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Standard

Method of Evaluating the Performance of Positioners with Analog Input Signals and Pneumatic Output

ISA-S75.13 — Method of Evaluating the Performance of Positioners with Analog Input Signals and Pneumatic Output

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Preface

This preface, as well as all footnotes and annexes, is included for informational purposes and is not part of ISA-S75.13.

This standard has been prepared as part of the service of the ISA, the international society for measurement and control, toward a goal of uniformity in the field of instrumentation. To be of real value, this document should not be static but should be subject to periodic review. Toward this end, the Society welcomes all comments and criticisms and asks that they be addressed to the Secretary, Standards and Practices Board; ISA; 67 Alexander Drive; P.O. Box 12277; Research Triangle Park, NC 27709; Telephone: (919) 549-8411; Fax: (919) 549-8288; E-mail: standards@isa.org.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrumentation standards, recommended practices, and technical reports. The Department is further aware of the benefits to USA users of ISA standards of incorporating suitable references to the SI (and the metric system) in their business and professional dealings with other countries. Toward this end, this Department will endeavor to introduce SI and acceptable metric units in all new and revised standards to the greatest extent possible. *The Metric Practice Guide*, which has been published by the Institute of Electrical and Electronics Engineers as ANSI/IEEE Std. 268-1992, and future revisions will be the reference guide for definitions, symbols, abbreviations, and conversion factors.

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This standard was originated by the Scientific Apparatus Makers Association (SAMA), within their Process Measurement and Control (PMC) Section. It was designated PMC TC 31b.1b dated 1977. SAMA turned the UNAPPROVED draft over to the ISA for refinement and processing, to lead to an American National Standard.

The ISA Standards and Practices Board approved the formation of a new Subcommittee, SP75.13, to work on this and other standards dealing with valve positioner performance. A committee was formed from former members of the SAMA Committee and members of the ISA Standards Committee on control valves.

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1 Scope

This standard specifies tests designed to determine the performance of positioners with analog input signals and pneumatic output. The method of evaluation described in this standard specifies the use of an actuator of the user's or manufacturer's choice. The positioner may be single-acting or double-acting.

2 Purpose

The methods of evaluation given in this standard are intended for use by manufacturers of valve positioners to determine the performance of their products and by users or independent testing establishments to verify performance.

Test conditions in this standard, such as the range of ambient temperatures, power supply, etc., relate to conditions that commonly arise in use. Consequently, the values specified shall be used where no other values are specified by the manufacturer or user. If other values are used, they must be stated. It is recognized that the manufacturer's specifications and instructions for installation and operation must be considered during all tests.

Tests specified in this standard are not necessarily sufficient for instruments specifically designed for unusually arduous conditions. Conversely, a reduced series of tests may serve adequately for instruments designed to perform within a more limited range of conditions.

The evaluating body should maintain the closest communication with the user and the 1manufacturer. Note shall be taken of the manufacturer's specifications for the instrument when the test program is being decided, and manufacturers should be invited to comment both on the test program and upon the results pertaining to their instrument.

3 Definitions

This standard introduces no new terms requiring definition. Terms used are defined in the following ANSI/ISA Standards:

ANSI/ISA-S26-1975, *Dynamic Response Testing of Process Control Instrumentation*

ANSI/ISA-S51.1-1995, *Process Instrumentation Terminology*

ANSI/ISA-S75.05-1983, *Control Valve Terminology*

4 Testing procedures

4.1 Introduction

4.1.1 When relating performance characteristics (such as values of accuracy) to values of other terms (such as conformity, hysteresis, dead band, and repeatability), equivalent units must be used.

4.1.2 The accuracy rating of the reference measuring means that relates to the characteristics being tested shall preferably be no greater than one-tenth of the tolerance allowed on the test specimen, but in no case greater than one-third of the allowed tolerance.

EXAMPLE: Dead band

Test specimen:	allowed dead band of 0.2 percent of range
Measuring means:	preferred dead band of 0.02 percent of range
Measuring means:	allowed dead band of 0.06 percent of range

When the accuracy rating of the reference measuring means is one-tenth or less than that of the device under test, the accuracy rating of the reference measuring means may be ignored. When the accuracy rating of the reference measuring means is one-third or less, but greater than one-tenth of that of the device under test, the accuracy rating of the reference measuring means shall be stated in the test report.

4.1.3 The positioner under test and the associated test equipment shall be allowed to stabilize under steady-state operating conditions. All testing shall be performed under these conditions. Those operating conditions that influence the test shall be observed and recorded. When the performance characteristic being determined requires reference operating conditions, the conditions of the test shall be maintained at reference operating conditions.

4.1.4 The number of test points to determine the desired performance characteristic of a device should be distributed over the range. They should include points at or near (within 10 percent) the lower- and upper-range values. There should not be fewer than five points, and preferably more. The number and location of these test points should be consistent with the degree of precision desired and the characteristics being evaluated.

4.1.5 Prior to recording these observations, the device under test shall be exercised by at least three full-range traverses in each direction.

4.1.6 At each point being observed, the input shall be held steady until the device under test becomes stabilized at its apparent final value.

4.1.7 Tapping or vibrating the device under test is not allowed unless the performance characteristic under study requires such action.

4.2 Test unit

4.2.1 For testing, the positioner should be fitted to any commercially available actuator for which it is intended. Test results should include a description of the actuator used, and the description shall include the following:

a) Supply pressure

b) Actuator pressure range

c) Travel

d) Nominal effective area

e) Type (single- or double-acting)

f) Volume at 0 percent and 100 percent travel (on both sides of double-acting actuator)

g) Friction force (see 4.2.2)

4.2.2 The positioner/actuator assembly shall be mounted on a valve or test rig that is designed to permit the implementation of tests with minimum friction (unless otherwise specified). Friction force may be measured by determining the force required to initiate travel when the actuator pressure is constant. This value shall be recorded.

4.2.3 The positioner shall be calibrated in accordance with the manufacturer's instructions to permit a specified input signal range to produce 100 percent travel.

4.2.4 Any mechanical stops should be adjusted so that they do not interfere with the measurements.

4.2.5 Where the gain of the positioner can be altered, it should be set at the manufacturer's recommended setting or the maximum value that permits stable positioning action of the positioner/ actuator assembly. This value shall be recorded.

4.2.6 All tests shall be conducted with the device in its normal mounting position, unless otherwise specified.

4.2.7 All tests shall be conducted with the supply pressure adjusted at the value recommended by the manufacturer, unless otherwise specified.

4.2.8 Positioners fitted with cams shall be tested with input/travel characteristics that are linear. Tests on positioners with other than linear input/travel characteristics may be performed as required.

4.2.9 All tests shall be conducted with positioner covers in place.

4.3 Environmental test conditions

4.3.1 Recommended range of ambient conditions for test measurements*

The recommended ranges of ambient conditions for test measurements are as follows:

Temperature:	15°C to 35°C (59°F to 95°F)
Relative humidity:	48% to 75%
Atmospheric pressure:	86 kPa to 106 kPa (12.47 psi to 15.37 psi)
Electromagnetic field:	Value to be stated, if relevant

*If ambient conditions are not within these ranges, actual values must be stated.

The maximum rate of temperature change during any test shall be 1°C (1.8°F) in 10 minutes (min).

4.3.2 Standard reference atmosphere

The standard reference atmosphere is as follows:

Temperature:	20°C (68°F)
Relative humidity:	65 %
Atmospheric pressure:	101.3 kPa (14.7 psi)

This standard reference atmosphere is that atmosphere to which values measured under any other atmospheric conditions are corrected by calculation. It is recognized that in many cases a correction factor for humidity is not possible. In such cases, the standard reference atmosphere applies to temperature and pressure corrections only. This standard reference atmosphere is equivalent to the normal reference operating conditions usually identified by the manufacturer.

4.3.3 Environmental envelope for reference measurements

When correction factors to adjust parameters sensitive to the atmospheric condition to their standard reference atmosphere values are unknown, and measurements under the recommended range of ambient atmospheric conditions are unsatisfactory, repeated measurements under closely controlled atmospheric conditions may be conducted.

For the purpose of this standard, the following atmospheric conditions are given for reference measurements:

	Nominal Value	Tolerance
Temperature:	20°C (68°F)	± 2°C (± 3.6°F)
Relative humidity:	65 %	± 5 %
Atmospheric pressure:	86 kPa (12.47 psi) to 106 kPa (15.37 psi)	

4.4 Supply conditions

4.4.1 Reference values

Reference values are the values specified by the manufacturer.

4.4.2 Tolerances

Electrical supply

Rated voltage:	± 1 %
Rated frequency:	± 1 %
Harmonic distortion:	less than 1 % (ac supply)
Ripple:	less than 0.1 % (dc supply)

Pneumatic supply

Rated pressure:	± 1 % (during static test conditions)
Supply temperature:	ambient temperature of ± 2°C (± 3.6°F)
Supply dewpoint:	dewpoint at least 10°C (50°F) below positioner body temperature
Oil- and dust-free:	per ISA-S7.3-1975 (R1981)

5 Static behavior

5.1 Measurement (calibration) cycle

Maintain test conditions and precondition the test unit as indicated in Section 4. Observe and record positioner feedback travel for each desired input value for one full-range traverse in each direction, starting near the mid-range value. The final input must be approached from the same direction as the initial input. Apply the input in such a way that neither input nor travel overshoot occurs.

5.2 Calibration curve

For the purpose of the following test procedures, the calibration curve will be prepared as a "deviation plot." Determine the difference between each observed measured travel and its corresponding ideal travel. This difference is the deviation and may be expressed as a percentage of ideal travel span. The deviation is plotted versus input or ideal travel. Figure 1 illustrates the plot of the percentage of deviation versus the percentage of input. A positive deviation denotes that the observed travel is greater than the ideal travel.

