ENGINEERING STANDARD

FOR

PROCESS REQUIREMENTS

OF

CRUDE DISTILLATION AND HYDROGEN PRODUCTION UNITS

FIRST EDITION

OCTOBER 2006

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0. INTRODUCTION

"Design of Major, Non-Patented Refining Processes" are broad and contains subject of paramount importance. Therefore a group of IPS Standards are prepared to cover the subject. The Process Engineering Standards of this group includes the following Standards:

STANDARD CODE	STANDARD TITLE
IPS-E-PR-491	"Process Requirements of Crude Distillation and Hydrogen Production Units"
IPS-E-PR-492	"Process Requirements of Caustic and Chemical Systems"
IPS-E-PR-500	"Process Design of LPG Recovery & Splitter Units"
IPS-E-PR-551	"Process Design of Gas Treating Units"

This Engineering Standard Specification covers:

"PROCESS REQUIREMENTS OF CRUDE DISTILLATION AND HYDROGEN PRODUCTION UNITS"

1. SCOPE

This Engineering Standard Specification set forth the content and the extent of the minimum process and control system requirements of Crude Distillation and Hydrogen Production Units. For design of any equipment inside the subject plants, reference shall be made to the relevant IPS standards. This Standard Specification is further intended to cover the minimum process requirements and guidelines for process engineers to define control systems of process plants.

This Standard Specification consists of two parts as described below:

Part I: Process Requirements of Crude Distillation Units.

Part II: Process Requirements of Hydrogen Production Units.

Note: This is a revised version of the standard No: IPS-E-PR-491 (0) Parts I & II Engineering Standard for process requirements of crude distillation and hydrogen production units, which is issued as revision (1) and will revise and issue as IPS-E-PR-491(1). Revision (0) of the said standard specification is withdrawn.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

IPS (IRANIAN PETROLEUM STANDARDS)

IPS-E-GN-100 "Engineering Standard for Units"

IPS-E-PR-200 "Engineering Standard for Basic Engineering Design Data"

3. DEFINITIONS AND TERMINOLOGY

3.1 Back Pressure

a) The pressure on the outlet or downstream side of a flowing system.

b) In an engine, the pressure which acts adversely against the piston, causing loss of power.

3.2 Cascade Control System

A control system in which one controller provides the command signal to one or more other controllers.

3.3 Company/Employer/Owner

Refers to one of the related affiliated companies of the petroleum industries of Iran such as National Iranian Oil Company (NIOC), National Iranian Gas Company (NIGC), National Petrochemical Company (NPC), etc., as parts of the Ministry of Petroleum.

3.4 Contractor

The persons, firm or company whose tender has been accepted by the Company and includes the Contractor’s personnel representative, successors and permitted assigns.

3.5 Control Element

A control element is a part of the process control system that exerts direct influence on the controlled variable that brings it to the set point position. This element accepts output from the controller and performs some type of operation on the process. The term "final control element" is also used interchangeably with control element.

3.6 Controlled Variable

Controlled variables are the basic process values being manipulated by a system. These values may vary with respect to time or as a function of other system variables, or both.

3.7 Controlled-Volume Pump

A controlled-volume pump is a reciprocating pump in which precise volume control is provided by varying effective stroke length. Such pumps also are known as proportioning, chemical injection, or metering pumps.

1) In a packed-plunger pump, the process fluid is in direct contact with the plunger.

2) In a diaphragm pump, the process fluid is isolated from the plunger by means of a hydraulically actuated flat or shaped diaphragm.

3.8 Dead Time

The time interval between a change in a signal and the initiation of a perceptible response to that change.

3.9 Deviation

The difference between the measured value of the controlled condition and command signal.

3.10 Disturbance

A physical quantity other than the system command signal, generated independently of the closed loop itself, which affects the control system. Disturbance may be of two kinds, direct and indirect.

3.11 Feedback

The transmission of a signal from a later to an earlier stage.

3.12 Feed Forward

The transmission of a supplementary signal along a secondary path, parallel to the main forward path, from an early to a later stage.

3.13 Hunting

Prolonged self-sustained oscillation of undesirable amplitude.

3.14 Multiple Feed

Multiple feed is the combination of two or more pumping elements with a common driver.

3.15 Slurry

A free-flowing mixture of solids and liquid.

3.16 Process Control System

A control system, the purpose of which is to control some physical quantity or condition of a process.

3.17 Process Time Lags

Most of the processes used in manufacturing operations perform quite well when variables are held within certain limits. When a process variable is subjected to some type of change, it obviously takes a certain amount of time for the process to correct itself. The term process time lag is commonly used to describe this condition. "Process time lag" refers to the time it takes a system to correct itself and seek a condition of balance after a variable has changed. Inertia, capacitance, resistance and dead time are typical causes of process time lag.

3.18 Programmed Controller

A controller incorporating a programmed controlling element.

3.19 Set Value, Set Point

The command signal to a process control system.

3.20 System Response

The main purpose of a control loop is to maintain some dynamic process variable (flow, temperature, level, etc.) at a prescribed operating point or set point. System response is the ability of a control loop to recover from a disturbance that causes a change in the controlled process variable.

4. SYMBOLS AND ABBREVIATIONS

AC	Analysis Controller.
BTM	Bottom.
CCR	Continuous Catalyst Regeneration.
DN	Diameter Nominal, in (mm).
DP	Differential Pressure.
F	Flow.
FC	Flow Controller.
FDF	Forced Draft Fans.
FF	Flooding Factor.
FR	Flow Recorder.
FRC	Flow Recorder Controller.
HLA	High Liquid Alarm.
HLL	High Liquid Level, in (mm).
HP	High Pressure.

HT	High Temperature.
ID	Inside Diameter, in (mm).
IDF	Induced Draft Fans.
IPS	Iranian Petroleum Standards.
KO	Knock-Out.
LC	Level Controller.
LLL	Low Liquid Level, in (mm).
LP	Low Pressure.
LPG	Liquefied Petroleum Gas.
LRC	Level Recorder Controller.
LSS	Low Signal Selector.
LT	Low Temperature.
max.	Maximum.
min.	Minimum.
No.	Number.
OVHD	Overhead Product.
ppm	parts per million.
PC	Pressure Controller.
PDC	Pressure Differential Controller.
PIC	Pressure Indicator Controller.
PRC	Pressure Recorder Controller.
PSA	Pressure Swing Adsorption.
PTB	Pounds per thousand barrels.
SFC	Spill-back Flow Controller.
SR	Straight Run and also Split Range (see Appendix A).
TC	Temperature Controller.
TDC	Temperature Differential Controller.
TDCR	Temperature Differential Controller Recorder.
TDR	Temperature Differential Recorder.

TE Temperature Element.

TI Temperature Indicator.

TIC Temperature Indicator Controller.

TPC Technical Practices Committee.

TRC Temperature Recorder Controller.

vol. Volume.

YC Heat Input Controller.

5. UNITS

This Standard is based on International System of Units (SI), as per IPS-E-GN-100, except where otherwise specified.

PART I

PROCESS REQUIREMENTS

OF

CRUDE DISTILLATION UNITS

6. PROCESS REQUIREMENTS OF ATMOSPHERIC AND VACUUM DISTILLATION UNITS

6.1 General

6.1.1 The purpose of the crude distillation Unit shall be to make the initial separation of crude oil into desired fractions.

6.1.2 The Crude Distillation Units typically produce the following products:

Butane and lighter material (Light Ends), light straight run naphtha, heavy straight run naphtha, (blending) naphtha, kerosene, light diesel, heavy diesel, waxy distillate (Hydrocracker Unit Feed), lubricating oils if any, slop vacuum gas oil, and vacuum bottoms. A part of vacuum bottoms is used for producing of paving and roofing asphalts.

6.1.3 The production rates of waxy distillate (Hydrocracker Unit Feed), lubricating oils, slop vacuum gas oil and vacuum bottoms will be depended upon the specific mode of operation in the lube Unit.

6.1.4 Provision shall be made for incremental increases in the withdrawal rate of waxy distillate (Hydrocracker Unit Feed), slop vacuum gas oil, and vacuum bottoms when the lube Unit is shutdown.

6.1.5 The Crude Distillation Unit typically consists of the following sections:

- **a)** Atmospheric Distillation Section.
- **b)** Vacuum Distillation Section.
- **c)** Straight Run Naphtha Fractionation Section.
- **d)** Off Gas Compressor Section.
- **e)** Lube Distillation Section, if required.

6.1.6 The purpose of lube distillation Unit shall be to charge light and heavy gas oil cuts made in vacuum distillation section and to produce in blocked operation the required quantities and specifications of required lube cut distillates.

6.1.7 Lube Distillation Section typically consists of the following facilities:

- **a)** Charge heater;
- **b)** Lube distillation column;
- **c)** Vacuum jets and all related equipment;
- **d)** Instrumentation and piping.

6.1.8 Tank heaters shall be provided in crude tanks to maintain 10-32°C Crude temperature before pumping to the Unit to prevent the crude wax sedimentation in the tanks.

6.1.9 Crude shall receive adequate preheat from hot process streams in Crude Distillation Unit. The heat exchanger configuration and temperatures shall be optimized using appropriate computer software's.

6.1.10 The crude outlet temperature of preheat exchangers shall be specified such that to avoid vaporization in the last exchanger(s).

6.1.11 Typically, streams of naphtha, vacuum tower top side cut, kerosene, light diesel, waxy distillate (Hydrocracker Unit Feed), SAE 10/20 lube cut, slop vacuum gas oil and vacuum tower mid side cut should be considered as heat source of crude preheat exchangers.

6.2 General Design Criteria

6.2.1 Where tray material is specified to be stainless steel, then the valves shall be of the same material as the tray.

6.2.2 Manways shall be provided as follows:

a) Horizontal vessels

900 to 1300 mm ID	Manway, on the head, 460 mm (18") ID.
Larger than 1300 mm ID	Manway, on the side or on the top 510 mm (20") ID.*

b) Vertical vessels

Under 900 mm ID	Top head flanged.
900 to 1300 mm ID	Manway, in shell, 460 mm (18") ID.
Larger than 1300 mm ID	Manway, in shell, 510 mm (20") ID.*

c) Packed Columns

Each packed bed shall have a manway at top and a manway at bottom of the bed.

d) Trayed columns

Manways shall be provided above the top tray, below the bottom tray, at any feed and side cut draw off tray and at intermediate points. The maximum number of trays between manways in the trayed section shall not exceed 10 trays.

