

# **Evaluation Report: E 2793 T 03-A**

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Index Classification 8.1

## **ELECTROPNEUMATIC VALVE POSITIONER Mod SVP 3000 Alphaplus AVP 302**

**(Results of dynamic testing program)**

**Manufacturer: Yamatake Corporation Japan.**

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Subject: **ELECTRO-PNEUMATIC VALVE POSITIONER, model SVP3000 Alphaplus AVP302**  
**Manufacturer: Yamatake Corporation, Japan**

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### **Appendix A: Control Valve Dynamic Specification**

(article from EnTech™ Control Inc.)

**Electro-Pneumatic Valve Positioner model SVP3000 Alphaplus AVP302**  
**Manufacturer: Yamatake Corporation, Japan**

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January, 2004

## **1. INTRODUCTION**

This report deals with tests of a single acting electro-pneumatic valve positioner model AVP302, manufactured by Yamatake Corporation, Japan.

The instrument was tested on behalf of WIB on a valve-simulator developed by InfraServ, Höchst, Germany in co-operation with the university of Kaiserslautern. The test programme drawn up by Infracerv was based on EnTech and DIN procedures. An article describing the EnTech methods is added as an Appendix to this report.

The test programme comprised:

- step response tests,
- hysteresis (backlash/stiction) measurement according to EnTech,
- stroke characteristic in linear friction-free configuration,
- frequency response measurements.

The simulator makes use of three real actuators with different sizes (respectively 120 cm<sup>2</sup>, 350 cm<sup>2</sup> and 700 cm<sup>2</sup>). The actuators (make Samson) have a spring package of 0,4 - 2 bar. The nominal stroke was 15 mm for the sizes 120 and 350 cm<sup>2</sup> and 30 mm for the 700 cm<sup>2</sup>.

The boundary conditions for the tests were:

- the instrument should be mounted on a (NAMUR) bracket (see NAMUR publication NE04)
- the manufacturer should commission the instrument in a "plug and play" fashion in a period not exceeding 2 h.
- The friction force was set to 5%.
- The supply pressure to the positioner was 3 bar.
- The instrument was connected to the supply source by a 6 mm OD tube.

InfraServ performed the tests and measurements on October 20, 2003. TNO processed the data in an agreed format.

## 2. TEST RESULTS

### 2.1 Results' summary

Note: Unless otherwise stated all percentages are quoted as a percentage of span

Unless otherwise stated the tests were performed under the following conditions:

Input: 4...20 mA, 2-wire system  
 Output: linear with stem travel  
 Ambient temperature: 20°C ± 1°C  
 Relative humidity: 65% ± 15% R.H.  
 Supply pressure: 3 bar(g)  
 Positioner settings: as described under 4.2.1  
 Actuator types: Stroke 15 mm, diaphragm area 120 cm<sup>2</sup>  
 Stroke 15 mm, diaphragm area 350 cm<sup>2</sup>  
 Stroke 30 mm, diaphragm area 700 cm<sup>2</sup>

#### 2.1.1 Positioner on 350 cm<sup>2</sup> actuator, 15 mm stroke

Test item	observation and measurements			
Accuracy of linear characteristic (friction free)				
Maximum	+0,47%			
Minimum	-0,07%			
Zero error	0,00%			
Span error	-0,07%			
Hysteresis	0,20%			
Hysteresis (backlash/stiction) according to EnTech procedure at:				
10%	1,25 %			
50%	0,69 %			
80%	0,71 %			
Step response test according to EnTech procedure:	T <sub>01</sub>	T <sub>63</sub>	T <sub>98</sub>	Overshoot/ Rest error (after 5 seconds)
+1 % step at 10%	1,50 s	1,58 s	1,64 s	0,25%/ 0,25%
-1 % step at 10%	1,73 s	2,48 s	2,98 s	0,23%/ 0,23%
+1 % step at 80%	0,72 s	0,92 s	---- s	0,00%/ -0,02%
-1 % step at 80%	1,14 s	1,67 s	1,99 s	0,42%/ 0,42%
+10 % step at 80%	0,53 s	0,83 s	1,32 s	0,64%/0,64%
-10 % step at 80%	0,65 s	1,78 s	2,64 s	1,18%/1,18%
Frequency response at 20% amplitude at 50%	bandwidth		Phase lag	
-3 dB	0,30 Hz		-92°	
-6 dB	0,49 Hz		-135°	

