

Effectively Control Column Pressure

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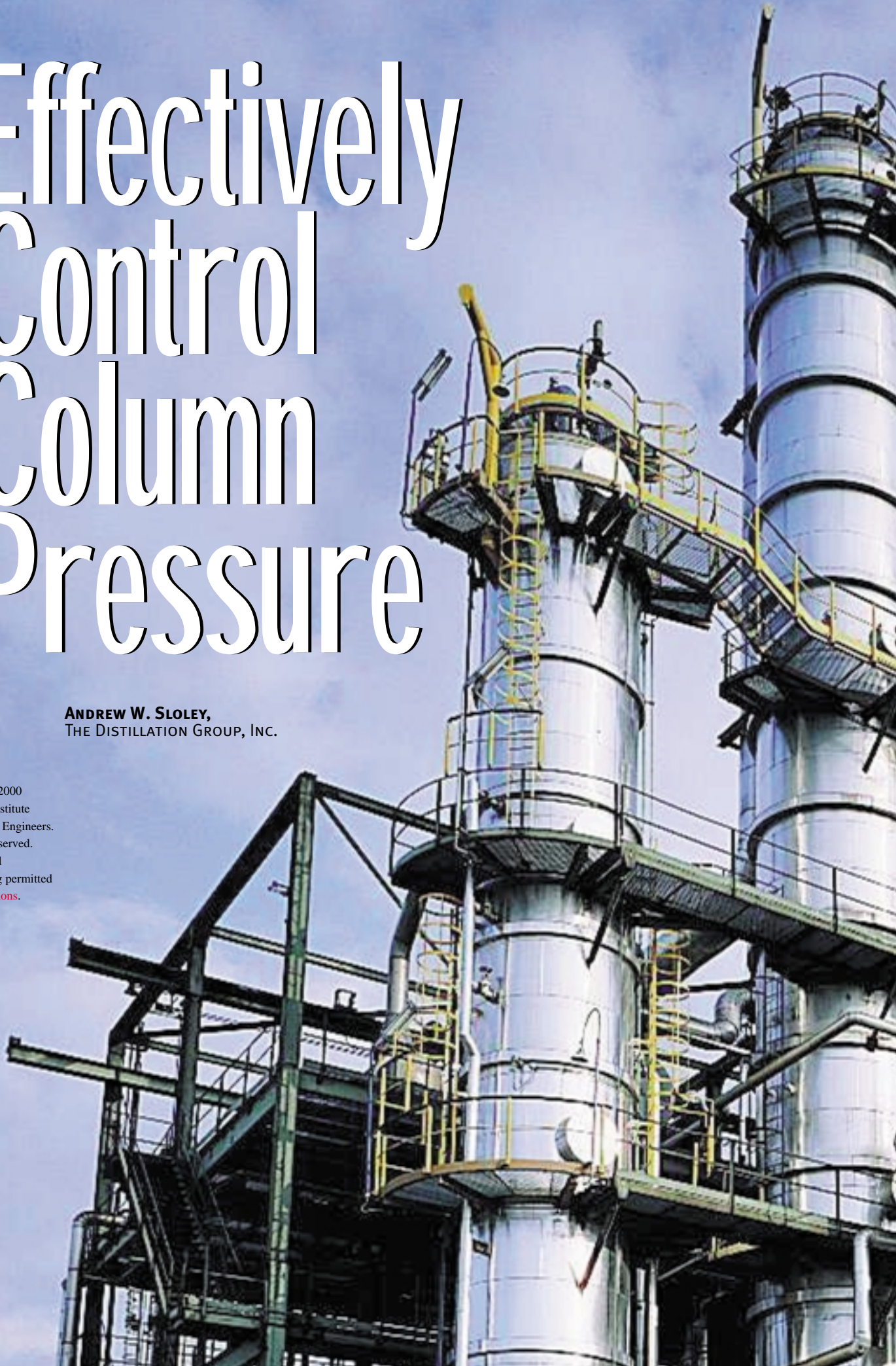
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Effectively Control Column Pressure

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Maintaining proper pressure can play a crucial role in the stable operation of a distillation column. Here's how to select the most appropriate pressure-control scheme.



Most distillation-column control systems, either conventional or advanced, assume that the tower operates at a constant pressure. Pressure fluctuations make control more difficult and reduce unit performance. Pressure variations alter column vapor loads and temperature profiles. So, when using temperature control as a substitute for composition control, pressure compensation is essential to maintain desired compositions (1). Pressure variations change relative volatilities and affect fractionation performance. Vacuum columns are especially susceptible to this problem. Other, less common problems can arise from pressure fluctuations. Pressure drops also may turn a normally single-phase feed into a

flashing feed. Two-phase feed in a column designed for single-phase feed can cause flooding (2).

Effective pressure control minimizes compensation requirements for temperature control, and prevents column flooding. It also improves advanced control and unit optimization by enabling more reliable operation close to the unit's maximum capacity. While distillation pressure-control systems are important, few sources (3,4) have thoroughly examined them. So, in this article, after reviewing major process factors involved in selecting pressure control schemes, we will examine the major types of column pressure control for both vacuum and pressure systems, their characteristics, and most suitable application.

Table 1. Common methods for pressure control of towers.

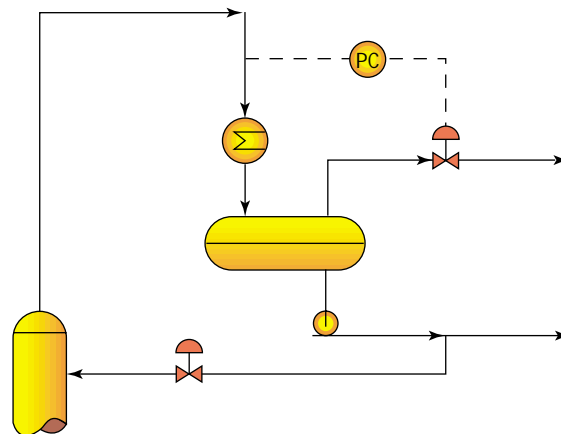
Method (Figure No.)	Type	Description <i>Net vapor rate always > zero</i>
1	1A	Direct control of vapor product rate
2	1A	Control recycle vapor rate to compressor
3	1A	Control recycle vapor rate to ejector: ejector discharge recycle
4	1A	Control makeup ejector load
5	1A	Control ejector motive-steam pressure
6	1A	Control recycle vapor rate to ejector: ejector discharge recycle
<i>Net vapor rate ≥ zero</i>		
7	2A+	Control vapor product rate in conjunction with a secondary method
8	2A	Control makeup vapor supply
<i>Net vapor rate = zero</i>		
9	3B	Control flow to condenser — condenser at low pressure
10	3B	Control flow from condenser — condenser at high pressure
11	3B	Control bypass flow to condensate receiver — “hot vapor bypass”
12	3B	Direct control of liquid product rate
13	3B	Dual pressure control of bypass and condensate
14	3D	Control vaporizing coolant level
15	3D	Control vaporizing coolant pressure
16	3E	Control condenser inlet coolant temperature — “tempered water”
17	3E	Control coolant rate
18	3E	Control of air-cooler coolant rate
19	3C	Control condensation temperature or pressure