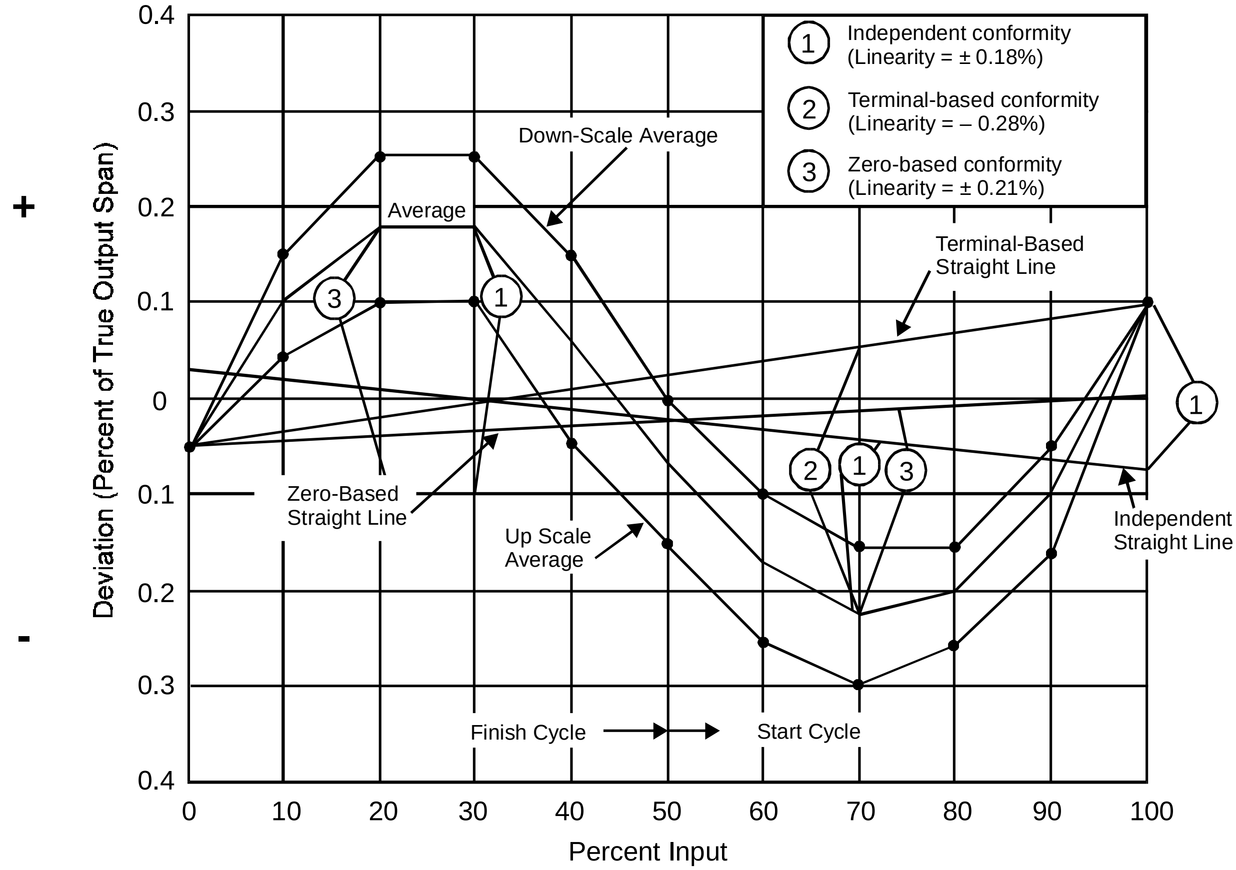


Figure 1 — Calibration curve (of data from Table 1)

Table 1 — Calibration report

Input	Error										Average Error
	Up Actual	Down Actual	Up Actual	Down Actual	Up Actual	Down Actual	Up Actual	Up Average	Down Average	Up Average	
Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
0		–0.04		–0.05		–0.06			–0.05		–0.05
10		+0.14	+0.04	+0.15	+0.05	+0.16	+0.06		+0.15	+0.05	+0.10
20		+0.23	+0.08	+0.26	+0.09	+0.26	+0.13		+0.25	+0.10	+0.175
30		+0.24	+0.09	+0.25	+0.10	+0.26	+0.11		+0.25	+0.10	+0.175
40		+0.13	–0.07	–0.15	–0.04	+0.17	–0.04		+0.15	–0.05	–0.05
50	–0.18	–0.02	–0.16	+0.01	–0.13	+0.01	–0.13	–0.15	0	–0.15	–0.075
60	–0.27	–0.12	–0.25	–0.10	–0.23	–0.08		–0.25	–0.10		–0.175
70	–0.32	–0.17	–0.30	–0.16	–0.28	–0.12		–0.30	–0.15		–0.225
80	–0.27	–0.17	–0.26	–0.15	–0.22	–0.13		–0.25	–0.15		–0.20
90	–0.16	–0.06	–0.15	–0.05	–0.14	–0.04		–0.15	–0.05		–0.10
100	+0.09		+0.11		+0.10			+0.10			+0.10

Measured Accuracy = +0.26 percent
–0.32 percent
Hysteresis plus Dead Band = +0.22 percent
Repeatability = 0.05 percent

NOTE — Accuracy of reference measuring means was not considered in the determination of the average error.

5.2.1 Accuracy, measured

Measured accuracy may be determined from the deviation values (see Table 1) of a number of calibration cycles. It is the greatest positive and negative deviation of the recorded values (from both an up-scale and a down-scale travel traverse) from the reference or zero deviation line. Measured accuracy may be expressed as a range from a plus to a minus percentage of ideal span.

EXAMPLE: The measured accuracy is +0.26 percent to –0.32 percent of travel span.

5.2.2 Dead band

Maintain test conditions and precondition the test device as indicated in Section 4 and proceed as follows:

a) Slowly vary (increase or decrease) the input to the device being tested until a detectable travel change is observed.

b) Observe the input value and record.

c) Slowly vary the input in the opposite direction (decrease or increase) until a detectable travel change is observed.

d) Observe the input value and record.

e) The increment through which the input signal is varied [difference between steps (2) and (4)] is the dead band. It is determined from a number of cycles [steps (1) through (4)]. The maximum value is reported. The dead band should be determined at a number of points to make certain that the maximum dead band has been observed.

Dead band may be expressed as a percentage of input span.

EXAMPLE: The dead band is 0.10 percent of input span.

5.2.3 Drift, point

Maintain test conditions and precondition the positioner/actuator as indicated in Section 4 and proceed as follows:

a) Adjust the input to the mid-range value without overshoot and record the position.

b) Maintain the input mid-range value constant throughout the test period of 30 days. Observe and record the position at least twice each day for the 30-day period, preferably at approximately the same times each day.

c) In evaluating the results of this test, the duration of the test will permit a display of the measurement of drift for any reasonable dead band. Point drift is the maximum change in the recorded travel value observed during the test period. It is expressed as a percentage of ideal travel span for a specified time period.

EXAMPLE: The point drift is 0.1 percent of travel span for a 30-day test.

5.2.4 Hysteresis

Hysteresis results from the inelastic quality of an element or device. Its effect is combined with the effect of dead band. The sum of the two effects may be determined directly from the deviation values (see Table 1) of a number of test cycles and is the maximum difference between corresponding up-scale and down-scale travels for any single test cycle. Hysteresis then is determined by subtracting the value of dead band from the corresponding value of hysteresis plus dead band for a given input. The maximum difference is reported. The difference may be expressed as a percentage of ideal span.

EXAMPLE: The hysteresis is 0.12 percent of span.

5.2.5 Conformity

Independent terminal-based and zero-based conformity may be determined from the calibration curve (plot of deviation versus percent input — see Figure 1) using the following procedures.

5.2.5.1 Independent conformity

Independent conformity may be determined directly from the calibration curve, which describes conformity to a linear characteristic (see Figure 1), using the following procedure:

a) Plot a deviation curve that is the average of corresponding up-scale and down-scale travel readings.

b) Draw a straight line through the average deviation curve so that it minimizes the maximum deviation. It is not necessary that the straight line be horizontal or pass through the end points of the average deviation curve.

Independent conformity is the maximum deviation between the average deviation curve and the straight line. It is determined from the deviation plots of a number of calibration cycles. It is measured in terms of independent nonconformity as a plus or minus percentage of ideal travel span.

EXAMPLE: The independent conformity is ± 0.18 percent of travel span.

5.2.5.2 Terminal-based conformity

a) Plot a deviation curve that is the average of corresponding up-scale and down-scale travel readings.

b) Draw a straight line such that it coincides with the average deviation curve at the upper-range value and the lower-range value.

Terminal-based conformity is the maximum deviation between the average deviation curve and the straight line. It is determined from the deviation plots of a number of calibration cycles. It is measured in terms of terminal-based nonconformity as a plus or minus percentage of ideal travel span.

EXAMPLE: The terminal-based conformity is ± 0.28 percent of travel span.

5.2.5.3 Zero-based conformity

a) Plot a deviation curve that is the average of corresponding up-scale and down-scale travel readings.

b) Draw a straight line such that it coincides with the average deviation curve at the lower-range value (zero) and minimizes the maximum deviation. Zero-based conformity is the maximum deviation between the average deviation curve and the straight line. It is determined from the deviation plots of a number of calibration cycles. It is measured in terms of zero-based conformity as a plus or minus percentage of ideal travel.

EXAMPLE: The zero-based conformity is ± 0.21 percent of travel span.

> **NOTE —** The average deviation curve is based on the average of corresponding up-scale and down-scale readings. This permits observation of independent, terminal-based and zero-based conformity, independent of dead band or hysteresis. This concept assumes that if no hysteresis or dead band were present, the deviation curve would be a single line midway between up-scale and down-scale curves.