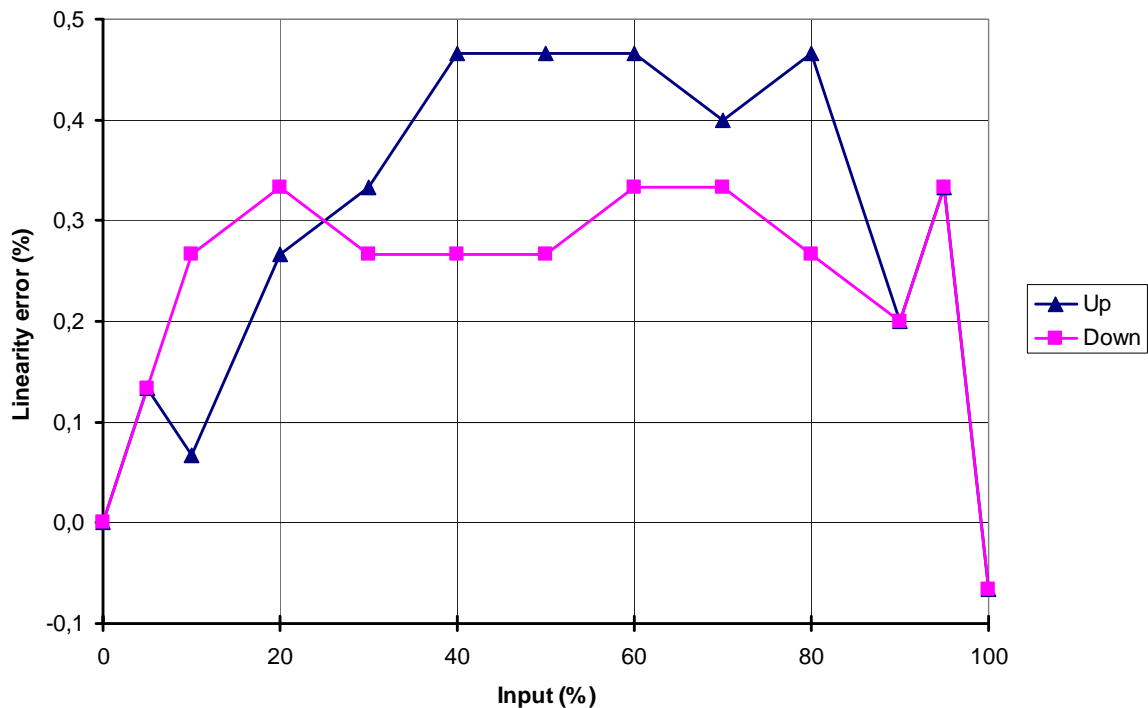
### 2.1.2 Positioner on 120 cm<sup>2</sup> actuator, 15 mm

Test item	observation and measurements			
Hysteresis (backlash/stiction) according to EnTech procedure at: 10% 50% 80%	0,85% 1,09% 1,10%			
Step response test according to EnTech procedure:	T <sub>01</sub>	T <sub>63</sub>	T <sub>98</sub>	Overshoot/ Rest error (after 5 seconds)
+1% step at 10%	0,47 s	0,73 s	2,96 s	0,00%/ 0,00%
-1% step at 10%	0,02 s	0,90 s	---- s	0,00%/ -0,11%
+1% step at 80%	0,45 s	1,21 s	---- s	0,00%/ -0,08%
-1% step at 80%	0,70 s	1,56 s	---- s	0,00%/ 0,09%
+10% step at 80%	0,35 s	1,62 s	---- s	0,00%/ 1,63%
-10% step at 80%	0,39 s	2,55 s	---- s	0,00%/ 1,38%

### 2.1.3 Positioner on 700 cm<sup>2</sup> actuator, stroke 30 mm

Test item	observation and measurements			
Step response test according to EnTech procedure:	T <sub>01</sub>	T <sub>63</sub>	T <sub>98</sub>	Overshoot/ Rest error (after 5 seconds)
+1% step at 10%	0,74 s	0,84 s	0,89 s	0,52%/ 0,52%
-1% step at 10%	4,65 s	5 s	---- s	0,00%/ -0,48%
+1% step at 80%	0,38 s	0,58 s	0,71 s	0,19%/ 0,19%
-1% step at 80%	3,40 s	3,93 s	---- s	0,00%/ -0,12%
+10% step at 80%	0,33 s	0,54 s	0,74 s	0,00%/ -0,12%
-10% step at 80%	0,50 s	0,73 s	---- s	0,00%/ -0,30%