The bases for control

Pressure control involves adjusting mass or energy balances by manipulating the amount of mass or heat flow into or out of the tower. Mass flow methods typically control the tower vapor inventory — either directly by throttling the vapor rate out of the system or indirectly by manipulating downstream equipment that evacuates gas from the system. Energy methods control the heat flux in the overhead condenser — via temperature (on either side of the condenser) or effective surface area.

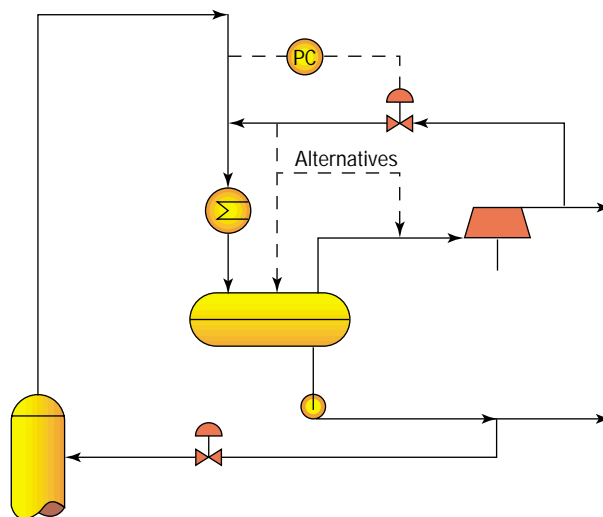
In general, it is best to use a method that manipulates a variable physically as close as possible to the controlled variable. Because the control objective usually is tower overhead pressure or condensate drum pressure, our control configurations will look at different ways to control pressure by varying condenser duty and overhead product rates. The literature includes systems that control overhead pressure by reboiler duty

Figure 1. Net vapor rate > 0, direct control of product rate.



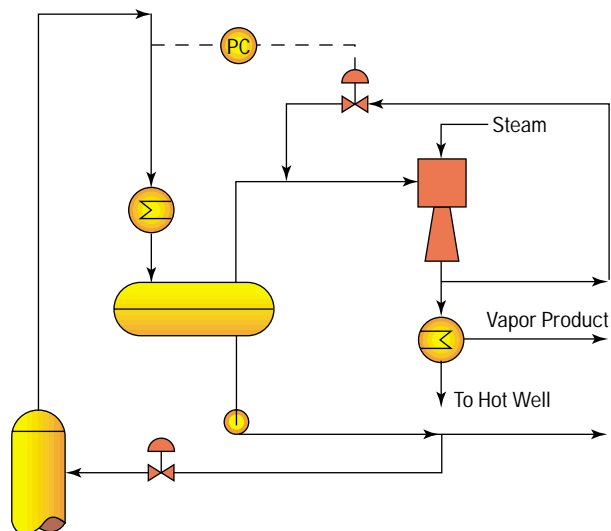
Method: Vary net vapor rate, no makeup gas.
Process: Must always have vapor product.
Advantages: Simple and direct.
Disadvantages: Generally none. Response may be slow when vapor rate is low.
Application: Usually the best choice when vapor rate is always positive.
Variants: Condenser outlet may enter bottom of drum (but, this is not necessary and adds extra pressure drop to the overhead system).
Configuration notes: Works best mounting condenser above the drum and allowing gravity flow of condensate to condensate drum. Exchanger outlet nozzle should allow for free draining of two-phase outlet.
Operation: Controller directly affects column vapor inventory and, hence, pressure.
Warnings: —

Figure 2. Net vapor rate > 0, control recycle vapor rate to compressor.



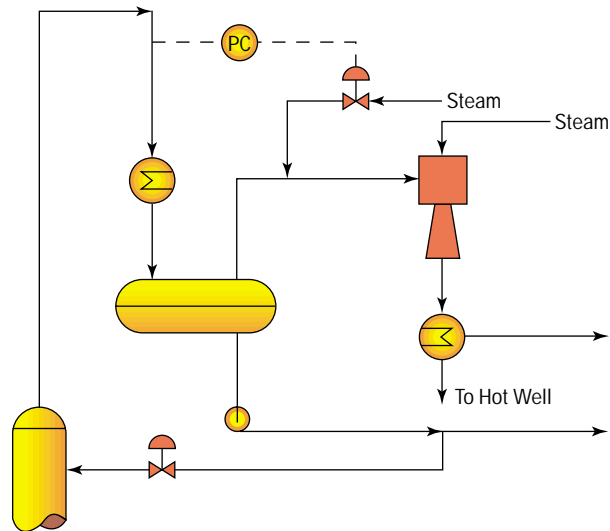
Method: Vary net vapor rate, no makeup gas.
Process: Must always have vapor product.
Advantages: Simple and rapid control.
Disadvantages: Compressor may need to be oversized to add required control margin.
Application: Vapor going to higher pressure equipment.
Variants: Vapor may return to upstream of condenser, to condensate drum, or to compressor suction.
Configuration notes: A bypass relief of gas to low pressure (flare, fuel) often is added to allow operation when compressor is down.
Operation: Material is recycled to maintain constant suction pressure.
Warnings: —

Figure 3. Net vapor rate > 0, control recycle vapor rate to ejector.