5.2.6 Repeatability

Repeatability may be determined directly from the deviation value (see Table 1) of a number of calibration cycles. It is the closeness of agreement among successive measurements of the travel, for the same value of input, approached from the same direction. Fixed operating conditions must be maintained.

Observe the maximum difference in the percentage of deviation for each set of deviations at each value of travel, considering up-scale and down-scale curves separately. The maximum value from either the up-scale or the down-scale curve is reported. Repeatability is the maximum difference in the percentage of deviation observed above and is expressed as a percentage of travel span.

EXAMPLE: The repeatability is 0.05 percent of travel span.

5.3 Effect of influence quantities

5.3.1 Supply pressure influence

Maintain test conditions and precondition the positioner/actuator assembly as indicated in Section 4 and proceed as follows:

a) At reference supply pressure, observe and record the travel at 25 percent increments of input span by performing a calibration cycle as described in 5.1.

b) Increase the supply pressure to a value 10 percent greater than the initial gage pressure and repeat the calibration cycle. Repeat this procedure with the supply pressure adjusted to 10 percent lower than the initial gage pressure and again at the initial supply pressure. The deviation of the travel at any supply pressure from the travel at the same input determined at the initial supply pressure is the supply pressure error at that input and supply pressure. Figure 2 shows an example for displaying the data and results.

EXAMPLE: The maximum supply pressure influence is 2 1/2 percent of travel span for a 10 percent supply pressure variation at 340 kPa (49.3 psi) nominal supply pressure.

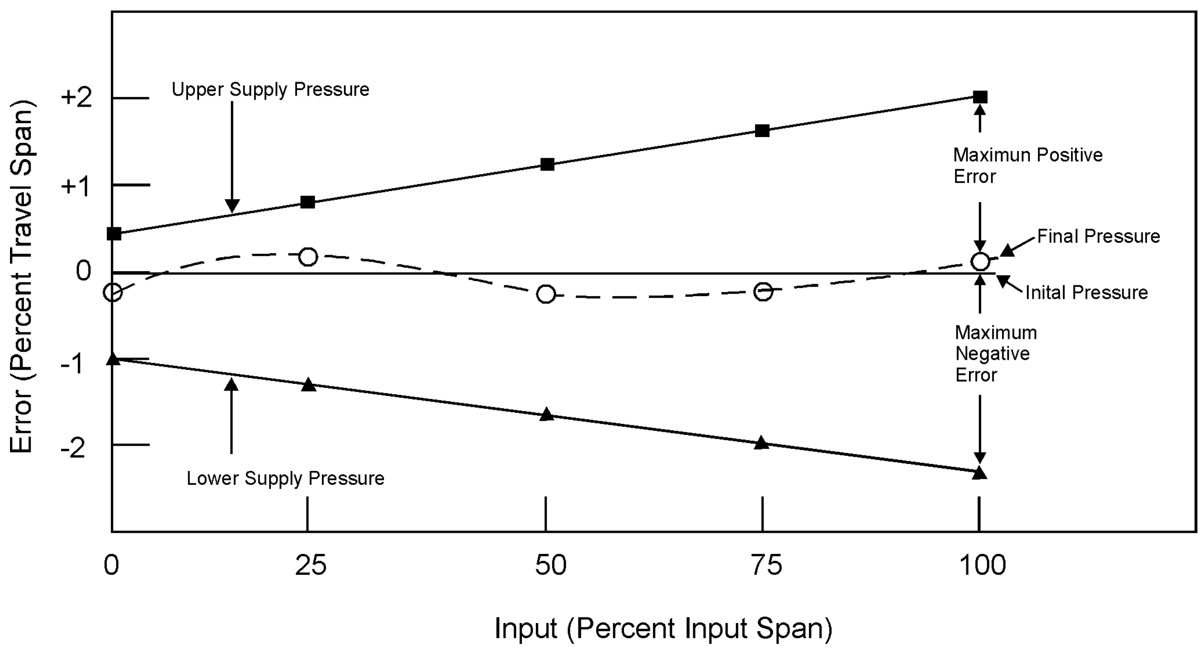


Figure 2 — Supply pressure influence

5.3.2 Ambient temperature influence

5.3.2.1 Maintain the test conditions and precondition the positioner/actuator assembly as indicated in Section 4, except place the entire actuator and positioner, including feedback linkage, inside a temperature-controlled test chamber. Extreme care should be taken to ensure that the travel measurement instrumentation is not influenced by the temperature. Sufficient tubing should be coiled inside the test chamber, or other means taken, to assure that supply air and pneumatic-input signal air are at the same temperature as the positioner/actuator.

5.3.2.2 Calibrate the positioner/actuator at room temperature. With the input signal maintained at mid-range, observe the travel. The temperature then shall be cycled to the maximum operating temperature specified by the manufacturer, then to the minimum operating temperature specified by the manufacturer, and then back to reference operating temperature (the same temperature at which the test was started) with the system allowed to achieve equilibrium at each temperature. Repeat this cycle until the difference between the output travel measurement before and after the cycle is small compared to the anticipated error. No further adjustments to the positioner/actuator shall be made.

5.3.2.3 At reference operating temperature, observe and record travel at 25 percent increments of input span by performing a calibration cycle as described in 5.1.

5.3.2.4 Increase the temperature to the maximum operating temperature value, allowing time for the system to reach equilibrium, and repeat the calibration cycle. Repeat this procedure at the minimum operating temperature and again at the reference operating temperature.

The deviation of the travel at any temperature from the travel at the same input determined at reference operating temperature is the temperature error at that input and temperature. Figure 3 shows an example for displaying the data and results.

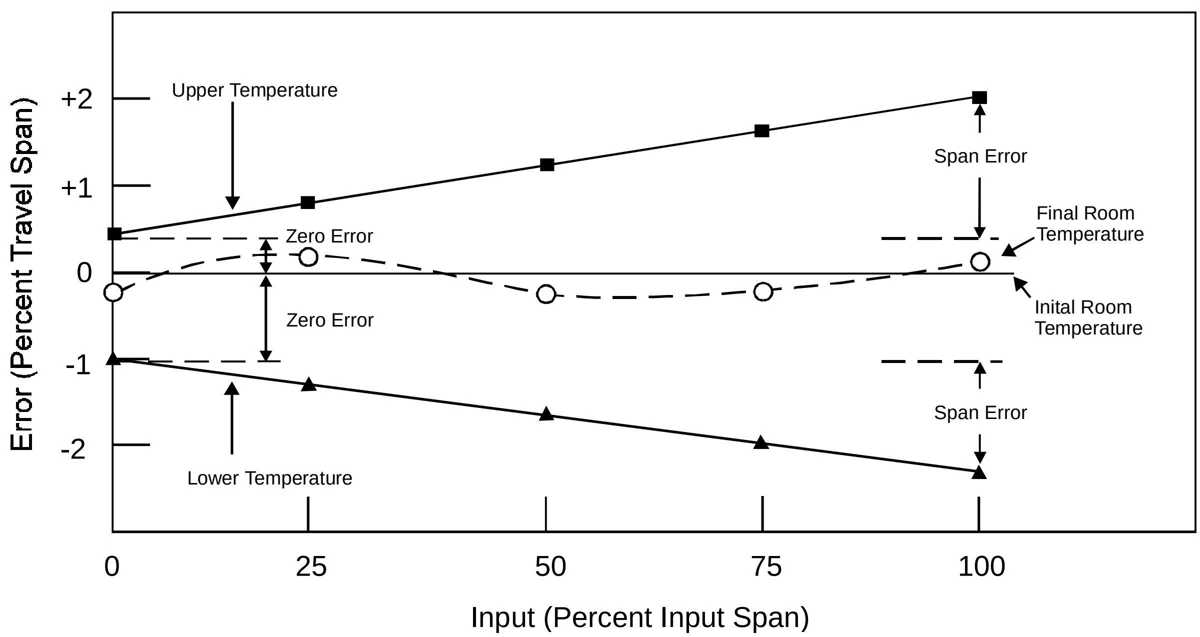


Figure 3 — Ambient temperature influence

NOTE — If data at other intermediate temperatures are desired, a procedure similar to that described above should be followed with data obtained by stopping at each desired temperature. It is important that the only time the temperature should be reversed is at the maximum or minimum temperature.

5.3.3 Mounting position effect

5.3.3.1 Mount the positioner/actuator assembly on a mechanism that will permit rotation in both planes (side-to-side and front-to-back).

5.3.3.2 Maintain and precondition the positioner as indicated in Section 4 and orient it in the normal mounting position. Observe and record the travel at 25 percent increments of input span by performing a calibration cycle as described in 5.1.

5.3.3.3 Rotate the positioner/actuator assembly front-to-back 90° from the initial calibration check taken in Step 5.3.3.2. Observe and record the travel at 25 percent increments of input span by performing a calibration cycle as described in 5.1. Repeat the procedure after rotating the assembly back-to-front 90°.

> **NOTE —** If data at other tilt positions are desired, a similar procedure as described, should be followed with data obtained by stopping at each desired tilt position.

5.3.3.4 Return the assembly to its normal mounting position and rotate to the left side 90°. Observe and record the travel at 25 percent increments of input span by performing a calibration cycle as described in 5.1. Repeat the procedure after rotating the assembly to the right side 90°.

5.3.3.5 Prepare a calibration curve as a deviation plot for each tilt position versus the data taken in Step 5.3.3.2. The difference may be expressed as percent of travel span for degrees rotation, with the maximum value reported.

EXAMPLE: The maximum mounting position effect is 1 percent of travel span for the 90° rotation.

5.3.4 Humidity (electropneumatic positioner only)

This test is performed to determine the ability of the positioner to maintain stated accuracy while exposed to the effects of high humidity. The test shall be performed with conduit connections open (not sealed) to the environmental conditions, unless prohibited by the manufacturer.

