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DISTILLATION COLUMN PROCESS CONTROL STRATEGIES

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ABSTRACT

This review paper contains the control strategies used for the working of distillation and how they are applied using various formulae. It will also give a brief idea of what points a process engineer should keep in mind while deciding the control strategy. Through this paper, one would get to know the basic process control strategies and how to select a suitable strategy for the distillation column to work in the desired way.

Key Words: Distillation Column, Control Strategies,

I INTRODUCTION

Today, distillation is one of the most used unit operations and is the largest consumer of energy in the process industries. Separation operations achieve their objective by the creation of two or more coexisting zones which differ in temperature, pressure, composition, and/or phase state. With its advent in China primarily for Wine making, Distillation is one of the oldest and still most common methods for both the purification and the identification of organic liquids. In chemical and process industries, distillation makes a major chunk of energy consumption and hence having a suitable process control strategy in order to save cost is a topic of great importance. Before looking at the various control strategies, we must understand the basic process variables and the degrees of freedom. The types of variables are as follows:

*Controlled Variable***:** The process variable which we want to maintain at particular value

*Manipulated Variable***:** Process variable that is adjusted to bring the controlled variable back to set point.

Disturbance Variable: Any process variable that can cause the controlled variable to change.

Controlled Variable	**Manipulated Variable**	**Disturbance Variable**
Distillate composition	Distillate flow	Feed Flow
Bottom Composition	Bottom Flow	Feed Composition
Accumulator level	Reflux Flow	Feed Temperature
Sump Level	Reboiler Duty	Reboiler heat supply
Column Pressure	Condenser Duty	Condenser cooling supply
		Weather

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General guidelines for identifying which manipulated variables to associate with which controlled variables are: [1]

1. Manipulate the stream that has the greatest influence on associated controlled variable
2. Manipulate the smaller stream if two streams have the same effect on controlled variable.
3. Manipulate the stream that has the mostly near linear correlation with controlled variable
4. Manipulate the stream that is least sensitive to ambient conditions.
5. Manipulate the stream least likely to cause interaction problems.

1.1 Degrees of Freedom analysis for a Distillation Column:-

The degrees of freedom of a process system are the independent variables that must be specified in order to define the process completely. [2] An approach was developed by Waller, V. (1992): There are five control valves, one on each of the following streams: distillate, reflux, coolant, bottoms and heating medium. The feed stream is considered being set by the upstream process. In this way, the column will have five degrees of freedom. Inventories in any process must be always controlled which involve liquid levels and pressures. This means that the liquid level in the reflux drum, the liquid level in the column base, and the column pressure must be controlled.

If we subtract the three variables that must be controlled from five, we end up with two degrees of freedom. Thus, there are two and only two additional variables that can (and must) be controlled in the distillation column. Notice that we have made no assumptions about the number or type of chemical components being distilled. Therefore a simple, ideal, binary system has two degrees of freedom; a complex, multi-component system also has two degrees of freedom.

1.2 Types of Column control and variables which are mainly controlled:

- Pressure
- Temperature
- Level
- Flow Rate
- Composition

1.2.1 Pressure Control

There are various Pressure Control Schemes used for an effective control of the overhead pressure of the column [3]. In controlling the pressure of a column, the key pieces of equipment are the condenser and the accumulator. First the overhead vapors enter the condenser (partial or total), and next the liquid condensate is collected in an accumulator vessel. Some of the accumulated condensate is returned to the column as reflux, while the remainder is withdrawn as overhead product (distillate). If the condensation is incomplete, the condenser is called a "partial" condenser, and the overhead product is withdrawn in both vapor and liquid phases. Most distillation columns are operated under constant pressure, because at constant pressure, temperature

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measurement is an indirect indication of composition, but floating the operating pressure can have advantages in many applications. When the column pressure is allowed to float, the composition must be measured by analyzers or by pressure-compensated thermometers. The primary advantage of floating-pressure control is that one can operate at minimum pressure, and this reduces the required heat input needed at the reboiler. Other advantages of operating at lower temperatures include increased reboiler capacity and reduced reboiler fouling

1.2.2 Temperature Control

The temperature control in a distillation column is done to avoid the decomposition of either distillate or bottoms or to keep the vapour flow from fluctuating. The control schemes include the following:-

- Overhead Condensation
- Overhead Reflux
- Feed Preheat
- Reboiler Steam

Temperature control is very common in industrial practice. There are a number of benefits of closing a reasonably fast temperature loop: [4]

(1) Stabilizes the column composition profile (and thus keeps disturbances within the column).

