Application Note 51268
(Revision NEW)
Original Instructions

Impact of Recursion Rate and Loop Delay on Effective Control

Compressor Anti-surge Control

⚠ **General Precautions**	**Read this entire manual and all other publications pertaining to the work to be performed before installing, operating, or servicing this equipment.** **Practice all plant and safety instructions and precautions.** **Failure to follow instructions can cause personal injury and/or property damage.**

⚠ **Revisions**	**This publication may have been revised or updated since this copy was produced. To verify that you have the latest revision, check manual *26311* , *Revision Status & Distribution Restrictions of Woodward Technical Publications*, on the *publications page* of the Woodward website:** **www.woodward.com/publications** **The latest version of most publications is available on the *publications page*. If your publication is not there, please contact your customer service representative to get the latest copy.**

⚠ **Proper Use**	**Any unauthorized modifications to or use of this equipment outside its specified mechanical, electrical, or other operating limits may cause personal injury and/or property damage, including damage to the equipment. Any such unauthorized modifications: (i) constitute "misuse" and/or "negligence" within the meaning of the product warranty thereby excluding warranty coverage for any resulting damage, and (ii) invalidate product certifications or listings.**

⚠ **Translated Publications**	**If the cover of this publication states "Translation of the Original Instructions" please note:** **The original source of this publication may have been updated since this translation was made. Be sure to check manual *26311* , *Revision Status & Distribution Restrictions of Woodward Technical Publications*, to verify whether this translation is up to date. Out-of-date translations are marked with ⚠. Always compare with the original for technical specifications and for proper and safe installation and operation procedures.**

Revisions—Changes in this publication since the last revision are indicated by a black line alongside the text.

Warnings and Notices

Important Definitions

⚠ This is the safety alert symbol. It is used to alert you to potential personal injury hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

- **DANGER**—Indicates a hazardous situation which, if not avoided, will result in death or serious injury.
- **WARNING**—Indicates a hazardous situation which, if not avoided, could result in death or serious injury.
- **CAUTION**—Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
- **NOTICE**—Indicates a hazard that could result in property damage only (including damage to the control).
- **IMPORTANT**—Designates an operating tip or maintenance suggestion.

⚠WARNING

Overspeed / Overtemperature / Overpressure

The engine, turbine, or other type of prime mover should be equipped with an overspeed shutdown device to protect against runaway or damage to the prime mover with possible personal injury, loss of life, or property damage.

The overspeed shutdown device must be totally independent of the prime mover control system. An overtemperature or overpressure shutdown device may also be needed for safety, as appropriate.

⚠WARNING

Personal Protective Equipment

The products described in this publication may present risks that could lead to personal injury, loss of life, or property damage. Always wear the appropriate personal protective equipment (PPE) for the job at hand. Equipment that should be considered includes but is not limited to:

- **Eye Protection**
- **Hearing Protection**
- **Hard Hat**
- **Gloves**
- **Safety Boots**
- **Respirator**

Always read the proper Material Safety Data Sheet (MSDS) for any working fluid(s) and comply with recommended safety equipment.

⚠WARNING

Start-up

Be prepared to make an emergency shutdown when starting the engine, turbine, or other type of prime mover, to protect against runaway or overspeed with possible personal injury, loss of life, or property damage.

⚠WARNING

Automotive Applications

On- and off-highway Mobile Applications: Unless Woodward's control functions as the supervisory control, customer should install a system totally independent of the prime mover control system that monitors for supervisory control of engine (and takes appropriate action if supervisory control is lost) to protect against loss of engine control with possible personal injury, loss of life, or property damage.

NOTICE

Battery Charging Device

To prevent damage to a control system that uses an alternator or battery-charging device, make sure the charging device is turned off before disconnecting the battery from the system.

Electrostatic Discharge Awareness

NOTICE

Electrostatic Precautions

Electronic controls contain static-sensitive parts. Observe the following precautions to prevent damage to these parts:

- **Discharge body static before handling the control (with power to the control turned off, contact a grounded surface and maintain contact while handling the control).**
- **Avoid all plastic, vinyl, and Styrofoam (except antistatic versions) around printed circuit boards.**
- **Do not touch the components or conductors on a printed circuit board with your hands or with conductive devices.**

To prevent damage to electronic components caused by improper handling, read and observe the precautions in Woodward manual *82715*, *Guide for Handling and Protection of Electronic Controls, Printed Circuit Boards, and Modules*.

Follow these precautions when working with or near the control.

1. Avoid the build-up of static electricity on your body by not wearing clothing made of synthetic materials. Wear cotton or cotton-blend materials as much as possible because these do not store static electric charges as much as synthetics.
2. Do not remove the printed circuit board (PCB) from the control cabinet unless absolutely necessary. If you must remove the PCB from the control cabinet, follow these precautions:
   - Do not touch any part of the PCB except the edges.
   - Do not touch the electrical conductors, the connectors, or the components with conductive devices or with your hands.
   - When replacing a PCB, keep the new PCB in the plastic antistatic protective bag it comes in until you are ready to install it. Immediately after removing the old PCB from the control cabinet, place it in the antistatic protective bag.

Compressor Anti-Surge Control: Examining the Impact of Recursion Rate and Loop Delay on Effective Control

Background

Dedicated or stand-alone, controllers have long enjoyed a prominent position in the compressor control market. But, there are sometimes other acceptable and practical solutions to the problem of compressor anti-surge control. Programmable process controls such as PLCs (Programmable Logic Controllers) and DCS systems (Distributed Control Systems) offer the flexibility of custom, often site-developed, software on existing or readily available and affordable hardware. Even a simple discharge pressure switch might perform adequately in some benign, non-critical applications. But, among the varied technologies, methods, and philosophies, and even among similar dedicated anti-surge controllers, there are many subtle but important considerations.

The historical motivations for dedicated controllers in critical applications are varied. Who at the plant level has access to the software? Dedicated controllers are often configurable, meaning that their primary functions are always active, but the user has the ability to configure and tune to his specific application. In any case, personnel who may not be properly trained or authorized are less likely to accidentally and adversely manipulate the software. DCS systems and PLCs, however, are often less guarded. It is not uncommon for operators, process engineers, maintenance technicians, and even IT (Information Technology) personnel to have access. Software complexity is another differentiator. While DCS systems and PLCs are the standard platforms for basic process controls and sequencing, compressor anti-surge control presents an altogether different problem: controlling a process similar in period to turbomachinery speed, but whose measurement and setpoint both vary with process conditions, some of which are non-measurable.

These complications and others are qualitative and can, with adequate engineering attention, be managed. Speed of response, however, is a more difficult proposition. Depending upon hardware performance, processor loading, and software architecture, the control system’s overall recursion rate can easily swell into the hundreds of milliseconds. And, lengthy base recursion rates may be further compromised with increased processor and/or hardware loading, as well as by the software’s response to transient field conditions. Consider a compression process susceptible to 100-millisecond surge cycles. Depending upon the random timing among the physical surge event, the field instruments’ measurements, the control’s software processing, and the final element’s action, it is highly unlikely that a 250-millisecond control, for example, can ever fully protect such a compressor from surge. And, loop delays are usually more prevalent outside the control system itself, therefore garnering less attention. What are the implications of time in the compressor control loop? Must a user simply tolerate inadequate control? What are the alternatives?

Woodward Software Architecture—Minimizing Recursion Rate

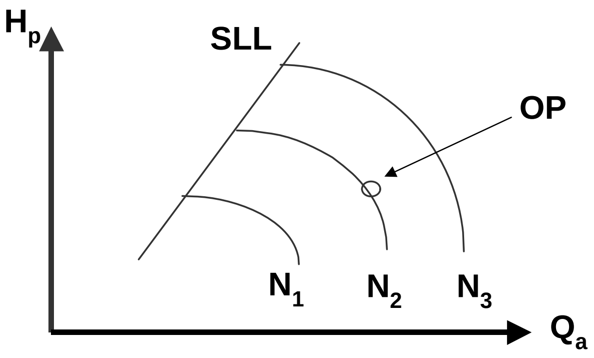
A key advantage incorporated into Woodward software applications is the unique rate group structure on which they operate. RateGroups are the recursion rates assigned to all software blocks. There are six RateGroups: 5-millisecond, 10-millisecond, 20-millisecond, 40-millisecond, 80-millisecond, and 160-millisecond. Whatever RateGroup a block is assigned will determine how often that block is executed. A block assigned to a RateGroup is guaranteed to run each time the RateGroup is scheduled to run. For example, a block in the 10-millisecond RateGroup will run once every ten milliseconds. Each block is placed into a RateGroup that makes sense in the application program based on the unit it will be controlling. For example, a block used for speed or anti-surge control (very fast control loops) may need to be in the 10-millisecond RateGroup. But, a raise speed Boolean input or various sequencing routines could run in the 80- or 160-millisecond RateGroups.