5.3.4.1 Maintain test conditions and precondition the positioner/actuator assembly as indicated in Section 4. Observe and record the travel at 25 percent increments of input span by performing a calibration cycle as described in 5.1.

5.3.4.2 The positioner/actuator shall then be subjected to a temperature of 40°C ± 2°C (104°F ± 3.6°F) at a relative humidity of not less than 95 percent at atmospheric pressure. This environment shall be maintained for at least 96 hours. During this time a 50 percent input signal shall be applied.

5.3.4.3 During the last 4 hours of the 96-hour exposure in Step 5.3.4.2, observe and record the travel at 25 percent increments of input span by performing a calibration cycle as described in 5.1, once each hour.

5.3.4.4 With a 50 percent input signal still applied, reduce the chamber temperature to fall below 25°C (77°F) at a rate of 1°C (1.8°F) per minute or greater. The humidity chamber shall remain closed, and saturation shall take place during this period. During the drop in temperature, the actuator travel position shall be monitored and recorded to identify transient effects due to moisture condensation. Following stabilization, observe and record the travel at 25 percent increments of input span by performing a calibration cycle as described in 5.1.

5.3.4.5 The positioner/actuator assembly shall be returned to standard test conditions as described in Section 4. After 24 hours, observe and record the travel at 25 percent increments of input span by performing a calibration cycle as described in 5.1.

5.3.4.6 A visual inspection shall be made after the positioner/actuator assembly is at standard test conditions to check for evidence of arcing, condensate, deterioration of components, etc.

5.3.4.7 Changes in accuracy shall be determined from those values measured initially under ambient conditions in Step 5.3.4.1 and expressed in percentage of travel span. Also to be reported are any evidences of damage due to humidity that are noted in the visual inspection. The report should include whether or not the conduit connection was open to the environment.

5.3.5 Vibration influence

This test will determine the effects of vibration on the operation and static performance of a positioner/actuator for the vibrating environment normally encountered during field service.

5.3.5.1 The positioner should be mounted on the actuator in the manner specified by the manufacturer. The actuator shall be mounted to the shaker table at the interface between the actuator and the final control element, with a suitable rigid mounting apparatus (to assure that the rectilinear sinusoidal vibration from the shaker table is transferred to the actuator with minimal loss) and with the center of gravity of the positioner/actuator located on the shaker table's centerline.

5.3.5.2 The positioner/actuator should be tested in each of three mutually perpendicular axes, two axes of which are in the plane of the positioner mounting surface, and the third of which is perpendicular to the mounting plane.

5.3.5.3 A reference accelerometer shall be mounted to the shaker table to measure accelerations in the axis of table motion. An accelerometer should also be mounted on the positioner housing in the axis of table motion to monitor the positioner acceleration levels. Pressure transducers should be installed to measure each of the positioner output pressures. A suitable pointer and scale combination to observe relative motion between the stem and actuator should be provided. Test measurements should be made with instrumentation capable of linear response from steady state to the maximum test frequency. Pressure transducers either should be insensitive to vibration throughout this frequency range or mounted with flexible tubing to a solid support.

5.3.5.4 Maintain the test conditions and precondition the positioner/actuator as described in Section 4. A calibration cycle as described in 5.1 should be performed prior to the vibration tests. The input signal should be maintained at 50 percent for all vibration tests, unless otherwise specified.

5.3.5.5 An initial resonant search should be conducted by running a continuous frequency sweep using the peak-to-peak amplitudes, acceleration levels, and frequency ranges specified by the manufacturer. In the absence of the manufacturer's specifications, the test conditions listed in Table 2 should be used. The sweep rate of this test shall not be greater than 0.15 decades per minute. During this test the positioner output pressure(s) should be continuously monitored, and visual and audible observations should be made to detect resonant frequencies of the positioner components. A strobe light is sometimes useful to assist in making visual observations of relative stem travel in some frequency ranges.

Table 2 — Vibration levels used in the absence of manufacturer's specifications

Frequency Range (Hz)	Peak-to-Peak Constant Displacement (mm) (in)	Constant Peak Acceleration (m/s^2) (ft/s^2)
5 - 15	4.0 (.157)	—
15 - 150	—	19.6 (64.3)
150 - 200	—	9.8 (32.2)

5.3.5.6 Evidence of a resonant frequency will be one or more of the following observations:

a) A change in the mean positioner output pressure(s) greater than 3 percent of the output pressure span

b) Visual structural resonance of positioner components

A mechanical resonance, for the purpose of this test, is defined as an amplification ratio of three or more.

c) A change in the mean stem position greater than 3 percent of the travel span

NOTE — A resonance of an actuator spring and stem system will normally be encountered during the resonant search tests. At frequencies at or above this resonance, relative motion between the actuator stem and the actuator may be observed. This resonance and the resulting relative motion of the positioner feedback are independent of the positioner and should not be interpreted as positioner resonances. Figure 4 shows the plot for a typical linear actuator, giving the ratio of stem motion to actuator motion.

d) Audible structural resonance (buzzing or rattling). In order to observe resonances within the positioner, the cover may be removed. If this seriously weakens the structure of the positioner, a suitable transparent cover should be provided.

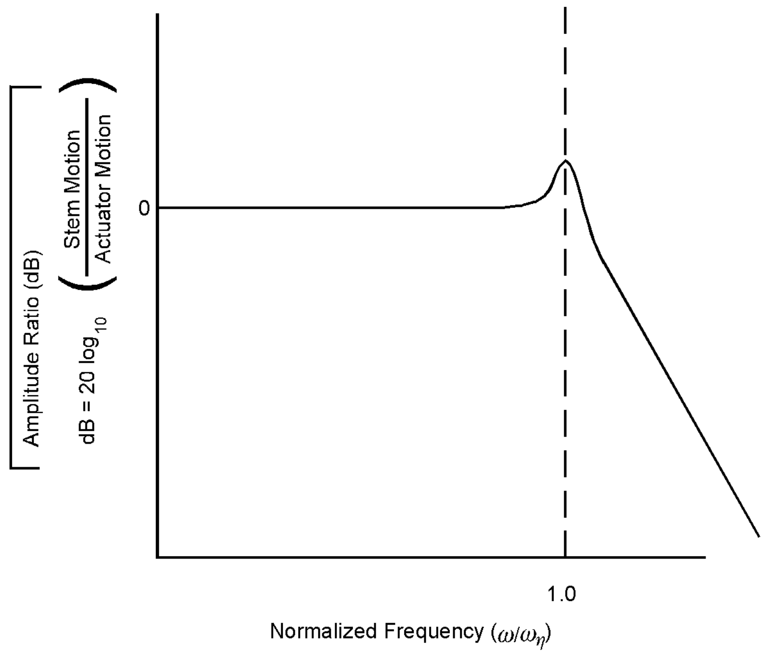


Figure 4 — Relative stem motion for typical linear actuator

5.3.5.7 An endurance test shall be run for 1/2 hour at each of the major resonances detected. Tests should be run only in the applicable plane(s) of the resonance. The table vibration level should be maintained at the same level used in the sweep test.

5.3.5.8 A static calibration cycle should be performed and recorded (1) before the sweep test, (2) after the sweep test, and (3) after each of the 1/2-hour dwell tests.

5.3.5.9 Data should be presented to describe changes in output during any of the vibration tests and to describe static performance changes prior to and following any vibration test. Malfunctions should also be documented.

Malfunctions are normally defined as

a) loss of output;

b) erratic output > ± 5 percent of output span;

c) major calibration shifts > ± 5 percent of output span; or

d) structural failure, broken, or loosened parts.

5.3.6 Electromagnetic susceptibility

Positioners with torque motors and voice coils are not affected by radio frequency interference (RFI), and the following tests are not required.

5.3.6.1 The purpose of this test is to evaluate the performance of electropneumatic positioners when subjected to electromagnetic fields, such as those generated by portable radio transceivers or other devices that generate continuous, wave-radiated electromagnetic energy.

5.3.6.2 The procedure defined herein requires the generation of electromagnetic fields within which the test sample is placed, and its operation is observed. To generate fields that are useful for simulation of actual (field) conditions, significant antenna drive power and the resultant high-field strength levels may be required. To comply with the Federal Communication Commission's regulations and to prevent biological hazards to the testing personnel, it is recommended that these tests be performed in a shielded enclosure or room.

5.3.6.3 The use of a shielded enclosure, however, creates difficulties in establishing and maintaining the required field strengths due to reflections of the radiated energy from the walls of the enclosure. These reflections will cause reinforcement and cancellation nodes to be established within the room.

5.3.6.4 A specific ground plane is not required. When a means is required to support the test sample, it should be constructed of nonmetallic material. However, grounding of the housing or of the case of the instrument shall be consistent with the manufacturer's installation recommendations.

5.3.6.5 The following test equipment is recommended. The use of other means of establishing and controlling the field is not ruled out and is acceptable, providing the required conditions can be verified.

a) Shielded room — size adequate to maintain distances shown by Figure 5

b) Signal source — signal generator(s) capable of covering frequency range, with capability of amplitude modulation (if automatic sweep, sweep rate should be capable of achieving 1.5×10^{-3} decades per second, or slower)

c) Power amplifier — to amplify the signal and provide antenna drive if the signal source is incapable of doing so

d) Antennas — signal source

   1) Biconical — reference manufacturer's specifications

   2) Conical logarithmic spiral — reference manufacturer's specifications

e) Field strength monitor — antennas with EMI (electromagnetic interference) meter

f) Associated equipment to monitor output and to establish operating power and signals for test sample

5.3.6.6 The test procedure assumes the use of biconical and log spiral antennas. Other methods of establishing the fields are acceptable, providing the proper fields can be generated and verified. Tests shall be conducted with a field strength of 10 V/m over a frequency range of 20 MHz to 1000 MHz.