*** Note: Higher size manway shall be provided if required to accommodate internals.**

6.2.3 Recommended minimum tray spacing are as follows:

1300 mm ID or less	460 mm (18").
1300 to 3000 mm ID	560 mm (22").
3000 mm ID and larger	610 mm (24").

6.2.4 Tray spacing shall be greater than the minimum figures given in 6.2.3 above where required for access to column internals, manway location, vapor disengaging, nozzle interference or other reasons.

6.2.5 Minimum distance from the top tray to top tangent line shall be 750 mm or as required to accommodate manway, internals or nozzles.

6.2.6 Minimum trayed column size shall be 800 mm inside diameter.

6.2.7 Leak tight trays shall be specified for the following services:

a) Once-through reboiler draw off boxes;

b) Side draw off tray draw pan;

c) Chimney trays.

6.2.8 Minimum hole diameter for perforated trays should be 13 mm (½"). However the lower range of 3-13 mm (1/8"- ½") from case to case can be applied if it is approved by the Company.

6.2.9 Vessels shall be provided with vent, drain and steam-out nozzles, in accordance with the IPS-E-PR-200, "Basic Engineering Design Data".

6.2.10 Drain nozzles on horizontal vessels shall be located at the opposite side of the liquid outlet line.

6.2.11 A blanked off ventilation nozzle shall be provided on top of the vessel (and at the opposite side of the manway in horizontal vessels).

The size will be in accordance with the following Table 1.

TABLE 1

VESSEL DIAMETER	NOZZLE SIZE
4500 mm ID or less	DN 100
4500 to 7500 mm ID	DN 150
7500 mm ID and larger	DN 200

6.2.12 Water draw-off boots, if any, will be welded to the vessels, regardless of boot diameter. If the vessel is lined, the boot will be lined and welded to the vessel, any exceptions shall be approved by the Company.

6.2.13 A blanked-off facility shall be provided on all connections to the flare headers.

6.3 Design Requirements

6.3.1 Design temperature

6.3.1.1 Columns with fired feed heater with/without side-cut strippers:

a) In the zone between the draw-off trays of two adjacent side cuts, the design temperature shall be the draw - off temperature of the heavier side cut plus 30°C.

b) In the zone between the heaviest sidecut draw-off tray and the bottom of the column, the design temperature shall be the flash zone temperature plus 30°C, or the reboiler outlet (whichever is greater) plus 30°C.

c) Sidecut strippers with stripping steam

The design temperature shall be the operating inlet temperature of the process stream plus 30°C.

d) Fractionators with reboiler

The design temperature shall be the reboiler return line temperature plus 30°C.

e) For vessels having a design pressure not higher than 350 kPa (ga), the minimum design temperature shall be 120°C.

6.3.2 Design pressure

a) Vessels

Vessels design pressure should be as indicated in Table 2.

TABLE 2

OPERATING PRESSURE	DESIGN PRESSURE
Under vacuum	min. value: full vacuum max. value : 350 kPa (ga)
0 up to 1800 kPa (ga)	350 kPa (ga) or operating pressure plus 180 kPa (ga) whichever is the highest value.
1800 kPa (ga) to 6900 kPa (ga)	Operating pressure plus 10%

b) Heat Exchangers

If a control or block valve is installed downstream the heat exchanger, the design pressure shall be the same of the upstream equipment or the actual shut-off pressure of the upstream pump.

If a control or block valve is installed upstream and no block valve existed downstream the heat exchanger, the design pressure shall be calculated as the design pressure of the downstream equipment at the inlet point plus 1.20 times the pressure drop of the circuit between the heat exchanger inlet and the inlet point of the downstream equipment plus static head (if any).

c) OVHD receiver

The overhead receivers shall be designed considering the same design pressure as the upstream columns.

6.4 Design Oversizing Factors

The philosophy of design oversizing factors to be used for sizing of equipment and machinery of the project shall be approved by the Company. The recommended oversizing factors are as follows:

6.4.1 Fired heaters

Heaters design duty (excluding Licensed Units heaters), shall be at least 110% of max. normal duty. Normal duty shall be based on lower inlet temperature.

6.4.2 Columns and drums

6.4.2.1 Tray design

Maximum normal load of the trays shall be considered for the design purpose.

6.4.2.2 Generally valve type trays should be used. Sieve trays may be applied, upon Company's approval, taking also into account the requirements of specified turndown ratio, for instance in pump-around if technically feasible.

6.4.2.3 Flooding factor for fractionating trays: 78% maximum.

6.4.2.4 Flooding factor for pumparound trays: 85% maximum.

6.4.2.5 Flooding factor for steam stripping trays

And side cuts strippers regardless of strip ping medium:

75% maximum.

6.4.2.6 Downcomer back-up: 50% maximum of the tray spacing.

6.4.2.7 Type of internals:

Structured packing may be applied provided that they are compatible with coke formation tendency of the service.

6.4.2.8 Random packings can be used in columns less than:

800 mm in diameter.

6.4.3 Hold-up time

Water settling requirements take priority over these times where applicable.

6.4.3.1 Columns feeding other Units:	900 seconds (HLL-LLL) on net liquid product. (Except when surge drum is provided for downstream Unit).
6.4.3.2 Columns discharging to storage only:	300 seconds (HLL-LLL) on net liquid product.
6.4.3.3 Columns feeding heat exchangers trains:	300 seconds (HLL- LLL) on net liquid product.
6.4.3.4 Columns feeding fired heater:	600 seconds with respect to the equivalent flowrate of the vapor generated in the fired heater plus 300 seconds on net bottom product full (HLL-LLL).
6.4.3.5 Vacuum column bottom:	240 seconds (HLL-LLL) with quench.
6.4.3.6 Feed surge drums:	1200 - 1800 seconds (HLL-LLL).

6.4.3.7 Columns or drums feeding multistage charge pumps (5 or more stages):

1200-1500 seconds (HLL-LLL).

6.4.3.8 Drums feeding other equipment for further processing:

600 seconds (HLL-LLL).

6.4.3.9 OVHD receivers:	300 seconds on reflux plus net product (HLL-LLL).
6.4.3.10 Drums feeding fired heaters:	600 seconds (HLL-LLL) on total liquid.
6.4.3.11 Gas and water separators:	300 seconds (HLL-LLL) on water flowrate.
6.4.3.12 Water boots:	300 seconds below normal interface level or 600 seconds on water (HLL-LLL), whichever is greater.

6.4.3.13 Compressor suction KO drums

14400 seconds (240 minutes) on maximum entrained liquid in the inlet line (HLL-LLL if level control is provided otherwise HLA-BTM tangent line).

Compressor suction drums will consider this time or the use of a 3.6 m (14") level range, whichever is greater, taking also into account the requirements of specified turndown ratio, for instance in pumparound services, if technically feasible.

6.4.3.14 Other types of KO drums:

A volume corresponding to 15 m of liquid slug in the inlet line (HLL-LLL if level control is provided otherwise HLABTM tangent line) or a 3.6 m (14") level range, whichever is greater.

6.4.4 Shell and tube heat exchangers

6.4.4.1 Cooled water condensers:	10% on maximum duty and flowrate.
6.4.4.2 Cooled water cooler:	10% on maximum duty and flowrate.
6.4.4.3 Pumparounds exchangers:	15% on rated surface.
6.4.4.4 Reboilers:	10% on maximum duty and flowrate.
6.4.4.5 Steam generators:	10% on maximum duty and flowrate.
6.4.4.6 Air cooler and air condensers:	10% on maximum duty and flowrate.

6.4.5 Pumps

6.4.5.1 Unit feed:	No over design unless otherwise specified by Company.
6.4.5.2 Feed booster:	No over design unless otherwise specified by Company.
6.4.5.3 Unit product:	10% on maximum normal flowrate.
6.4.5.4 OVHD reflux:	20% on maximum normal flowrate.
6.4.5.5 Pumparound:	20% on maximum normal flowrate.
6.4.5.6 Reboiler feed:	15% on maximum normal flowrate.
6.4.5.7 Boiler feed water:	10% on maximum normal flowrate.
6.4.5.8 Surface condensers condensate:	10% on maximum normal flowrate.
6.4.5.9 Chemical injection:	20% on maximum normal flowrate.
6.4.5.10 Metering pumps:	100% on maximum normal flowrate.

6.4.5.11 Reciprocating and rotary pumps:	15% on maximum normal flowrate.
6.4.5.12 All other pumps:	10% on maximum normal flowrate.
6.4.5.13 Pump shut-off pressure:	Suction maximum operating pressure plus 120% of differential pressure at design capacity plus static head.
6.4.6 Compressors and blowers:	10% on maximum normal flowrate as minimum (not Licensed Units).
6.4.7 Turbines:	Steam turbines: 10% on design brake horse power in kW of the driven pump or compressor.

6.4.8 Heaters and waste heat boiler fans

6.4.8.1 Induced draft fans:	15% on design (100 percent) flowrate (including any defined leakage from the preheater and the other system losses) at design excess air.
6.4.8.2 Forced draft fans:	15% on design (100 percent) flowrate (including any defined leakage from the preheater and other system losses) at design excess air.

6.5 Process Requirements for Distillation Unit

6.5.1 Product fractionation

6.5.1.1 Fractionation between two adjacent products is defined the difference, positive (gap) or negative (overlap), between the temperatures of the 5% point on ASTM distillation of the heavier product and the 95% point on ASTM distillation of the lighter product. The fractionation between adjacent products, as defined below, shall be in accordance with the project requirements. However, the following figures could be used in case of no requirements specified in the project.

1) Light SR Naphtha-Heavy SR Naphtha	+ 15°C
2) Heavy SR Naphtha-Blending Naphtha	+ 10°C
3) Blending Naphtha-Kerosene	+ 8°C
4) Kerosene-Atmospheric Gasoil	+ 14°C

6.5.1.2 The pentanes and heavier components contained in the unstabilized LPG shall be 1 vol. % max. referred to butanes content.

6.5.1.3 The butanes and lighter components contained in the light SR Naphtha shall be 1 vol. % max.

6.5.2 Other design requirements

6.5.2.1 The Unit turndown shall be 60% of design throughput, without loss of efficiency in fractionation while meeting the product specifications.

6.5.2.2 By-passing of Vacuum Distillation Section shall be feasible. The Unit (Light End Section included) should be able to operate at a minimum rate of 75% of design capacity, while the Vacuum Distillation Section is out of service.

6.5.2.3 Compression facilities shall be provided for crude Unit overhead gases. Spare compressor is not required.

6.5.2.4 The Atmospheric Distillation Section and Vacuum Distillation Section can be integrated for maximum recovery within their own battery limit (Light End Section excluded).