### 2.1.4 Accuracy at 350 cm<sup>2</sup> actuator

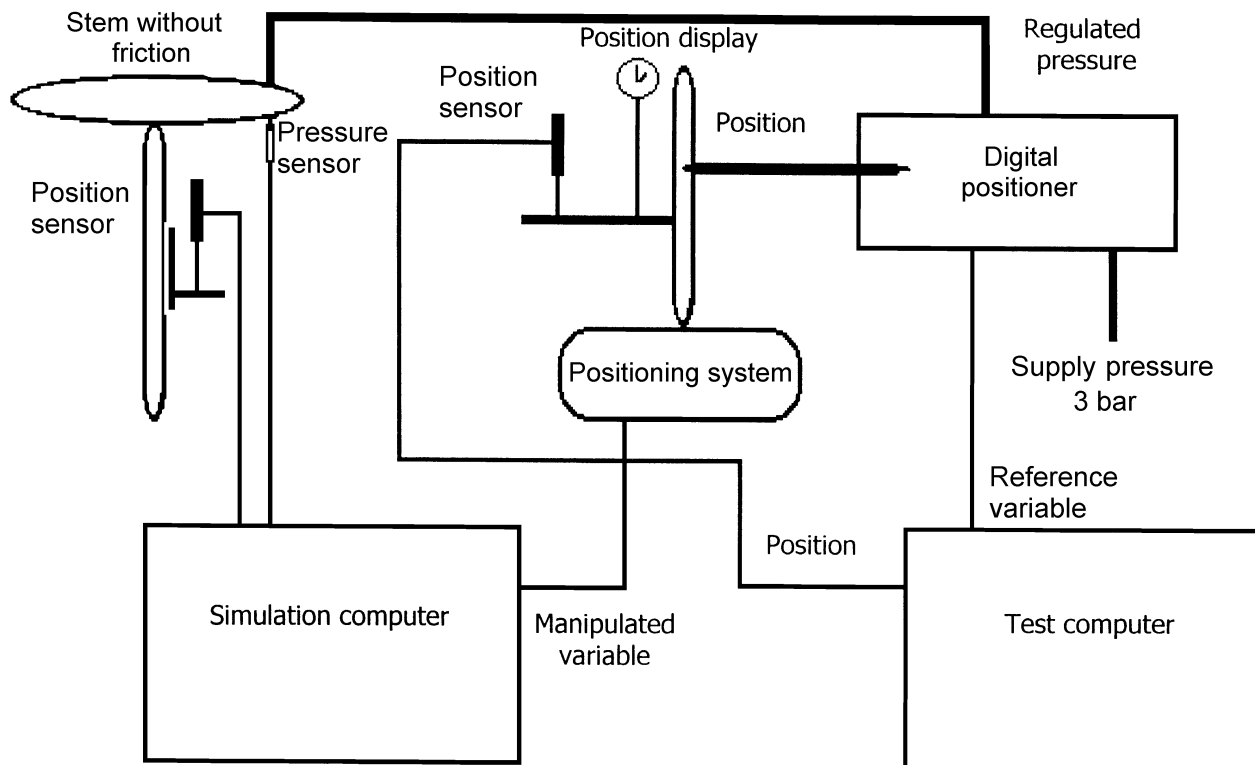


## **2.2 Manufacturer's comments**

The manufacturer agreed with the contents of the report and had no additional comments.

### 3. TEST METHODS AND REFERENCES

#### 3.1 Test set-up



#### 3.2 Test program

##### 3.2.1 General

The instrument was mounted on a positioning system, which is part of a valve simulation system as shown in the above figure. The simulation system operates as follows. The output pressure of the positioner is fed into a conventional actuator with no stuffing box and thus frictionless. The position of the stem is measured together with the pressure. These signals are processed in the simulation computer and friction effects are added. The output (manipulated value) of this computer controls through the positioning system a second stem, which is connected to the lever mechanism of the digital positioner under test.

The frictionless actuators can be exchanged. For this test the 3 types mentioned below were used.