(2) Gives indirect level control: Reduces the need for level control.

(3) Gives indirect composition control: Strongly reduces disturbance sensitivity.

(4) Makes the remaining composition problem less interactive and thus makes it possible to have good two-point composition control.

(5) Makes the column behave more linearly.

1.2.3 Level Control (Control Configuration)

The term control 'configuration' for distillation columns usually refers to the two combinations of the four flows L, V, D and B that remain (unused) as degrees of freedom (inputs) after the level loops have been closed. For example, we use the two product flows D and B to control condenser and reboiler level, respectively, and (before we add the feedforward block to get L/F and the feedback temperature loop), reflux L and boilup V remain as degrees of freedom—this is therefore called the LV-configuration. The LV-configuration is the most common or 'conventional' choice. Another common configuration is the DV-configuration, where L rather than D is used to control condenser level. Changing around the level control in the bottom gives the LB configuration. The DV- and LB-configurations are known as 'material balance configurations' because the direct handle on D or B directly adjusts the material balance split for the column. Changing around the level control in both ends gives the DB-configuration with a direct handle on both D and B. This seems unworkable because of the steady-state material balance D+B=F, but it is actually workable in practice for dynamic reasons. Levels may also be controlled such that ratios remain as degrees of freedom, for example the L/DV- and L/DV

L – Liquid

V – Vapour

B – Bottoms

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D – Distillate

1.2.4 Flow Rate

The flow control of a distillation column is done, principally at the reflux and reboiler. The amount of feed is usually kept constant and other variables are manipulated. The feed control is not manipulated as it would cause the whole of the system preceding the distillation column to change. If the feed conditions change, it is usually the reflux or reboil that is changed.

Fundamentally there are two things which we can manipulate-the feed split and fractionation. An overall material balance for a column tells us that the distillate flow plus the bottoms flow must equal the feed flow. The feed split is simply the amount of feed that leaves as distillate versus the amount that leaves as bottom. The other fundamental manipulative variable is the fractionation which is the amount separation that occurs per stage.

The overall fractionation in a column depends on the number of stages, the energy input and difficulty of separation. [5]

1.2.5 Composition Control

The composition measurement and control is done by direct method or indirectly. The direct measurement of composition is more expensive. An on-line analyzer will have an installation cost in the range of £100 K per instrument [6]. But they are more accurate and versatile than is indirect temperature measurement. Intermittent analyzers, such as chromatographs (with cycle times of a few minutes), are often provided with dead time compensation for closed-loop control. The analyzer update time must always be less than the response time of the process. For improved accuracy, one usually measures the impurity concentration in the controlled stream. This way the upsets caused by feed composition changes, tower pressure or efficiency variations can be more accurately corrected.

If the feed composition and the column pressure are constant, temperature can be used as an indirect measure of composition. If the column pressure is not constant, the temperature measurement must be pressure-compensated. When the bottom product composition is controlled, the temperature sensor is located in the lower half of the column, and when overhead composition is controlled, in the upper half. The temperature sensor should be located on a tray that strongly reflects changes in composition.

1.3 Choosing a Process Control Scheme

Skogestad (2004) has given a plantwide control procedure and has subsequently applied it to the distillation column. The first step is the 'top-down' steady state approach and the second step is the bottom-up identification of a simple regulatory control layer.

The first step includes the calculation of the degrees of freedom as stated in the 'Degrees of Freedom analysis section' where the degrees of freedom for any distillation are two. Here, we also try to minimize the cost of the overall operation. Thus, we look for the optimal operation of the distillation column.

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In the second step, we try to stabilize the distillation column to avoid any drift. Here, we use the temperature measurement by feedback control due to its fast response and consequently there is a short time for the composition to change at the column ends. Luyben (2006) has discussed temperature sensor location criteria.

II CONCLUSION

Various factors are needed to be considered while determining a suitable control strategy for distillation column. The paper includes all the possible control strategies which are applied and how they are used. The scope of the paper is limited mostly to steady state operation but an introductory approach to the plantwide control is given. This paper can be used for the primary selection of the process control strategy especially to develop a suitable (but not the final) control strategy.

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