6.5.2.5 System of Light Ends shall be designed to allow continued operation of Distillation Unit while the Light End Section is out of service.

6.5.2.6 Heat exchanger network optimization should be considered for distillation units (e.g., pinch method).

6.5.2.7 The Unit shall be equipped with desalter and relevant chemical injection facilities. The desalted crude shall have a total salt content of 2.85 kg/1000 m^3 (1 PTB) maximum as minimum requirement.

6.5.2.8 The stripped water from the Sour Water Stripper Unit shall normally be used as desalter feed water. Suitable treated water supply to the desalter shall be considered as an alternative source.

6.5.2.9 The Unit heaters shall be designed for 10 percent excess capacity for flow and duty.

6.5.2.10 Firing system of all the heaters (fuel gas, fuel oil or combination of them) shall be in accordance with the project requirements.

6.5.2.11 All heaters shall be designed for maximum energy conservation. Minimum efficiency of 90 percent should be considered for the charge heaters.

6.5.2.12 Crude and vacuum heaters shall have forced draft fans and air preheat system. Heater forced draft fans shall have a spare.

6.5.2.13 The fuel gas knock-out drum shall be provided in the Unit.

6.5.2.14 Atmospheric Crude Tower shall have kerosene and gas oil circulation refluxes.

6.5.2.15 Coalescers shall be provided for the Atmospheric and Vacuum gas oils for the cases that they are considered as finished products.

6.5.2.16 Vacuum column ejectors shall have 50% spare capacity for each set.

6.5.2.17 All continuous pumps shall have individual spares. Spare pumps shall be provided as follows:

No. OF OPERATING PUMPS	No. OF SPARE PUMPS
1	1
2	1

6.5.2.18 All the machineries shall be electrically driven with exception of the following spare pumps which shall be steam driven:

a) Flashed crude pump.

b) Atmospheric residue pump.

c) Atmospheric column top reflux pump.

d) Vacuum residue pump.

6.5.2.19 Where the fin fan coolers are utilized, space for additional one bay for future expansion shall be provided.

6.5.2.20 Inhibitor injection facilities to the atmospheric tower overhead streams shall be provided.

6.5.2.21 Local level gages, and control room level indicators are required on all draw off trays of vacuum column.

6.5.2.22 Tempered water system shall be provided where required for cooling of products with high pour point.

6.5.2.23 Transfer lines

Transfer lines between furnace and tower shall be designed for proper fluid velocity such that to avoid coke deposition and vibration.

6.5.2.24 In general the pressure drop through the vacuum tower should not exceed one-half the absolute pressure in the flash zone.

6.5.2.25 Control of vacuum tower flash zone entrainment

The entrainment should be controlled by proper design of tower loadings and by keeping the first section above the flash zone (wash section) irrigated with a minimum flow of heavy vacuum gas oil reflux. This reflux commonly referred to as "overflash" shall be set at no less than 2 vol.% of the vacuum charge. This flow rate shall be designed to yield at least 2 vol.% overflash leaving the bottom. Liquid flow to the wash section shall be uniformly distributed for optimum performance.

6.5.2.26 Vacuum tower leak proof draw trays

For maximum thermal efficiency and gas oil yield, all product draw trays shall be essentially leak proof.

6.5.2.27 Stability of vacuum residuum

If downstream processing requires a substantial holding time in vacuum tower, a recirculating quench system shall be provided to reduce holding temperatures to 315°C or less. In designing such a quench system, care shall be taken to avoid possible reabsorption effect due to improper introduction of the cooled residuum recycle.

6.5.2.28 Vacuum tower furnace temperature

Pressure drop between the furnace outlet and the tower flash zone shall be kept low enough so that heater outlet temperatures are below the accelerated cracking region.

6.5.2.29 Control Scheme Design

Control scheme design of Crude Distillation Units can be as per Appendix A, "Control Scheme Design" as a guideline.

PART II

PROCESS REQUIREMENTS

OF

HYDROGEN PRODUCTION UNIT

7. PROCESS REQUIREMENTS OF HYDROGEN PRODUCTION UNIT

7.1 General

7.1.1 The process shall involve the conversion of light hydrocarbon gases, primarily methane to hydrogen.

It shall consist of the following main processing sequence:

a) Steam hydrocarbon reforming.

b) Shift conversion.

c) Pressure Swing Adsorption (PSA) System.

7.1.2 Feedstock to the Unit may consist of one or a mixture of the followings:

a) Natural gas.

b) Platformer Unit off-gases.

c) HP Amine contactor gas.

d) Propane gas.

e) Naphtha fraction (if gas feed is not available).

7.1.3 Steam is consumed as a reactant for the reforming and shift conversion reactions.

7.1.4 The quantity of steam needed shall be generated within the Unit by utilizing the waste process heat available.

7.1.5 The plant shall be designed with proper steam to carbon ratio, considering the following purposes:

a) To maximize the conversion of hydrocarbons in the reforming operation;

b) To suppress coke formation on the catalyst;

c) To use later in the shift conversion reaction.

7.1.6 Performance

The minimum and guaranteed hydrogen purity in the product shall be 99.99 mol.% based on PSA System performance at design conditions.

7.1.6.1 The Unit is to be designed for maximum on - stream efficiency.

7.1.6.2 The Unit shall be capable of reaching normal operating conditions smoothly within a reasonable time after feed gas is introduced.

7.1.6.3 The supplier has:

- To determine and specify the governing case in each section of the Unit, sections being:

a) Feed treating (dechlorination and H2S removal);

b) Reforming (steam-hydrocarbon reforming);

c) High temperature shift converter;

d) PSA section; and

- To design each section to be capable to handle each case of feedstocks.

7.1.7 Feed

7.1.7.1 The supplier shall state the product purity if one of the Units providing the feed is down.

7.1.7.2 Feed gas coming from the platforming separator may contain chlorine ion. This should be removed entirely in the hydrogen Unit by dechlorination catalyst in a separate vessel at the required temperature.

7.1.7.3 Zinc oxide beds in two separate vessels sufficient for suitable duration of operating without renewal shall be provided for reducing sulfur to 0.1 mg/kg in feed stream. Piping arrangement shall be such that the vessels can be put in parallel service or in series when required. However, the plant shall be designed based on operation of one vessel in service while meeting the maximum sulfur requirement at the outlet of the vessel.

7.1.7.4 Feed gas to ZnO vessels shall be preheated with appropriate device for carrying out the reaction, this temperature shall be selected as high as possible to maximize the reformer inlet temperature and hence reduce reformer heater duty.

7.1.7.5 The Unit turndown shall be at least 40% of design throughput while meeting the hydrogen product quality of 99.99 mol. %.

7.1.8 Product specifications

The hydrogen product gas should have the following composition unless otherwise specified by the Company for specific requirements:

H_2	: min. 99.99 vol.% (dry basis)
$CO + CO_2$	: max. 15 mg/kg
HCl	: Nil.

7.1.9 Steam generation and boiler feed water

7.1.9.1 During normal operation, the Unit shall generate steam required for its process requirements by utilizing the maximum excess heat available by the reformed gas and convection section of the reformer furnace.

7.1.9.2 Maximum recovery of condensate for use in hydrogen plant shall be considered.

7.1.9.3 Steam pressure produced in the waste heat boiler should be just enough to meet hydrogen plant requirements.

7.1.9.4 External temperature control should be considered for the waste heat boiler.

7.1.9.5 A separate transmitter shall be provided for the level control on the steam drum. The steam drum shall also have high and low level alarms.

7.1.9.6 Steam generated in the Unit should have necessary control and safety valves.

7.1.9.7 Suitable stainless steel, for impellers of boiler feed water pumps and lining of deaerator(s) shall be considered.

7.1.9.8 Condensate shall be used for any processing purpose and the use of treated water should be avoided.

7.1.9.9 Chemical injection facilities for waste heat boiler shall be provided.

7.1.9.10 Provisions shall be made for automatic running of stand-by pump of steam generating pumps in boiler.

7.1.10 Reformer heater shall be tubular type, with the following typical characteristics.

7.1.10.1 Burners shall be designed based on gaseous fuel(s). liquid fuel(s) could also be used as secondary fuel(s), if required by the Company.

7.1.10.2 Various services shall be considered for heat recovery from the flue gas.

7.1.10.3 Heating steam/hydrocarbon blend in convection section shall be below the cracking temperature.

7.1.10.4 The thermal efficiency shall be approached to 90 percent with optimizing the flue gas temperature outgoing the stack.

7.1.10.5 Suspended from counter mass or spring devices should be designed for vertical tubes in radiation section, to prevent creep due to expansion, connected at the top and bottom to inlet and outlet distributors and collectors.

7.1.10.6 Catalyst filling in tubes shall be carefully performed, so that the pressure drop from one tube to the next, which may be as high as 500 kPa (ga) shall not undergo variations of more than 5 per cent about the average value. Otherwise, the resulting changes in flow rates may cause substantial local overheating.

7.1.10.7 The tubes shall be alloyed steel capable of withstanding skin temperatures as required by the furnace design.

7.1.10.8 The outlet collectors of tubes could be followed by expansion loops (pigtails) to offset the mechanical forces due to rapid temperature variations.

7.1.10.9 Heater outlet temperature shall be controlled by TRC-PRC whereas, PRC is located on the fuel header to the burners. Additionally a start-up fuel gas pressure regulator shall be provided on bypass.

7.1.10.10 Air purged thermocouples to be provided for at least 15% of reforming tubes and be monitored in the process control room.

7.1.10.11 Necessary provisions shall be made for measuring of emissions at flue gas outgoing from the stack.

7.1.11 Instrumentation

7.1.11.1 An online total sulfur analyzer should be considered for monitoring the sulfur content on feed gas at ZnO bed inlet, inter-bed and outlet.

7.1.11.2 A feed gas density meter and ratio controller for the feed shall be provided.

7.1.11.3 A suitable recording analyzer shall be provided for CO and CO2 in the product gas.

7.1.11.4 Online hydrogen analyzer for the product gas shall be furnished.

7.2 Pressure Swing Adsorption (PSA) System

7.2.1 General

7.2.1.1 Facilities to be supplied by the Vendor

a) Each PSA system shall be consisted of adsorbers, off gas surge drum, prefabricated piping, fully assembled and pretested valve skids, instrumentation and prefabricated pipe supports, control panels including control units, sequential chart boards and alarm annunciators, etc.

b) Provisions shall be considered to avoid water condensation and to prevent wet CO_2 corrosion.

c) The PSA facilities shall be fully automatic-operated.

