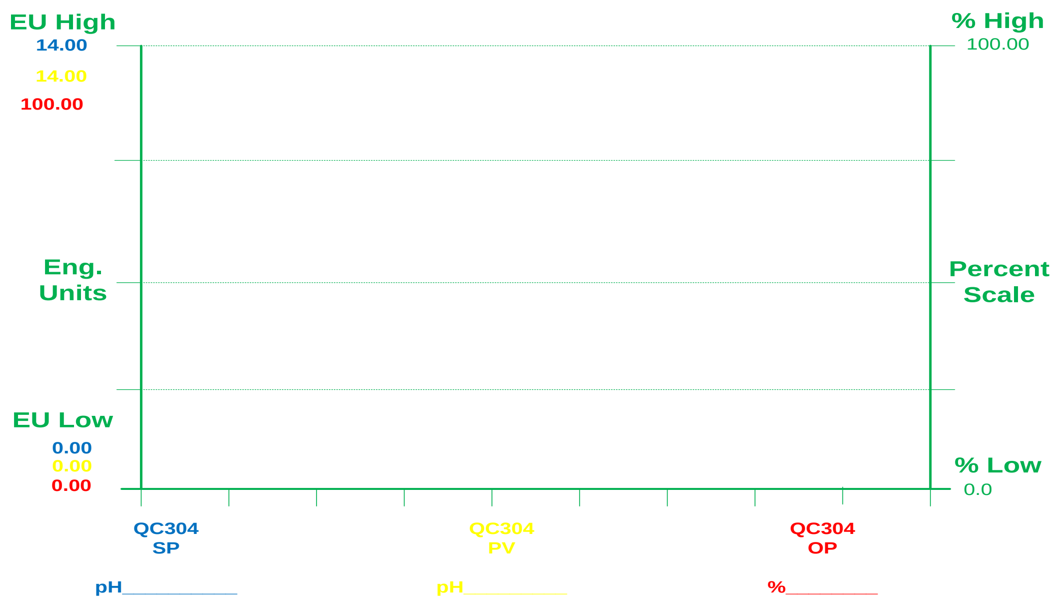


Figure 2: pH of strong Base

Exercise 4: The Titration Curve

ACTION: Take the data that was collected the previous two exercises and make a complete titration curve.

RESULT: The non-linearity of the process becomes apparent.

TREND: QC304 Time base:________

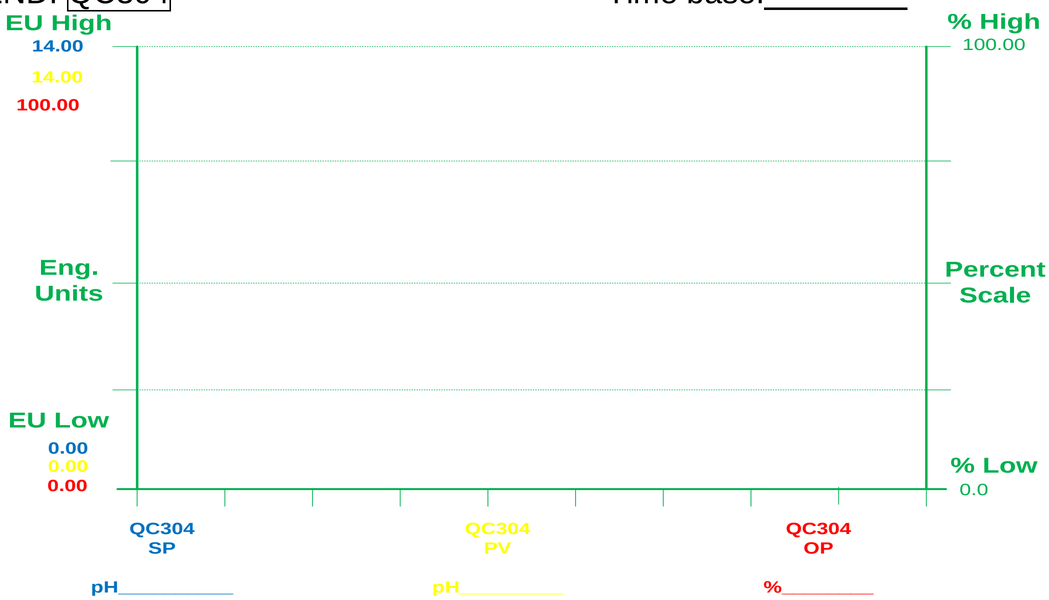


Figure 3: Complete Titration Curve of QC304

12.3.2 Section 2: Tuning a PH Controller

The controller should be placed into automatic for these exercises. This section will look at various pH control situations.

Exercise 5: A well-built pH system

ACTION: Set the setpoint of QC304 to 8.2 and tune the controller. Bump the controller between 7.8 and 8.4 to determine “good “Tuning constants.

RESULTS: This setpoint is a high- gain portion of the titration curve

DISCUSSION: The controller has been tuned to respond in a reasonable amount of time to return to a pH of 8.2.

Exercise 6: Testing Control System Performance

ACTION: Change the setpoint to 9.4 without changing the controller tunings.

RESULTS: The tuning constant that works for exercise 1 is no longer valid.

DISCUSSION: Due to the linearity of the process it is not possible to use the same tuning constants for different pH ranges.

Exercise 7: A poorly built pH system

ACTION: On the instructor (Fault 2, 1) turn the agitator in the pH tank, vessel V-301 to off.

RESULT: Control of the system is virtually impossible as the PH electrode sees very wild patterns.
DISCUSSION: It is important that a good mixing occurs inside the tank or else the pH electrode will see very wild oscillations of unmixed globules of acid-base-acid etc.; A pipe-tee mixer is used instead of a tank would exhibit even worse oscillations.

Exercise 8: Another poorly built pH system

ACTION: On the instructor, move the pH probe position downstream of the vessel V-301 (Fault 2, 2). Change the setpoint of QC304 to 8.5 and tune the controller for "good response".

RESULT: The student finds that control is much more difficult than it was before.

DISCUSSION: Moving the position of the electrode downstream of the tank increases the dead time of the loop. This causes the pH of the tank to oscillate to a much higher degree than before.

12.3.3 Section 3: Trouble shooting PH systems

This section tests the students' knowledge of troubleshooting a problem condition in the pH Module. Each of these exercises should be setup without the students' knowledge of the problem.

Exercise 9: The Controller is Broken

ACTION: On the instructor lower the pH of the NaOH stream to 9.5 (IV 3, 3). Change the setpoint of QC304to 8.0.
RESULT: The QC304 completely opens the NaOH stream valve. However, the pH of the base is not high enough to achieve the desired pH of 8.0.

DISCUSSION: The student is told that the controller seems to be broken since the output is up against the stops. Does putting the controller into manual help?

Exercise 10: The lab says "fixed it"

ACTION: On the instructor introduce a calibration error on the pH probe (Fault 2, 4).
RESULT: The controller QC304 compensates for the error but the actual reading is wrong.

DISCUSSION: The student should ask to test the pH with a portable pH meter. Does the student get the root of the problem?

Exercise 11: The new pH system doesn't work

ACTION: on the instructor, fail the pH electrode (fault 2, 3).Change the set point of QC304 to 7.8.

RESULT: The control will begin to close the NaOH valve, but the process variable of QC304 does not respond and the valve continues to close, but the actual pH reading inside the V-301 is much lower.

DISCUSSION: Sensors can get corroded and stop functioning.

12.4 Heat Exchanger

12.4.1 Section 1: Heat Exchanger Characteristics

The objective of this first exercises is to find out what heat exchangers are and how they work.

Exercise 1: Heat flows from High to Low Temperature

ACTION: Have the instructor reduce the instructor variable steam header pressure to 3.0 BarG (IV No.2)

RESULT: The outlet stream temperature TC402 reduces dramatically.

DISCUSSION: The potential to exchange heat is much greater for higher-pressure steam than it is for lower pressure steam, that is, high-pressure steam is hotter than low pressure steam.

Exercise 2: A Hot Liquid Doesn't Need Heating

ACTION: Place TC402 into manual and change the output to 100%. Have the instructor increase the feedstock temperature to 170˚C (IV No.1).
RESULT: The liquid outlet temperature is about equal to the inlet temperature.