Variable execution time blocks have been avoided. This means that under an unanticipated set of conditions (system upset, surge), the processor will not become overburdened, and will have time to complete its assigned tasks. Only with predictable execution times can a multitasking operating system have a guaranteed update rate. Woodward software guarantees that a task programmed to run every five milliseconds (or whatever the assigned rate group), will run exactly every five milliseconds, no matter what other functions the control system is presently exercising. Additionally, these rate groups can be optimized, effectively customizing the control's overall recursion rate while at the same time eliminating excessive processor loading.

The execution of I/O reads and writes is equally important. Woodward software and hardware work together to ensure that the control application is always executing instructions on the latest available field information. All inputs are read as fast or faster than the shortest software RateGroup (five milliseconds). Additionally, all I/O are properly synchronized within the RateGroups in which they run. In other words, inputs required by 10-millisecond logic are scanned at the onset of that RateGroup's execution, and outputs are written after all necessary 10-millisecond logic has been executed. I/O scheduling is also independent of the hardware layout. An analog input used by the 10-millisecond RateGroup can be located adjacent to another used by the 160-millisecond RateGroup without disrupting either's synchronized use.

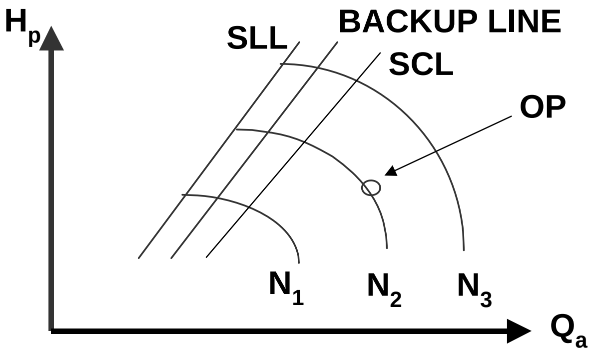
Typical Anti-Surge Control Philosophy

Compressor performance is generally presented as an operating map. While there are many ways to characterize it, the performance map usually relates compressor flow to some variation of head (head, discharge pressure, pressure ratio, etc.), as shown below.



Here, actual flow at suction conditions (Q_a) is mapped against polytropic head (H_p). The Surge Limit Line (SLL) depicts the safe operating boundary for the compressor operating point (OP). For a given speed (N), increasing head and decreasing flow move the compressor toward its surge limit, beyond which operation is unstable.

The functionality of Woodward's standard anti-surge control software is not unlike that of other control or compressor manufacturers. Such systems typically employ a variety of open- and closed-loop routines that work together to modulate the recycle, or anti-surge valve, decreasing head and increasing flow, thereby keeping the compressor away from its surge limit or breaking the surge cycle if it occurs. This requires a flow setpoint or Surge Control Line (SCL) positioned a safe distance to the right of the SLL. This distance, referred to as the safety or control margin, is determined by the user for a given application. A second control "line," positioned between the SCL and SLL, is the Backup Line, which provides additional protection from surge.



The locations of these control lines and tuning of the routines activated at or near them constitute the controller's surge prevention and recovery functionality. But, they can also be manipulated to improve a control response degraded by slow recursion rates or excess loop delays. Such a strategy does not come free, however.

Recursion Rate Test Method

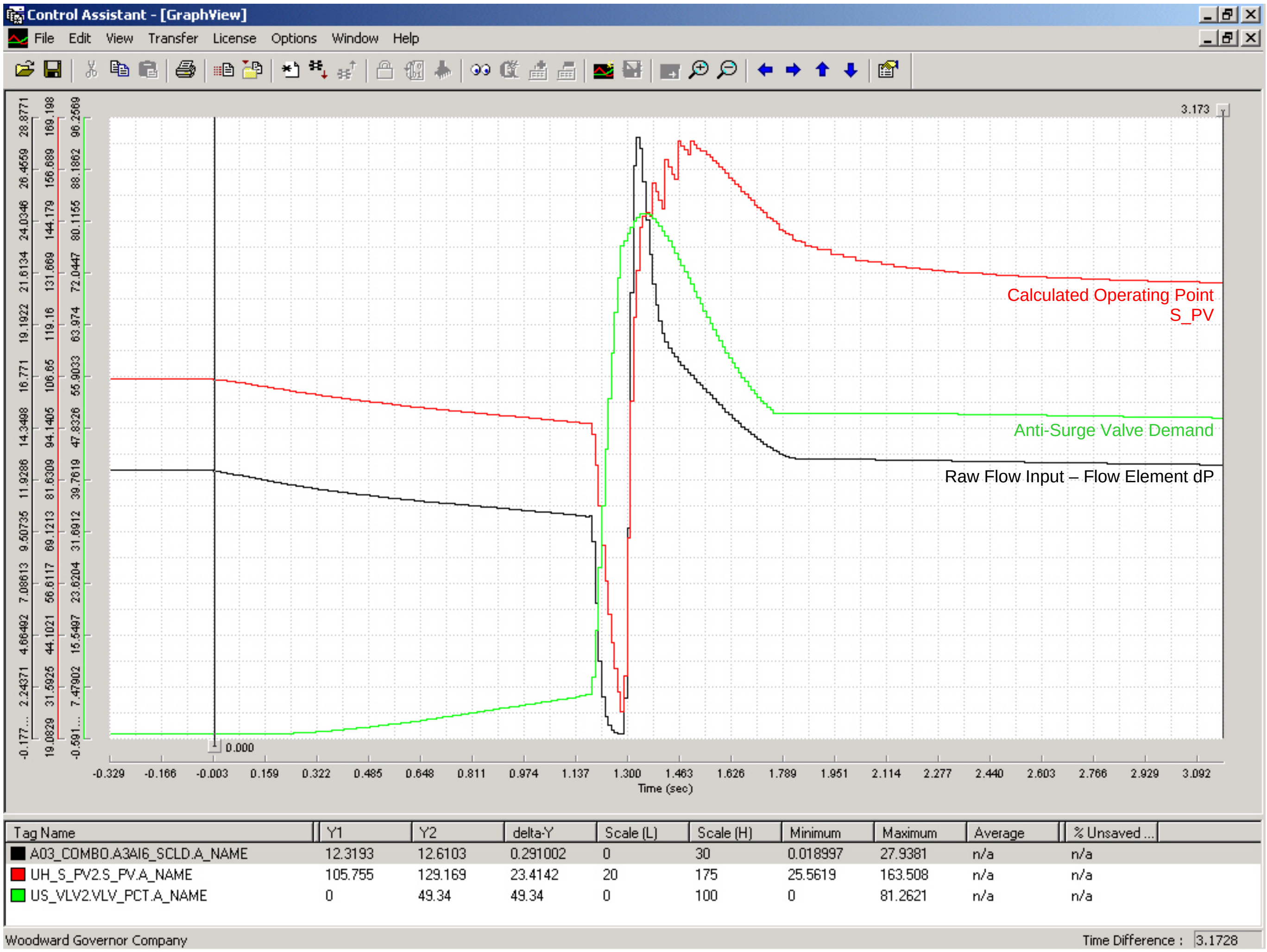
To properly compare a Woodward control with another dedicated anti-surge controller or similar anti-surge software running on a DCS or PLC, test hardware and fully developed software written for that hardware would be required. Without access to such systems, the following test was performed using a sophisticated software modeling process, comparing the performance of Woodward’s standard anti-surge control application executing at different speeds. The software application is that from Woodward’s 505CC-2 Steam Turbine and Compressor Control, which utilizes a 10-millisecond RateGroup for compressor flow measurement, control, and anti-surge valve output. This architecture allows the control to sense and respond to even the fastest of flow disruptions. In lieu of a proper test subject, the same software was reconfigured to run entirely in 160-millisecond scans.