7.2.1.2 Facilities arrangement

a) Vendor shall provide the layout drawing including plan and elevation showing pipe ways, valve skids, and walkways.

b) All valves, instruments, pressure relief valves etc. shall be installed so as to access easily from ground level.

7.2.2 System definition

7.2.2.1 The PSA system shall be used to recover hydrogen gas from hydrogen rich gases.

7.2.2.2 In refineries with CCR platformer Unit, the platformer off-gases can be purified directly in the PSA Section.

7.2.3 Vendor shall guarantee typically the following items:

a) Hydrogen recovery efficiency.

b) Fluctuation of pressure/flow rate for PSA product gas, and pressure/flow rate/heating value for PSA product off gas.

c) Throughput.

d) Hydrogen product specification.

e) Hydrogen product flow rate.

7.2.4 Vendor's proposal

7.2.4.1 Vendor shall fill all blanks of PSA process data sheet, process data sheet-pressure vessel and also specified adsorbent type and quantity, attached to his submitted proposal.

7.2.4.2 Appendix B represents typically PSA process data sheet and process Data sheet-pressure vessel.

APPENDICES

APPENDIX A

CONTROL SCHEME DESIGN

A.1 General

A.1.1 At least the following controllers can be used:

1) Fixed program controllers (for single loops including cascade control).

2) Programmable controllers for complicated strategies like feed-forward, furnace control, distillation column control, etc.

A.1.2 The entire system shall be suitable for future upgrading and expansion requiring no major modification.

A.1.3 The Contractor shall furnish typical instrumentation drawings for simple control loops and detailed drawing for complex control loops.

A.1.4 Selection of control objects, measuring points and controlling points shall be based on a thorough study of process type/nature, equipment types/sizes and their allowances.

A.1.5 The following points must be considered in the planning of control systems and the execution of the engineering:

1) Owner’s philosophy of process control;

2) Grade, operability and safety of control systems.

A.2 Selection of Controlled Variables and Manipulated Variables

For selection of controlled variables and manipulated variables among many process variables, the following points shall be followed (as a general criteria).

A.2.1 Selection of controlled variables

A.2.1.1 Process variables which are representative of the process objectives shall be distinguished.

A.2.1.2 Other process variables which can affect the above variables considerably shall also be distinguished (for cases of difficulty of measurement and large time lags for direct control).

A.2.1.3 Controlled variables shall then be selected based on the review of the fluctuation ranges and degree of importance of product quality and yield with consideration given to ease of their measurement, their dynamic characteristics, the effects of external disturbances and other relevant matters.

A.2.2 Selection of manipulated variables

Manipulated variables shall be selected as those process variables which can vary the selected controlled variables primarily, namely variables which can change the intended variables considerably without affecting other conditions (variables).The controllable ranges of the variables must be sufficiently large for the correction control, namely, their allowances must be sufficient for changes in the set point and for external disturbances, while having small time lag.

A.3 Basic Control Loops

A.3.1 Single feedback control

Single feedback controls shall be only used in cases where the effects of external disturbances on the process operation are sufficiently small, compared with the required control range and the cycles of the external disturbances are long, compared with the response in the process operation.

A.3.2 Multi-variable control

Depending on the conditions of process disturbances, there are cases for which single feedback controls may not serve the purpose, in such cases the following alternatives shall be studied:

1) Disturbances can be removed by using minor loops before they affect the controlled variables (e.g., cascade control).

2) External disturbances can be measured/predicted in order to adjust the manipulated variables to offset the disturbances before their effects appear (e.g., feed-forward control).

3) The control loop can be switched to another which is suitable for the type and/or size of the disturbance (e.g., selective control and split range control).

A.3.2.1 Cascade control

The general concept of cascade control is to place one feedback loop inside another feedback loop. In effect, one takes the process being controlled and finds some intermediate variable within the process to use as the set point for the main loop.

Cascade control (set point of secondary controller adjusted by the primary controller output) is intended to improve the response, reducing the effects of time lag and/or several other disturbances.

If the response of the secondary controller is not sufficiently prompt, compared with that of the primary controller, interference may occur between the two controllers. In order to determine the best cascade control arrangement, it is necessary to make a specific determination of the most likely disturbances to the system. It is helpful to make a list of these in order of increasing importance. Once this has been done, the designer must review the various cascade control options available and determine which best meets the overall strategy, i.e., to have the inner loop as fast as possible while at the same time receiving the bulk of the important disturbance.

A.3.2.2 Selective control

In cases where two or more variables are to be controlled by the same manipulated variable, the most important variable must be selected for control (selection of measurement signals/selection of manipulated signals).

A.3.2.3 Split range control

Depending on the control range, split range may be used for control of a variable in a broad range [split range control (similar to selective control) uses different manipulated variables for the same controlled variable].

A.3.2.4 Ratio control

Ratio control may be used in cases where the direct measurement of final controlled variable is difficult or the response is very slow, so as to improve the controllability against quick disturbances, such as flow rate fluctuations, typical applications of which are:

- Calorie control for gas blending;

- Fuel-air ratio control for boilers (including waste heat boilers) and heaters;

- Feed ratio control for reactors.

It is also possible to implement a ratio control system if the primary instrument is not a controller but rather a transmitter. In such a situation, the set point of the controller is set in direct relation to the magnitude of the primary controlled variable.

A.3.3 Feed-forward control

There are some significant problems with feed-forward control. The configuration of feed-forward control assumes that the disturbances are known in advance, that the disturbances will have sensors associated with them and that there will be no important undetected disturbances.

A.4 Control Scheme Patterns

A.4.1 Control schemes for distillation tower

Unless otherwise specified, in distillation towers product composition shall be substantially maintained by temperature control with the pressure kept at the set point as follows:

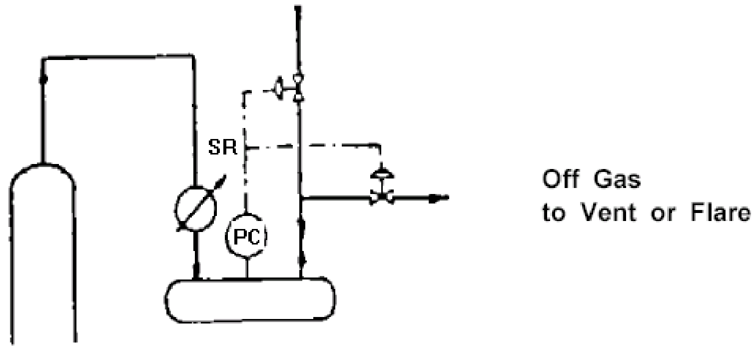
A.4.1.1 Pressure control

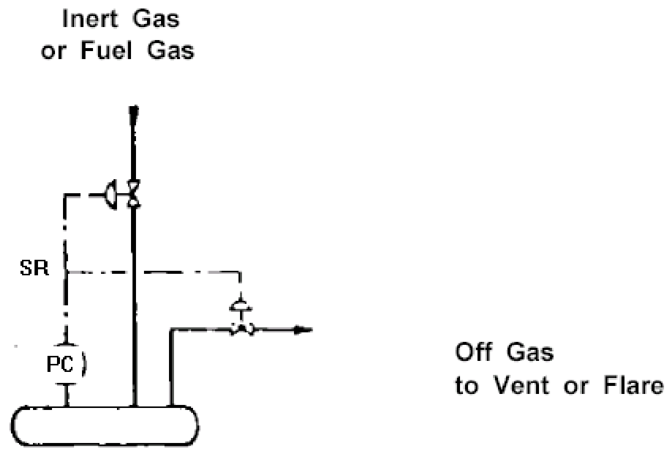
1) Pressure is atmospheric or slightly positive and non-condensible gas is not existing: pressure control can be carried out by introducing inert gas in case of general distillation towers as shown in Fig. A.1-(a) or fuel gas (in case of petroleum distillation towers) into the receiver and by releasing gas from the receiver through a vent or to flare. In this case, as pressure hunting will occur if the size of the piping from the receiver nozzle to the flare header is excessively small, the piping must have a size sufficient for the purpose. The possibility of hunting may be reduced by using the control shown in Fig. A.1-(b). In this control the gas to be introduced must be insoluble in tower’s liquid.

Inert Gas or
Fuel Gas

(a)

(b)





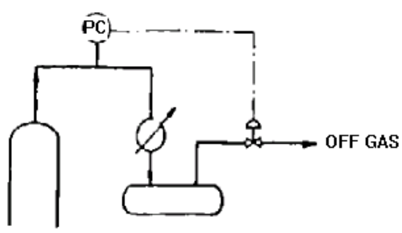
SR: Split Range

PRESSURE CONTROL OF DISTILLATION TOWER

(PRESSURE POSITIVE, NON-CONDENSIBLE GASES ARE NOT EXISTING)

Fig. A.1

2) Pressure is positive and non-condensible gas is existing: in this case, gas introduction to the system is not required (e.g., deethanizers, hydrodesulfurization strippers, catalytic reforming stabilizers, etc., Fig. A.2).

