Designing Innovative Vacuum Gauges and Controllers for Over 40 Years

WHITE PAPER

PID CONTROL IN VACUUM SYSTEMS

PID TUNING QUICK GUIDE

A simple method of tuning is to set the **Integral** and **Derivative** terms to zero and the **Proportional** term to a small value. This should result in stable operation with a fairly large residual Error.

Double the **P** term and make some large changes to the set-point and look for oscillations in the vacuum level. Keep doubling and disturbing the set-point until oscillations are seen. Once oscillations are seen, drop the **P** term back to about 40% of the current value.

Increase the **I** term slowly until the vacuum level is either stable at the set-point or oscillating slightly around it.

Leave **D** alone if response is acceptable, or increase **D** to remove unwanted overshoot/undershoot.

To improve the overshoot/undershoot situation slowly increase the **D** term, disturb the set-point, and repeat until satisfactory response is observed.

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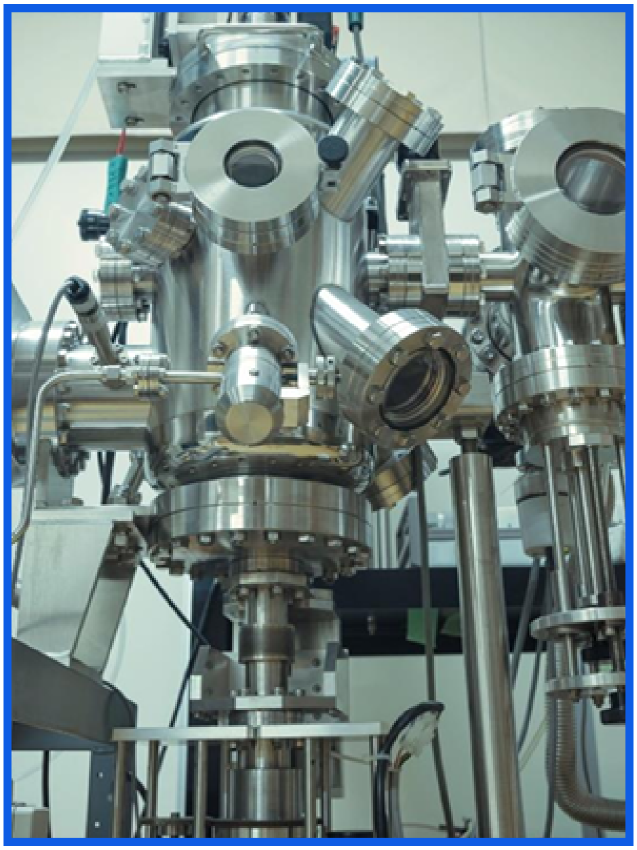
WHITE PAPER / PID CONTROL IN VACUUM SYSTEMS

ABSTRACT:

This white paper will focus on an overview of PID control with special focus on the use of PID upstream control in vacuum systems. A simple, intuitive description of upstream vacuum control with a PID controller consists of a vacuum pump, vessel, vacuum gauge, and a bleed valve. A method of tuning is also given. This type of vacuum control is also referred to as bleed control.

In addition, applications may require downstream vacuum control also referred to as throttle control which will be covered separately. This type of operation and tuning of a system is accomplished utilizing a pump, throttling valve, vacuum gauge, and a vessel. The operation is quite similar. In both downstream and upstream vacuum control examples, the valve may be either truly proportional or act as an ON/OFF valve which is opened for an amount of time proportional to the output of the controller.



PID CONTROL OVERVIEW:

A control loop feedback system is used widely in industrial control systems. Many times this is accomplished by utilizing a PID controller, which is a proportional integral derivative controller. Since the PID controller algorithm involves three separate constant parameters, it is sometimes called a three-term controller.

PID controllers have been in use since late in the 19th century. One of the reasons that it has been a mainstay in industrial processes is that it is straightforward to configure, but tuning a PID controller is an art form! Finding the right balance between the 3 variables is a good way to keep your automated processes running smoothly. It has been the solution of choice when a closed loop controller is needed and provides a designer a larger number of options for changing the dynamics of the system.

A PID controller operates on the error in a feedback system and does the following in automatic control systems:

- Calculates a term proportional to the current error - the P term (control action given by today's information)
- Calculates a term proportional to the integral of the past error - the I term (control action given all past information)
- Calculates a term proportional to the rate of change or derivative of the error the D term (control action given the direction of future changes)
- The three terms - the P, I and D terms, are added together to produce a control signal that is applied to the system being controlled

The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, a damper, or the power supplied to a heating element.*****

PID CONTROL TERMS RELATED TO VACUUM SYSTEMS:

Set-point (SP) - The set-point is the desired level of vacuum in the vessel.

Error (ERR) - The error is the difference between the set-point and the actual vacuum level in the vessel as measured by the vacuum gauge.

Proportioning Band (PB) or Proportional Gain (Kp or 1/PB) - The proportioning band is the amount of error (usually expressed as a percentage of the full scale range of the vacuum gauge) that is required to drive the valve from fully open to fully closed.

The proportioning band may be centered on the set-point (valve is 50% open when the vacuum greater than the set-point) or off to one side of the set-point (valve is either 100% open or 0% open when the vacuum equals the set-point).

This may also be expressed as Proportional Gain which is the reciprocal of Proportioning Band (1/PB). A large value of Proportional Gain corresponds to a small Proportioning Band.