5.3.6.7 Basic radiation susceptibility test

The basic radiation susceptibility test is as follows:

a) Mount the positioner and the transmitting antenna in accordance with the distance restrictions of Figure 5 for the biconical and log spiral antennas. When using the biconical transmitting antenna, adjust it so that the electromagnetic field is polarized vertically.

b) Establish the field strength of 10 V/m from 20 MHz to 1000 MHz by replacing the positioner with the EMI receiver antenna.

c) Replace the receiving antenna with the positioner and sweep through the required frequency band. Maintain the input signal at the 50 percent value. Record the travel versus the radiation frequency. Automatic sweep rate will be at 1.5 x 10^{-3} decades or less per second. If annual sweep is utilized, data points should be taken at a rate of ten (10) frequencies per decade. For frequencies below 50 MHz, the test shall be conducted with amplitude modulation of 90 percent with a 1000 Hz sine wave. (See 5.3.6.8 for digital equipment.)

d) Step 3 shall be repeated to expose the positioner on all six sides.

e) If a polarized signal is used, change electromagnetic wave polarization to horizontal and repeat Steps 2, 3, and 4.

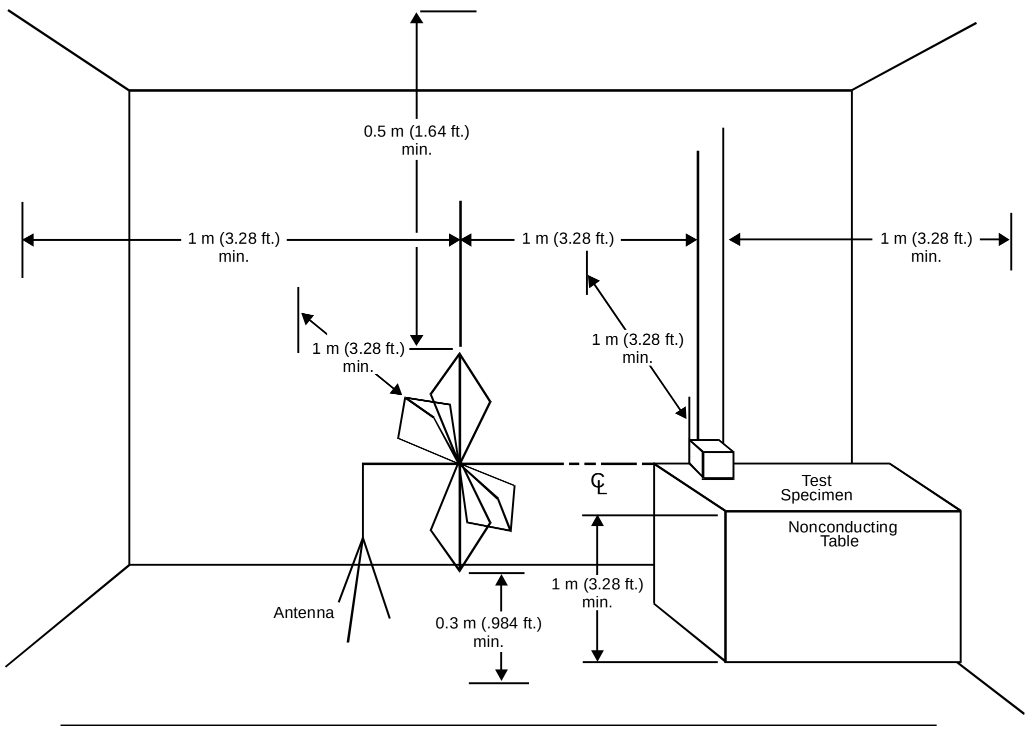


Figure 5 — Test arrangement for electromagnetic susceptibility

5.3.6.8 Digital equipment modulation test

All digital equipment using a clock shall also be subjected to electromagnetic radiation that is 90 percent amplitude (pulse or square wave) modulated at a frequency close to 10 kHz, but not phase-locked with the digital clock frequency. The 1000 Hz sine wave modulation listed in Step 3 of 5.3.6.7 may be omitted when the 10 kHz modulation test is performed.

5.3.6.9 Keying test

Some equipment is susceptible to repeated operation of a transmitter. This test is to evaluate the instrument in this mode. To simulate keying of a transceiver, the signal source shall be switched between 0 and 100 percent of the continuous-wave amplitude as defined by 5.3.6.7, Step 3. The switch signal shall have an "on" and "off" duration of at least one second each and shall have rise and fall times of no greater than 50 µs. There shall be at least ten keying cycles per frequency decade. If manual sweep is utilized, the test shall be run at ten frequencies per decade. Exposure shall be to the most susceptible side of the instrument, as identified by 5.3.6.7, Step 4.

5.3.6.10 Electromagnetic susceptibility shall be reported as the maximum shift in percentage of output span.

EXAMPLE: Electromagnetic susceptibility is 0.25 percent of output span at 10 V/m (10 V/3.28 ft) at frequencies of 20 to 1000 MHz.

5.3.7 Normal mode interference influence (electropneumatic positioners only)

This test determines the effect of a form of interference that appears between the input terminals of an electropneumatic positioner.

5.3.7.1 The test circuit of Figure 6 shall be connected to the input terminals of the electropneumatic positioner with the isolation switch open.

5.3.7.2 Maintain test conditions and precondition the positioner/actuator assembly as indicated in Section 4. Observe and record actuator travel for one full-range six-point traverse in both directions.

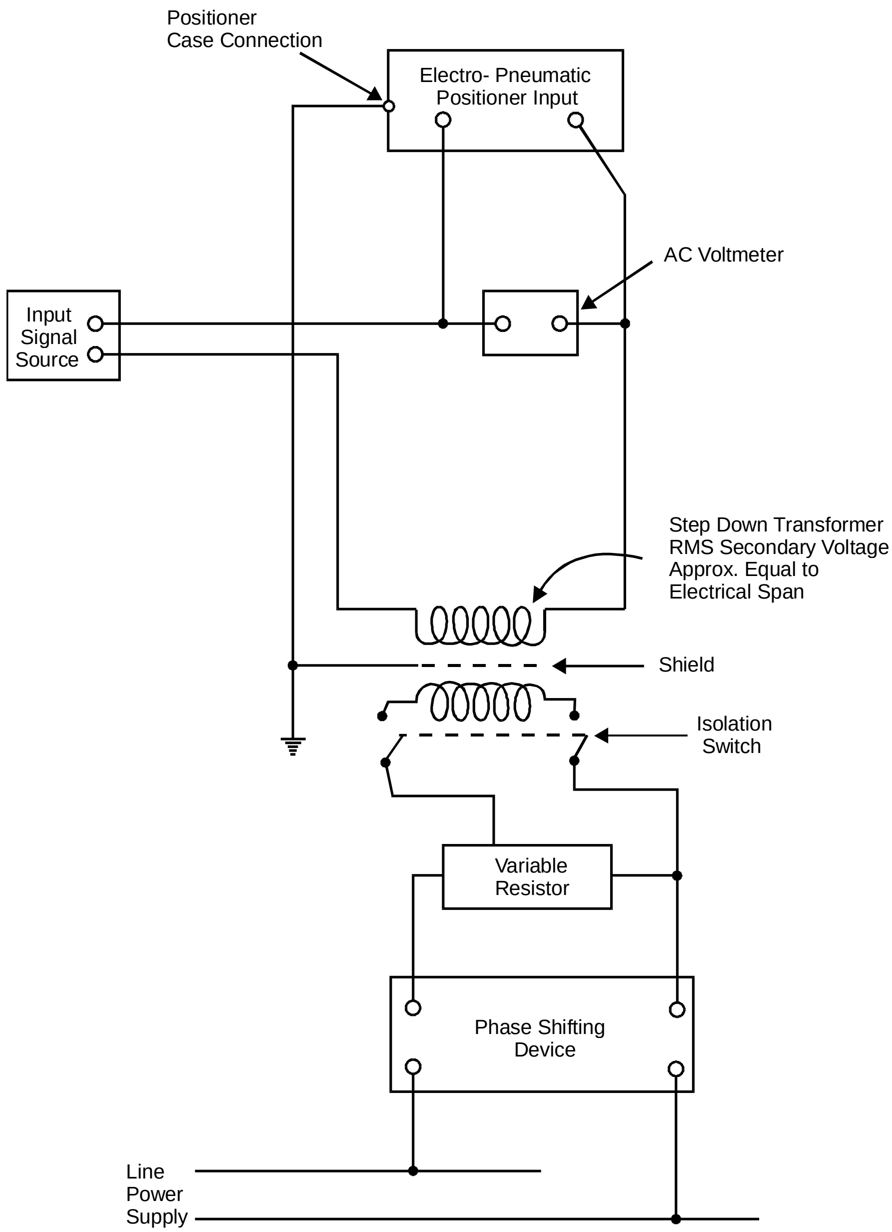


Figure 6 — Test circuit for normal mode interference influence

5.3.7.3 The input to the positioner shall be set at 50 percent span, and the isolation switch shall be closed. Normal mode interference shall be artificially introduced by applying a voltage of operating-power supply frequency between the input circuit terminals of the positioner. The rms magnitude of the normal mode interference shall be adjusted to the manufacturer's stated value for extreme operating conditions.

5.3.7.4 A slow sweep over the range of 0 to 360° phase angle shall be made. The sweep shall be at a rate not to exceed 4°/min. During the sweep, constant monitoring of actuator travel shall be made to detect changes in travel or oscillations. The principal phase angles where a major effect was identified shall be noted.

5.3.7.5 The phase angle shall then be set at the principal angle(s) that had the most significant effect on actuator travel. A full-range six-point traverse in both directions and a check of dead band shall be made while this phase angle is maintained (see 5.2.2).