Method: Vary net vapor rate, no makeup gas.
Process: Vacuum systems, always must have vapor product.
Advantages: All ejector discharge available for recycle, often gives the most stable operation.
Disadvantages: Difficult to implement in systems with the ejector directly attached to its condenser, relatively large recycle line and control valve frequently are required.
Application: The best ejector pressure-control system for ejectors that are not stable to zero load, often the most economical system for stable ejector control.
Variants: *Recycle to upstream of condenser:* This requires a process compatible with water and water removal in condensate drum. Most of the recycle may be condensed in the condenser — if this happens, recycle of off-gas from the ejector condenser to upstream of the tower condenser is recommended instead.
Recycle ejector condenser vent to upstream of ejector: This variant is not recommended. Noncondensable recycle often can have a limited operating range due to low noncondensable flow rates. In tight batch systems, noncondensable load after startup can approach zero. This mandates use of condensable recycle immediately downstream of the ejector.
Configuration notes: Vapor product may be either a true vapor product or a nonproduct material to be evacuated from the system. In multistage systems, the recycle stream must loop only around the initial ejector. Recycle from the last ejector stage to the primary ejector can cause unstable operation due to increased noncondensable load on the intermediate or final ejector.
Operation: Recycle gas moves the vacuum jet ejector along its operating curve — the higher the load to the ejector, the higher the ejector suction pressure.
Warnings: —

Figure 4. Net vapor rate > 0, control makeup ejector load.



Method: Vary net vapor rate, makeup vapor (steam).
Process: Vacuum systems, always must have vapor product.
Advantages: Easily added to systems after construction, control valve and piping are small and relatively cheap.
Disadvantages: Increases steam use and hot-well water makeup, and raises cooling water load.
Application: Often added after-the-fact to vacuum systems for improved control, and frequently used in batch distillation systems. After startup, tight batch systems may have nearly zero load from the tower to the ejector.
Variants: Instead of steam, air or inert gas may be used to bleed into the jet suction.
Configuration notes: Using air or inert gas instead of steam will add a larger inert gas load to the condenser and may affect condenser operation. In multistage ejector systems, using noncondensable gas (air or inert gas) will load up all ejectors in the system. Steam will load the ejector only with the steam injection directly upstream.
Operation: Added load moves the vacuum jet ejector along its operating curve — the higher the load to the ejector, the higher the ejector's suction pressure.
Warnings: Wet steam may cause ejector erosion from water droplets. A combination of electrical tracing, superheated steam, local water knockout before addition to the system, or other measures may be required to reduce erosion to allowable levels.

(5); these are unusual, however, and will not be covered here. Most of the control systems detailed are in current use in refineries and petrochemical plants. Other industries may have specific control options available that are not covered here.

Process considerations

The two major earlier reviews of pressure control took different approaches to categorizing the methods. Boyd (3) broke down the control systems into groups based on distilla-

tion pressure, presence of inert gas, and product type (vapor or gas). Chin (4) classified methods by product type, and then by general method (mass or energy flow control); some of the decisions on grouping the energy flow methods into subgroups appear somewhat arbitrary, however.

Here, we follow Chin's general approach, but without straining to over-categorize the energy-removal control methods. Instead, we reuse Chin's major groupings, namely:

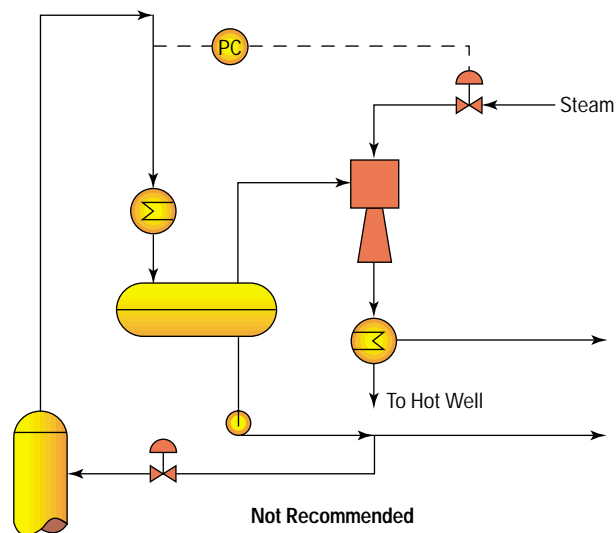
1. vapor product *always* present;
2. vapor product greater than or equal to zero at steady-state, negative vapor flow-rate transients possible; and
3. vapor product rate zero at steady state (total condenser), negative vapor flow-rate transients possible.

But, we modify the subgroups to:

- A. mass flow control (vapor rate control);

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Figure 5. Net vapor rate > 0, control ejector motive steam.



Method: Vary ejector driving steam pressure — *not normally recommended*.

Process: Vacuum systems, always must have vapor product.

Advantages: Minimizes total steam demand, hot-well water generation, and condenser cooling needs; requires a small control valve but minimum piping changes.

Disadvantages: Often only a very small control range available.

Application: Added to vacuum ejector systems after construction — never should be selected as the primary control system in preconstruction design.

Variants: —

Configuration notes: —

Operation: Lower-pressure supply steam reduces the mass rate of steam to the ejector. This lowers the pressure ratio across the ejector and the ejector suction pressure rises.

Warnings: Ejectors have limited motive-steam-mass and volume operability ranges. Sometimes this method works, other times it does not. Improper ejector operation can result in rapid and unstable shifts in vacuum pressure. The author has seen sudden swings from 10 torr (10 mm Hg) vacuum to 40 torr (40 mm Hg) vacuum and back resulting from minute changes in motive steam pressure. In other systems, motive steam pressure could be varied by as much as 10–20% with reasonable control still achieved.