Reset (I) or Integral Gain (Ki or 1/I) - The Reset or I term is a time constant controlling how fast the residual Error is eliminated.

Rate (D) or Derivative Gain (Kd or 1 / D) - The Rate or D term is a time constant controlling how fast the output is allowed to change.

*****Araki, M. "PID Control."

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THE PID CONTROLLER BALANCING ACT FOR OPTIMAL AUTOMATIC PROCESS PERFORMANCE:

In operation, the PID controller will attempt to minimize the Error by changing the percentage opening of the valve. The percentage opening of the valve is equal to the Error multiplied by the Proportional Gain. Since any given set of conditions (Pumping capacity, vacuum level, and leak rate) require a specific percentage opening, with only Proportional control there will always be some residual Error.

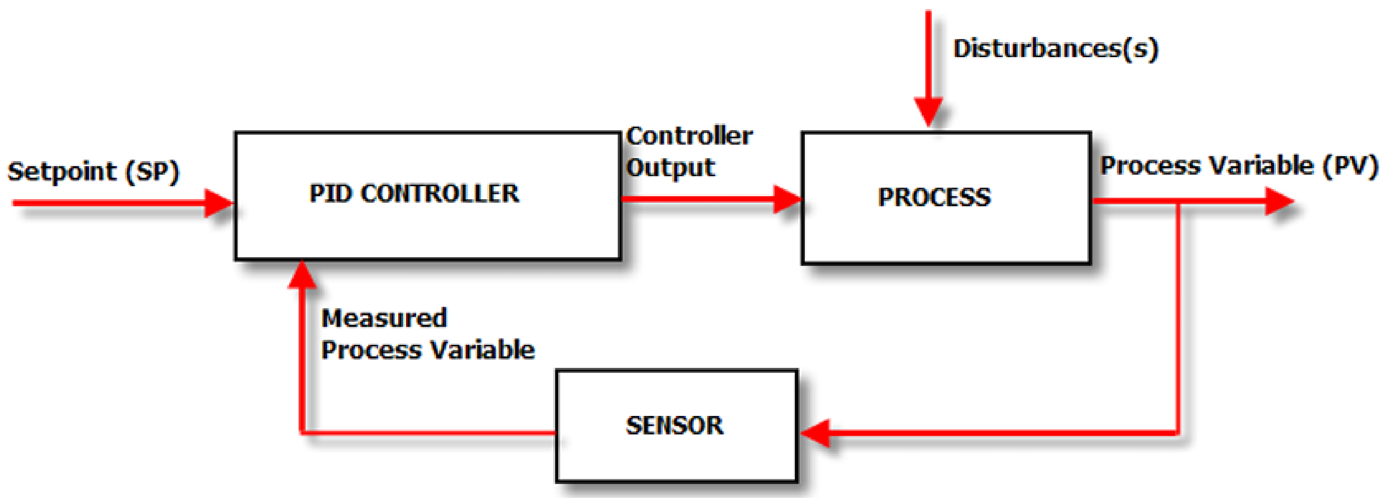
A large value of **Proportional Gain** will correspond to a small residual Error, but too large a gain will cause instability or oscillation.

The **Integral** term provides a means to eliminate this residual Error over time. The percentage opening of the valve is slowly modified by an amount proportional to the Error, the time the Error has been present, and the Integral Gain. When the Error is zero, the percentage opening is no longer changed.

A large value of Integral Gain will cause the Error to reach zero more quickly, but again, too large a gain will cause instability or oscillation.

The **Derivative** term provides a means of minimizing overshoot and undershoot of the set-point when either the set-point is changed or the system conditions change.

A large value of Derivative gain can eliminate overshoot and undershoot, but too large a gain can increase the time for the vacuum level to reach the set-point and may even cause the vacuum level to approach the set-point in a series of steps.



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PID CONTROLLER TUNING:

PID Tuning can be complicated, but it is important to obtain balance by fine tuning the system. When poorly tuned, the temperature can oscillate around the set-point, be slow to respond to changes, or overshoot the set-point excessively at start-up or the when the set-point changes. This impacts productivity by making operators wait, reduces yield, and can increase premature failures. To get the best results when tuning, make sure conditions are like those at which the system will normally function.

A simple method of tuning is to set the **I**ntegral and **D**erivative terms to zero and the **P**roportional term to a small value. This should result in stable operation with a fairly large residual Error.

Double the **P** term and make some large changes to the set-point and look for oscillations in the vacuum level. Keep doubling and disturbing the set-point until oscillations are seen. Once oscillations are seen, drop the **P** term back to about 40% of the current value.

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PID CONTROLLER APPLICATIONS:

Controllers are used in industry to regulate temperature, pressure, flow rate, chemical composition, speed and practically every other variable for which a measurement exists. Common applications for PID control in vacuum systems include: atmospheric and vacuum distillation, Refinery processes, milking processes, thermal vacuum tests, distillation of volatile liquids, composite research, and industrial processes such as freeze drying, plasma treating, plastic extrusion, heat treatment or semiconductor processing. Most PID controllers in use today are programmable logic controllers (PLCs) or digital controllers. DigiVac manufactures two types of digital controllers for vacuum control that implements a PID control scheme: the StrataVac for upstream vacuum control and the Model 450 for downstream vacuum process control.

Got a Vacuum Related Problem that You Would like to Solve?

Contact us! We'd Love to Help!

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