DISCUSSION: This underscores the point made in Exercise 1.

Exercise 3: Foul Heat Exchanger

ACTION: PlaceTC402 into manual and change the output to 100%. Have the instructor change the Heat Exchanger Fouling to 50% (IV No.3).
RESULT: When the Heat Exchanger is fouled, the heat transfer is less and the cold feedstock isn't heated as much.

DISCUSSION: As a heat exchanger becomes fouled, the transfer of heat form the hot side to the cold side is reduced and the outlet temperature is reduced.

Exercise 4: Heat Energy is conserved

ACTION: Place TC402 into Manual and vary the output from 5% to 95%. This varies the steam flow rate into the heat exchanger.
RESULT: Increased steam flow and heat transfer.

DISCUSSION: The two (2) concepts underlying this exercise are: (1) Steam condenses and contributes a latent heat of condensation as well as the sensible heat associated with the temperature difference so that the heat supplied is proportional to the steam flow, and (2) liquids are heated as a function of specific heats involved….a large Cp requires more units of heat to cause a unit temperature rise. Remember also that steam flow is a function of inlet valve position and pressure drop across the valve.

Exercise 5: Steam Dynamics

ACTION: Place TC402 into Manual. Make a step change in the output of the TC402 controller to 40.0% and monitor the steam pressure at PI400.
RESULT: The steam pressure at PI400 slowly varies from 3.1 BarG to 0.5 BarG.

DISCUSSION: The lesson here is that it takes time for the steam pressure to achieve the final value. The reasons that the steam pressure change is instantaneous are: steam valve-plus-positioner dynamics, the volume of the steam side of the exchanger, and the response times of the heat exchanger metal and liquid temperatures.

Exercise 6: Overall Exchanger Dynamics

ACTION: Place TC402 into Manual. Make a step change in the output of TC402 controller relative in size to change made in exercise 6 and monitor the liquid outlet temperature.

RESULT: The outlet temperature varies according to the direction and magnitude of the change.

DISCUSSION: Even more time is required for the full result to develop. The reason that the outlet temperature change is not instantaneous are: steam valve-plus-positioner dynamics, the volume of the steam side of the exchanger, response time of the heat exchanger metal and liquid temperatures, and the liquid-side temperature measurement.

12.4.2 Section 2: Instrumentation and Control Hardware Exercises

Exercise 7: Temperature Measurement Errors

ACTION: Have the instructor introduce a temperature measurement error of +15˚C for TT402 (IV No. 4)

RESULT: The controller TC402 will take some time to stabilize at 80˚C, and settle at a different output. TC402 valve opening initial was 63.2% and now it is around 38%. But liquid out let temperature is the same as before 80˚C.

DISCUSSION: Note that something is abnormal. It is important that “knowing what is normal” includes not only the inlet and outlet readings, but also the valve positions, etc.

Exercise 8: Good and Bad Instrument Spans

ACTION: Have the instructor increase the liquid inlet temperature to 90˚C and change the setpoint of TC402 to 110˚C. Next have the instructor change the controller scheme to the TC402A Controller (Fault No.5). This switches the temperature span of the TC402 controller from 0-200˚C to 85-125˚C. This new temperature span is much more sensitive than the previous span. Adjust the setpoint of the TC402A to 110˚C. Wait until temperature reading stabilizes at 110˚C.
RESULT: The loop gain increases and the operator must “re-tune” the controller. Try using new values; K = 1.0 & T1 = 0.5.

DISCUSSION: The overall point of this exercise is to show that range of scale has a significant effect on tuning parameters.

Exercise 9: Sluggish Measurement

ACTION: Have the instructor reset the system and introduce the “Transmitter TT402 thermocouple is sluggish” fault (Fault No.1). Have the instructor increase the liquid inlet temperature to 90˚C. From the student side, increase the setpoint of TC402 from 80˚C to 110˚C and observe the trend by clicking TC402.
RESULT: Controller output starts hunting and the adjustment of the valve position becomes more difficult.

DISCUSSION: The lag in the control loop makes control difficult, almost impossible in the case of feedback control alone.

Exercise 10: Valve Capabilities

ACTION: Have the Instructor Click “Reset to IC” & then Click “Operate”. Use instructor variable (IV3:4, 5) to increase the steam valve capacity by 50%. Observe and wait until system stabilized, steam valve will open around 42% compared to 63.2% in the beginning. Re-tune the controller TC402 with settings “K” 1.1 & “T1” 0.12. Check the performance by changing the set point between 70˚C to 80˚C.

RESULT: The student finds that he has a lot more leverage on the process.

DISCUSSION: The concepts of loop control can now be expanded. The larger steam valve necessitates smaller control action. So retuning the controller is required.

Exercise 11: More about Valve Capabilities

ACTION: This exercise is a continuation from exercise 4. Have the instructor maintain the larger steam valve capacity but reduce the steam supply to 7 BarG (IV No.2).
RESULT: Steam valve opening is more, behaves as if it were a smaller.

DISCUSSION: Valve capabilities depend on the valve stem position as well as the pressure drop.

12.4.3 Section 3: The Laws of Control

In this section student will vary the output based on the process variables that he “sees”. The real controller will remain in manual.

Exercise 12: Modes of Control

ACTION: Attempt to keep the outlet temperature constant while the instructor introduces upsets by varying the incoming flow rate at FC401.
RESULT: An understanding of various modes of control is developed.

DISCUSSION: The instructor slowly varies the incoming feedstock flow. The student sets the valve position to maintain the outlet temperature at 80˚C. Once the temperature error is zero, the students put back the valve position to normal. The student should see the limitation of proportional-only control, and the need for integral control should be discussed.

Exercise 13: Tuning means selecting loop gain

ACTION: This exercise is a continuation from exercise 1. Have the instructor increase the stem valve size by 50% (IV no.5). Maintain the outlet temperature at 80˚C.
RESULT: The controller must be re-tuned to offset the changes.

DISCUSSION: Loop gain depends on all the elements of the control loop. This includes the controller gain, the valve gain, and the process gain. To further demonstrate this fact, have the instructor change the heat exchanger fouling (IV No.5).

Exercise 14: Lags affect Tuning

ACTION: Have the instructor introduce a sluggish thermocouple (lag) on TC402 (Fault No.1). Maintain the outlet temperature TC402 at 80˚C by positioning the valve manually.

RESULT: The student find that the controller changes are larger than normal. It is difficult to maintain the outlet temperature at 80˚C.

DISCUSSION: Feedback control can fail if there is too much lag in a loop and can actually make the loop unstable.

Exercise 15: One reason for cascade Control

ACTION: Introduce the concept of cascade control by slowly reducing steam pressure. Have the instructor change the steam supply pressure to 8.0 barG. The temperature of TC402 will start to decrease. Adjust the output of TC402 to maintain the outlet temperature TC402 at 80˚C. Have the instructor change the supply steam pressure to 10.0 barG. The temperature of TC402 will start to increase. Again, adjust the output of TC402 to maintain the outlet temperature TC402 at 80˚C.

RESULT: The loop gain is changing and it is necessary to re-tune the loop.

DISCUSSION: The gain of the steam valve changes as the pressure drop changes.

12.4.4 Section 4: Tuning Controllers- in Automatic mode

Exercise 16: Tuning a proportional controller

ACTION: Click TC402 and turn off integral portion by entering T1 = “9999”. Now increase the K (P-Gain) of TC402 to K = 2.5. Change the setpoint of TC402 from 80˚C to 65.5˚C and wait until the process to stabilize.

RESULT: The difference between the setpoint (SP) and process variable (PV) is called offset/Error.

DISCUSSION: Entering “9999” for the integral portion of the controller TC402 will turn off the integral action. The “offset” limitation of a proportional controller resurfaces.

Exercise 17: Practice Tuning a Two-Mode Controller

ACTION: This is a continuation from previous exercise 1. The controller is change to PI type controller. To do this, reduce the integral term to 0.5 and re-tune the loop by assigning new value for K (P-Gain) until the offset/ error is reduced to zero.

RESULT: Learn how the PI controller responds.

DISCUSSION: The basic purpose of integral action is to drive the process back to the setpoint when a disturbance occurs. An integral action reduces the offset seen in the previous exercise to zero. However, integral action degrades the dynamic response of a control loop. The loop will become more oscillatory if adjusted too high.