B. energy flow control: variable surface area, process-side control;

C. energy flow control: variable heat flux, process-side control;

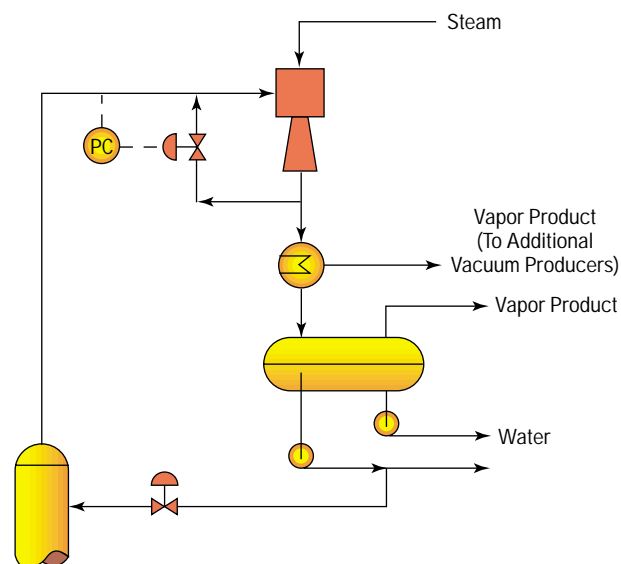
D. energy flow control: variable surface area, utility-side control; and

E. energy flow control: variable heat flux, utility-side control.

These subgroups concentrate our attention on the method of control (surface area or heat flux) and the controlled medium (process or cooling utility).

Additional process considerations that can affect control method selection include the breadth of the boiling range of the process stream, as well as the presence and relative quantity of noncondensable gas. Such considerations are noted, as appropriate, in the explanatory text for the control methods.

Figure 6. Net vapor rate > 0, control recycle vapor rate to ejector.



Method: Vary net vapor rate, no makeup gas.

Process: Vacuum systems, always must have vapor product. The system shown is commonly referred to as a “dry” or “damp” system, depending upon the application, because there is no condenser before the vacuum ejector.

Advantages: All ejector discharge available for recycle, often gives the most stable operation.

Disadvantages: Difficult to implement in systems with the ejector directly attached to its condenser. Relatively large recycle line and control valve frequently are required. Overhead product must be compatible with water.

Application: The best ejector pressure-control scheme for ejectors connected directly to the tower that are not stable to zero load. Often, the most economical system for stable ejector control.

Variants: System frequently is used without reflux return to the tower (external liquid feed or pumparound reflux generation).

Configuration notes: In multistage systems, the recycle stream must loop only around the initial ejector. Recycle from the last ejector stage to the primary ejector can cause unstable operation due to increased noncondensable load on the intermediate or final ejector.

Operation: Recycle gas moves the vacuum jet ejector along its operating curve — the higher the load to the ejector, the higher the ejector suction pressure.

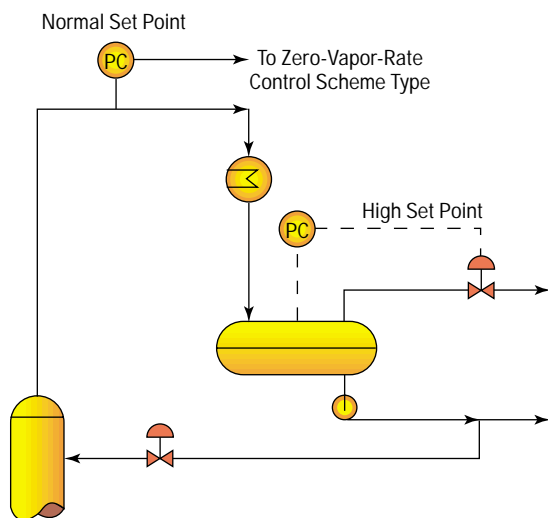
Warnings: —

All told, we detail 19 methods (see Figures 1–19). This does not encompass all options — indeed, many other methods of pressure control are available (6) — but covers the most common ones. Table 1 cross-references the method with its figure number, general type (1A, 3B, etc., per the above categorization), and provides a brief description of the method.

Using this guide

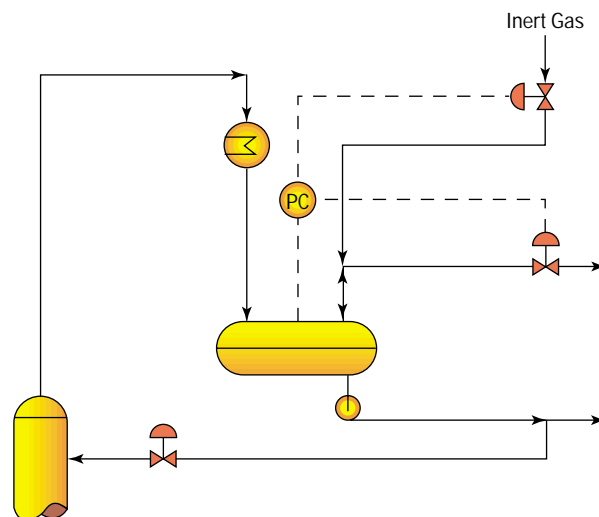
For each pressure-control method, a figure provides a basic process and instrumentation diagram. Most of the configurations shown require other control loops for condensate liquid-level control, piping for venting noncondensable gas,

Figure 7. Net vapor rate ≥ 0 , control vapor product rate combined with a secondary method.



Method: Various.
Process: Net vapor rate positive or zero.
Advantages: —
Disadvantages: —
Application: Effective choice for systems that require inert venting.
Variants: Many.
Configuration notes: Can be used with methods that allow for variable condenser duty. See Figures 9–11 and 13–19 for examples. The flooded drum (Figure 12) is not suitable for addition to this basic method.
Operation: Direct control of overhead pressure. Differential pressure (DP) is manipulated to control condensation temperature in condenser — this varies the condenser's log-mean temperature difference (LMTD). When pressure rises above the high set point on the receiver, the high-set-point controller opens and gas leaves the system.
Warnings: —

Figure 8. Net vapor rate ≥ 0 , control makeup vapor supply.



Method: Vary blanketing vapor above drum.
Process: Net vapor rate positive or zero.
Advantages: Simple, fast response.
Disadvantages: Net consumption of pressurizing gas, requires two control valves, and may pose tuning problems.
Application: Pressure towers.
Variants: Adding makeup gas upstream of the condenser may reduce the gas rate required, due to partial vapor blanketing of the condenser. Response time will be slightly slower, however. Another variant in which the drum is open to the atmosphere provides partial exchanger vapor blanketing, but is rarely used today due to potential emission of material.
Configuration notes: Pressurizing gas must be compatible with the process. Some pressurizing gas may enter the distillate product and reflux. Equalizing line is not required. Works best if the control settings have a slightly overlapping range: a small operating band is present where there is inert gas coming in and some vented gas going out.
Operation: When pressure drops below the desired set point, vapor is added to the receiver. When pressure rises above the desired set point, the vapor product line is opened.
Warnings: —

water boots on condensate drums, and other equipment. To keep the diagrams clear and concise, they only include information required for discussion of the pressure control problem. In addition to the P&ID, each figure includes the following descriptive information and guidelines:

- method: a brief description of the method;
- process: type of process for which the method is appropriate;
- advantages: common reasons to use the method;
- disadvantages: common reasons not to use the method;
- application: specific application notes;
- variants: modifications of the method in common use;
- configuration notes: specific design and operating issues related to equipment design, installation, operation, or troubleshooting;
- operation: how the method works; and
- warnings: special problems to watch out for.