5.3.7.6 Normal mode interference influence shall be reported as shift in percentage of travel span.

5.3.8 Common mode interference influence (electropneumatic positioners only)

This test determines the effect of a form of interference that appears between the input terminals of an electropneumatic positioner and ground.

5.3.8.1 The test circuit of Figure 7 shall be connected to the input terminals of the electropneumatic positioner with the isolation switch open.

5.3.8.2 Maintain test conditions and precondition the positioner/actuator assembly as indicated in Section 4. Observe and record actuator travel for one full-range, six-point traverse in both directions.

5.3.8.3 The input to the positioner shall be set at 50 percent span, and the isolation switch shall be closed. The selector switch shall be placed in Position 1, and the common mode interference shall be artificially introduced by applying a voltage of operating-power supply frequency between the positioner input terminal connected to the selector switch's Position 1 and the positioner case. The rms magnitude of the common mode interference shall be adjusted to the manufacturer's stated value for extreme operating conditions.

5.3.8.4 A sweep over the range of 0 to 360° phase angle shall be made at a rate not to exceed 4°/min. During the sweep, constant monitoring of actuator travel shall be made to detect changes in travel or oscillations. The principal phase angles where significant effects were identified shall be noted.

5.3.8.5 The phase angle shall then be set at the principal angle(s) that had the most significant effect on actuator travel. A full-range, six-point traverse in both directions and a check of dead band shall be made while this phase angle is maintained (see 5.2.2).

5.3.8.6 Repeat Steps 5.3.8.3 through 5.3.8.5 with the selector switch set in Position 2.

5.3.8.7 Common mode interference influence shall be reported as "shift in percent of travel span."

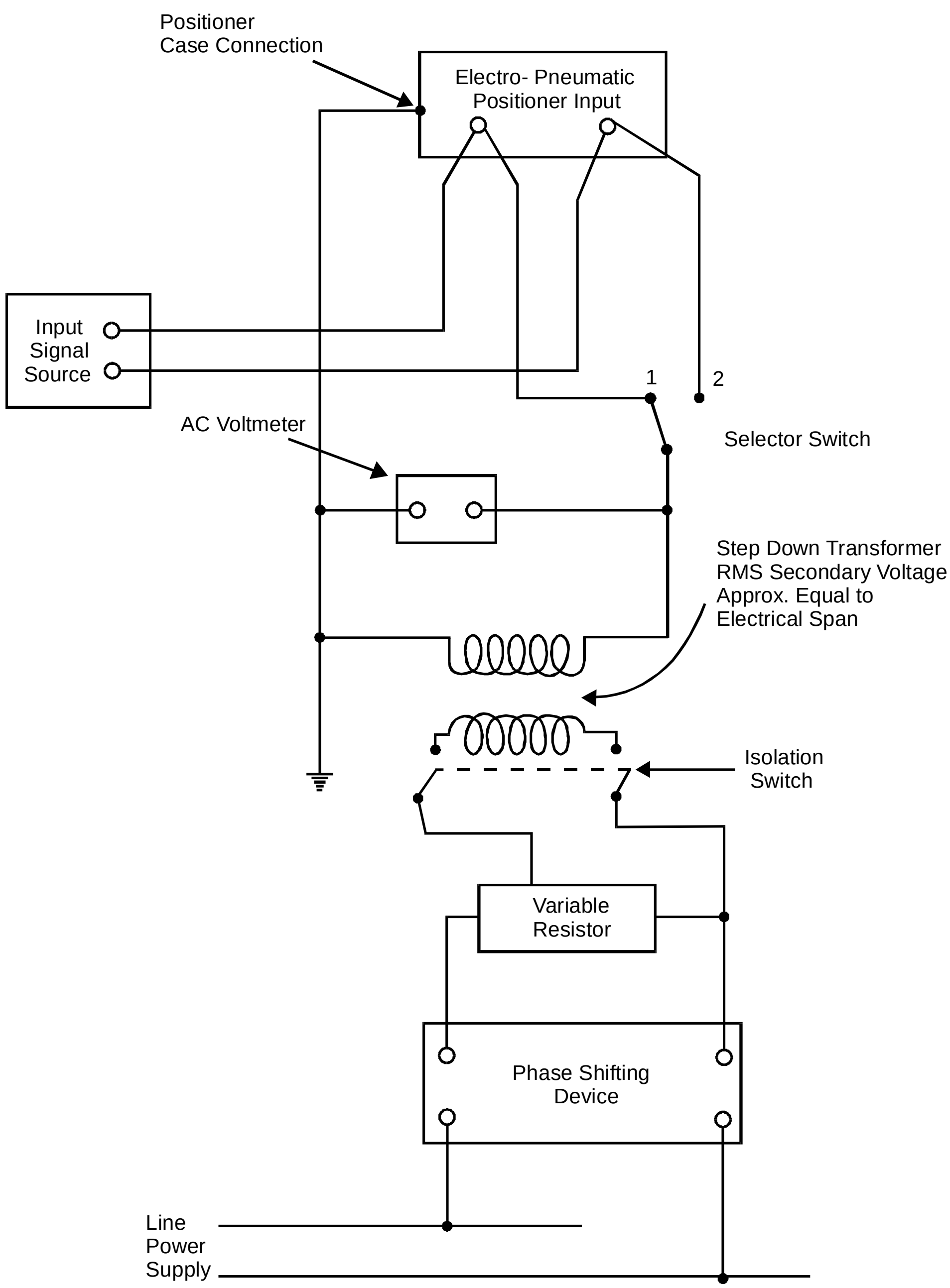


Figure 7 — Test circuit for common mode interference influence

5.3.9 Overrange

This test is performed to determine the ability of the positioner to maintain stated accuracy after exceeding maximum input span (up to the maximum designed overrange capability).

5.3.9.1 Maintain test conditions and precondition the positioner/actuator assembly as indicated in Section 4 and perform a calibration cycle as described in 5.1. Return the input signal to the mid-range value and proceed as follows.

5.3.9.2 Increase the input signal to the maximum overrange value specified by the manufacturer. After the overrange has been applied for one minute, return the input signal to the mid-range value and perform another calibration cycle as described in 5.1.

5.3.9.3 Repeat the steps in 5.3.9.2, except apply the minimum overrange value specified by the manufacturer. Overrange effect is expressed in percent change of full travel span per percent of maximum input span.

EXAMPLE: 0.5 to 100 percent overrange

5.3.9.4 For electropneumatic positioners only, reverse the leads and repeat the steps in 5.3.9.2.

5.3.10 Shocks

Maintain test conditions and precondition a positioner/actuator assembly as indicated in Section 4. Perform a calibration cycle as specified in 5.1.

5.3.10.1 Remove the positioner from the actuator for the "topple" shock test.

a) Stand the positioner in its normal orientation of use on a smooth, hard, rigid test surface (i.e., concrete, steel, etc.). Slowly tilt the positioner about one bottom edge until it falls. The adjacent plane and test surface will thus "hit" together.

b) Repeat (a) for each bottom edge; i.e., perform a total of four "topple" shock tests.

c) Positioners with an irregular bottom edge shall be subjected to four "topple" shock tests to "hit" four positioner planes approximately 90° apart.

5.3.10.2 Examine the positioner and report any damage incurred.

5.3.10.3 Re-install the positioner on the actuator, recalibrate, and perform a calibration cycle as specified in 5.1. Report any abnormalities that occurred as a result of this test.

5.4 Flow capacity — supply and exhaust

Maintain test conditions and precondition the positioner/actuator assembly as indicated in Section 4 and proceed as follows.

5.4.1 Connect a suitable test apparatus to measure positioner supply pressure, output pressure, and flow rate in both supply and exhaust directions. The test apparatus should include an external means to permit adjustment of the output pressure. The flow measurement piping to and from the positioner should be sized and arranged to have a pressure drop less than 2% of supply pressure at maximum flow rate. The piping size used in the test shall be reported. See Figure 8 for a typical schematic.

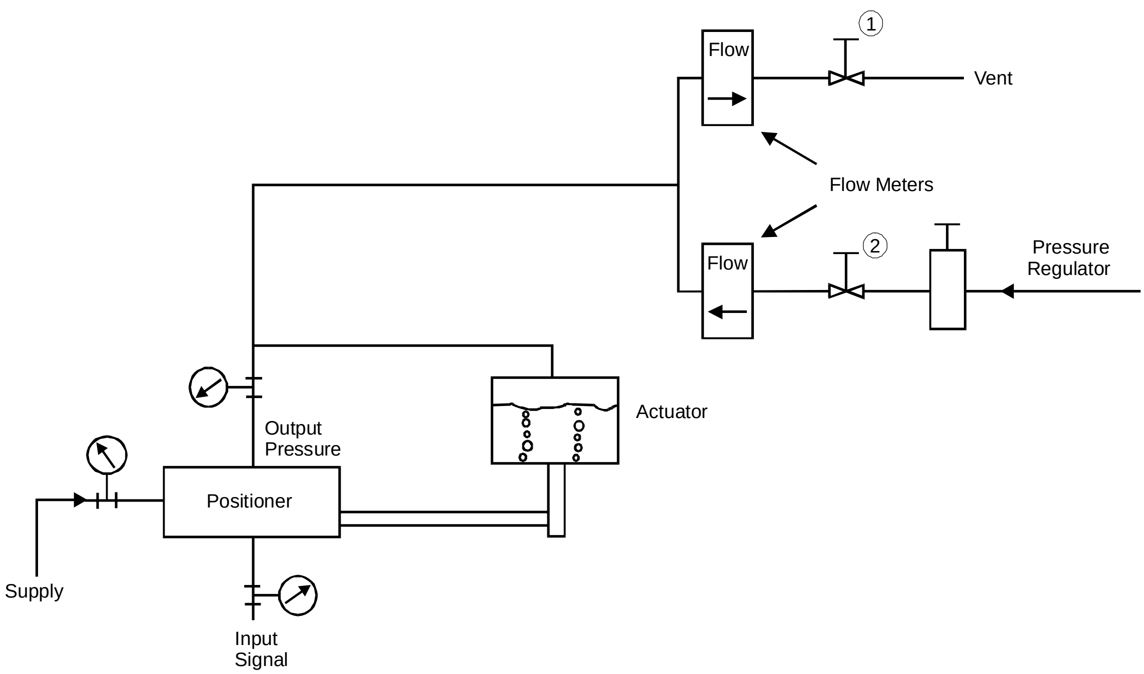
5.4.2 Set and maintain the supply pressure constant at the value recommended by the manufacturer. Additional tests may be performed at other supply pressures as required.