Exercise 18: Practice tuning a two mode controller

ACTION: Have the instructor reset the system. Click TC402. Change the integral term from existing 0.12 to 0.5. Change the setpoint of TC402 from 80˚C to 70˚C. Wait until the process become stable and observe the trend of TC402 on screen. Change the integral term from 0.5 to .2, this time change the set point from 70˚C to 80˚C.

RESULT: The process variable equals the setpoint, there was no offset/error observed.

DISCUSSION: This exercise demonstrates that controller tuning should be objective-based. For example, in most cases, it is useless to tune a level controller so that the level returns to the setpoint as quickly as possible. This in effect eliminates the storage capacity of the tank and passes the disturbances along to the next unit.

Exercise 19: Practice tuning a two mode Controller

ACTION: Have the instructor Reset to IC and click “Operate”. Click TC402, change the integral term T1 from existing 0.12 to 0.1 and K (P-Gain) from 1.5 to 3.0. Change the setpoint of TC402 from 80˚C to 70˚C and allow the system to stabilize. Observe the trend of TC402.
RESULT: The control loop reaches the new setpoint fast due to controller settings, but with some oscillations.

DISCUSSION: System can be tuned for quick or slow response depending upon the requirement.

Exercise 20: The need for Cascade Control

ACTION: This is a continuation from exercise 4. With instructor variable (IV3:4, 2) change the steam supply pressure to 7.0 barg. Observe the performance of the controller TC402 through the Trend. You can see the performance of the loop degraded as oscillation of process variable & steam valve opening fluctuations increased.

RESULT: The performance of the loop is degraded as oscillation of process variable & steam valve opening fluctuations increased. .

DISCUSSION: This exercise demonstrates that the process loop gain also affects the performance of a control loop. When the steam header pressure was reduced the “good” tuning constants did not behave as before. The point is that “good” settings only remain good as long as the loop gain is constant.

Exercise 21: Working with cascade control

This is continuation of exercise 5.

ACTION: Have the instructor enable the TC402 and PC400 cascade control scheme (Fault, F2: 2, 4). This control scheme will now be displayed on the graphic. Put controllers TC402B and PC400 into manual. Set the tuning constant of TC402B at K=2.0 and T1=0.5. Also set the tuning constant of PC400 at K=1.5 and T1=0.12. Click PC400 and put in cascade mode. Click TC402B and put in auto mode. Now observe the performance of the loop by changing the steam supply pressure to 10 bagG. With instructor variable (IV3:4, 2). Observe the trend for cascade and see that heat exchanger shell pressure is maintained even if the steam supply pressure in increased. Also observe the outlet temperature is maintained smoothly without variation.

RESULT: A further understanding of control systems and control laws will be developed.

DISCUSSION: In many cases the performance of a loop can be significantly enhanced when a master-slave control scheme is used.

12.5 Three Element Boiler

12.5.1 Section 1: Getting acquainted with a boiler

Place all controllers in manual at design.

Exercise 1: The Feed water Bypass

ACTION: Place controllers LC502, PC503 and FC501 into Manual. Vary the setting of HC-505 and monitor the effects in drum level by clicking LC502.

RESULT: The student sees that this valve is in parallel with the feed water control valve FC501.

DISCUSSION: It is possible to play the hand control valve against the flow control valve to obtain the desired flow rate.

Exercise 2: Feed Water Flow Effects

ACTION: Have the instructor reset the system. Place FC501 in manual and increase the controller output to 40%. Wait until process stabilizes. Next decrease the controller output to 10%, again wait until process stabilizes.

RESULT: The drum level initially shows the effects of shrink and swell. Eventually, the drum level responds in the “normal” direction.

DISCUSSION: It is up to the operator to maintain a level in the drum by setting the feed water flow so that it matches the steam demand. Wrap up this exercise by getting a constant level reestablished. Example, steam demand matches feed water flow.

Exercise 3: Feed water Pump Capabilities

ACTION: Have the instructor reset the system. On the instructor station increase the feed water wear to 25%.

RESULT: The pump delivery rate is decreased; this could be due to wear, worn bearings, etc. The student should increase the output of the feed water valve, FC501 to maintain the level in the boiler.

DISCUSSION: An automatic controller would compensate for this sort of (slow) change in the performance characteristics of the pump. In this case, the feed water flow control valve would open more than normal. It was necessary to increase the output of the controller in the same way.

Exercise 4: Inaccurate Flow Measurement

ACTION: Have the instructor “Reset to IC” and click operate. Introduce an error on the measurement sensor of FC501 by increasing the instructor variable to 10%. Instructor variable (IV3: 3, 4).

RESULT: Feedwater flow rate and steam demand flow rate are not matching but the drum level is maintained. The result should not affect the process.

DISCUSSION: This kind of fault would not bother an automatic controller; the controller would simply compensate for the error. The controller call for whatever is needed to keep the level constant in the boiler and the controllers don’t care if they think of the federate as 29 ton/hr or 35 ton/hr, so long as the drum level is held constant. However the displayed flow rate is not correct. The transmitter should be repaired.

Exercise 5: Pressure Effects

ACTION: Have the instructor Reset the system. Place controller PC503 in manual and reduce the output to 51%.

RESULT: The pressure of the system decreases.

DISCUSSION: The drum level shrinks and the steam production rate is lower than normal.

Exercise 6: Load effects

ACTION: Have the instructor Reset the system and ask to increase the steam demand to 35 tons/hr. Monitor the system to determine the effects. Next, decrease the steam demand to 20 tons/hr and observe the effects this has on the system.

RESULT: When the steam demand is increase the swell phenomenon is observed, and the pressure of the system falls. When the steam demand is decrease the shrink phenomenon is observed and the pressure of the system increases. It is necessary to change the feedwater flow rate to maintain the level in the boiler.

DISCUSSION: The pressure controller is not quick enough, so there is a pressure change in boiler, V-501. This is the cause of the swell & shrink effect.

12.5.2 Section 2: Discovering the three element control

Exercise 7: Tuning the flow controller

ACTION: have the instructor Reset the system. Tune the flow controller FC501 to work as proportional-only controller. Change T1=9999 and change the setpoint to 25%. The setpoint should match the steam demand of FI502.

RESULT: The student exhibits his knowledge of tuning procedures.

DISCUSSION: The controller FC501 acts as a single–loop controller with its own set point.

Exercise 8: Simulating Two-Element control

ACTION: Have the instructor Reset the system. Put the controller FC501 to Auto from CASCADE. Now FC501 acts as single loop controller. With instructor variable(IV3:5,7) change the steam demand to 25t/h. Ask the student to change the set point of flow controller FC501 so that the feedwater flow rate & steam demand remain in balance. And the level LC502 also remains 50%.

RESULT: The student should find that swell and shrink causing trouble.

DISCUSSION: Swell and shrink are known as “false-start” phenomena. A Simple controller can’t grapple with a variable that goes two directions in response to one upset. In this exercise the student acts as the second element changing the setpoint of FC501 in response to steam demand.

Exercise 9: Feed forward Control Alone

ACTION: Have the instructor Reset the system. Keep FC501 in cascade mode while LC502 in manual. Ask the instructor to change the steam demand to 25 t/hr. This will simulate a feed forward only type control.
RESULT: The student will find out that without feedback the drum level is prone to slow drifting.

DISCUSSION: The feed forward control will match the steam demand with the flow controller FC501, however without the feedback from the level controller LC502, the feed drum level will drift. Thus, the output of the FY-502 elements simply the steam demand rate, FI502.

Exercise 10: Adding Feedback

(Continuation from previous exercise)

ACTION: Place the level controller, LC502, into automatic Mode; Change the set point to 50%. This adds the third element to the loop, feedback control, making this loop a feed forward-feedback loop. If necessary tune both the Master controller LC502 and the Slave controller FC501 to maintain the level in the drum.

RESULT: Feedwater flow rate increases to maintain the drum level. Feed water flow rate FC501 and steam flow FI502 become equal.

DISCUSSION: An alternative approach to tuning this loop would be to increase the level controller proportional gain from 0.2 to 1.0 all with minimum reset action (reset=9999). Test the changes against steam demand changes and see that control objectives are meet. Finally introduce integral action so that the drum level has a slight overshoot in response to load changes.