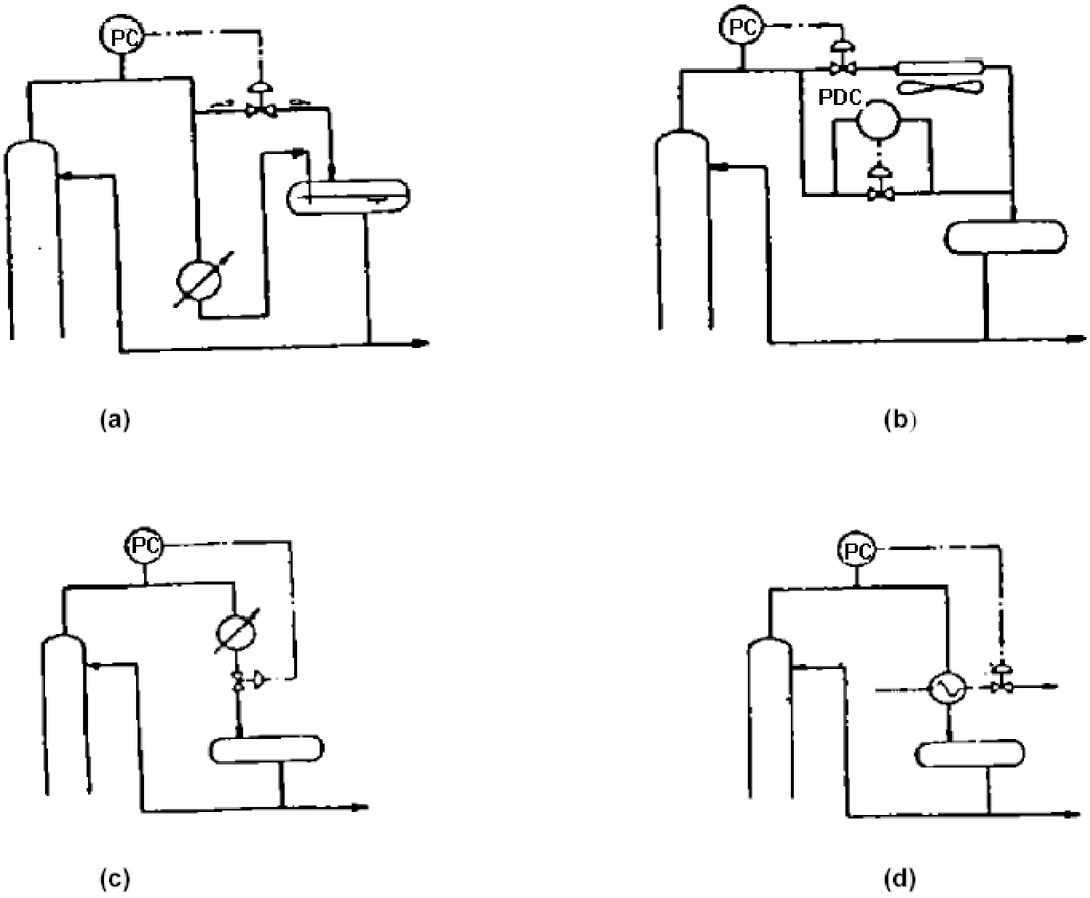


PRESSURE CONTROL OF DISTILLATION TOWER

(PRESSURE POSITIVE, NON-CONDENSIBLE GAS IS PRESENT)

Fig. A.2

3) Pressure is positive and all gases are condensible: for the control scheme shown in Fig. A.3-(a), adequate hot bypass flow calculation and condenser design shall be considered. If the condensers are air fin coolers, the control shown in Fig. A.3-(b) must be used, as the receiver cannot be elevated above them. For this case, a bypass shall be provided to control the differential pressure to keep the receiver pressure at a certain level. In the control scheme shown in Fig. A.3-(c), a valve is provided on the condensate line and the pressure is controlled by adjusting the heat transfer area for condensation. In the control scheme shown in Fig. A.3-(d), pressure is controlled by adjusting the condensation rate and the condensation rate is controlled by regulating the flow rate of the cooling water. This control system shall be only used for cases where subcooling difficulty and excessive cooling water outlet temperature rise are tolerable.

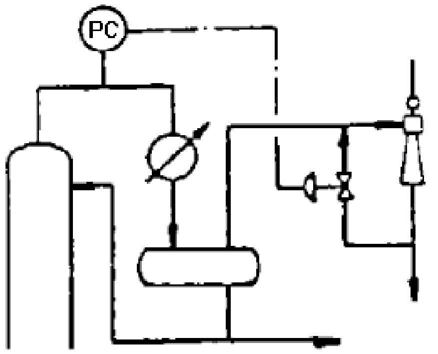


PRESSURE CONTROL OF DISTILLATION TOWER

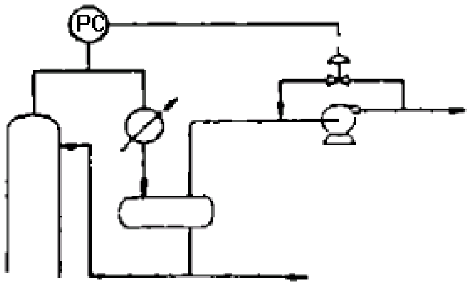
(PRESSURE POSITIVE, ALL GASES CONDENSIBLE)

Fig. A.3

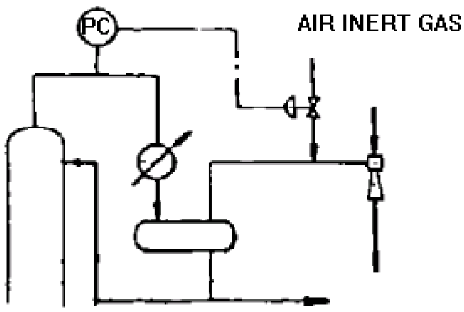
4) Vacuum distillation towers: unless otherwise specified, pressure control in vacuum towers shall be conducted by regulating the load of the vacuum producing equipment and this load regulation shall be carried out by circulating a part of the exhaust gases from the ejector or vacuum pump or by air introduction (Fig. A.4).



(a)



(b)



PRESSURE CONTROL OF VACUUM DISTILLATION TOWER

Fig. A.4

A.4.1.2 Temperature control

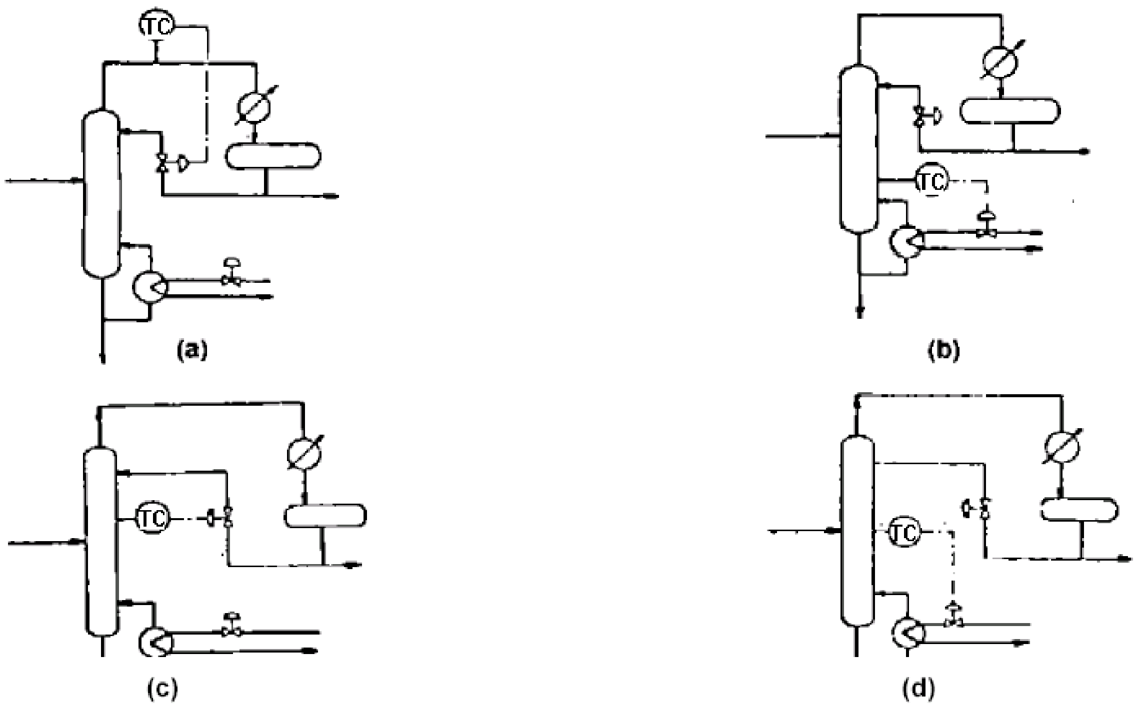
For the purpose of maintaining the composition application of overhead or bottom temperature control shall be considered for distillation towers, in conjunction with previously discussed pressure control as follows:

- The temperature of the intended product shall be controlled as a rule;

- In cases where fluctuation of the purity/composition of the intended product is expected to be minor, temperature control shall be conducted for the purpose of maintaining the yield.

Normally, control valves are provided on the reflux line in the case of overhead temperature control and on the reboiler heating medium line in the case of bottom temperature control.

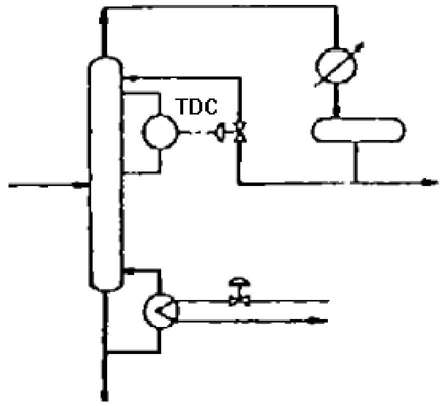
As shown in Fig. A.5-(a) and Fig. A.5-(b), temperature sensor is placed on the overhead line or on the bottom line in usual cases, but in cases where temperature variations related with composition fluctuations are too small at those locations, temperature measurement has to be at an intermediate tray where it can be done with high accuracy as shown in Fig. A.5-(c) and Fig. A.5-(d).



TEMPERATURE CONTROL OF DISTILLATION TOWER

Fig. A.5

In the case of super-fractionation (where a large number of trays are used and the temperature difference between the top section and the bottom section is small), the temperature difference between the two points, several trays apart, is measured to control the product purity as shown in Fig. A.6. In such a case, as temperature variations are caused by pressure fluctuations rather than by composition fluctuations, mere temperature control cannot serve the requirement of quality control of the intended product.



TEMPERATURE DIFFERENCE CONTROL OF DISTILLATION TOWER (TYPICAL FOR SUPER FRACTIONATORS)

Fig. A.6

For this reason, the effects of pressure fluctuations (which will be possible) may be offset by the application of a control scheme based on the temperature difference (in which case, pressure control is required). For cases of temperature control at intermediate trays and temperature difference control, suitable locations shall be selected from the standpoint of dynamics, to avoid the problem of an excessively large number of trays between the two points or between the top or bottom and the intermediate tray (required by high accuracy consideration). Further, in special cases, where no temperature control is provided at any point in the tower, other considerations (for instance flow control in each section) are required to maintain stable operating conditions and at the same time, some allowances shall be considered for the operating conditions, which may affect the design of the related equipment.