The test method introduces a flow disturbance (surge) of identical speed and magnitude to both software subjects. This surge is characterized by a rapid step of the flow input toward zero and a subsequent recovery. As in a real process, the surge cycle period varies, but in this software model, it ranges between 130 and 200 milliseconds (fast, but not unrealistic). Closed-loop tuning parameters and open-loop control responses are configured identically. The results are detailed in the trends below. In each trend, pens have been assigned as follows:

Black	Raw Flow Input Sensed by the Control
Red	Calculated Operating Point (Normalized to a setpoint of 100% at the Surge Control Line)
Green	Anti-Surge Valve Demand

Trend lengths and axes scales have also been adjusted to provide an accurate visual comparison.

Recursion Rate Test Results



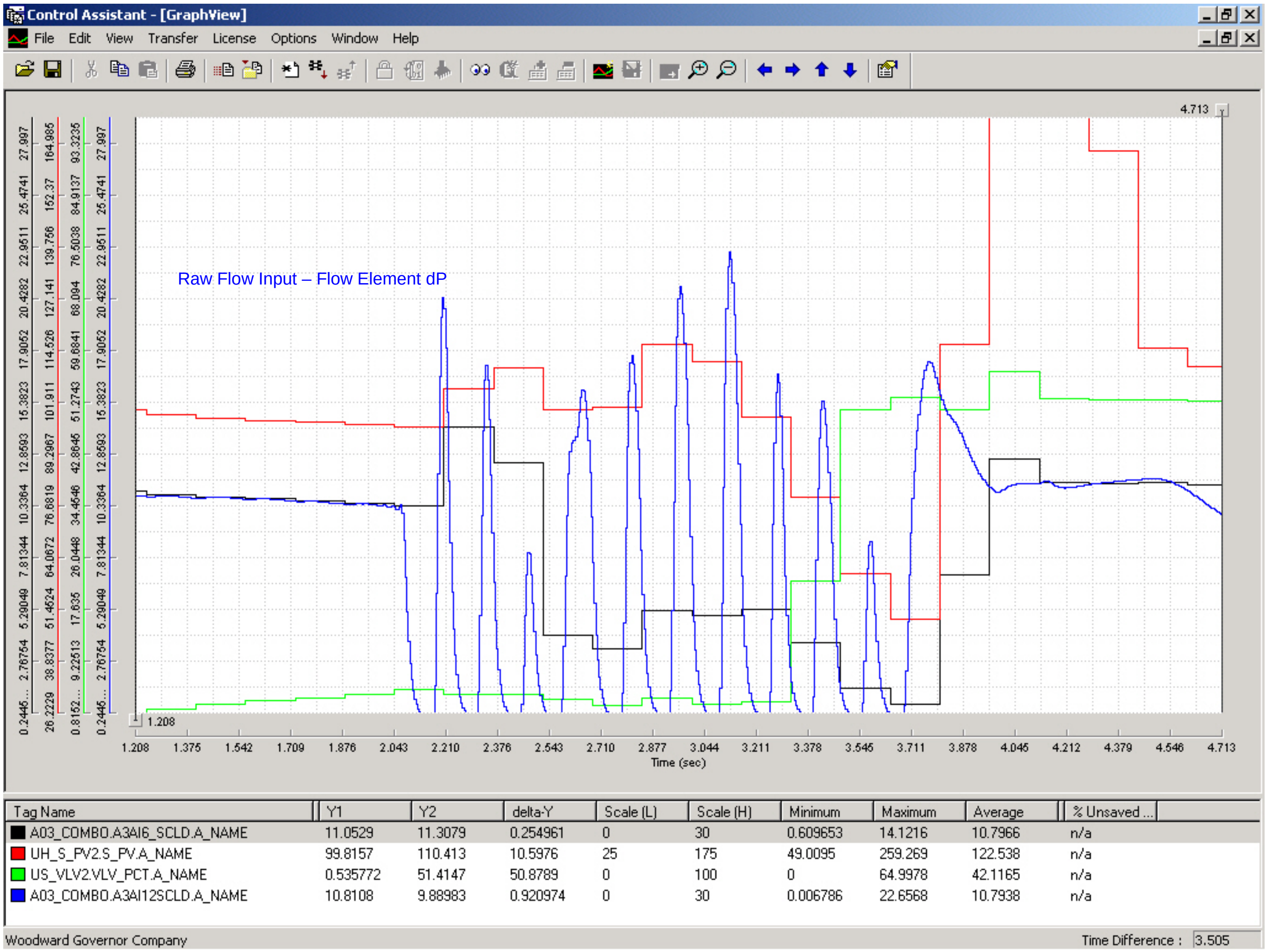
Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ A03_COMBO.A3AI6_SCLD.A_NAME	12.3193	12.6103	0.291002	0	30	0.018997	27.9381	n/a	n/a
🟥 UH_S_PV2.S_PV.A_NAME	105.755	129.169	23.4142	20	175	25.5619	163.508	n/a	n/a
🟩 US_VLV2.VLV_PCT.A_NAME	0	49.34	49.34	0	100	0	81.2621	n/a	n/a

Time Difference : 3.1728

In the trend above, the flow disruption is seen clearly as the **black** pen. The early, gradual decrease in flow preceding the surge event simulates a slower movement of the compressor toward its surge limit. The valve demand responds accordingly, but not significantly enough (tuning is reduced for demonstration).

At surge, the calculated operating point (**red**) follows quickly, and the valve demand (**green**) increases quickly to open the anti-surge valve in response. When configured to detect a surge based upon high rate of change of the flow input, the control detected this surge within 50 milliseconds of the initial drop in flow. Opening of the anti-surge valve had recovered compressor operation to its setpoint (Surge Control Line) within 124 milliseconds, before the normal overshoot and settling-out of the open-loop and PID controls.

In comparison, the same surge event is introduced to the 160-millisecond control. In the trend below, the **blue** pen has been added to illustrate the *actual* field flow measurement at 5-millisecond scans compared with that read by the control (**black** pen) every 160 milliseconds.



Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ A03_COMBO.A3AI6_SCLD.A_NAME	11.0529	11.3079	0.254961	0	30	0.609653	14.1216	10.7966	n/a
🟥 UH_S_PV2.S_PV.A_NAME	99.8157	110.413	10.5976	25	175	49.0095	259.269	122.538	n/a
🟩 US_VLV2.VLV_PCT.A_NAME	0.535772	51.4147	50.8789	0	100	0	64.9978	42.1165	n/a
🟦 A03_COMBO.A3AI12SCLD.A_NAME	10.8108	9.88983	0.920974	0	30	0.006786	22.6568	10.7938	n/a

Woodward Governor Company Time Difference : 3.505

The negative effect of the additional recursion delay is immediately obvious. This 160-millisecond control, under identical conditions as before, requires as much as 1.4 seconds to detect a surge, even though nine surge cycles have already occurred. In fact, this control detected only two of the eleven surges. 322 milliseconds and yet another surge cycle pass before the increased valve demand recovers the compressor operation to its setpoint.

	10-millisecond Control	160-millisecond Control
Number of Undetected Surges	0	9
Number of Surges after Initial Detection	0	1
Time to Initial Detection	50 ms	1.4 s
Time from Detection to Recovery	74 ms	322 ms

The same trend is expanded below to provide a higher-level view of the event.

Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ A03_COMBO.A3AI6_SCLD.A_NAME	12.3507	11.5235	0.827196	0	30	0.609653	14.1216	10.7966	n/a
🟥 UH_S_PV2.S_PV.A_NAME	105.826	136.823	30.9972	20	175	49.0095	259.269	122.538	n/a
🟩 US_VLV2.VLV_PCT.A_NAME	0	63.0743	63.0743	0	100	0	64.9978	42.1165	n/a
🟦 A03_COMBO.A3AI12SCLD.A_NAME	12.3507	11.5374	0.813268	0	30	0.006786	22.6568	10.7938	n/a

Time Difference : 8.069

It is important to note here that the timing between the actual surge event and the control’s sampling interval has a significant impact on the *appearance* of these test results. In the trend above, the first nine surges occurred, by random chance, immediately after the flow input was sampled, or flow had recovered immediately prior to the sample. Had the initial surge occurred exactly at the same time as a software scan, the results would obviously be improved. In a sequence of ten identical tests, the number of undetected surge cycles was as few as two but as many as twelve. Even in the former, most positive case, the control still labors for several hundred milliseconds to increase valve demand and break the cycle. (The same would be true if the control was relegated to simple minimum flow recycling instead of the more advanced flow derivative surge detection.) A similar sequence of ten identical tests on the 10-millisecond control shows no such variation—Surge is detected the first time, every time. Simply put, the slower control is handicapped by its 160-millisecond recursion rate throughout the input-control-output cycle, subjecting the compressor and overall process to significant and unnecessary risk.