Unless otherwise stated the tests shall be performed under the following conditions:

Input:	4...20 mA, 2-wire system
Output:	mA - to - stem travel characteristic linear.
Ambient temperature:	20°C ± 2°C
Relative humidity:	65% ± 15% R.H.
Supply pressure:	3 bar(g)
Friction force:	5%
Positioner types:	Stroke 15 mm, diaphragm area 120 cm <sup>2</sup> Stroke 15 mm, diaphragm area 350 cm <sup>2</sup> Stroke 30 mm, diaphragm area 700 cm <sup>2</sup>

Positioner settings during the test were:

Parameter	Settings for 120 cm <sup>2</sup> actuator	Settings for 350 cm <sup>2</sup> actuator	Settings for 700 cm <sup>2</sup> actuator
Positioner model	AVP302-FSD40	AVP302-FSD40	AVP302-FSD40
Device serial number	G-00943-32-000-3	G-00943-32-000-3	G-00943-32-000-3
Lower range value	4 mA	4 mA	4 mA
Upper range value	20 mA	20 mA	20 mA
Low shut-off	0,5%	0,5%	0,5%
High shut-off	99%	99%	99%
Nominal stroke	15 mm	15 mm	30 mm
Tag. No.	WIB No.3	WIB No.3	WIB No.3
PROM#	2005823837	2005823837	2005823837
Embedded software version	3.0	3.0	3.0
Failsafe	Downscale	Downscale	Downscale
Form (characteristic)	Linear	Linear	Linear
Actuator action	Reverse	Reverse	Reverse
Positioner action	Direct	Direct	Direct
Valve action	Direct	Direct	Direct
Actuator size	Param 1	Param 1	Param 3
Hysteresis	Heavy	Medium	Light

### 3.2.2 Test schedule

#### 3.2.2.1 Travel characteristic (at 350 cm<sup>2</sup> actuator)

The travel characteristic was adjusted to linear and the input-to-stroke characteristic was determined at 0%, 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 100% input. From the test results the minimum and maximum errors, zero and span error, static hysteresis were determined.

#### 3.2.2.2 Hysteresis (backlash/stiction) measurement according to EnTech procedure (at 350 cm<sup>2</sup> and 120 cm<sup>2</sup> actuators)

The backlash/stiction measurements as described in the appendix A chapter 3.1.1 were performed at 10%, 50% and 80% position. The measurements were at these positions performed over a stroke area of 4% in 44 steps.

#### 3.2.2.3 Step response (all 3 actuators)

Steps of +1%, -1%, +10%, and -10% were applied to the input. The output was recorded over a period of 5 s and the following data were determined from the record: T01 (s), T63 (s), T98 (s), overshoot (%) and the remaining (rest) error.

#### 3.2.2.4 Frequency response (at 350 cm<sup>2</sup> actuator)

The frequency response measurements were performed with a sinusoidal input signal with an amplitude of 20% at an average position of 50% in the frequency band of 0,1 – 2 Hz. From the data the phase shift and frequency at the -3 dB and -6 dB were determined.

### **3.3 Test Program References**

- EnTech™ Control Valve Dynamic Specification (Version 2.1, 3/94).
- ISA S75.13 1989 Method of Evaluating Performance of Positioners with Analog Input Signals and Pneumatic Output.
- IEC 1514 1999 Method of Evaluating the Performance of Valve Positioners for Use in Industrial-Process Control Systems (draft standard).

## Appendix A: Control Valve Dynamic Specification

(article from EnTech™ Control Inc.)

### Control Valve Dynamic Specification (version 2.1, 3/94)

#### 1.0 COMPETITIVE MARKET PLACE BACKGROUND

As the global market for manufactured products continues to focus on product quality and uniformity, more and more attention is being paid to process control equipment and its condition. EnTech™ Control Engineering Inc. has specialised in the analysis and optimisation of pulp and paper manufacturing, where product uniformity specifications are now approaching 1%. Paper product can be rejected when it deviates outside specified limits, or when variability characteristics of the products adversely affect the operation of the customer's secondary manufacturing, such as printing press. Mill audits have shown that product variability is caused mainly by the combined behaviour of the many upstream process variables. In many cases it is possible to trace these causes right down to individual control valves. Of equal importance is the impact of process variability on manufacturing efficiency, in which small and subtle improvements in the process variability of key variables can have a large impact. Audits have identified that the cyclic behaviour of control loops is a major cause for destabilising pulp and paper production. To date about two-third of all control loops surveyed were found to oscillate in automatic mode. Of these, well over half were found to oscillate directly due to the behaviour of pneumatic control valves. **The undesirable behaviour of control valves is hence the biggest single contributor to poor control loop performance and the destabilisation of product uniformity.**

#### Control Valve Dynamic Specification - Purpose

This specification is aimed at providing a guide for control valve dynamic behaviour that is suitable for the highly competitive process industry environment. It is intended as a guide for end users to gauge control valve performance in-situ and also as a guide for both control valve purchase and sizing. While by no means 'the-last-word' in competitive control valve performance, the specification is intended to fill a void in an industry, which has essentially no guidelines in this critically important area.