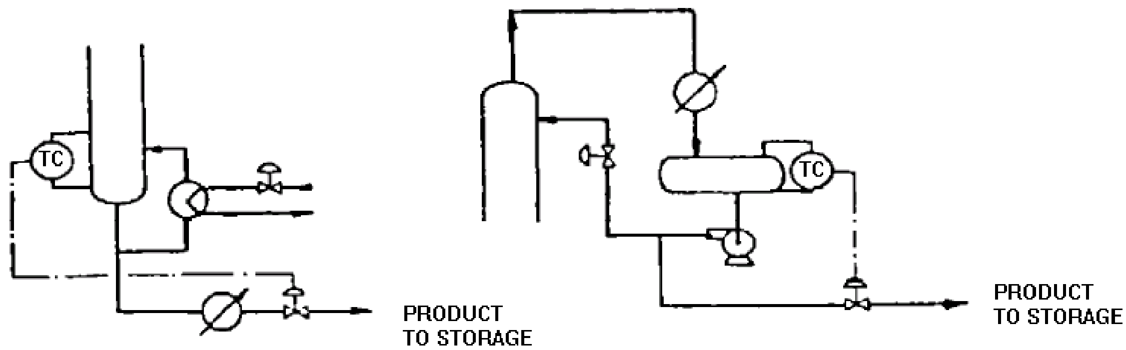
A.4.1.3 Flow control

In the case of single distillation tower, flow controls shall be provided for the feed, reflux and reboiler heating medium if neither pressure control nor temperature control are provided.

Overhead and bottom products are normally withdrawn under level control, but in cases where they are directly fed to other equipment, flow control may be required, demanding a thorough study of the whole system.

A.4.1.4 Level control

In the case of distillation towers, where the flow stability of overhead/bottom liquids is not important (in cases where the liquids are run down as products), level control has to be used, with control valves provided on the relevant lines as shown in Fig. A.7.



(a) **(b)**

LEVEL CONTROL OF DISTILLATION TOWER

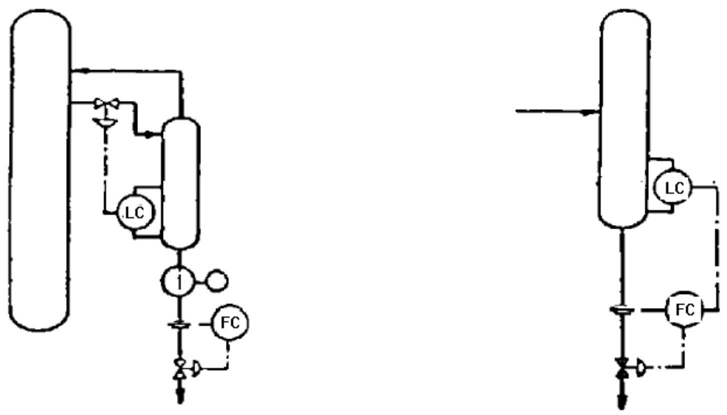
(PRODUCT FLOW STABILITY IS NOT REQUIRED)

Fig. A.7

In the case of high temperature fractionators where bottom liquid deterioration is probable, even if the flow stability of bottom product is sacrified, the liquid level must be held as low as possible to minimize the holding time. For cases where these liquids are utilized for heat recovery in reboilers and/or feed preheaters, selection of required control schemes shall be based on a thorough study of the whole system.

In cases where flow stability is required for the feed to the downstream equipment, the outgoing stream shall be flow controlled and the level of the liquid shall be controlled by regulating the inlet rate as shown in Fig. A.8-(a).

The level control and flow control may be cascaded as shown in Fig. A.8-(b) for cases where large disturbances are expected to occur or product properties are affected by flow rate variation and in single loops with long response cycles.



(a) (b)

LEVEL CONTROL OF DISTILLATION TOWER

[(a) PRODUCT FLOW STABILITY IS REQUIRED (b) CASCADE CONTROL]

Fig. A.8

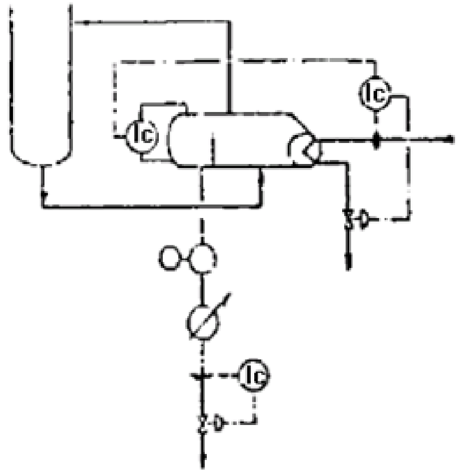
A.4.1.5 Reboiler control

A.4.1.5.1 Reboilers in which steam is used as the heating medium

Reboiler control scheme can be classified as flow control and temperature control [Fig. A.9-(a) and Fig. A.9-(b)], depending on the conditions of the tower, for which special attention shall be paid to the location of control valve and flow measuring point. Fig. A.10 shows a typical control scheme for the outlet stream from a kettle type reboiler.

(a) (b)

CONTROL OF REBOILER
(HEATED BY STEAM)
Fig. A.9



CONTROL OF REBOILER

(KETTLE TYPE, HEATED BY STEAM)

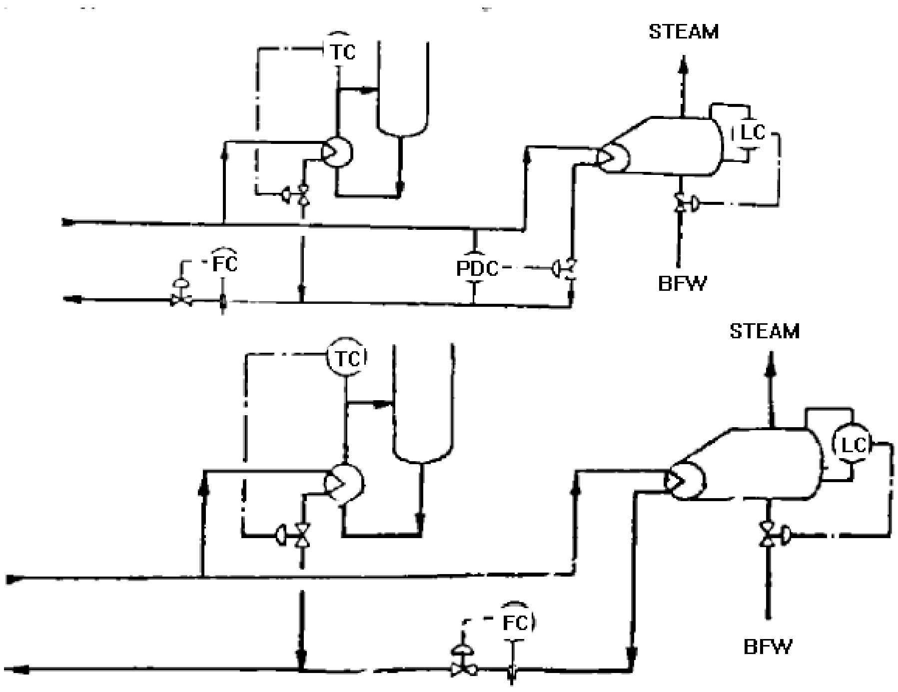
Fig. A.10

A.4.1.5.2 Reboilers in which main fractionator side-stream or effluent is used as the heating medium

Fig. A.11-(a) and Fig. A.11-(b) show typical control schemes for this kind of reboiler in topping Units. Fig. A.11-(a) presents typical reboiler control scheme for cases where the heating medium is a fractionator side-stream, while Fig. A.11-(b) shows typical reboiler control scheme where the heating medium is fractionator bottom effluent.

(a)

(b)



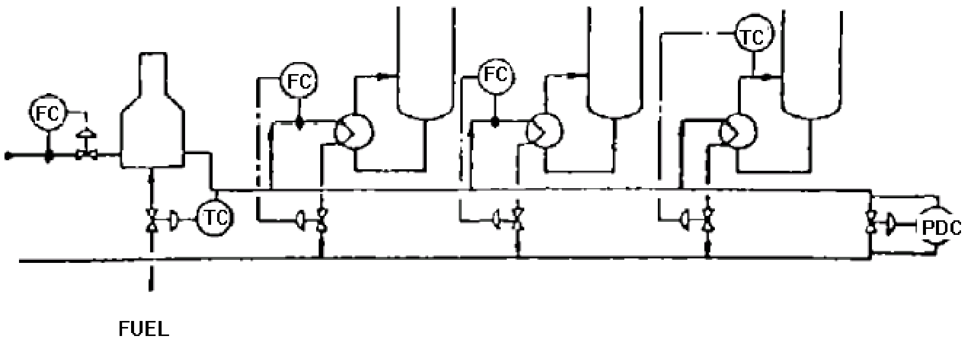
CONTROL OF REBOILER

(HEATED BY FRACTIONATOR SIDE-STREAM OR EFFLUENT)

Fig. A.11

A.4.1.5.3 Hot oil system

Fig. A.12 shows a typical control scheme of an hot oil system covering several reboilers. Flow control or temperature control may be provided for each individual reboiler, depending on the conditions/configuration of the fractionator side.

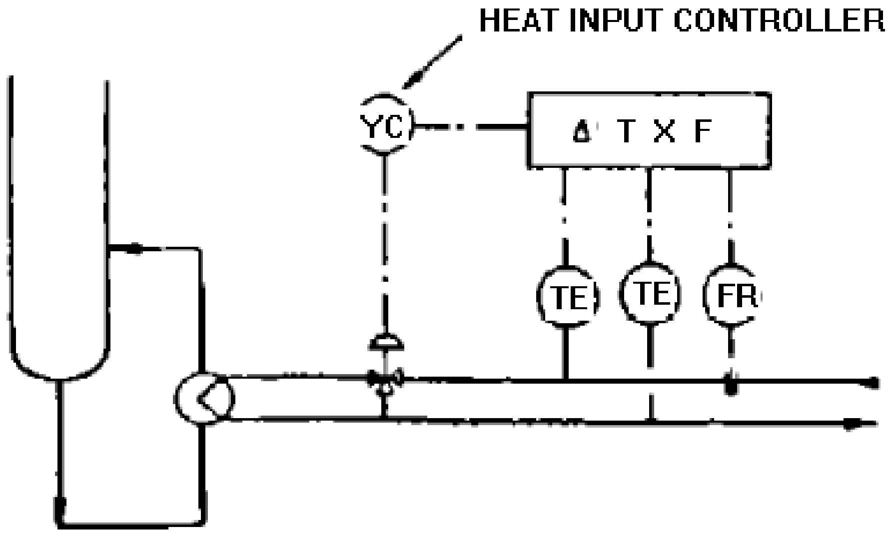


REBOILER CONTROL FOR HOT OIL SYSTEM

Fig. A.12

A.4.1.5.4 Reboilers with heat input controller

There are cases where heat input control is required other than flow, level, pressure and temperature control. The principle of heat input control is as shown in Fig. A.13, the amount of the heat input is calculated from the flow rate and inlet/outlet temperatures and is controlled to keep required value of heat input to the reboiler.