All figures show refluxed towers. Many of the configurations work equally well with conventional fractionation towers and towers that have no reflux, such as many refinery and petrochemical main fractionators. These include columns

with reflux provided by pumparounds, internal condensers, or external streams.

All figures depict columns with a liquid product. Group 1 methods (vapor rate > 0) easily adapt to units without a liquid distillate product.

Recommendations

Many factors specific to the particular column must be considered in deciding which control method to use. As a starting point, however, consider the following suggestions for common situations:

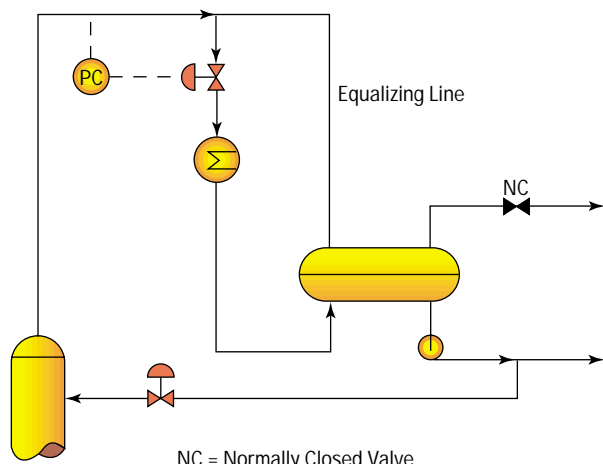
Net vapor always > 0 or vapor product only. Method 1 usually is the simplest and best.

Vapor product to compression system. Method 2 is recommended for such situations.

Steam jet ejector systems. Method 3 is suggested for systems with precondensers or with the vacuum system taking

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Figure 9. Net vapor rate = 0, control flow to condenser at low pressure.



NC = Normally Closed Valve

Method: Vary condensing area.

Process: Net vapor rate zero.

Advantages: Simple.

Disadvantages: Liquid level control in drum affects pressure balance, requires relatively large control valve, as well as extra exchanger area.

Application: Generally a stable and effective control scheme for many processes.

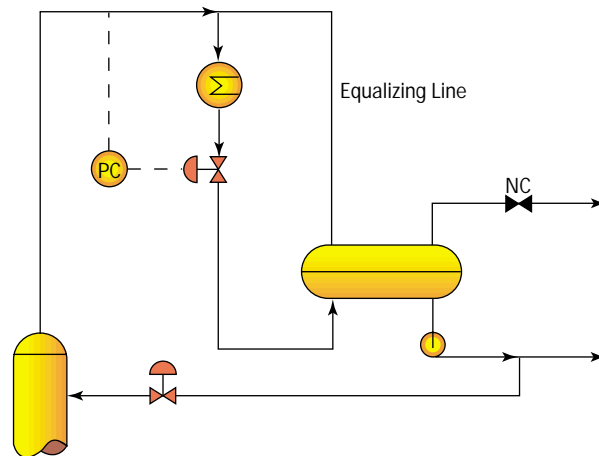
Variants: —

Configuration notes: Pressure in the drum and column overhead are the same. Equalizing line is needed for stable control. Liquid from condenser must enter the drum in the liquid layer so that control valve changes can affect liquid level in the condenser. Preferred application is liquid entry into drum from below (shown). If air-fins are used for the condenser, they should be angled to allow for gradual surface-area changes with liquid level changes. Cooling is done at the lowest possible utility temperature (potential problem for cooling water, potential advantage for heat-integrated cryogenic systems).

Operation: Control valve imposes a variable DP in main flow line through condenser. Liquid level in control line up to exchanger varies with DP changes. This exposes or submerges tubes, shifting area from condensation to subcooling.

Warnings: —

Figure 10. Net vapor rate = 0, control flow from condenser at high pressure.



Method: Vary condensing area.

Process: Net vapor rate zero.

Advantages: Simple, requires relatively small control valve.

Disadvantages: Condensate from condenser to drum must allow for gravity flow of liquid. Great attention must be paid to layout and control valve sizing. Extra exchanger area is necessary.

Application: Generally a stable and effective control scheme for many processes.

Variants: Liquid may enter through top of condensate drum.

Configuration notes: Pressure in the drum and column overhead are the same. Equalizing line is needed for stable control. If air-fins are used for the condenser, they should be angled to allow for gradual surface-area changes with liquid level changes.

Operation: Control valve imposes a variable DP in main flow line after condenser. Liquid level in control line up to exchanger varies with DP changes. This exposes or submerges tubes, shifting area from condensation to subcooling.

Warnings: —

vapor from the condensate drum instead of directly from the tower. Method 6 is recommended for systems with the ejector connected directly to the tower. Method 5 never should be specified as the main control method unless a backup method is provided.

Large quantities of noncondensable gas requiring venting from system. Method 1 is preferred, but Method 19 may be used as an alternative.

Net vapor rate \geq zero. Many of the variants of Method 7 do a good job. Method 7 plus Method 10 works well. Method 7 plus Method 17 can be used to maintain the condensate drum pressure, if cooling utility fouling can be avoided.

Narrow condensing-temperature range on process side. Method 11 should be avoided.

Wide condensing-temperature range on process side. Method 11 works well in many applications.

Heavy exchangers, exchangers requiring frequent cleaning, cooling boxes. Method 13 is recommended for exchangers sited below the reflux drum. Method 11 works well for wide condensing-temperature range processes.

Vaporizing coolant. Method 14 is used most often.