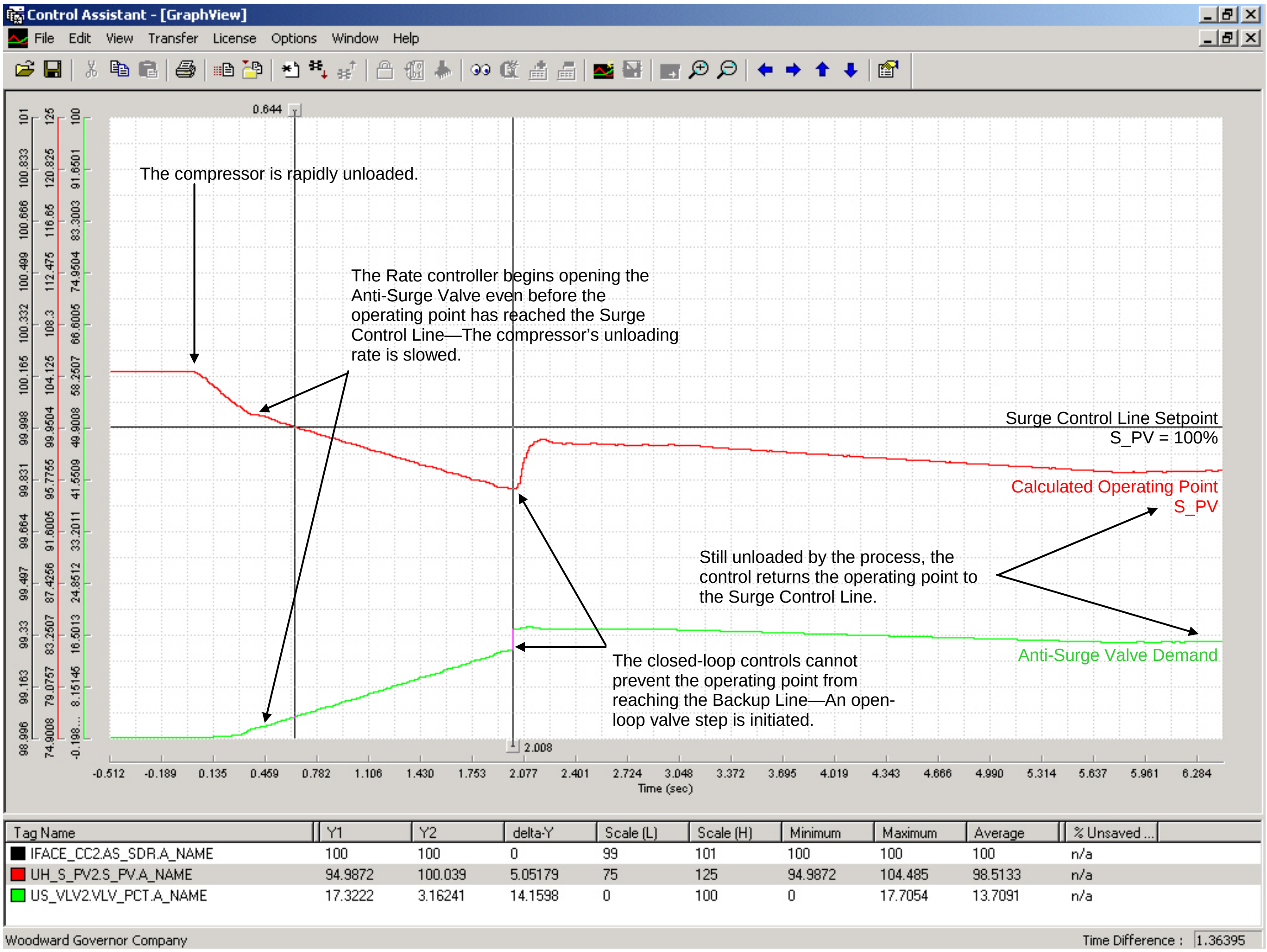
Loop Delay Test Method

Regardless of the control software's performance characteristics, there are several sources of additional loop delay that may or may not be avoidable. Field process measurements have intrinsic time constants that vary across technologies and manufacturers. Even how the transmitter is installed can impact signal response. Signal conditioners, isolators, and other loop instruments add minute but critical delays. Valve slew and response rates, as always, should be minimized, but I/P transducers, positioners, volume boosters, and any other devices in the output loop must also be scrutinized.

A simple lag block was added to the base control software described previously. This lag, in the flow input signal, is adjustable to simulate the cumulative effect of these loop delays. The results are presented below—Trends (pens) are configured similarly to those previously, but a horizontal line has been added to locate the Surge Control Line setpoint.

Loop Delay Test Results

The control for this test is the same software noted previously, running at its normal recursion rate, with no artificial delay. Similar to the previous tests, a flow disturbance is introduced simulating a rapid unloading of the compressor. Control responses and tuning have not been optimized so as to illustrate the response of each individual function. In other words, the overall response could be improved with diligent tuning and configuration, but this test is meant to compare the same control configuration subjected to varying degrees of loop delay.



The compressor is rapidly unloaded.

The Rate controller begins opening the Anti-Surge Valve even before the operating point has reached the Surge Control Line—The compressor's unloading rate is slowed.

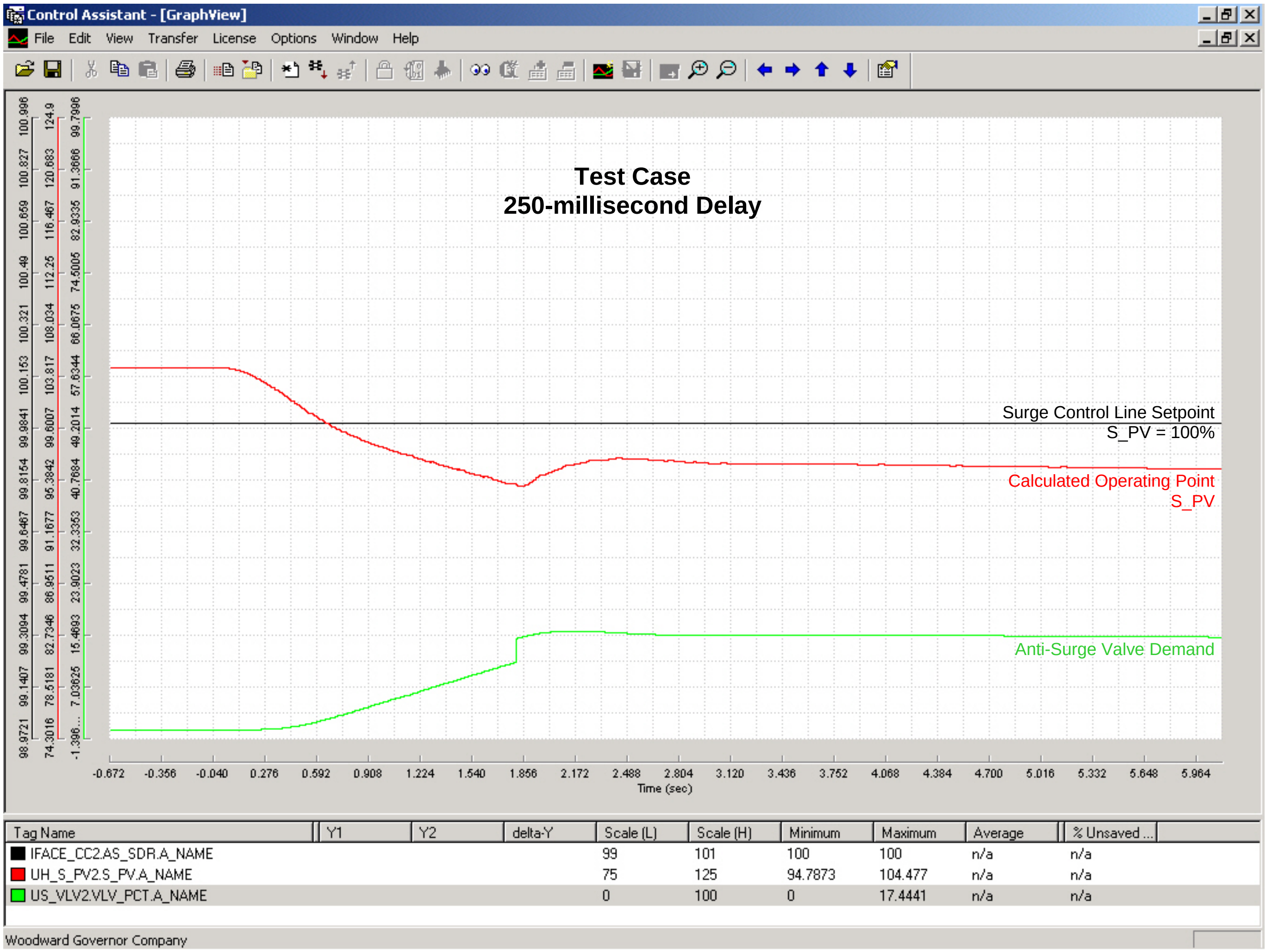
Still unloaded by the process, the control returns the operating point to the Surge Control Line.