#### About Version 2.1

The original EnTech™ Control Valve Specification was issued in early 1992. Version 2.0 (11/93) was originated to provide the end user with a 'how-to' guide for in-situ testing. Version 2.1 is a minor revision to Version 2.0 intended to stress three points which have caused some confusion. a) The Backlash/Stiction specification is by far the most important part of Version 2.1 and it is critical that the process variable moves in response to small input step changes (1% and less) indicating that an actual change in the valve Cv has occurred. Valve stem movement alone is not an adequate indication. b) There is a need to clarify terminology as used in both Versions 2.0 and 2.1 regarding backlash/stiction. These terms are defined in [2] and result in a phenomenon known as signal dead band in the valve travel. The terms 'backlash/stiction' emphasise the mechanical cause of the problem and are used throughout Version 2.1 to imply "dead band". c) Finally ISA Specification S75.13 [3] is not equivalent to Version 2.1. The former applies to a test stand procedure for valve positioners only and is not adequate for today's in-situ process control performance requirements. Version 2.1 specifies in-situ control valve performance requirements for the whole valve assembly, under process operating conditions, in order to meet end-use performance and final product uniformity requirements.

#### 2.0 CONTROL PROBLEM DEFINITION – LINEAR CONTROL

Most control valves are used as final control elements in simple feedback control loops with PID control algorithms. The feedback controller is essentially a linear device. This implies that if all elements of a control loop were also truly linear there would be a few control problems. What does 'linear' mean in the control context? A linear dynamic element will respond to its input signal in a uniform fashion over its operating range with unchanging dynamics regardless of the size or amplitude of the change in the input signal. Hence, if the time constant of the step response is 2 seconds, then this will apply to steps of 0.01%, 1% and 100% equally well. If this is not true, then the system is non-linear. In fact, all control valves are highly non-linear.

This is a major source of problems for control loop tuning and control loop performance because the apparent process dynamics, to which the control loop tuning is matched, keep on changing. As a result, the loop no longer works as intended.

## Definitions

**Process dynamics:** the way a process variable responds, over time, to a change in controller output. This is best characterised by the step response, modelled by a transfer function and expressed in terms of Process Gain, Time constants and Deadtime.

**Process Gain:** the ratio of process variable change to controller output change after a step change in controller output.

**Time constant:** the time required for a first order process to reach 63% of the full change when a step change has been made.

**Deadtime:** the time after a step change prior to the start of the process reaction, taking place.

**Linear Dynamics:** a single set of dynamic parameters (gain, time constants) applying equally well over the whole operating range.

**Non-linear Dynamics:** dynamic parameters (gain, time constants) which change over the operating range.

**Limit Cycle:** a sustained control loop cycle or 'hunting' caused by a non-linear element in the loop. Limit cycles cannot be corrected by loop tuning.

## 3.0 CONTROL VALVE NONLINEARITIES

Control valves have several forms of non-linear behaviour, which can be split into two categories:

- Valve tracking non-linearities
- Sizing and flow characteristic non-linearities.

Valve tracking non-linearities include behaviour such as 'stiction' and are primarily a function of valve design, shut-off requirements, actuator sizing, valve wear, maintenance, age, installation and other related factors. The common practice of demanding tight shut-off for a control valve often compromises control performance by greatly increasing the plug/seat friction and resulting stiction forces. In the future, high performance control may require control valves, which do not have tight shut-off, hence requiring a separate additional shut-off valve.

Valve sizing is generally a function carried out during the engineering phase of a project and results in the installed process gain characteristic of the control loop. Ideally an installed loop process gain of 1.0 is desirable for self regulating processes, as it allows for full valve travel over the full span of the transmitter. However, in many cases valves have been severely oversized in the quest for more than adequate production capacity. This results in control valves with very high process gains, which are nearly closed during normal operation. The normal operating region for these control valves is hence very narrow. The valve tracking non-linearities can be magnified to the extent that good control is impossible.

Flow characteristic non-linearities are a function of valve plug characteristics and the pressure drop distribution between the control valve and the rest of the process piping, pumps and other equipment. The impact of this is that the installed process gain will vary in a certain way over the operating range of the process. These process gain changes further complicate the control loop tuning and performance problem, since a fixed gain controller cannot cope well with these changes.