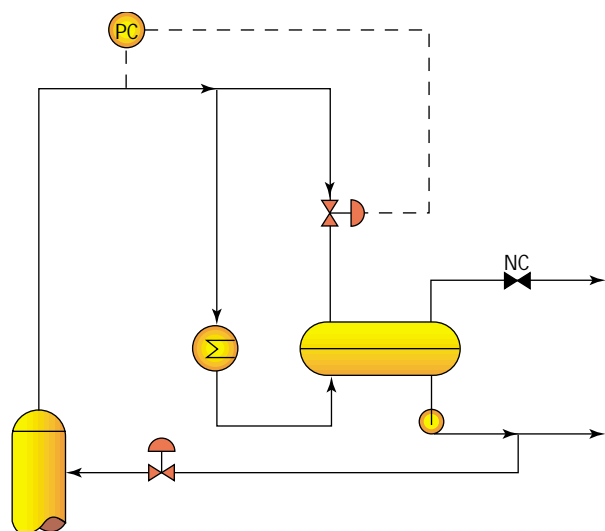
Solidification possible on process side. Method 16 and its variants are suggested.

To sum up

Effective pressure control improves distillation operations. Many control configurations are possible. Choice depends upon process and cooling-utility conditions, equipment configuration, and operating objectives. This article has presented a variety of pressure control methods, as well as a general system of classification for them. It also has provided a guide to selection according to these classifications, and some general recommendations.

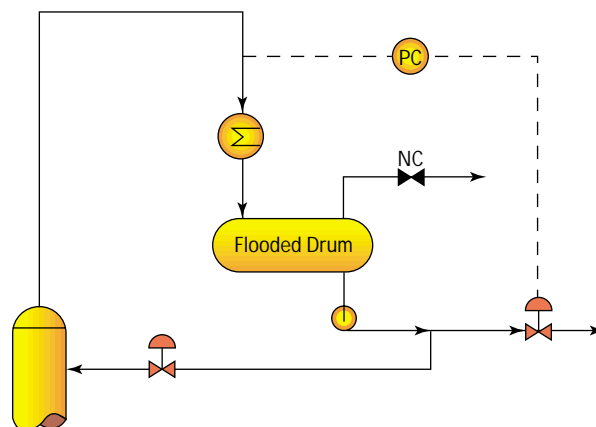
Of course, the choice of a control method for a specific

Figure 11. Net vapor rate = 0, control bypass flow to condenser receiver.



Method: Vary condensing surface area vs. subcooling surface area.
Process: Net vapor rate zero.
Advantages: Condenser may be mounted below condensate drum.
Disadvantages: Concept is not straightforward, and method requires subcooling area in condenser.
Application: Often used with very large and heavy condensers or with equipment requiring recurring cleaning or maintenance (exchangers at grade).
Variants: Condensate drum pressure instead of tower overhead pressure may be controlled. Works for units with continuous vapor products as well. In this case, vapor product composition is tower overhead composition and the condenser does not count as a separation stage.
Configuration notes: General method often is referred to as "hot vapor bypass." A liquid level must be maintained in the exchanger at all times. Careful attention to piping is required. Liquid must enter the drum without mixing with the drum's vapor space (7). This mandates either having the liquid enter the drum from the bottom or having an internal pipe down from the top. The author prefers bottom entry as it creates less liquid turbulence. The control valve and bypass line must be sized so that the bypass flow-rate changes allow for a DP change that corresponds to the liquid level range available in the condenser.
Operation: To maintain pressure, the control valve DP is manipulated. As the control valve DP changes, the pressure balance between the bypass and the condenser flows varies the liquid level in the condenser. This changes the allocation of condensing vs. subcooling surface available. The liquid and vapor are not in equilibrium. A thin layer of hot liquid separates the bulk liquid pool from the vapor. This essentially allows for maintaining drum pressure with a blanketing layer of tower overhead vapor instead of externally supplied vapor.
Warnings: Some units have worked very well with this scheme, but others have failed. Selection of bypass rates and exchanger surface required is mostly empirical. Some general problem areas for this method are:
High purity products: This method does not work well with high purity products that have narrow boiling ranges. The liquid insulating layer between the bulk condensate pool and the vapor space fails to adequately insulate the liquid. Control is erratic.
Self-refluxing condensers: Heavy material in the overhead vapor condenses first. Some liquid falls to the bottom of the exchanger and runs along it to the outlet. This may change the composition of the vapor enough that, at the outlet of the condenser, the vapor is no longer fully condensable.
Corrosion of internal pipe: If a top entrance of liquid into the drum is used, the internal pipe must not corrode through. A hole corroded in the internal pipe above the liquid level can lead to mixing of the topmost hot liquid layer and, thus, to unstable operation. Keep in mind that the internal pipe may corrode from both sides.

Figure 12. Net vapor rate = 0, direct control of liquid product rate.



Method: Vary condensing area.
Process: Net vapor rate zero.
Advantages: No liquid control system for condensate drum is required.
Disadvantages: Control action in changing surface area varies distillate product rate. This may cause problems due to unsteady feed to downstream units. It may be difficult to vent inert gas or noncondensable material from upsets.
Application: Often used with very large and heavy condensers, or with equipment requiring recurring cleaning or maintenance (exchangers at grade).
Variants: No condensate drum, reflux rate may be controlled instead of distillate product.
Configuration notes: A liquid level must be maintained in the exchanger at all times. The purpose of the drum, where present, often is to decant a second phase from the overhead, for example, water from a hydrocarbon system — this has not been shown in the figure.
Operation: To maintain pressure on the tower overhead, the DP of the control valve in the condenser line is manipulated. As the control valve DP changes, the pressure balance between the bypass and the condenser flows varies the liquid level in the condenser. This changes the allocation of condensing vs. subcooling surface available. To maintain drum pressure, the control valve in the bypass line varies flow through the bypass.
Warnings: Mounting the condenser below the drum requires subcooling in the condenser for stable operation.