The closed-loop controls cannot prevent the operating point from reaching the Backup Line—An open-loop valve step is initiated.

Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ IFACE_CC2.AS_SDR.A_NAME	100	100	0	99	101	100	100	100	n/a
🟥 UH_S_PV2.S_PV.A_NAME	94.9872	100.039	5.05179	75	125	94.9872	104.485	98.5133	n/a
🟩 US_VLV2.VLV_PCT.A_NAME	17.3222	3.16241	14.1598	0	100	0	17.7054	13.7091	n/a

The trend above illustrates the combined effect of three different control responses. The first to take action on the valve is the Rate controller, responding as the operating point approaches the Surge Control Line faster than the configured rate setpoint. The Rate controller does its job (note the decrease in slope of the **red** pen just above the **black** pen [setpoint line]). But, the primary Anti-Surge controller still acts to open the valve further as the operating point continues below the Surge Control Line. The process disturbance is significant enough to force the operating point to the Backup Line (S_PV = 95%). At this point, an open-loop step response is triggered to the Anti-Surge Valve to quickly halt the approach to the Surge Line. This routine also does its job, but as the response slowly ramps out, the Anti-Surge controller must still modulate the valve open to regain stability at the Surge Control Line (beginning at the end of the trend).

In the trend below, the same disturbance is input to the identically configured control, but an artificial loop delay of 250 milliseconds is introduced. The response signature is similar. But, the added delay is modestly indicated by the slower overall trend and, most noticeably, by the muted response to the open-loop valve step.



Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ IFACE_CC2.AS_SDR.A_NAME				99	101	100	100	n/a	n/a
🟥 UH_S_PV2.S_PV.A_NAME				75	125	94.7873	104.477	n/a	n/a
🟩 US_VLV2.VLV_PCT.A_NAME				0	100	0	17.4441	n/a	n/a

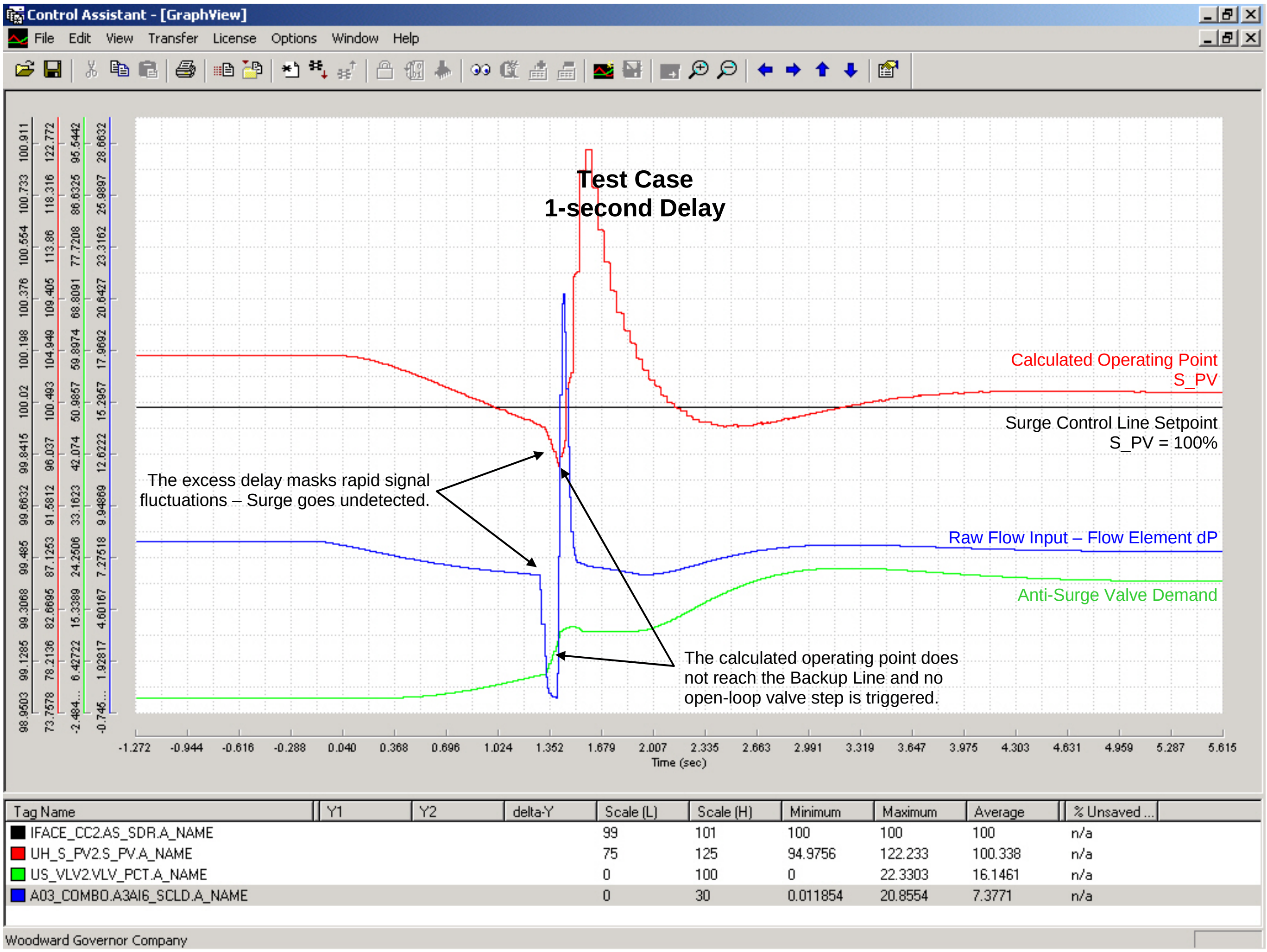
Woodward Governor Company

The delay is now increased to 500 milliseconds. The **blue** pen is added to the trend to indicate the raw flow input. The effect of the excess delay is obvious—A surge in the compression process goes undetected because of the 500-millisecond loop delay, the cumulative effect of field transmitter time constants, software sampling intervals, electro-mechanical inaccuracies, etc.

Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ IFACE_CC2.AS_SDR.A_NAME				99	101	100	100	100	n/a
🟥 UH_S_PV2.S_PV.A_NAME				75	125	88.6012	124.956	101.556	n/a
🟩 US_VLV2.VLV_PCT.A_NAME				0	100	0	25.016	16.3886	n/a
🟦 A03_COMBO.A3AI6_SCLD.A_NAME				0	30	0.008228	21.6255	7.52731	n/a

Extended to one second, the delay presents a similar dilemma as the 500-millisecond test case. Note, however, that in this test, the calculated operating point never reaches the Backup Line. Therefore, the open-loop valve step is never triggered to address the flow excursion.