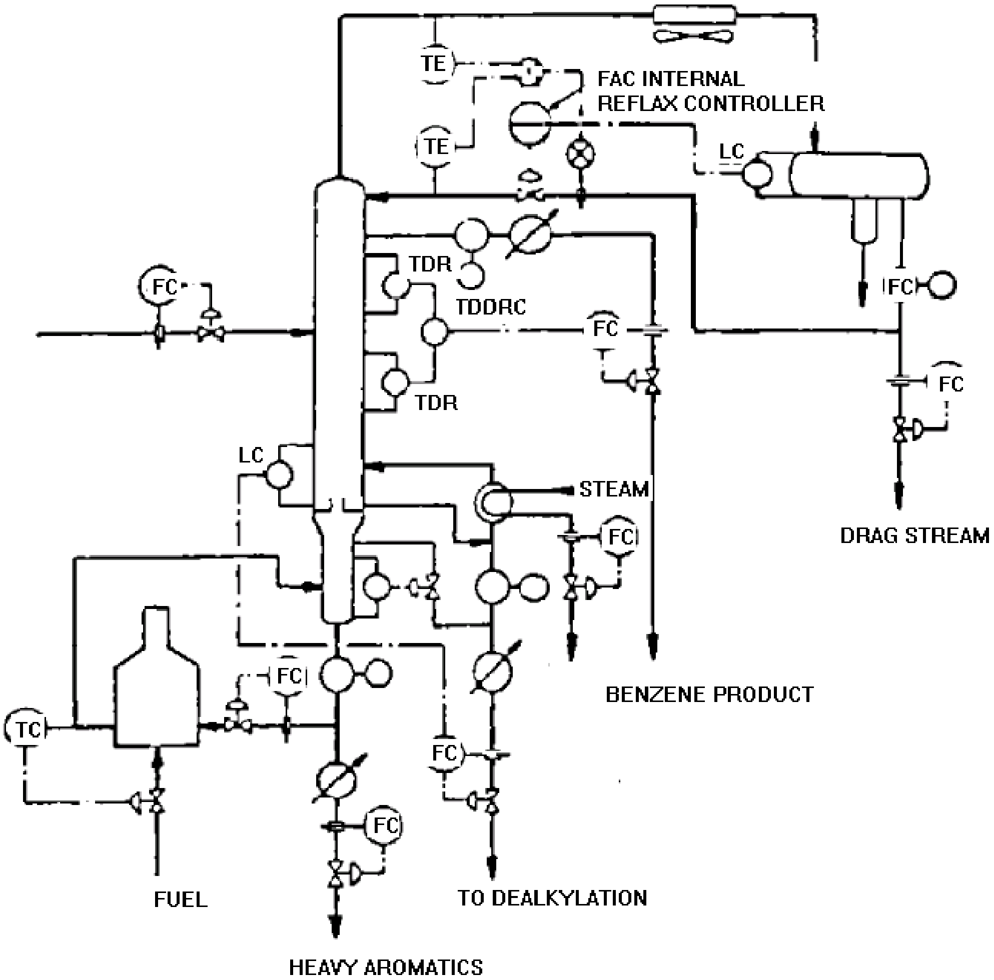


HEAT INPUT CONTROL OF REBOILER

Fig. A.13

A.4.1.6 Internal reflux control

In cases where the reflux rates are controlled in fractionation, if only the external reflux rates are controlled without regulating their temperatures, the rates of the internal refluxes which are the substantial refluxes, will vary with temperature, namely temperature variations will act as disturbances. Such disturbances must be precluded in the case of towers designed to produce high purity products. Hence, controllers must be provided for the purpose of controlling the internal reflux rates as typically shown in Fig. A.14 (the internal reflux controller is cascaded with the overhead receiver level controller and the difference between the overhead temperature and reflux temperature is measured to correct the external reflux rates).



INTERNAL REFLUX CONTROL

Fig. A.14

A.4.1.7 Quality control and distillation tower control

Distillation tower control generally used are based on either of the following which are to be selected for the purpose and conditions in each individual case after review and discussion.

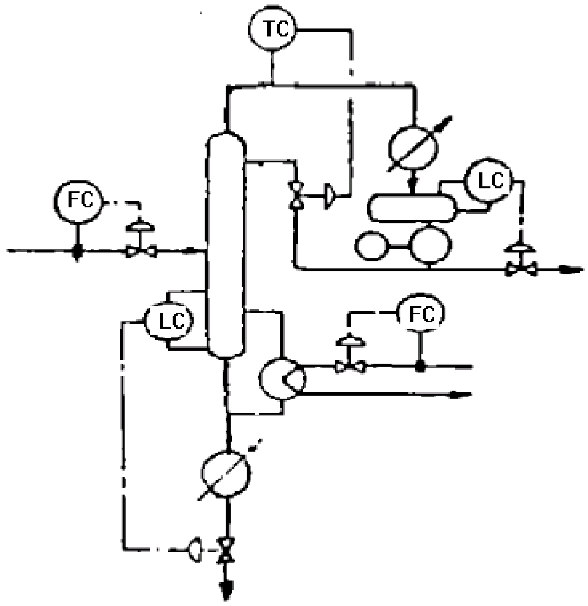
Since pressure controls can be used in combination with any of the above-mentioned controls, most suitable combinations can be selected for the conditions involved in each individual case.

Fig. A.15-(a) shows a typical case of product quality control in which the heat input to the bottom section is kept at a fixed level and the overhead temperature is regulated by a temperature controller.

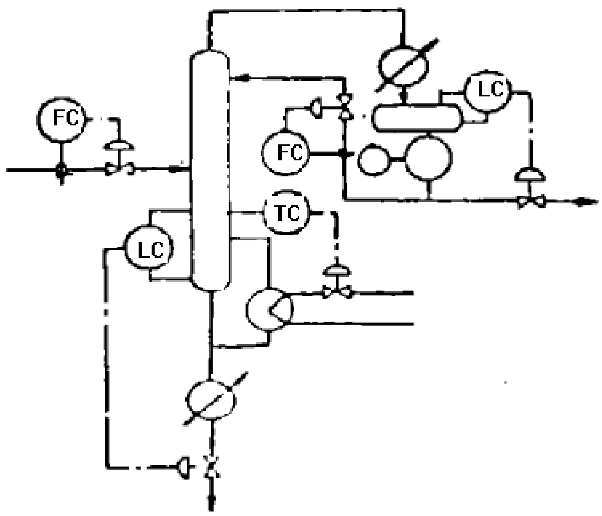
Inversely, in Fig. A.15-(b), the reflux rate is fixed and a temperature controller is provided in the bottom section to control the bottoms quality.

In high reflux ratio towers (separation of component with small boiling point difference), the product composition and flow rates are considerably affected by variations in the reflux ratio.

(a)



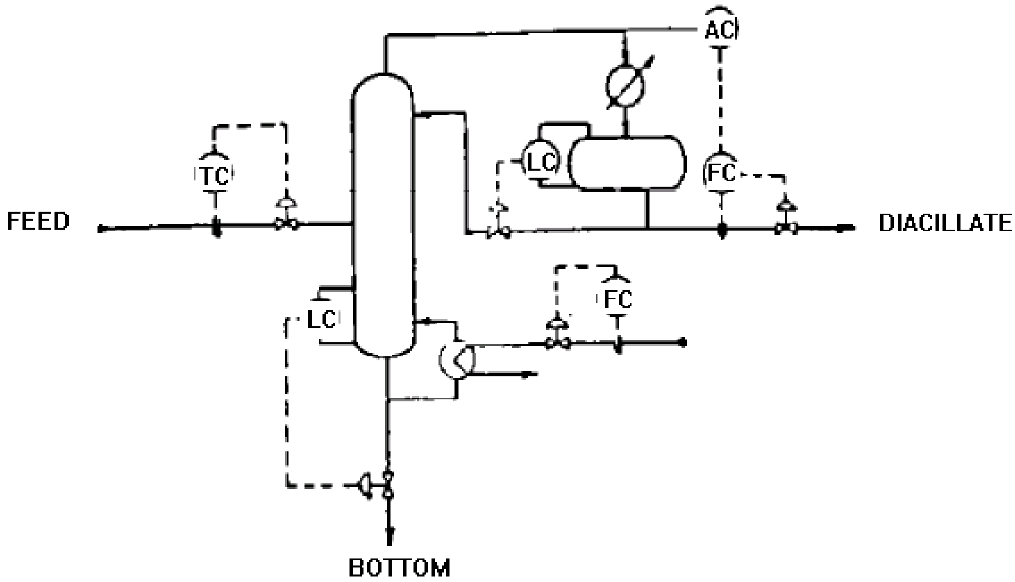
(b)



PRODUCT QUALITY CONTROL

Fig. A.15

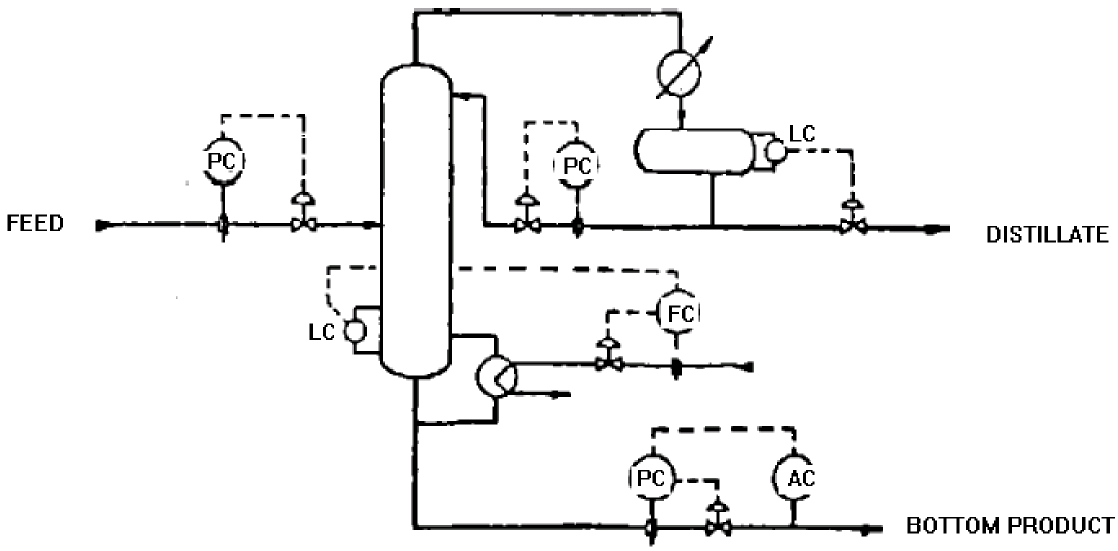
In order to maintain an appropriate material balance, the distillate rate must be regulated by flow control and the product composition must be monitored by analyzers (as shown in Fig. A.16).