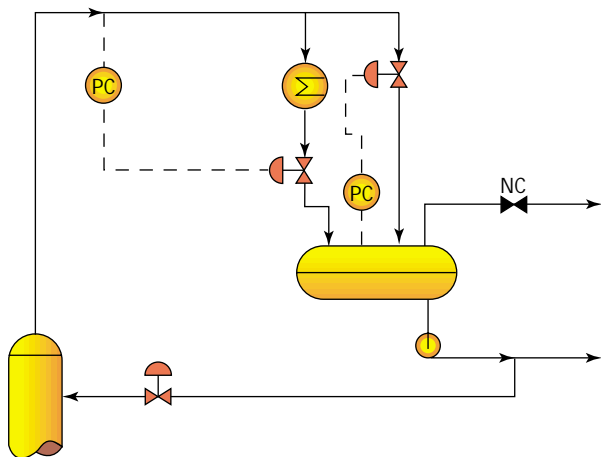
situation depends upon the needs of the individual operating unit or tower. Units and processes are not identical. The configurations shown here only cover the basic selections possible. Many other control schemes are in use. Remember that reliable, stable operation of the unit proves the value of any control scheme, not general or theoretical considerations.

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Continues on p. 46

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Figure 13. Net vapor rate = 0, dual pressure control of bypass and condensate.



Method: Vary condensing area.

Process: Net vapor rate zero, condensate drum runs at a lower pressure than tower pressure.

Advantages: Condenser may be mounted below condensate drum.

Disadvantages: Requires two control valves and subcooling area in condenser.

Application: Often used with very large and heavy condensers or with equipment requiring recurring cleaning or maintenance (exchangers at grade). It is the preferred system to use with cooling boxes as condensers, as cooling boxes have too high an internal heat capacitance on the cooling water side to allow for rapid changes in cooling water level.

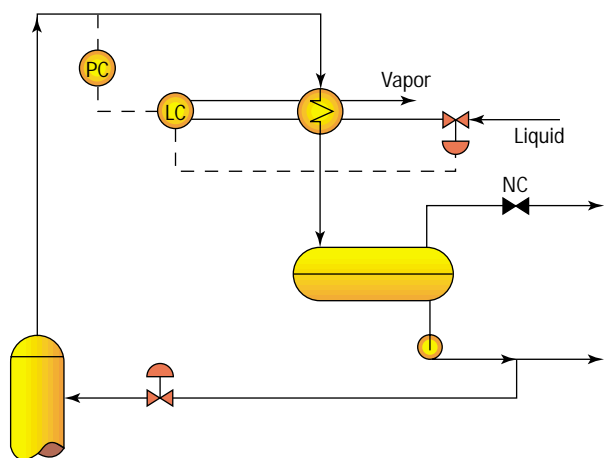
Variants: —

Configuration notes: A liquid level must be maintained in the exchanger at all times.

Operation: Variable product rate changes the level in the condenser.

Warnings: —

Figure 14. Net vapor rate = 0, control vaporizing coolant level.



Method: Vary vaporizing area (coolant side).

Process: Net vapor rate zero, heat recovery into vaporizing utility stream.

Advantages: —

Disadvantages: Difficult to add blowdown on vaporizing coolant.

Application: Used with heat recovery by having condenser reboil another tower or vaporize a utility stream (water to steam).

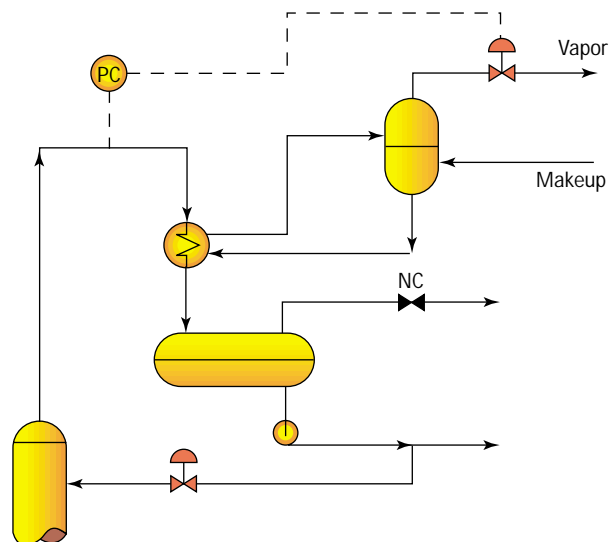
Variants: The pressure controller may directly control the utility flow without a reset to the utility level.

Configuration notes: Most common in cryogenic plants.

Operation: Control valve varies the level of the vaporizing stream on the utility side of the condenser.

Warnings: —

Figure 15. Net vapor rate = 0, control vaporizing coolant pressure.



Method: Vary heat flux, vary vaporizing temperature (coolant side).

Process: Net vapor rate zero, heat recovery into vaporizing utility stream.

Advantages: Blowdown, if required, can be easily made from drum.

Disadvantages: Extra drum required.

Application: Used with heat recovery by having condenser reboil another tower or vaporize a utility stream (water to steam). Most often used in systems with multiple parallel shells. Controlling drum pressure affects all the condensers simultaneously.

Variants: —

Configuration notes: Unusual.

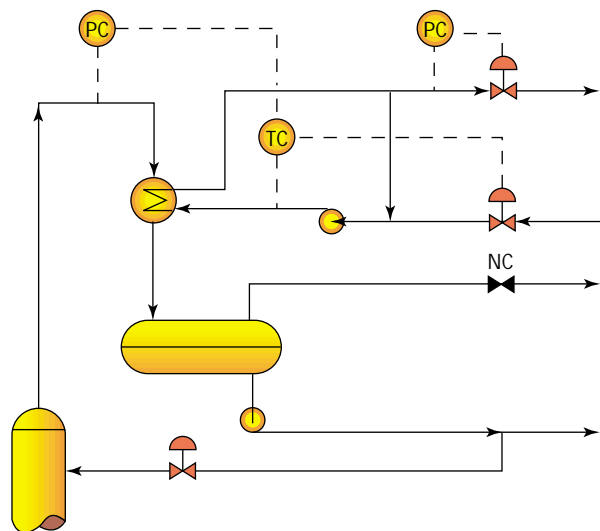
Operation: Control valve varies the pressure of the vaporizing stream on the utility side of the condenser. This, in turn, controls the condenser LMTD.