In the initial control test, the operating point was restored, with stability, within 200 milliseconds of reaching the Backup Line. In this example, the settling-out time is on the order of seconds, not milliseconds, and only after an undetected surge. The resultant excess recycling wastes valuable energy in the prime mover as well as to cool the compressed process gas being recycled to the compressor suction. And, likely the most undesirable, and immediate, consequence of the surge shown here is the cascading effect it has on the downstream process.

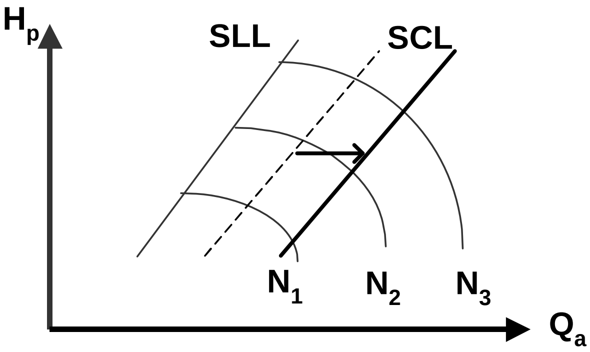


The excess delay masks rapid signal fluctuations – Surge goes undetected.

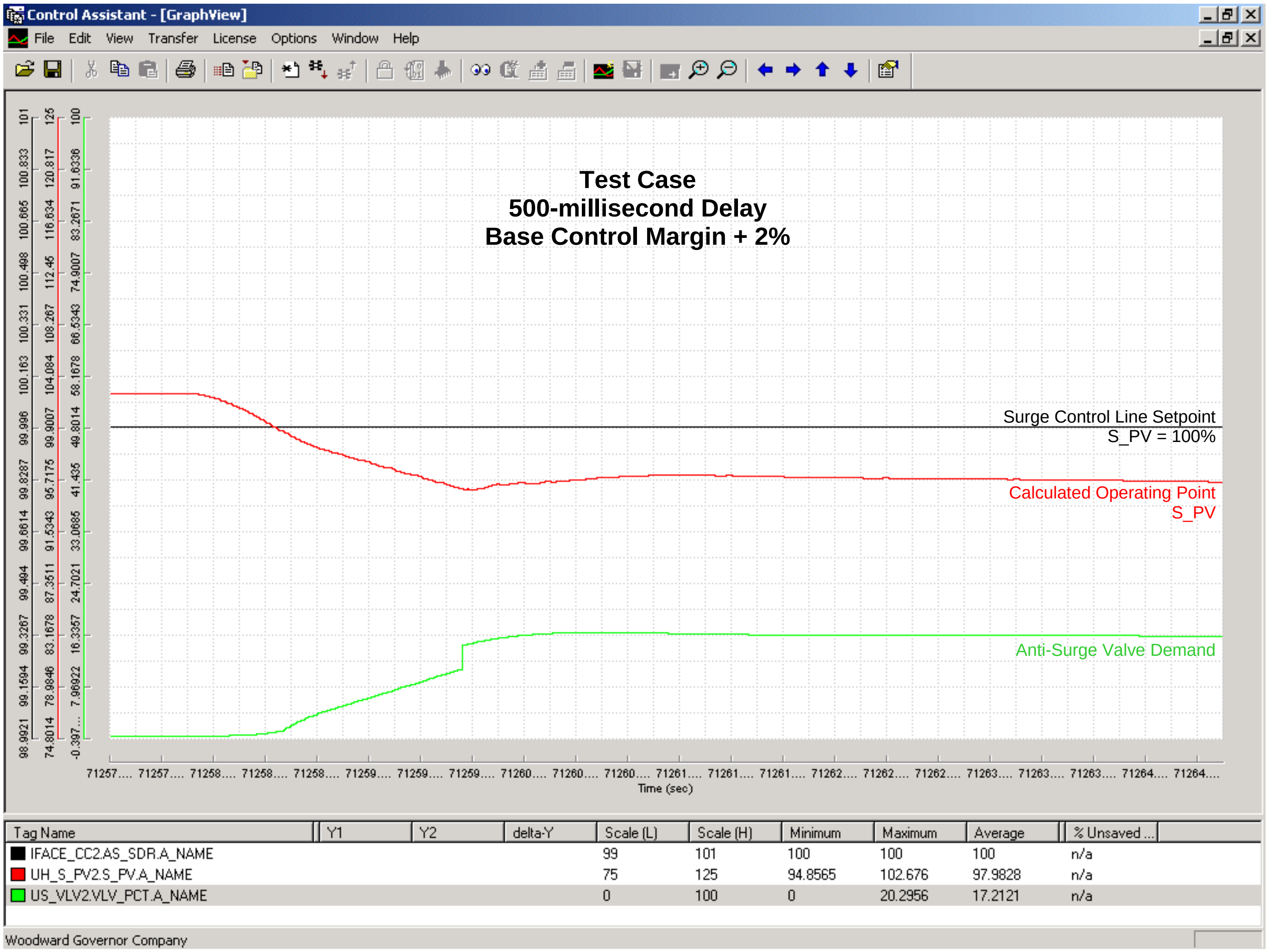
The calculated operating point does not reach the Backup Line and no open-loop valve step is triggered.

Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ IFACE_CC2.AS_SDR.A_NAME				99	101	100	100	100	n/a
🟥 UH_S_PV2.S_PV.A_NAME				75	125	94.9756	122.233	100.338	n/a
🟩 US_VLV2.VLV_PCT.A_NAME				0	100	0	22.3303	16.1461	n/a
🟦 A03_COMBO.A3AI6_SCLD.A_NAME				0	30	0.011854	20.8554	7.3771	n/a

As indicated by these test scenarios, extraneous loop delay, in any form, of any origin, degrades control loop performance and, obviously, speed. If such delays cannot be engineered out of the control loop or are intrinsic to the control software, what methods are available to alleviate the negative consequences described above? Typically, there are only two approaches: more aggressive closed-loop tuning and open-loop responses or increased control margin (moving the Surge Control Line farther away from the Surge Line). The former solution is acceptable is some applications, but often leads to the same excessive recycling and process disturbances against which it is intended to protect. The same can be said for increasing the control setpoint, or moving the Surge Control Line, but this method might be more suitable, especially if the compressor's normal operation is sufficiently loaded.



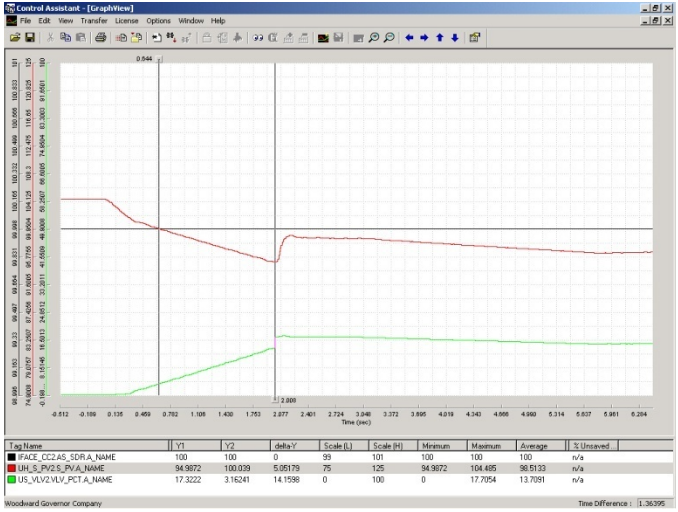
To illustrate, the same tests were repeated but with increased control margins. The objective is to determine how much additional margin must be configured to achieve a similar response under the same conditions as the base test with no delay. Consider the trend below: the 500-millisecond delay test case with an extra two percent control margin.



Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
IFACE_CC2.AS_SDR.A_NAME				99	101	100	100	100	n/a
UH_S_PV2.S_PV.A_NAME				75	125	94.8565	102.676	97.9828	n/a
US_VLV2.VLV_PCT.A_NAME				0	100	0	20.2956	17.2121	n/a

Note the initial opening ramp of the valve, the Backup Line step response, and the eventual settling-out of the responses. The positions of the valve and operating point at the end of this trend are similar to those of the base condition test, shown on the left below. Compare again with the 500-millisecond delay and base control margin shown on the right.