### 3.1 Control valve tracking nonlinearities

Valve tracking non-linearities are caused by problems in the positioner/actuator/valve system with the result that the valve plug does not follow the input signal in a linear fashion. There are three regions of operation (referred to as A, B and C in this document). For a very small input signal step change (say 0.1%), the plug is not likely to move at all (Region A). Above an initial threshold (say 0.1% to 1%), there will be motion (Region B), but this will be subject to backlash or hysteresis or lost motion in the mechanical linkages, together with stiction or transitions from static to dynamic friction, causing sudden jumps in the plug position as successive step changes are called for. This behaviour (Regions A and B) is especially destabilizing because it causes the controller output to 'wind up' while there is no response to the small actions requested. When motion does finally occur after stiction release, (stored potential energy release) the results are often an overshoot in the plug position. This overshoot can be even more damaging to control performance than the original stiction behaviour.

When the input steps get much larger than the initial threshold, then a second threshold is reached (steps of say 10%), at which point the valve plug will respond to every change called for (Region C), but the motion will be velocity limited by the rate at which power air can flow to and from the actuator. In this region the valve is non-linear in a different way because the dynamics get progressively longer with the size of step change. For process control regulation in steady state, the normal and most important region of operation is for step changes below this second threshold (Regions A and B). In this region, the problem with pneumatic control valves is non-linearities of the backlash/hysteresis/stiction/overshoot type, which may often cause the control loop to limit cycle.

### 3.1.1 Backlash/Stiction

Backlash and stiction behaviour is caused by mechanical tolerances and friction in the control valve/positioner/actuator system. The resulting limit cycles can only be corrected by reducing these. They cannot be addressed through loop tuning.

#### Specification

**The combined Backlash and Stiction or Dead band is not to exceed 1.0%, as installed, during normal process operation. [reference 2].**

#### In-Situ Testing for Backlash/Stiction

In-Situ testing for backlash/stiction or dead band can be done for most control loops with reasonably fast non-integrating process dynamics such as flow or pressure.

#### Procedure:

1. Connect the channels of a data collection device to the controller output and process variable signals at the terminal strip. Since the step changes for this test sequence will be small and the process signal is likely to be noisy, an analog input filter with a time constant of a few seconds is advisable. Set up to collect data at a rate of about 1 sample per second and start data collection (sampling time can be one third of the filter time constant).
2. Put the loop on manual and allow the process to stabilise. Observe the process variability change from 'auto' to 'manual'.
3. At the control console or controller face-plate, initiate a series of small step changes or 'bump tests', each time waiting for the process to stabilize before making the next move. Each step should be as near to a clean step as possible. This is best done by entering a new value through a keyboard, rather than using a slew button. If a slew button or manual output adjustment must be made by hand, this should be a single move of approximately the right size, made as rapidly as possible. Start with a series of 0.5% bumps to begin with, in one direction (either up or down). If no response is observed, increase the size of the bump tests being used. When equal process reactions are noticed for two successive bumps, then the backlash has been taken-up in that direction. Reverse the direction of the bumps and repeat the test in the opposite direction. Estimate the backlash by counting the number of bumps after a direction reversal for which no response, or only a partial response occurred. For improved accuracy, repeat the test procedure with smaller bump tests. It is important that these bumps be less than the initial motion threshold (Region A) in order to properly measure backlash and 'stiction'.
4. For the smallest bump test used in 3) above (say 0.2%), initiate a series of bumps in one direction and continue in that direction to observe the effects of combined backlash and 'stiction'. For small bumps, the valve will not move previous bumps since the last move. Once it has moved and stopped, it will again be 'stuck' and several more bumps will be necessary to cause another move. Record the input signal and the process variable (PV) initial and final values in a table for each bump. Continue the test over at least two 'stiction' cycles as described above. Then reverse the direction by first applying the number of bumps needed to take up the backlash as estimated from 3) above. Continue the test in the new direction until the process value has returned to the initial value at the start of the test. Draw an X-Y plot of PV vs Input signal similar to that of Figure 1. Estimate the combined backlash/stiction or deadband by estimating the maximum width of the resulting hysteresis plot as illustrated in Figure 1. Repeat the test, if necessary, to obtain a better estimate.