12.5.3 Section 3: Faulty control system Performance

Exercise 11: FY-Adder Error

ACTION: Have the instructor introduce an error of 5% in the FY-adder element. (IV3: 5, 6). Monitor the level LC502 and the feedwater flow FC501.

RESULT: There is a transient, but the control recovers.

DISCUSSION: What is change is the output of the level controller, LC502. This change is enough to offset the adder error. Thus, the setpoint command to the flow controller ends up unchanged. The FY-502 adder element should be repaired.

Exercise 12: Flow measurement Error

ACTION: Have the instructor reset the system, and asks to introduce 5% error in the flow transmitter FT501, instructor variable (IV3:5, 4). Monitor the level LC502 and the feedwater flow FC501.

RESULT: There is a transient, but the control recovers.

DISCUSSION: What is change is the output of the level controller, LC502. This change is enough to offset the error in measurement (Feed water flow indication is 5% more than steam demand, but drum level is maintained). Thus, the setpoint sent to the flow controller, FC501 is change to the extent that the same old flow is achieved. The transmitter should be repaired.

Exercise 13: Level Measurement Error

ACTION: Have the instructor reset the system and introduce an error in the level transmitter, LT502. Instructor variable (IV3:5, 5). Monitor the level LC502 and the feedwater flow FC501.
RESULT: There is a transient, but the control recovers.

DISCUSSION: Apparently nothing is changed. However, the actual level is not what the operator thinks it is and the transmitter should be repaired.

Exercise 14: Broken Level Transmitter

ACTION: Have the instructor reset the system and introduce a transmitter fail, LT502. Have the instructor change the steam demand flow rate. Monitor the level LC502 and the feed water flow FC501. Put FC501 in manual and control the feed water flow manually to resolve the situation.

RESULT: The control valve FC501 fully closed. The flow loop FC501 should be put in manual. The level transmitter LT502 should be repaired.

DISCUSSION: LT502 sends input signal to controller LC502 and the output signal of LC502 serves as the setpoint for FC501 (Cascade control loop). At the event LT502 fails, it is necessary to put FC501 into manual in order to maintain the drum level at safe side, 50%.

12.6 Distillation Column

This module emphasizes the effect of large scale interactions of heat balances, material balance and control loops.

12.6.1 Section 1: Getting acquainted with the unit

Exercise 1: Feed In, Product out

ACTION: Reduce the set point of FC-601 to 195 m3/h. Note the reading (PV) of FI-611_____, FI-614______, FC-607_____, FC616_____ and FC-603______.

RESULT: Less feed enters the unit. Eventually, FI-611, FI-614, FC-607 and FC616 will decrease. There is less load in the system so FC603 decreases.

Exercise 2: Process interactions

This is continuation of exercise 1.

ACTION: Increase the set point of FC-601 to 230m3/h. Monitor the output of PC604_______, and PC-613________.

RESULT: Due to high flow pump head is reduced, the pressure controllers must compensate by reducing the output.

Exercise 3: Heat Balance

ACTION: Have the instructor reset the system and ask to reduce the setpoint of TC-604 to 98˚C.

RESULT: Less heat flows into the Depropanizer Column. Therefore less top reflux, FC-606 is needed.

Exercise 4: Reflux Drum Level V-601 and V-602 Logic action

ACTION: Have the instructor reset the system. Change the output of HC602 to 10% and observe the effect on PC604 valve, LC602, FC607 and pump P-603. Allow reflux drum level V-601 to continue to decrease until the pump P-603 trips.

1. In what percent level as seen on LC602_____ the pump P-603 trip? Note the PV of FC606 at its stable reading______?

2. When the level LC602 reaches 20%, reset HS615 and re-start the pump P-603.
3. Change the output of HC602 to 100%, wait until PC604 valve turn to close. Note the PV of FI605______?

RESULT: Reflux drum V-601 is equipped with logic circuit that protect from a total loss of liquid level. When the level in reflux drum falls below 5.0%, the reflux pump automatically shutdown to allow liquid to accumulate in the respective drum.

Exercise 5: Depropanizer Bottom Group Display

(Please refer to Group Edit Display, page no's 35 & 36 for the steps.)

ACTION: Have the instructor reset the system. Create a sample group display in DCS screen up to eight (8) analog points as shown in the table below, label the group name as Distillation Column.

	FC601 m³/h FEED	FI611 m³/h BTM PROD	FI614 KNm³/h TO FLARE	FC607 m³/h TOP PROD	FC616 m³/h TOP PROD	FC603 t/h STEAM	PC604 Barg TOP	PC613 Barg TOP
SP								
PV								
OP								
MODE:								

1. Note the present reading for the SP, PV, OP and the modes of controllers in the table above.

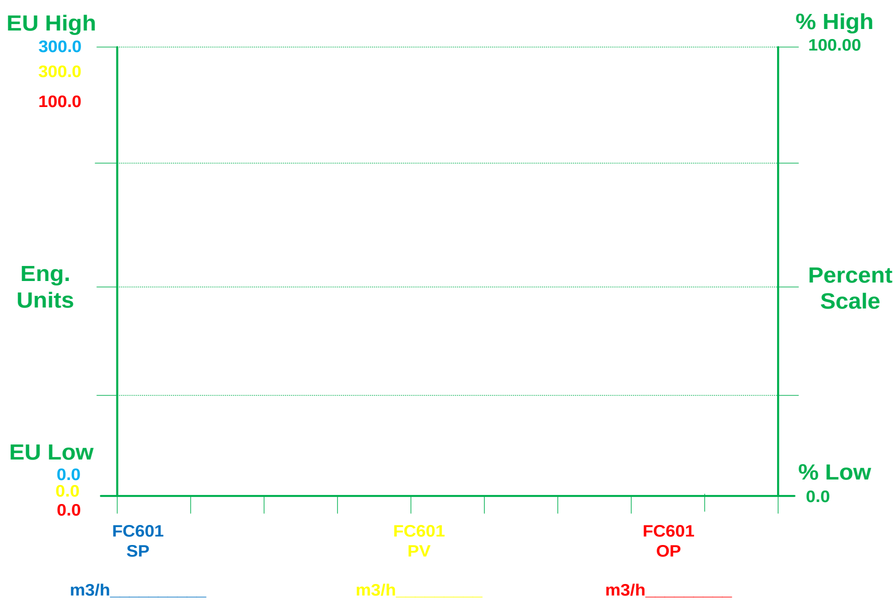
2. Change the setpoint (SP) of FC601 to 180_ m³/h and wait until the PV equals the SP.

3. Note the present reading for the SP, PV, OP and the modes of controllers in the table below.

	FC601 m^3/h FEED	FI611 m^3/h BTM PROD	FI614 KNm^3/h TO FLARE	FC607 m^3/h TOP PROD	FC616 m^3/h TOP PROD	FC603 t/h STEAM	PC604 Barg TOP	PC613 Barg TOP
SP								
PV								
OP								
MODE:								

4. Call your instructor to check your job.
5. Draw the trend of FC601 and label your drawing showing the PV, SP and OP.

Time base: _________



DISCUSSION: The primary purpose of the Group Display is to:

1. monitor and manipulate the primary operating parameters (such as SP, PV, and MODE) of up to 8 points (tags or loops),

2. call up trends,

3. Show bar-graphs of analog SP, PV, and OP; and show status lamps (filled/empty boxes) for digitals, flags, lights, and switch points.

12.7 Review Exercises- Practical

Process: SELF REGULATING PROCESS

Exercise: 1

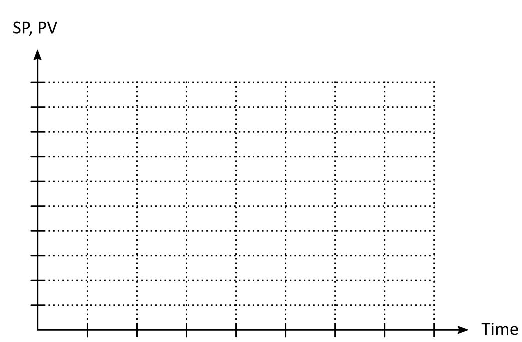
Title: Test P-only Controller and understand the behavior of P-only Controller.