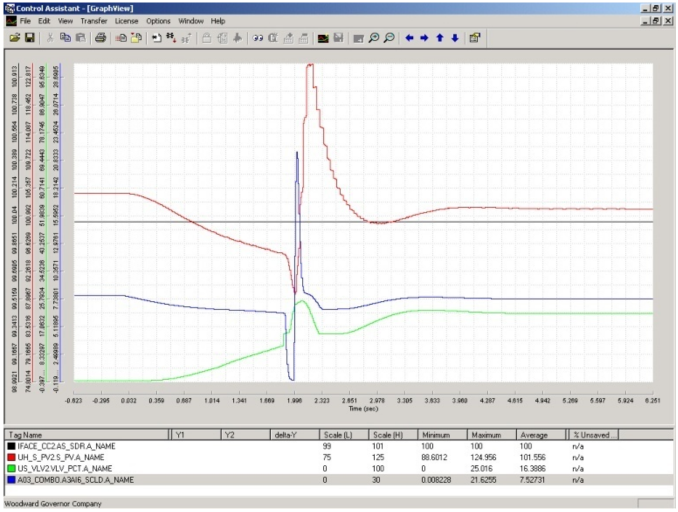
Base Control Case
No Delay
Base Control Margin



Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ IFACE_CC2.AS_SDR.A_NAME	100	100	0	99	101	100	100	100	n/a
🟥 UH_S_PV2.S_PV.A_NAME	94.9872	100.039	5.05179	75	125	94.9872	104.485	98.5133	n/a
🟩 US_VLV2.VLV_PCT.A_NAME	17.3222	3.16241	14.1598	0	100	0	17.7054	13.7091	n/a

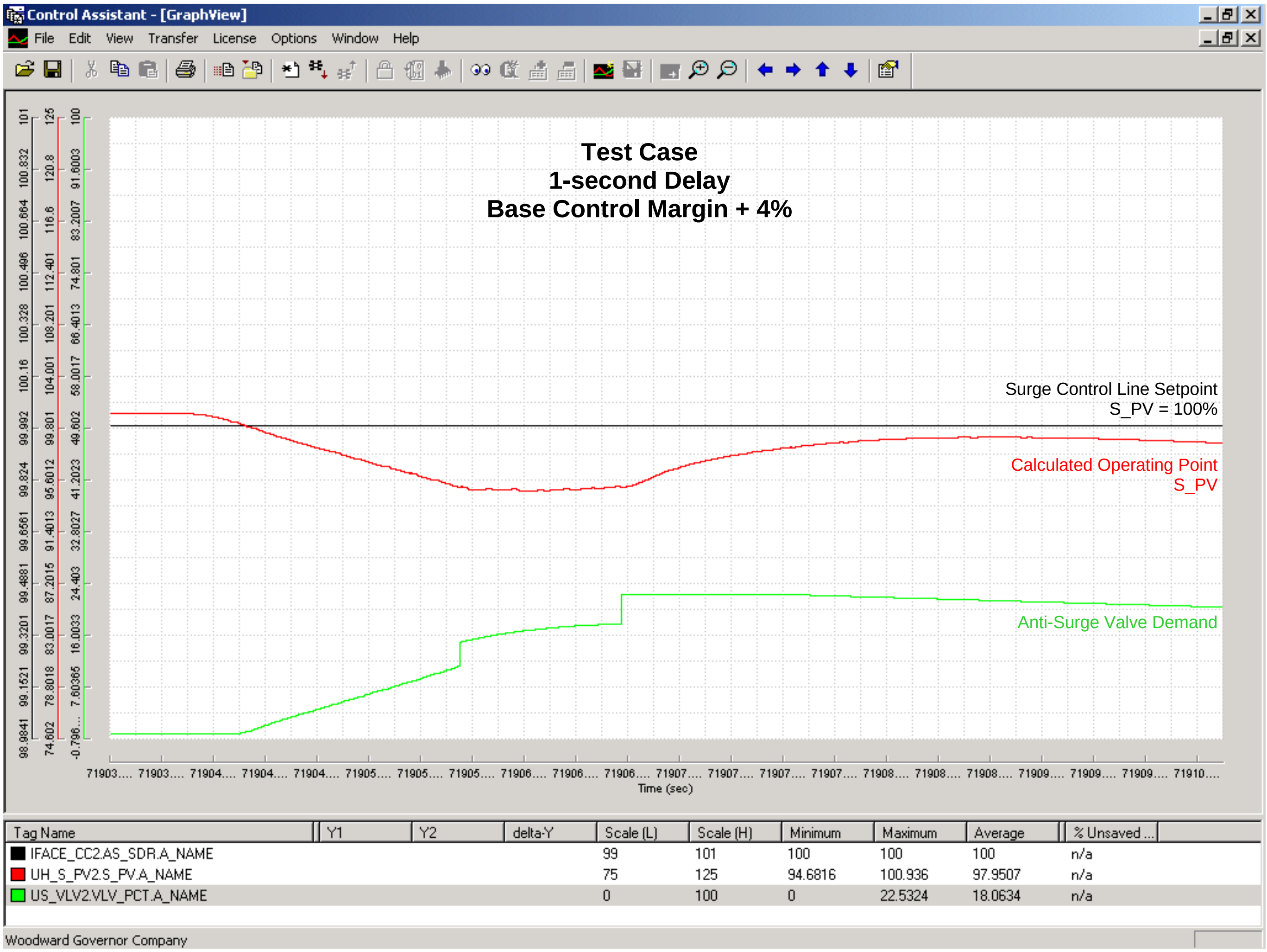
Time Difference : 1.36395

Test Case
500-millisecond Delay
Base Control Margin



Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ IFACE_CC2.AS_SDR.A_NAME				99	101	100	100	100	n/a
🟥 UH_S_PV2.S_PV.A_NAME				75	125	88.6012	124.956	101.556	n/a
🟩 US_VLV2.VLV_PCT.A_NAME				0	100	0	25.016	16.3886	n/a
🟦 A03_COMBO.A3AI6_SCLD.A_NAME				0	30	0.008228	21.6255	7.52731	n/a

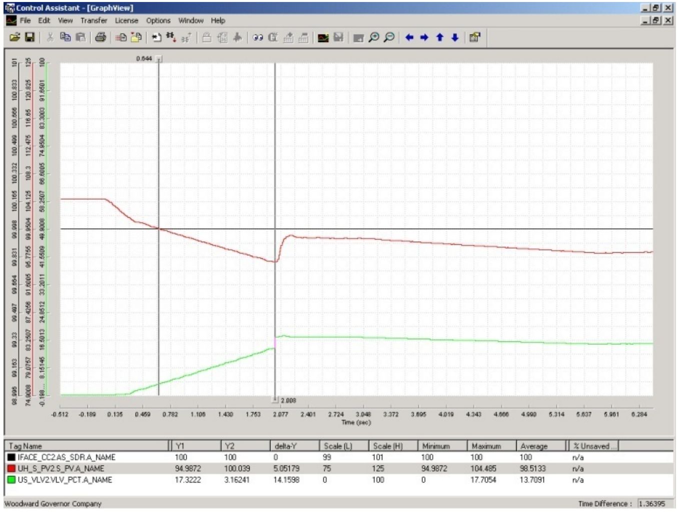
Consider the same scenario with the one-second delay …



Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
⬛ IFACE_CC2.AS_SDR.A_NAME				99	101	100	100	100	n/a
🟥 UH_S_PV2.S_PV.A_NAME				75	125	94.6816	100.936	97.9507	n/a
🟩 US_VLV2.VLV_PCT.A_NAME				0	100	0	22.5324	18.0634	n/a

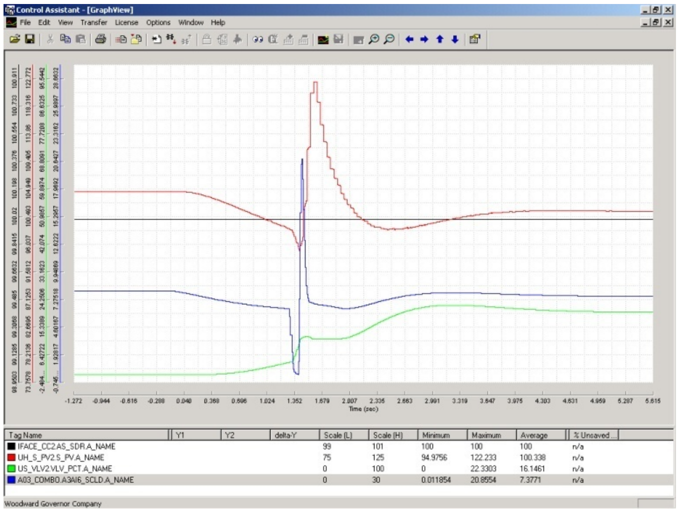
Above, the control margin was extended by four percent to yield an overall response approximating the base control case. Note, however, due to the extended delay time, an additional Backup Line step response is required to prevent the surge shown on the right below.