5.4.3 Adjust the input signal to 50 percent, or as required to achieve an output pressure of 50 percent of the nominal actuator range. This will be termed a "balanced condition." With the positioner in this balanced condition, lock the actuator stem and record the output pressure.

NOTE — For single-acting, spring-return actuators, the actuator stem can be locked by blocking the positioner output line leading to the actuator and by manually positioning the actuator to mid-travel with a separate regulator.

5.4.4 Starting at the 50 percent input signal level, slowly adjust the input to the desired value. Using the output pressure adjustment, return output pressure to the value noted in Step 5.4.3. Record the flow at each input value. Data will be taken at input values 0, 25, 40, 45, 47, 49, 51, 53, 55, 60, 75, and 100 percent. If any discontinuities are discovered, additional data points shall be included to permit a true graphical representation of the discontinuity.

NOTE — If the positioner is double-acting, the same test shall be performed and recorded for each output connection independently.



1 Hand valve to adjust and maintain output pressure when positioner output is in a supplying condition.

2 Pressure regulating and hand valve to adjust and maintain output pressure when positioner is in exhausting condition.

Figure 8 — Typical schematic for flow capacity tests

Data will be presented by a flow-capacity-characteristic curve plotted as the percentage of input signal change (ΔW) from the balanced condition versus flow rate, expressed in standard cubic meters per second (see Figure 9). The maximum supply and exhaust flow rate may also be reported from Figure 9 for a 50 percent input signal change (expressed as standard cubic meters per second for a 50 percent input signal change).

EXAMPLE: Maximum supply or exhaust flow is 47 x 10^{-4} standard m^3/s (0.166 ft^3/sec) for a 50 percent input signal change at 340 kPa (49.3 psi) supply pressure.

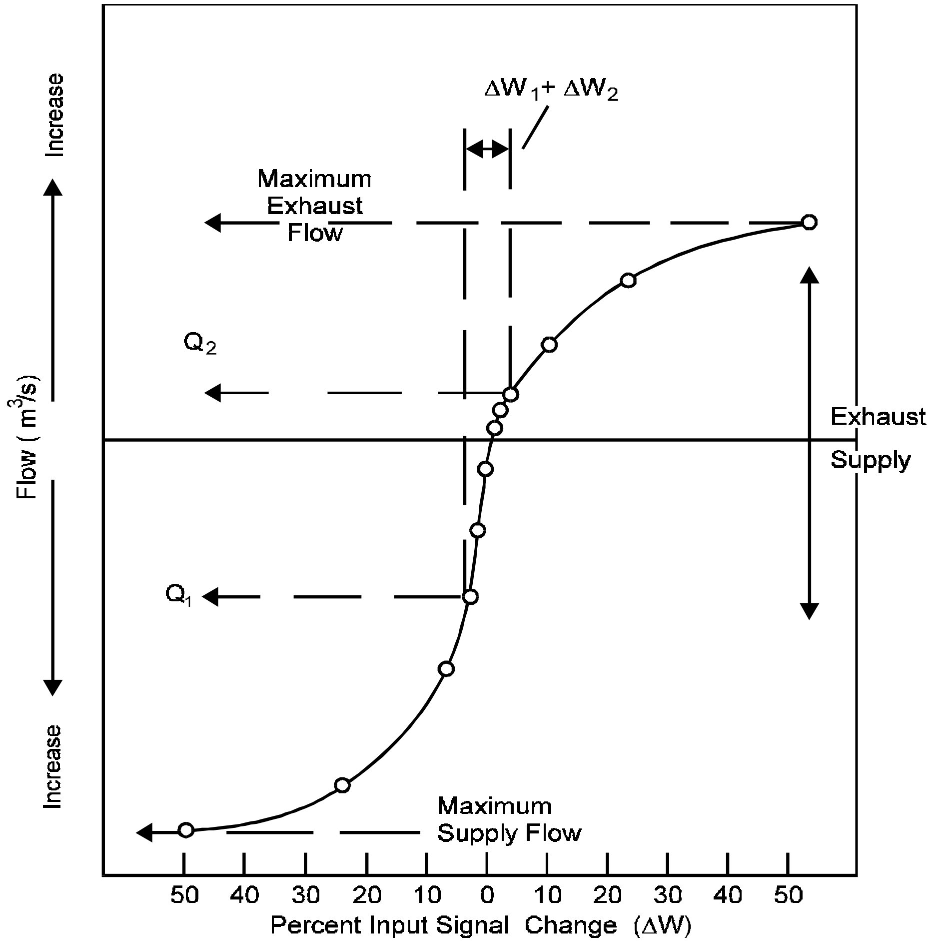


Figure 9 — Flow characteristic curve

5.5 Flow gain (K_Q)

Flow gain may be calculated from the data taken to develop the flow capacity curve (see Figure 9) as follows.

5.5.1 For single-acting positioners,

$$K_Q = \frac{Q_1 + Q_2}{\Delta W_1 + \Delta W_2}$$

where

Q_1 = Absolute value of flow rate in supply direction for a 5 percent ΔW.

Q_2 = Absolute value of flow rate in exhaust direction for a 5 percent ΔW.

ΔW_1 = Percent input signal change to obtain Q_1.

ΔW_2 = Percent input signal change to obtain Q_2.

5.5.2 For double-acting positioners,

$$K_Q = \frac{(Q_{T1} + Q_{T2}) + (Q_{B1} + Q_{B2})}{(\Delta W_{T1} + \Delta W_{T2}) + (\Delta W_{B1} + \Delta W_{B2})}$$

where subscripts *T* and *B* designate each of the two positioner outputs, respectively.

EXAMPLE: Flow gain is 47 x 10^{-4} standard m^3/s (0.166 ft^3/sec) for a 10 percent input signal change at 340 kPa (49.3 psi) supply pressure.

> **NOTE —** It is possible that a positioner will reach its maximum flow capacity at less than 5 percent input signal change. In this case, flow gain shall be calculated on the basis of the input signal change required to produce 90 percent of the maximum flow rate in either direction.

5.6 Steady-state consumption

5.6.1 Use a test apparatus similar to Figure 8, except install the flow-measuring device in the supply line to the positioner and close the output pressure adjustment valves. Supply pressure shall be set at the value recommended by the manufacturer.

5.6.2 Record the flow rate with the positioner in the balanced condition at 25, 50, 75, and 100 percent input signals. Consumption is expressed as standard cubic meters (cubic feet) per second for each input at the designated supply pressure. If one value is to be reported, it will be the maximum value.

EXAMPLE:

a) Steady-state consumption is 0.57 x 10^{-4} m^3/s (0.20 ft^3/s) with a 100 kPa (14.5 psi) supply and 50 percent input signal; or

b) Maximum steady-state consumption is 0.57 x 10^{-4} m^3/s (0.20 ft^3/s).

5.7 Locked-stem pressure gain (K_p)

Locked-stem pressure gain for a single-acting positioner is the ratio of the percentage of change in the positioner output pressure to the percentage of change in its corresponding input signal, with the travel kept constant. Locked-stem pressure gain for a double-acting positioner is the ratio of the percentage of change in the positioner differential output pressure to the percentage of change in its corresponding input signal, with the travel kept constant.

5.7.1 Single-acting positioner

Maintain test conditions and precondition the positioner/actuator assembly as described in Section 4 and proceed as follows.

5.7.1.1 Adjust the positioner input signal and record the positioner output pressure range required to produce rated actuator travel without external load on the actuator.

5.7.1.2 Adjust the positioner input signal to mid-range and lock the actuator stem. Then adjust the input signal to maintain the output pressure at 10 percent of supply pressure and record the input signal.

> **NOTE —** For single-acting, spring-return actuators, the actuator stem can be locked by blocking the positioner output line leading to the actuator and manually positioning the actuator to mid-travel with a separate regulator.

5.7.1.3 Slowly vary the input signal in sufficiently small increments without reversing direction to define the steady-state relationship between input signal and output pressure for output pressures from 10 percent to 90 percent of supply pressure. Figure 10 shows an example for displaying the data.

Locked-stem pressure gain can be determined by evaluating the percentage of input signal change for a particular percentage of output pressure change centered about the mid-range input signal. The dimensionless ratio of the percentage of output pressure change to the percentage of input signal change for a stated change in output pressure is the locked-stem pressure gain (K_p). Locked-stem pressure gain is commonly reported as the value determined for a 10 percent change in output pressure.