Warnings: —

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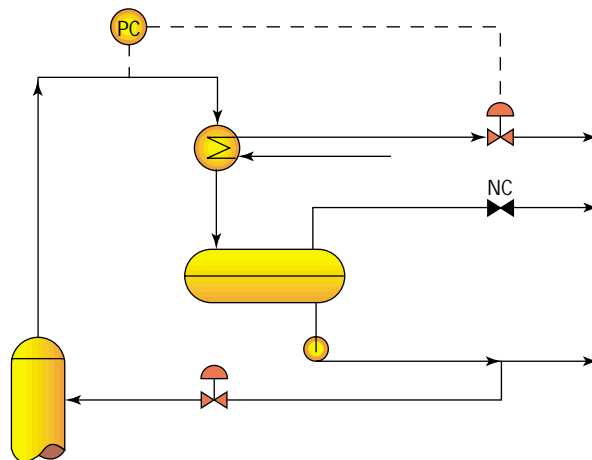
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Figure 16. Net vapor rate = 0, control condenser inlet-coolant temperature.



Method: Vary heat flux, vary utility supply temperature.
Process: Net vapor rate zero.
Advantages: Cooling stream leaves unit at maximum temperature, and condenser film temperature is at maximum.
Disadvantages: Local pump required, and response may be slow due to system liquid inventory.
Application: Used for heat recovery to liquid streams from condenser. Condenser coolant always runs at maximum temperature consistent with duty removal. This can be useful to prevent localized solidification in some processes.
Variants: Pump may be installed at exchanger outlet.
Configuration notes: When used with cooling water, this often is referred to as a "tempered water" system.
Operation: Variable recycle changes the temperature of the cooling stream. This, in turn, changes the exchanger LMTD.
Warnings: —

Figure 17. Net vapor rate = 0, control coolant rate.

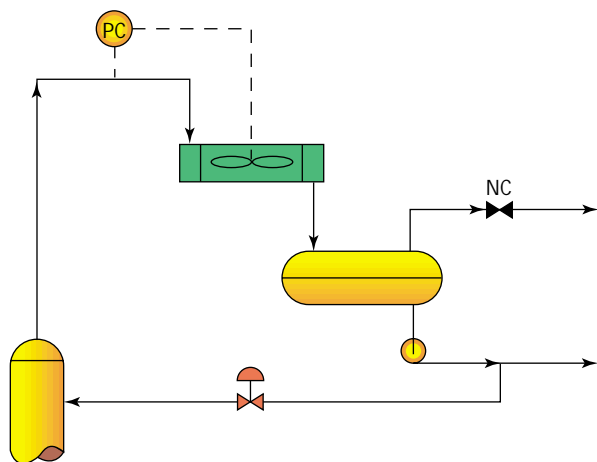


Method: Vary heat flux to vary cooling medium rate.
Process: Net vapor rate zero.
Advantages: Simple.
Disadvantages: Coolant return temperature may be high.
Application: Frequently used in older plants (8,9), but no longer commonly called for in the design of new plants. Often added to existing units when the original control schemes prove inadequate. Generally, a "manual" form of this control scheme is used. Block valves on the cooling water are pinched to reduce cooling water flow on a seasonal basis or when column turndown is necessary. Then, a more conventional pressure-control scheme handles day-to-day control to the set point.
Variants: —
Configuration notes: Cooling water fouls more rapidly with increasing temperature and decreasing velocity. A minimum rate or return temperature over-ride with a secondary pressure control system may be required.
Operation: Varying coolant rate causes the LMTD to change. This modifies total heat flux.
Warnings: Low velocity and high temperature cooling water increases the probability and severity of condenser fouling.

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Distillation

Figure 18. Net vapor rate = 0, control of coolant rate with air cooler.



Method: Vary heat flux to vary cooling medium rate.
Process: Net vapor rate zero.

Advantages: Simple.

Disadvantages: High maintenance for louvers and variable-pitch configurations. Variable speed rarely used due to cost.

Application: Most common method of control with air-fins.

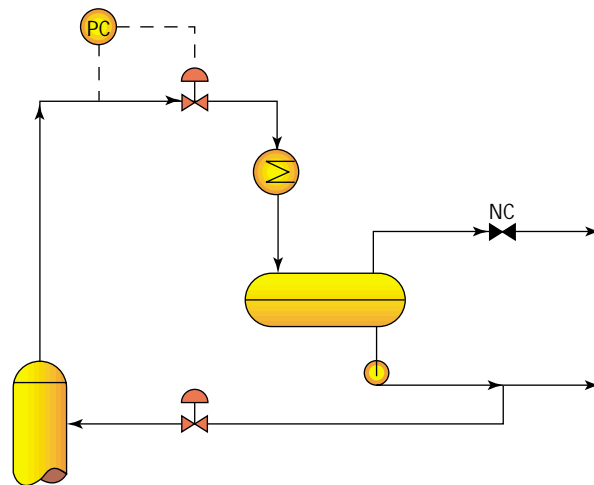
Variants: Fan pitch, louver position, or motor speed can be manipulated.

Configuration notes: Variable position louvers tend to be troublesome. Louvers must be designed for automatic control. Do not refit an automatic positioner to a set designed for manual operation. Variable fan pitch also is subject to maintenance problems and fans have to be shut down before the pitch mechanism can be worked on. Controlling speed using a variable frequency motor is most reliable, but most expensive and, so, is rarely used. Systems can be combined in multiple bay units. In such units, gross control often is achieved by shutting down entire fans on units, then achieving fine control with louvers, variable-pitch, or variable speed fans on a few units.

Operation: Variable flow rate controls the air outlet temperature; variable LMTD controls heat removal.

Warnings: —

Figure 19. Net vapor rate = 0, control condensation temperature or pressure.



Method: Vary heat flux.

Process: Net vapor rate zero.

Advantages: Simple, fast response.

Disadvantages: Control valve is bigger than for other options. Condenser and condensate drum pressure are variable. This may create a problem with condensate pump head and drum level control.

Application: Pressure towers — good system for towers with large quantities of noncondensable gas in overhead vapor (8).

Variants: —

Configuration notes: Cooling is done at lowest possible utility temperature (9) (potential problem for cooling water, potential advantage for heat integrated cryogenic systems).

Operation: Direct control of overhead pressure, DP is manipulated to control the condensation temperature in the condenser, which varies condenser LMTD.

Warnings: In vacuum systems, the minimum pressure drop across the control valve may have significant utility and equipment costs. This applies to a lesser extent to any system with downstream compression on a vapor product. In liquid-ring vacuum pump systems, suction throttling can create the conditions for vaporizing the seal fluid.

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