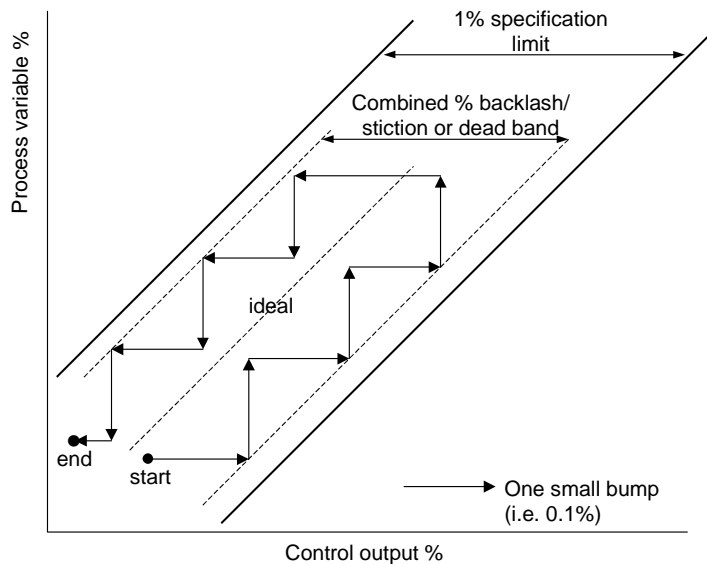


figure 1

### 3.1.2 Speed of Response and Overshoot

Consistent speed of response of a control valve is crucial for the operation of a control loop. For small step changes in input signal, the plug or trim should track the input signal with at least the speed of response listed in Table 1 and illustrated in Figure 2, over a range of step changes ranging from 10% of travel, down to the combined backlash/stiction limit achieved above, plus 1%. (Down 1.5% if combined backlash/stiction is 0.5%).

#### Definitions:

- Td = dead time before any response is visible (seconds).
- T63 = time to reach 63% of a step change in input signal (seconds).
- T98 = time to reach 98% of a step change in input signal (seconds).
- BW = bandwidth (Hz), the frequency at which the plug or trim position amplitude is attenuated by – 6 dB. Bandwidth has been included in the specification for completeness, even though it is difficult to test for in most cases.

### Speed of Response

3.3.1 Table 1					
Valve Size		Td	T63	T98	BW
(inches)	(cm)	(sec)	(sec)	(sec)	(Hz)
0-2	0-5	0.1	0.3	0.7	1.6
>2-6	>5-15	0.2	0.6	1.4	0.8
>6-12	>15-30	0.4	1.2	2.8	0.4
>12-20	>30-50	0.6	1.8	4.2	0.27
>20+	>50+	0.8	2.4	5.6	0.2

The above specification allows for large valves to be progressively slower than small ones. The Td, T63, T98 and BW specifications are a compatible set of numbers for a second order critically damped system with deadtime, representing positioner hesitation equal to one time constant. All the responses have the shape illustrated in Figure 2. Responses for larger valves are identical, except that time is re-scaled appropriately.

#### Overshoot

Overshoots will be present if the step responses do not increase monotonically but rather overshoot and then return to a steady state value. The % overshoot is absolute value of each overshoot expressed as a percentage of the steady state change.

## Specification

The percent overshoot should be less than or equal to 20% of the step magnitude for steps ranging from 10% of travel down to steps equal to the backlash/stiction limit plus 1%.

## In-Situ Testing for Speed of Response and Overshoot

In-Situ testing for speed of response is very similar to that for backlash/stiction. The differences are as follows:

The data collection equipment should collect data at a rate, which is at least 5 times faster than the expected time constant of the valve, typically 0.02 to 0.03 seconds. The input filtering should be reduced to a time constant of 0.02 seconds approximately.

To measure the valve speed of response, it may not be possible to use existing process instrumentation, such as a magnetic flow meter, since this may have a time constant of 3 seconds or longer. Hence, it may be necessary to install additional instrumentation, such as a position transmitter, to measure as close as possible to the valve plug position. Alternatively, it may be possible to measure line pressure some distance after the valve, or the differential pressure across the valve itself. In all cases the time constant of the measurement must be at least three times as fast as the expected time constant of the valve. (Table 1, T63/3. For a 4 inch valve, time constant is 0.2 seconds, hence the measurement time constant should be 0.06 seconds).

Initially, steps of 10% of travel should be done. Plot the process variable response as in Figure 2. Calculate the % overshoot on the basis of the final process value. Tests can vary in direction to suit process conditions at the time although small steps should be done in the same direction so as not to incur backlash. Now repeat the tests for successively smaller steps, down to steps equal in size to the previously achieved combined backlash/stiction limit plus 1%. Measure  $T_d$ , T63, T98 and % overshoot for each test. The results should comply with Table 1 and Figure 2.