Steps:

1. On Instructor Computer Click “Reset to IC” on Instructor session window.
2. Observe that controllers FC101 & LC102 in Auto.
3. Click on FC101 to Display the trend of this point on right hand side.
4. Implement P-only controller by entering ____________T1(Intr),_____________T2(Derv.)
5. Keep K (P-Gain) at 0.5. Change the set point of FC101 to 550 kg/hr and allow the system to stabilize. Note down PV= _____________t/h flow even though set point is 550 t/h.
6. Now increase the K(P-Gain) to 1.0. and allow the system to stabilize. Note down inlet flow (PV)= ___________t/h. even though the set point is 550t/h.
7. Now change the set pint to 600t/h. and after stabilizing Note down inlet flow (PV)= ___________t/h
8. Decrease the ‘K” from 1.0 to 0.5. and after stabilizing note down inlet flow

   (PV)=_____________ t/h.

Note: Offset is an error, when process is at steady state (Set point – Controlled variable value). Offset Error=_____________________________



Process: HEAT EXCHANGER

Exercise: 1

Title: Testing P-only controller

Steps:

1. Tune TC402 as P-only controller. Turn off the integral portion (T1) of controller TC402.
2. Increase the gain of TC402 to <u>2.5</u>
3. Adjust the set point of TC402 to <u>75 ºC</u>, wait until the PV become stable.
4. Draw the trend of TC402 showing the SP, PV, OP and offset/error.

<u>Trend</u>: TC402 Time base: _________

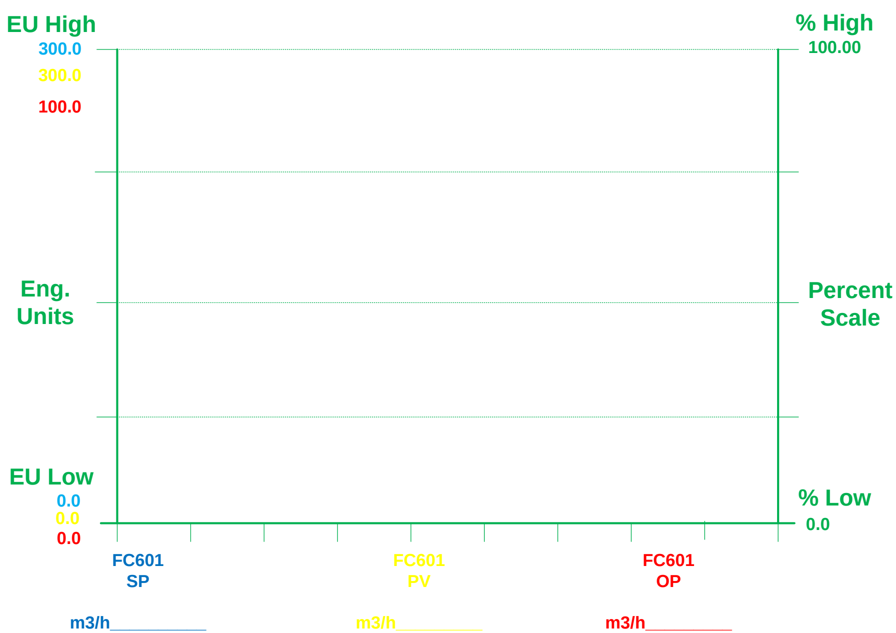


Figure 1

5. Note the present value for the gain (K) = ____, Integral (T1) = ____ & Derivative (T2) = ______ of TC402.

6. Determine the offset/error in degrees centigrade _______ ºC.

7. Describe the trend of TC402 in terms of offset/error and stability.

____

____

Exercise: 2 (continuation of exercise-1)

Title: Tuning a PI controller.

Steps:

1. Tune TC402 as PI controller. Tune the controller TC402 by assigning new values for the gain (K) = _______, Integral (T1) = _______ & Derivative (T2) = _______, until the PV and set point become equal. Fill in the blanks above with the new tuning constants.
2. Draw the trend of TC402 showing the SP, PV and OP.

Trend: TC402

Time base: _________

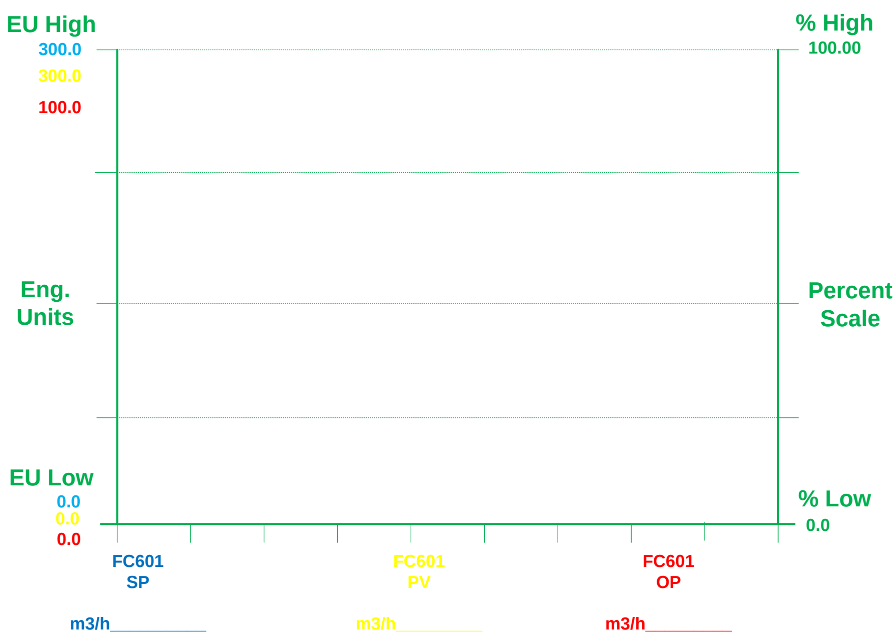


Figure 2

3. Determine the offset/error in degrees centigrade __________ ºC.
4. Describe the trend of TC402 in terms of offset/error and stability.

____

____

____

Exercise: 3

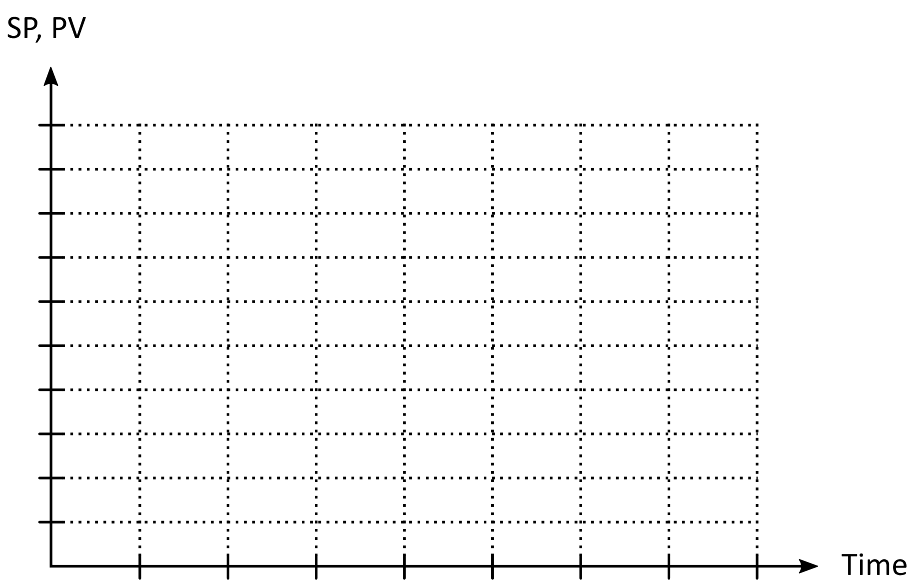
Title: heat energy is conserved.

Steps:

1. On the Instructor station Click “Reset to IC” & then Click “Operate”.
2. On student terminal Place controller TC402 into manual and change output to 5% and allow the system to stabilize.
3. Vary the output of TC402 from 5% to 95%, leave small gap between each increment.
4. Click on TC 402 to observe the trend of heat exchanger out let temperature.

Result: Increased steam flow increases the heat transfer & Heat exchanger out let temperature increased.

Draw the graph of TC402



Exercise 4:

Title: To find out ultimate gain of P-only controller.