Base Control Case
No Delay
Base Control Margin



Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ IFACE_CC2.AS_SDR.A_NAME	100	100	0	99	101	100	100	100	n/a
🟥 UH_S_PV2.S_PV.A_NAME	94.9872	100.039	5.05179	75	125	94.9872	104.485	98.5133	n/a
🟩 US_VLV2.VLV_PCT.A_NAME	17.3222	3.16241	14.1598	0	100	0	17.7054	13.7091	n/a

Test Case
1-second Delay
Base Control Margin

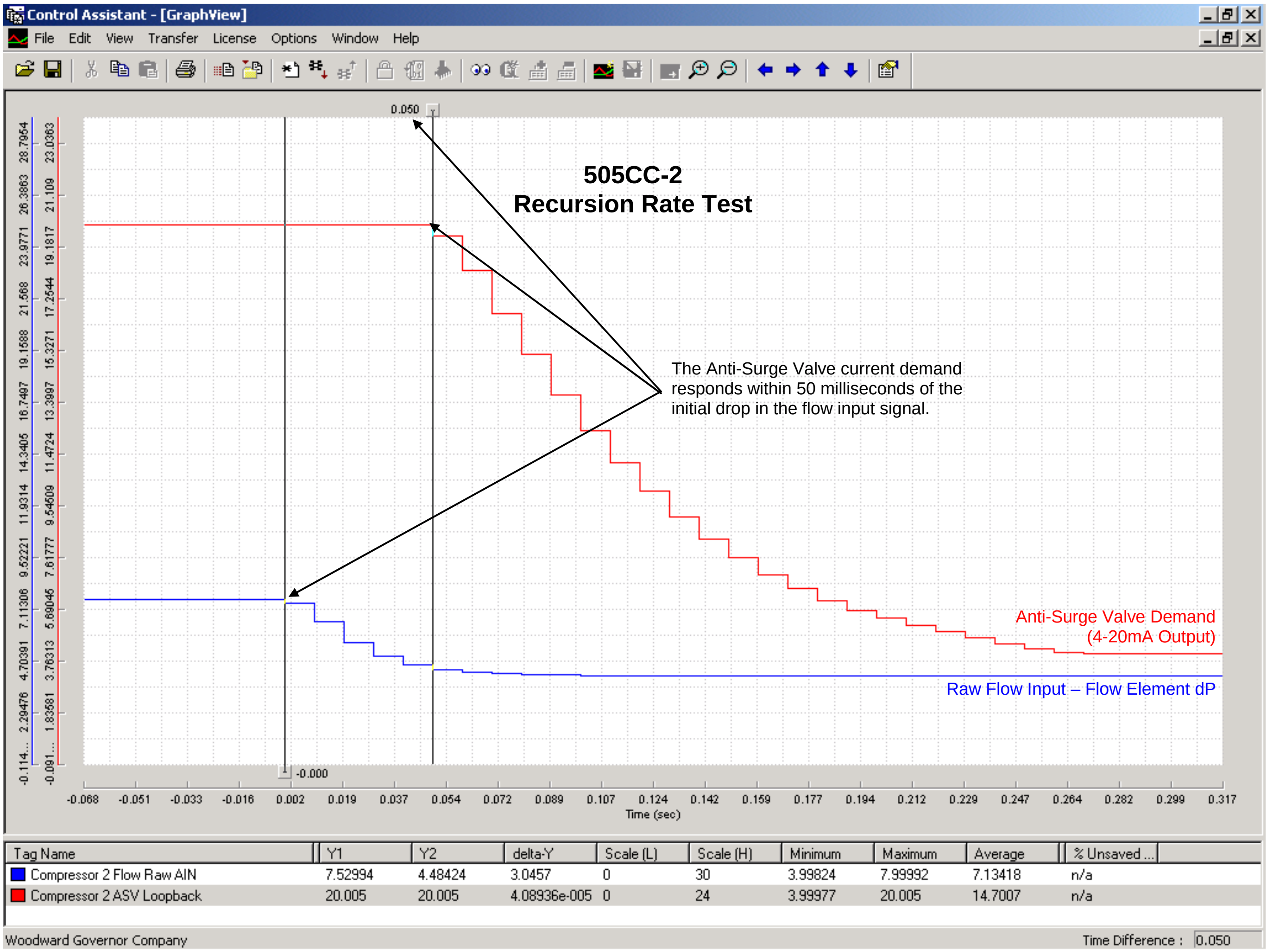


Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
■ IFACE_CC2.AS_SDR.A_NAME				99	101	100	100	100	n/a
🟥 UH_S_PV2.S_PV.A_NAME				75	125	94.9756	122.233	100.338	n/a
🟩 US_VLV2.VLV_PCT.A_NAME				0	100	0	22.3303	16.1461	n/a
🟦 A03_COMBO.A3AI6_SCLD.A_NAME				0	30	0.011854	20.8554	7.3771	n/a

Summary

The previous pages demonstrate the potential negative effects of two common anti-surge control loop complexities. The fact that control recursion rates, and loop delays in general, have a significant impact on anti-surge control performance cannot be overstated. And, when specifying controls or designing compressor loops, these are only two of the difficult problems to be addressed—Attention must be paid to all elements of the control loop and its installation. Without a properly designed and dedicated anti-surge controller, specialized control processors and I/O handling as well as significant resources (time, energy, engineering expertise) may be required to optimize control software in all but the most forgiving anti-surge control applications.

To compare, for example, the overall recursion rate of Woodward’s 505CC-2 Steam Turbine and Compressor Control is 50 milliseconds or less, including I/O processing synchronized with predictable and repeatable control software execution.



505CC-2
Recursion Rate Test

The Anti-Surge Valve current demand responds within 50 milliseconds of the initial drop in the flow input signal.

Tag Name	Y1	Y2	delta-Y	Scale (L)	Scale (H)	Minimum	Maximum	Average	% Unsaved ...
🟦 Compressor 2 Flow Raw AIN	7.52994	4.48424	3.0457	0	30	3.99824	7.99992	7.13418	n/a
🟥 Compressor 2 ASV Loopback	20.005	20.005	4.08936e-005	0	24	3.99977	20.005	14.7007	n/a

Woodward Governor Company

Time Difference : 0.050

In addition to static control recursion rate, excessive safety margins and/or aggressive tuning might be required to compensate for inadequate response characteristics. These strategies inevitably lead to excess recycling, degraded surge detection and prevention capability; and increased probability of initiating downstream process upsets. Consider the test case requiring an extra four percent control margin to produce a response similar to that of the base control. The excess recycling requires excess cooling capacity. Also, an additional four percent flow requires, roughly, an extra 12.5 percent power from the prime mover—at substantial, unnecessary extra cost.

Woodward’s proven technologies and advanced software speed and architecture ensure that cost is minimized while performance is improved. Processes and compressors may vary, but Woodward designs its controls for the most rigorous applications—and has for decades.

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please reference publication 51268.

WOODWARD™

PO Box 1519, Fort Collins CO 80522-1519, USA
1000 East Drake Road, Fort Collins CO 80525, USA
Phone +1 (970) 482-5811 • Fax +1 (970) 498-3058

Email and Website—www.woodward.com

**Woodward has company-owned plants, subsidiaries, and branches,
as well as authorized distributors and other authorized service and sales facilities throughout the world.**

Complete address / phone / fax / email information for all locations is available on our website.

2012/12/Colorado