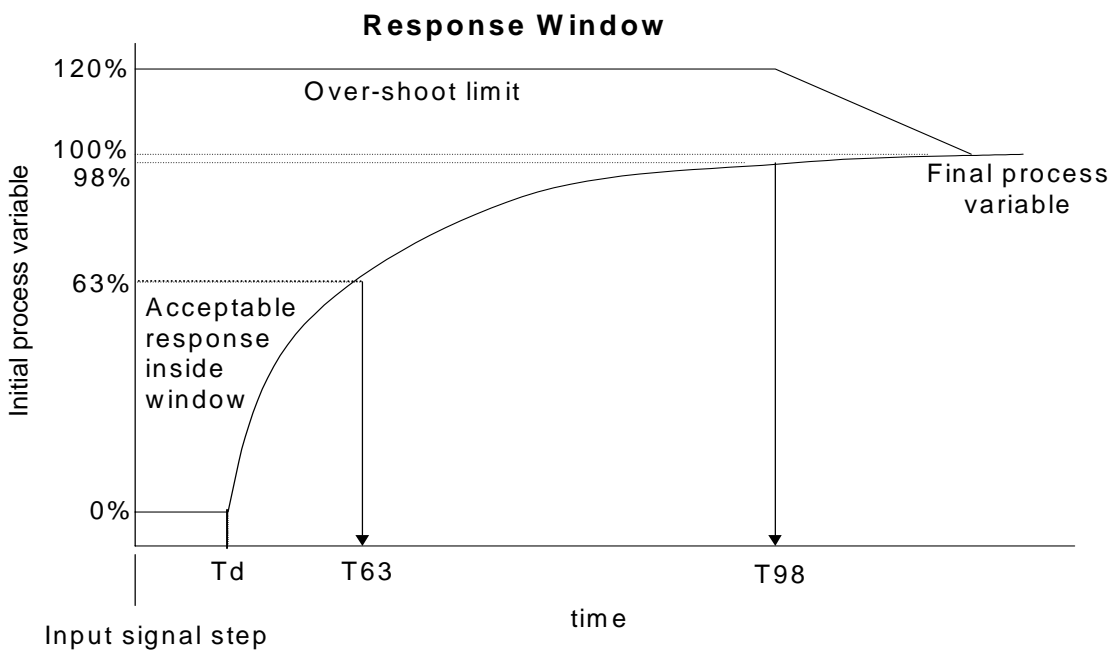


Figure 2

## Sizing and Flow Characteristic Nonlinearities

Control valves are sized for a given plant capacity. Normally an allowance is made for future throughput increases, together with a safety margin. Most valves have nonlinear flow characteristics. This results in the fact that the 'process gain', the relationship between input signal change and the resulting process change, itself changes with the operating point. The process gain combined with the controller gain, determine how a control loop behaves. These changes in process gain are a major source of loop tuning problems, and can often result in loop instability. Over-sizing the valve makes this problem much more severe.

To minimise this effect, the overall process gain for non-integrating process variables (e.g.: most flows, pressures, temperatures, but not tank levels) as determined by both valve sizing and transmitter span should have a nominal value of 1.0 and be kept in the range:

0.5 – 2.0 (% of span)/(% output).

e.g.: for a bump test, the controller output was stepped by 5%, the flow changed by 7.2% of span.

Process gain =  $7.2\%/5\% = 1.44\%/%$

### Summary of Control Valve Dynamic Performance Specification

- 1) **Combined backlash/stiction:** not to exceed 1% of input signal span.
- 2) **Speed of response:** rate of change of valve position in response to step changes ranging in size from 10% in input signal (see table 1 and figure 2) down to backlash/stiction limit plus 1%.
- 3) **Overshoot:** percent overshoot in valve position to be less than 20% for all steps made.
- 4) **Sizing and Flow Characteristics (Engineering Design):**  
Loop Process Gain = 1.0 (% of transmitter span)/(% controller output)  
Nominal range: 0.5 – 2.0 %/%%.

### References

- 1 EnTech™ – Control Valve Dynamic Specification (Version 2.0, 3/94)
- 2 ANSI/ISA – 51.1 – 1979 – Process Instrumentation Terminology.
- 3 ISA Standard – S75.13 – 1989 Method of Evaluating Performance of Positioners with Analog Input Signals and Pneumatic Output.