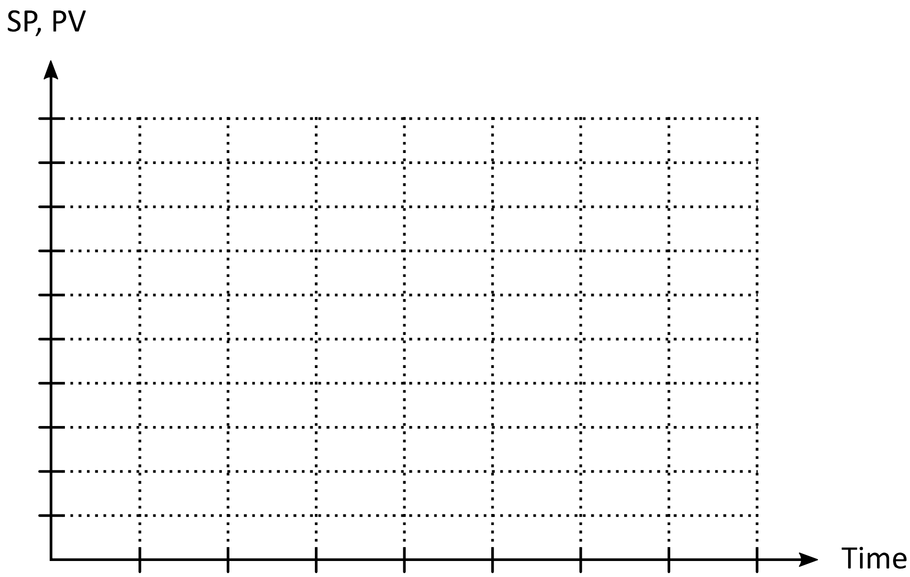
Steps:

1. On the Instructor station Click “Reset to IC” & then Click “Operate”.
2. Click on controller FC401 & Turn off integral portion by entering ___________ T1(Intr), ________________T2(Derv).
3. Change the set point of controller FC401 from 25 T/h to 20T/h and allow the system to stabilize.
4. Observe a constant gap between set point and Process value, it is called offset.
5. Now slowly increase the K (P-Gain) in steps and allow the controller to stabilize at each step.
6. Observe that offset error is reducing as the gain K increased.
7. Observe that above certain value of K if you increase unstable temperature situation exits. It is called K ultimate.

Discussion: “Offset is the limitation of proportional controller.

K ultimate: ___________________

Draw Graph of S.P and P.V v/s time:



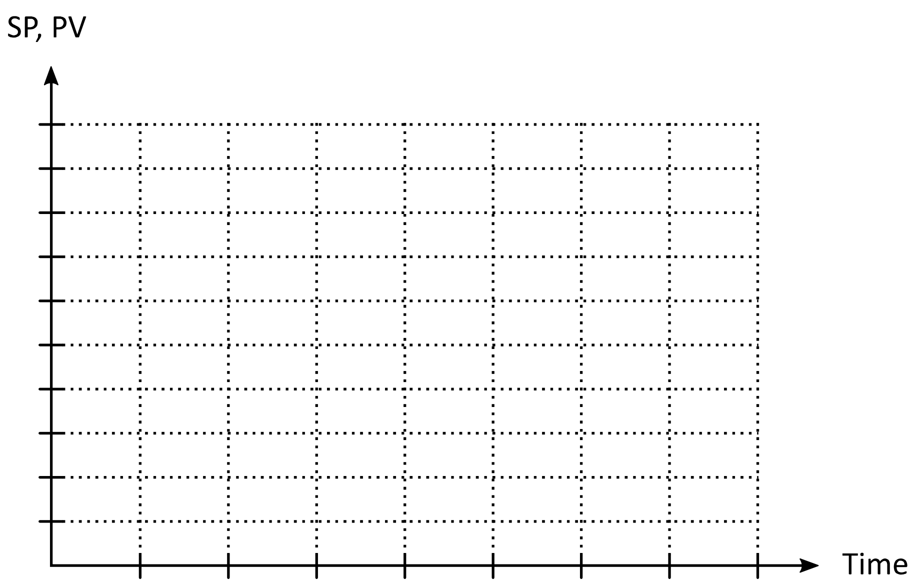
Exercise 5:

Title: Effect of increasing P-Gain on Process value in proportional Controllers.

Steps:

1. On the Instructor station Click “Reset to IC” & then Click “Operate”.
2. Click on controller TC402 & Turn off integral portion by entering ___________ T1(Intr), ________________T2(Derv).
3. Now increase K(P-Gain) of TC402 to K=2.5
4. Change the set point of controller TC402 from 80˚C to 65.5˚C and wait for 2 minutes.. Note PV of TC402 =____________
5. Observe a constant gap between set point and Process value, it is called offset.
6. Decrease K(P-Gain) of TC402 to K=2.0 and wait for 2 minutes , note PV of TC402 =_________
7. Decrease K(P-Gain) of TC402 to K=1.0 and wait for 2 minutes, note PV of TC402 =_________
8. Now increase K(P-Gain) of TC402 to K=3.5 and wait for 2 minutes, note PV of TC402 =_________

Draw Graph of S.P and P.V v/s time :



Process: pH Mixing Tank

Exercise: 1

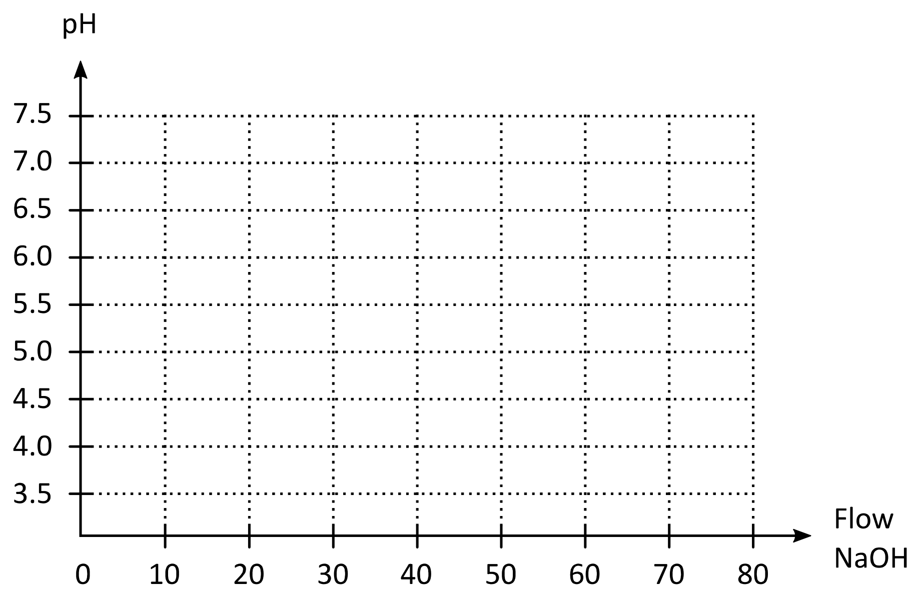
Title: pH Titration for strong acid and strong base

Task A- Titration Curve: PH of a strong Acid

Steps:

Put FC301, QC304 and LC304 into manual mode. Set the output of FC301 to 50%, the output of QC304 to 50%, and the output of LC304 to 100%. Ask the instructor to increase the valve size to 1.5 times design. Allow the system to stabilize. The ph of the test stream starts out at 4.0. Slowly decrease the output of QC304 from 50% to 25%. Allow the process to stabilize at each change and take reading in table provided and draw the titration curve in the space provided below for the strong acid side.