MATERIAL BALANCE CONTROL SYSTEM 1

Fig. A.16

Fig. A.17 shows the typical control scheme to be used when the bottom product rate is smaller than the distillate rate.

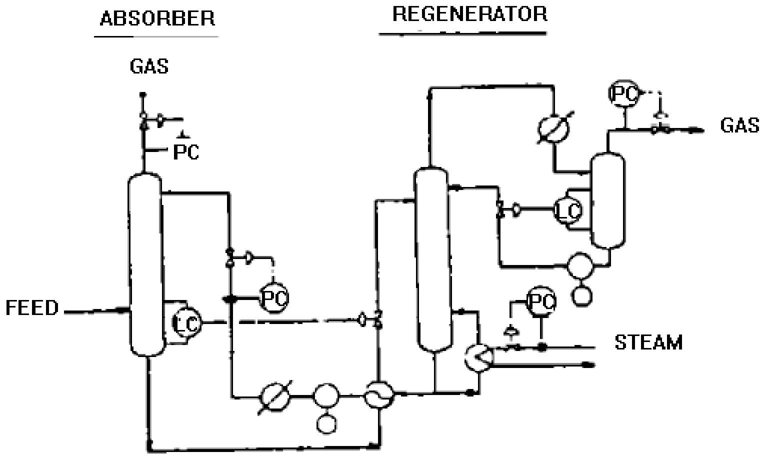


MATERIAL BALANCE CONTROL SYSTEM 2

Fig. A.17

A.4.2 Control scheme for absorber-regenerator

Typical control scheme for absorber-regenerator is shown in Fig. A.18 (acid gas removal process).

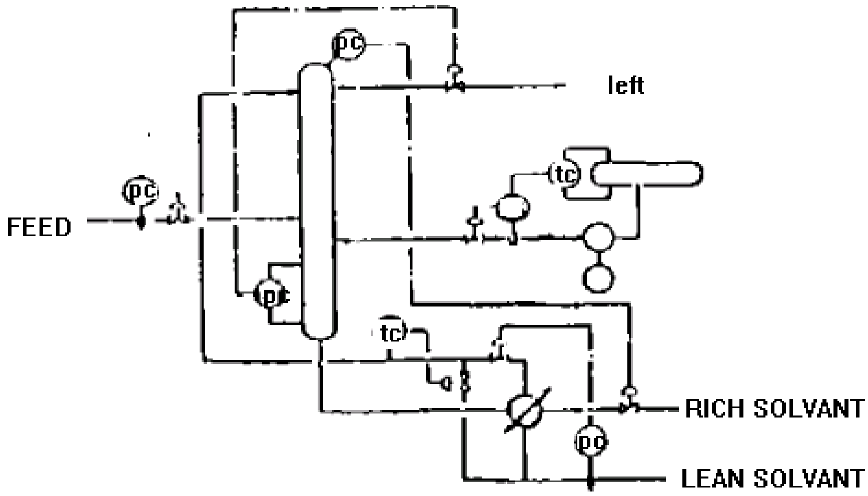


CONTROL OF ACID GAS REMOVAL PROCESS

Fig. A.18

A.4.3 Control scheme for extractor

Fig. A.19 shows typical control system for the extractor of a process for which a liquid-liquid interface controller is provided in the bottom. Operating temperature of this extractor is governed by the temperature of the lean oil charged to the tower for which a temperature control loop has been provided.



CONTROL OF EXTRACTOR

Fig. A.19

A.4.4 Control schemes for pumps

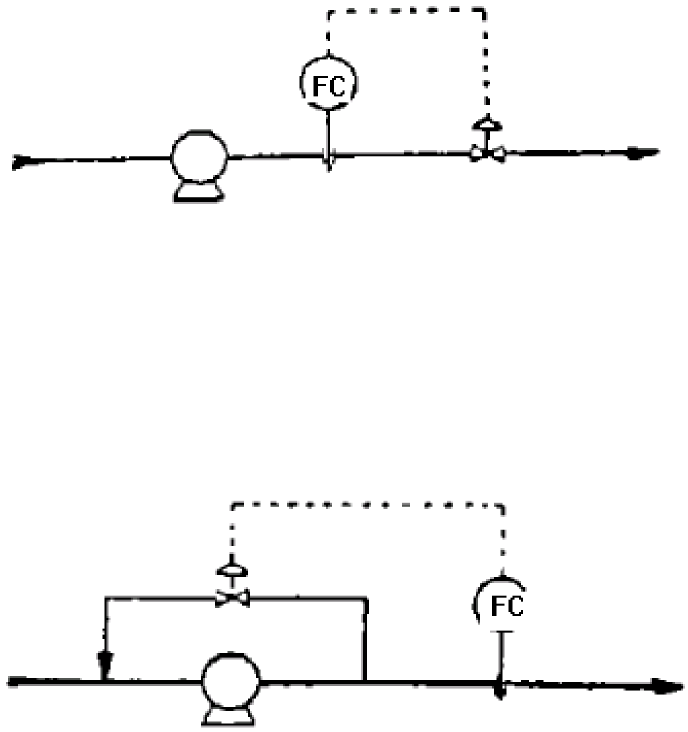
Pump control systems can be classified basically into the following two categories:

1) Flow control with control valve on discharge (Fig. A.20-(a));

2) Flow control with control valve on spill-back line (Fig. A.20-(b)), used in the case of high capacity pumps expected to conduct shut-off operation to prevent pump seizure.

(a)

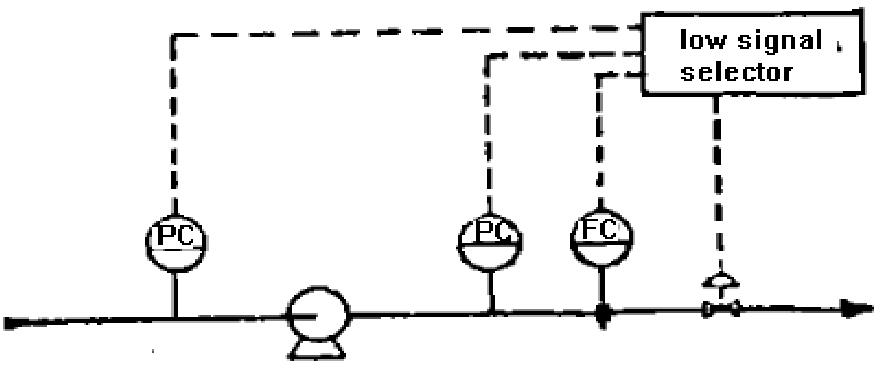
(b)



PUMP CONTROL SYSTEM 1

Fig. A.20

In the case of high capacity pumps as those used in offsite facilities, necessity of application of override control shall be checked for the purpose of pump protection (Fig. A.21).



PUMP CONTROL SYSTEM 2

Fig. A.21

APPENDIX B

TYPICAL VENDOR'S PROPOSAL ATTACHMENT FOR PSA SYSTEMS

B.1 PSA Process Data Sheet
B.1.1 Guarantee items
B.1.1.1 Throughput (for each case)
B.1.1.1.1 Total products as H_2 gas (for each case)
B.1.1.1.2 Feed to each PSA as H_2 feed gas (for each case)
B.1.1.2 Hydrogen recovery efficiencies (for each case)
B.1.1.3 Product specification

(1) H_2 purity (%)
(2) $CO + CO_2$ content
(3) HCI content

B.1.1.4 Absorbent life

(1) Guaranteed
(2) Expected

B.1.2 Design basis
B.1.2.1 Operation condition

(1) Turn down (%)
(2) Continuous operation time (hours)
(3) Expected on-stream factor (%)
(4) Product gas pressure [bar (ga)] temperature (°C)
(5) PSA off gas pressure [bar (ga)] temperature (°C)
(6) Number of equalization steps
(7) Number of adsorber in one adsorption step
(8) Operation with reduced number of adsorbers and change of H_2 recovery efficiency

B.1.2.2 Adsorbers

(1) Number of adsorber vessels
(2) Vessel size (mm)
(3) Adsorbent volume

B.1.2.3 Surge drum

(1) Number of drums
(2) Drum size (mm)
(3) Total drum volume

B.1.3 Utility requirements
B.1.3.1 Operation utilities

(1) Instrument air (Nm^3/h)
(2) Electric power (kW)

B.1.3.2 Start-up utilities

(3) Nitrogen (Nm^3)

B.1.4 Control system

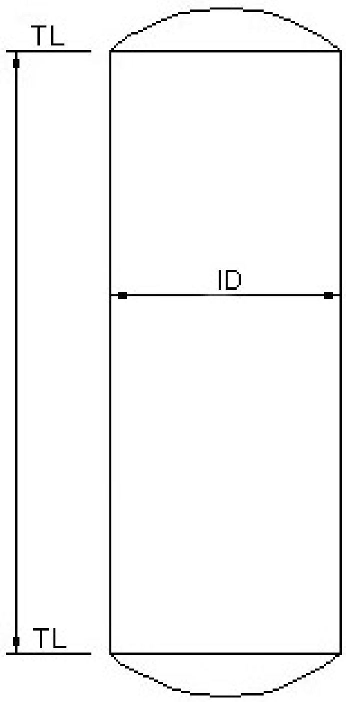
(1) Automation feature
(2) Control unit
(3) Trouble shooting and detection
(4) Switchover system
(5) Maintenance of control valves and instruments.

(to be continued)

APPENDIX B (continued)

B.1 PSA Process Data Sheet

SERVICE				ITEM
		TEMPERATURE	PRESSURE	
	SHELL			
	JACKET			
DESIGN CONDITION	SHELL		INL.	
			EXT.	
	JACKET		INL.	
			EXT.	
	COIL			
FLUID		DENSITY		
POSTWELD HEAT TREATMENT (FOR PROCESS)			YES ☐ NO ☐	
	MATERIAL		C.A.	
SHELL				
LINING				
HEADS	TOP			
	BTM			
JACKET				
INSULATION YES ☐ NO ☐ THICKNESS		HEAT CONSERVATIVE		
		COLD ☐ HOT ☐		
		FIRE PROTECTION		
		PERSONNEL PROTECTION		



NOZZLES			
ITEM	NO	RATE&FACE	SERVICE

NOTES:

	REV.		DATE	PREP.	CHK.	APP.