QC304 OUTPUT	FI302 NaOH flow	PH QC304



Flowrate of NaOH, kg/hr

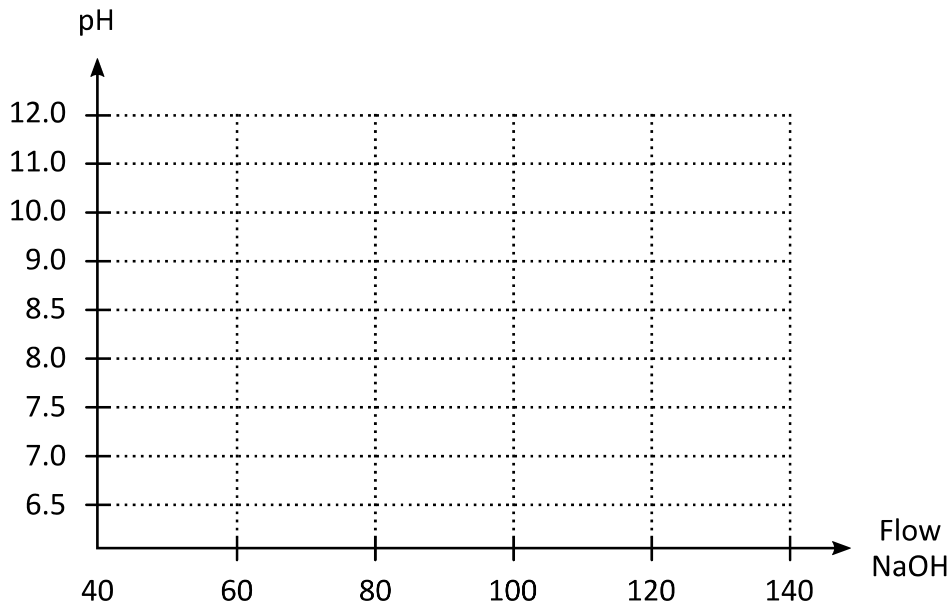
Titration Curve: PH of a strong Acid

Task B- Titration Curve: PH of a strong Base

Steps:

Slowly decrease the output of QC304 from 25% to 0%. Allow the process to stabilize at each change and take reading in table provided and draw the titration curve in the space provided below for the strong base side.

QC304 OUTPUT	FI302 NaOH flow	PH QC304



Flow rate of NaOH, kg/hr

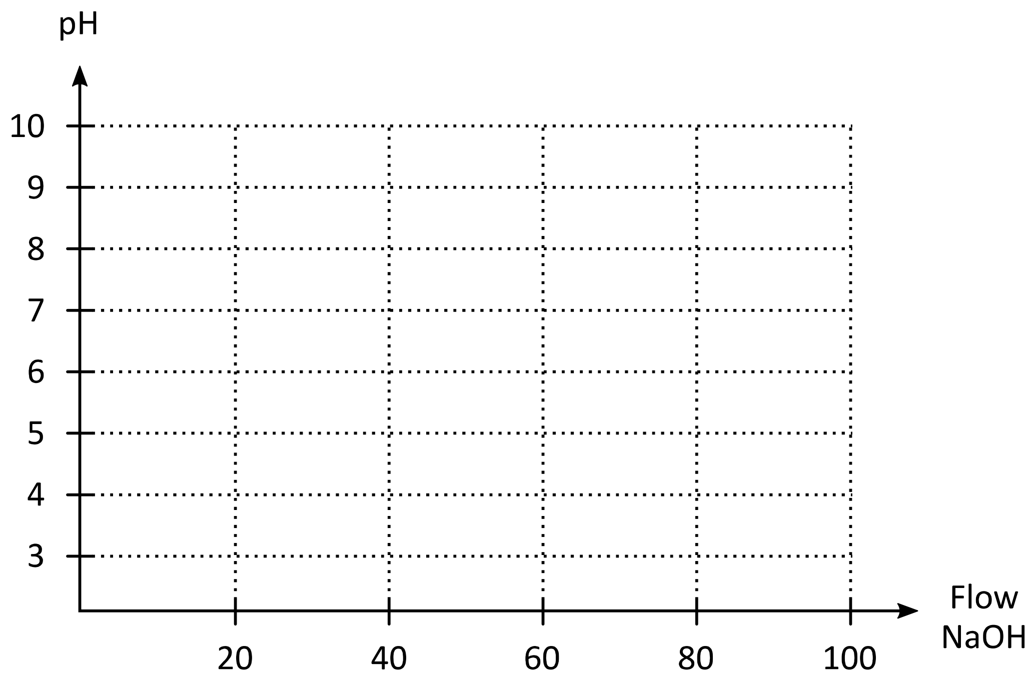
Titration Curve: PH of a strong base.

Task C- Titration curve for both base and acid.

Steps:

Take the data that was collected from Task-A and Task-B. Draw a complete titration curve in the space below.

Titration Curve:



Flow rate of NaOH, Kg/hr

Process: THREE ELEMENT BOILER

Exercise: 1

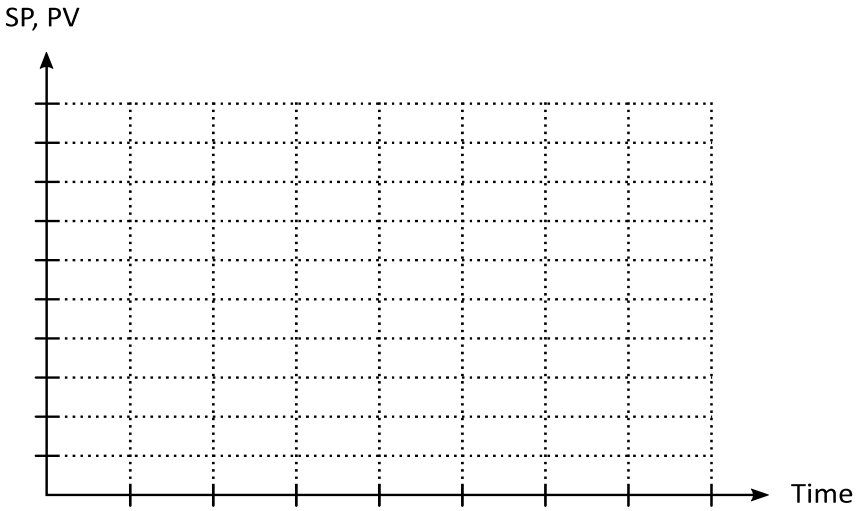
Title: Feed water flow Effects.

Steps:

1. On the Instructor station Click “Reset to IC” & then Click “Operate”.
2. Place controller FC501 into manual. Increase OUTPUT of FC501 to 40%.
3. Observe that feed water flow rate is increased from initial 29.5 t/h. and drum level also started increasing (initially shows shrink & swell effect).
4. Now decrease the FC401 Controller out put to 10%.Onserve that feed water flow rate starts decreasing and eventually drum Level also starts decreasing.

Discussion: It is up to the operator to maintain a level in the drum by setting the feed water flow so that it matches with steam demand.

Draw the graph:



Write down the alarm summary:

Time:	Tag no.	Status	Description:	Process Value:

Process: DISTILATION COLUMN

Exercise: 1

Title: Effect of Flow changes on depropanizer bottom due to P-only controller.

Steps:

1. Turn off integral portion of FC601.
2. Adjust the set point of FC601 to 175 m3/hr. wait until the PV become stable reading.
3. Draw the trend of FC601 showing the PV, SP and OP.

Time base: _________

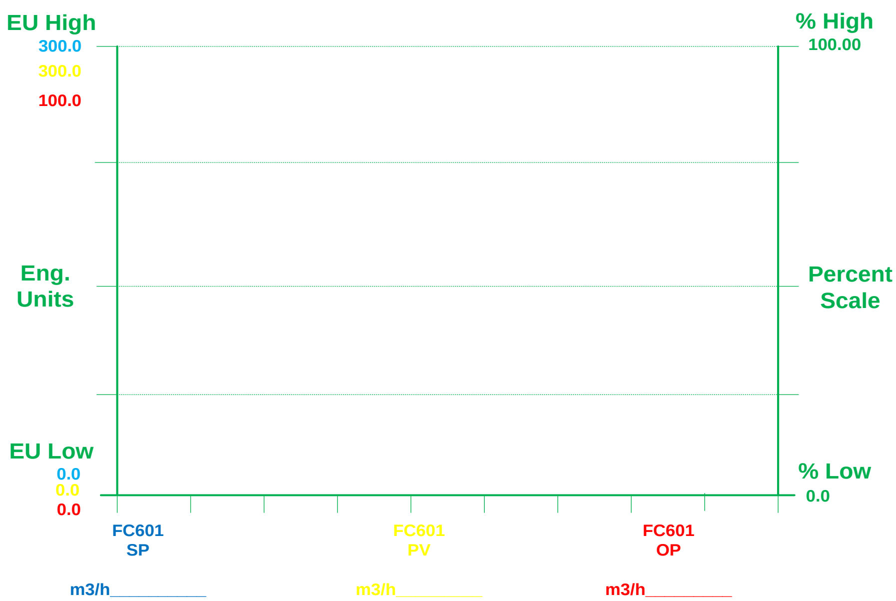


Figure 3

4. Determine the offset/error = _______m3/hr.
5. Adjust the gain (K) of FC601 to 2.4 and observe the behavior of the controller.
6. Note the present value for the gain (K) = ____, Integral (T1) = ____ & Derivative (T2) = _____of FC601.
7. For step 5, describe the trend of FC601 in terms of offset/error and stability.

____

____

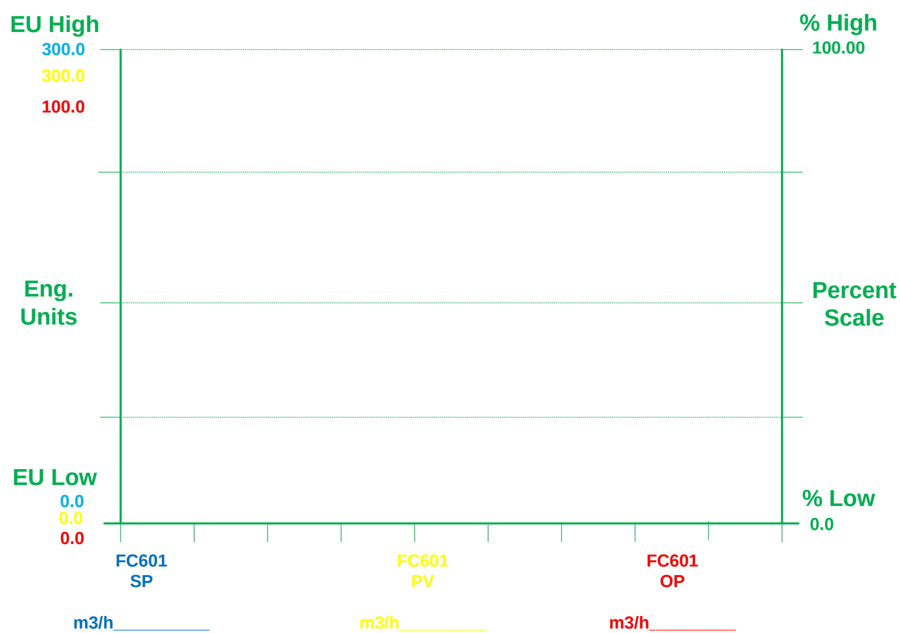
Exercise 2:

Title: Tuning of PID controller (Continuation of Exercise -1)

Steps:

1. Tune the controller FC601 by assigning new value for the gain (K) =______, Integral (T1) = ______, and derivative (T2) = ______ until the PV equals SP. Fill in the blanks with the new tuning constants.
2. Draw the trend of FC601 showing the PV, SP and OP.

Time base: __________



3. Describe the trend of FC601 in terms of offset/error and stability.

____

____

____

13. PROCESS REPORT: Student Guide for the Controller PID Settings

JUNE 19, 2014 PROCESS REPORT INSTRUMENTATION TRAINING PROGRAM: 5900M TRIDENT COMPUTER RESOURCES, INC.								
SELF REGULATING HOLDING TANK								
CONTROLLER	**SET POINT**	**PROCESS VARIABLE**	**OUTPUT**	**ACTION**	**P**	**I**	**D**	**ACCUMULATED ERROR**
FC101	500.00 KG/HR	500.00 KG/HR	50.00	REV	0.5000	0.1000	0.0000	0.0
LC102	50.00 PCT	50.00 PCT	83.22	DIR	6.0000	2.0000	0.0000	0.0
NON-SELF REGULATING HOLDING TANK								
CONTROLLER	**SET POINT**	**PROCESS VARIABLE**	**OUTPUT**	**ACTION**	**P**	**I**	**D**	**ACCUMULATED ERROR**
FC201	500.00 KG/HR	500.00 KG/HR	50.00	REV	0.4000	0.1000	0.0000	0.0
LC203	50.00 PCT	50.00 PCT	44.58	DIR	1.2000	6.0000	0.0000	0.0
NON-LINEAR CONTROL PH MIXING TANK								
CONTROLLER	**SET POINT**	**PROCESS VARIABLE**	**OUTPUT**	**ACTION**	**P**	**I**	**D**	**ACCUMULATED ERROR**
FC301	35.00 KG/HR	35.00 KG/HR	35.00	REV	1.2000	0.2000	0.0000	0.0
LC304	50.00 KG/HR	50.00 PCT	49.98	DIR	6.0000	2.0000	0.0000	0.0
QC304	8.20 PH	50.00 PH	50.00 PH	DIR	1.2000	6.0000	0.0000	0.0
HEAT EXCHANGER								
CONTROLLER	**SET POINT**	**PROCESS VARIABLE**	**OUTPUT**	**ACTION**	**P**	**I**	**D**	**ACCUMULATED ERROR**
FC401	25.00 TPH	25.00 TPH	45.93	REV	0.2000	0.0200	0.0000	0.0
PC400	3.10 BAR G	3.10 BAR G	63.54	REV	1.5000	0.1200	0.0000	0.0
TC402	80.00 DEG C	80.00 DEG C	63.54	REV	1.5000	0.1200	0.0000	0.0
TC402A	80.00 DEG C	80.00 DEG C	63.54	REV	1.5000	0.1200	0.0000	0.0
TC402B	41.36 DEG C	80.00 DEG C	20.68	REV	2.0000	0.5000	0.0000	0.0
THREE ELEMENT BOILER								
CONTROLLER	**SET POINT**	**PROCESS VARIABLE**	**OUTPUT**	**ACTION**	**P**	**I**	**D**	**ACCUMULATED ERROR**
FC501	25.00 TPH	29.50 TPH	32.11	REV	0.2000	0.0200	0.0000	0.0
LC502	50.00 PCT	50.00 PCT	50.00	REV	3.0000	5.0000	0.0000	0.0
PC503	64.20 BAR G	64.20 BAR G	72.99	REV	2.0000	0.0000	0.0000	0.0
DISTILLATION COLUMN								
CONTROLLER	**SET POINT**	**PROCESS VARIABLE**	**OUTPUT**	**ACTION**	**P**	**I**	**D**	**ACCUMULATED ERROR**
FC601	210.00 TPH	210.00 TPH	72.63	REV	0.1000	0.0050	0.1000	0.0
FC603	27.06 M3/HR	27.06 M3/HR	54.11	REV	0.7000	0.1000	0.0000	0.0
FC606	168.20 M3/HR	168.20 M3/HR	61.31	REV	0.1000	0.0100	0.0000	0.0
FC607	61.31 M3/HR	119.60 M3/HR	61.45	REV	0.3000	0.1000	0.0000	0.0
FC612	13.67 TPH	13.67 TPH	74.67	REV	0.7000	0.1000	0.0000	0.0
FC615	101.60 M3/HR	101.60 M3/HR	32.41	REV	0.2000	0.2000	0.0000	0.0
FC616	51.58 M3/HR	51.58 M3/HR	17.54	REV	0.1000	0.1000	0.0000	0.0
LC601	50.00 PCT	50.00 PCT	28.12	DIR	2.0000	10.0000	0.0000	0.0
LC602	0.00 PCT	50.00 PCT	79.74	DIR	2.0000	10.0000	0.0000	0.0
LC611	0.00 PCT	50.00 PCT	32.15	DIR	2.0000	10.0000	0.0000	0.0
LC612	50.00 PCT	50.00 PCT	68.78	DIR	2.0000	6.0000	0.0000	0.0
PC604	16.24 BAR G	16.24 BAR G	23.92	DIR	2.0000	0.5000	0.0000	0.0
PC613	4.71 BARG	4.71 BARG	23.97	DIR	2.0000	3.0000	0.5000	0.0
TC604	50.00 DEG C	103.21 DEG C	54.13	REV	1.0000	8.0000	0.0000	0.0
TC613	106.30 DEG C	106.30 DEG C	68.36	REV	1.0500	4.0000	0.0000	0.0
NOTES: P is Gain, **I** is minute / repeat, **D** is 1/minutes. Accumulated error is loop PV hours.								
Refer to the program manual for a description of TC402A, TC402B, & PC400								