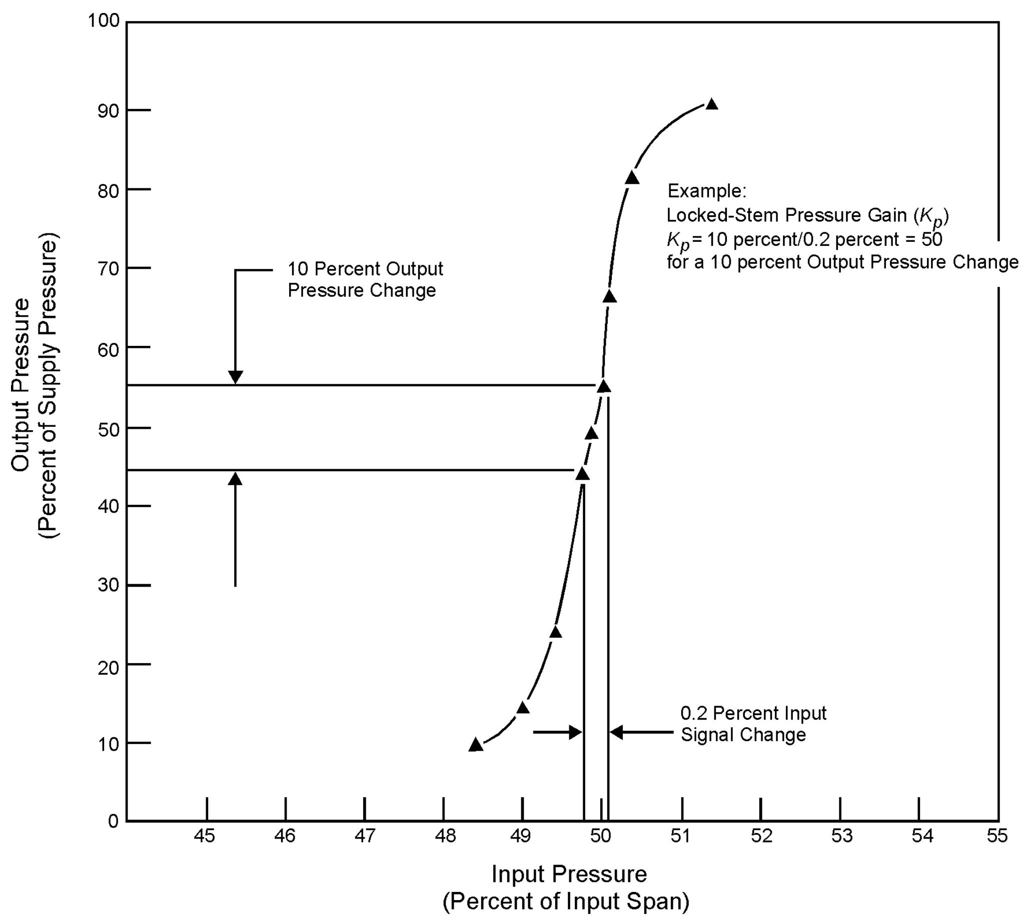


Figure 10 — Locked-stem pressure gain (single-acting)

5.7.2 Double-acting positioner

Maintain test conditions; calibrate and precondition the positioner/actuator assembly as described in Section 4 and proceed as follows.

5.7.2.1 Adjust the positioner input signal to mid-range and lock the actuator stem; then decrease the input signal until the positioner output pressure differential is a value equal to 90 percent of the supply pressure and record the input signal.

> **NOTE —** For double-acting actuators, the actuator stem can be locked by blocking the positioner output lines leading to the actuator and manually positioning the actuator at mid-travel.

5.7.2.2 Slowly increase the input in small increments, without reversing direction, to define the steady-state relationship between the input signal and the output pressure. Continue until the output pressure differential is a value equal to 90 percent of the supply pressure, but reversed from the previous pressures. Figure 11 shows an example for displaying the data.

The locked-stem pressure gain can be determined by evaluating the percentage of input signal change for a particular percentage of output differential pressure change centered about the balance output signal. The dimensionless ratio of a stated output differential pressure change to the input signal change is the locked-stem pressure gain (K_p). Locked-stem pressure gain is commonly reported as the value determined for a 20 percent change in output differential pressure.

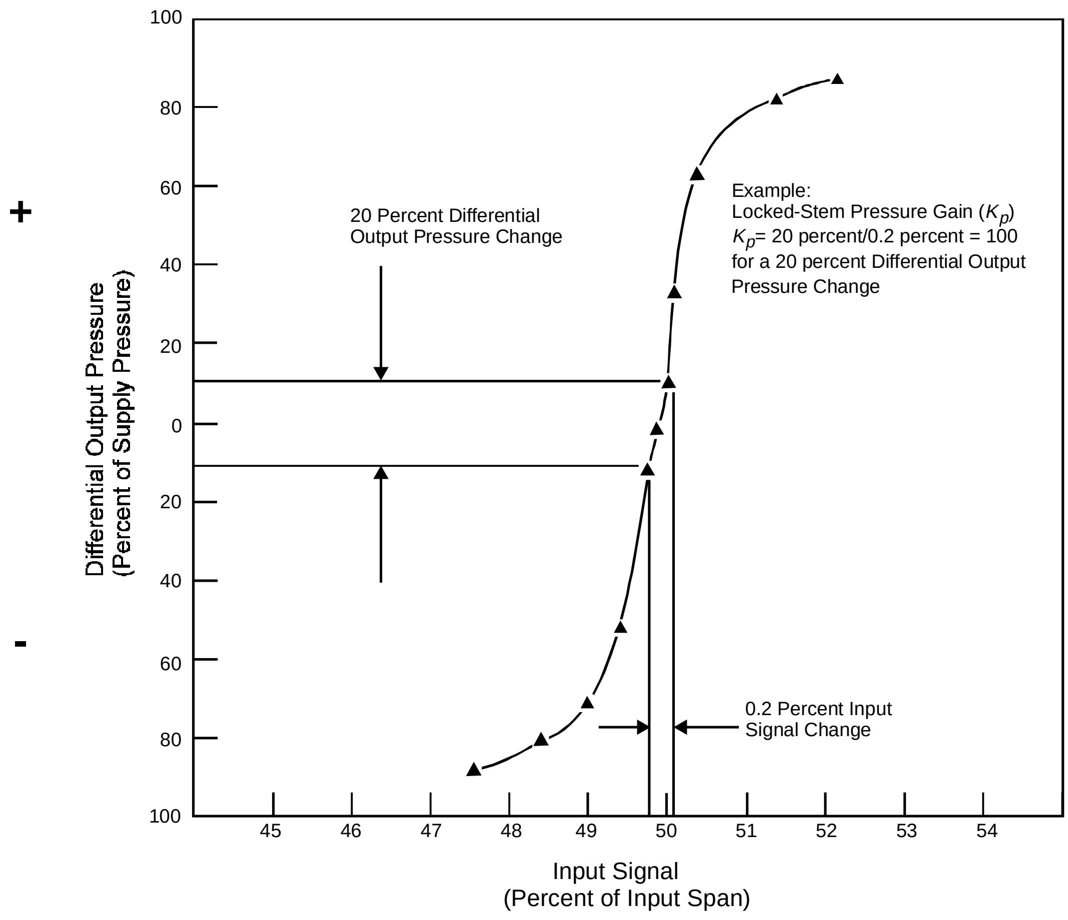


Figure 11 — Locked-stem pressure gain (double-acting)

5.8 Accelerated life-cycle test

The life-cycle test shall be performed on the positioner/actuator assembly with preconditioning and maintenance of test conditions as indicated in Section 4 to obtain the required performance data described below.

5.8.1 Hysteresis, dead band, zero, and range span (for input signal and travel) shall be measured and recorded prior to applying the 500,000 cycles.

5.8.2 Apply a cyclic input signal to the positioner with a peak-to-peak amplitude equal to 100 percent of range span, centered at mid-range. The frequency of oscillation shall be such that travel is not attenuated below 80 percent of zero frequency travel. Unless otherwise stated, the unit shall be subjected to 500,000 cycles.

5.8.3 After completion of the 500,000 cycles, measure hysteresis, dead band, zero, and range span as in Step 5.8.1 and record any deviations from the original measurement. Also, any component failures, signs of excessive wear, or loosening of critical components should be recorded.

6 Dynamic response

6.1 Introduction

Dynamic response of a device is defined as the comparison of the time-dependent output signal change resulting from a defined time-dependent input signal. Commonly used input signals include impulse, pulse, step, ramp, and sinusoidal. Dynamic analysis of the design requires data in addition to that obtained from the static tests. This additional information needed is defined in this section of the standard.

6.1.1 All data shall be taken and presented as outlined in the appropriate sections of this standard, so that judgments can be made whether the device meets the requirements for a specific application. This standard does not preclude additional requirements or relaxed requirements set by mutual agreement.

6.1.2 Dynamic response is heavily dependent on such nonlinearities as friction, hysteresis, velocity limiting, and saturation. Nonlinearities can have a profound effect on the dynamic response of a positioner/actuator, particularly in causing significant variations in measured performance with changes in output load or input signal value. They not only cause distortion of the output signal, but also result in additional phase shift and attenuation. It is therefore necessary to adhere to the test requirements as closely as possible, with any variation noted. Nonspecific descriptions such as "flat response" or "good response" shall not be used in interpreting the data. The dynamic response tests fall into two categories: frequency response testing and step response testing; both are described below.

6.1.2.1 Frequency response testing

A frequency response test measures the output signal amplitude and phase angle as a function of a sinusoidal input signal as the input signal frequency is changed. Strictly speaking, a frequency response analysis is restricted to linear systems. However, since much valuable information can be obtained on the behavior of a real system from its frequency response, the test is useful.

With nonlinear elements the results are amplitude-dependent, so signal magnitudes become important and must be noted.

6.1.2.2 Step response testing

Step response testing makes use of a step input test signal to the device, and observes output as a function of time. Step response data provide a qualitative evaluation of nonlinearities in the positioner/actuator.

6.2 Test system

Dynamic response testing requires a signal generator with a test signal compatible with the positioner input and instruments to measure both the input signal and the travel of the positioner/actuator. Figure 12 is a schematic of a simple test system. For a positioner with a pneumatic input, the input signal shall be measured as close as possible to the device input port to avoid input signal distortion caused by the piping.

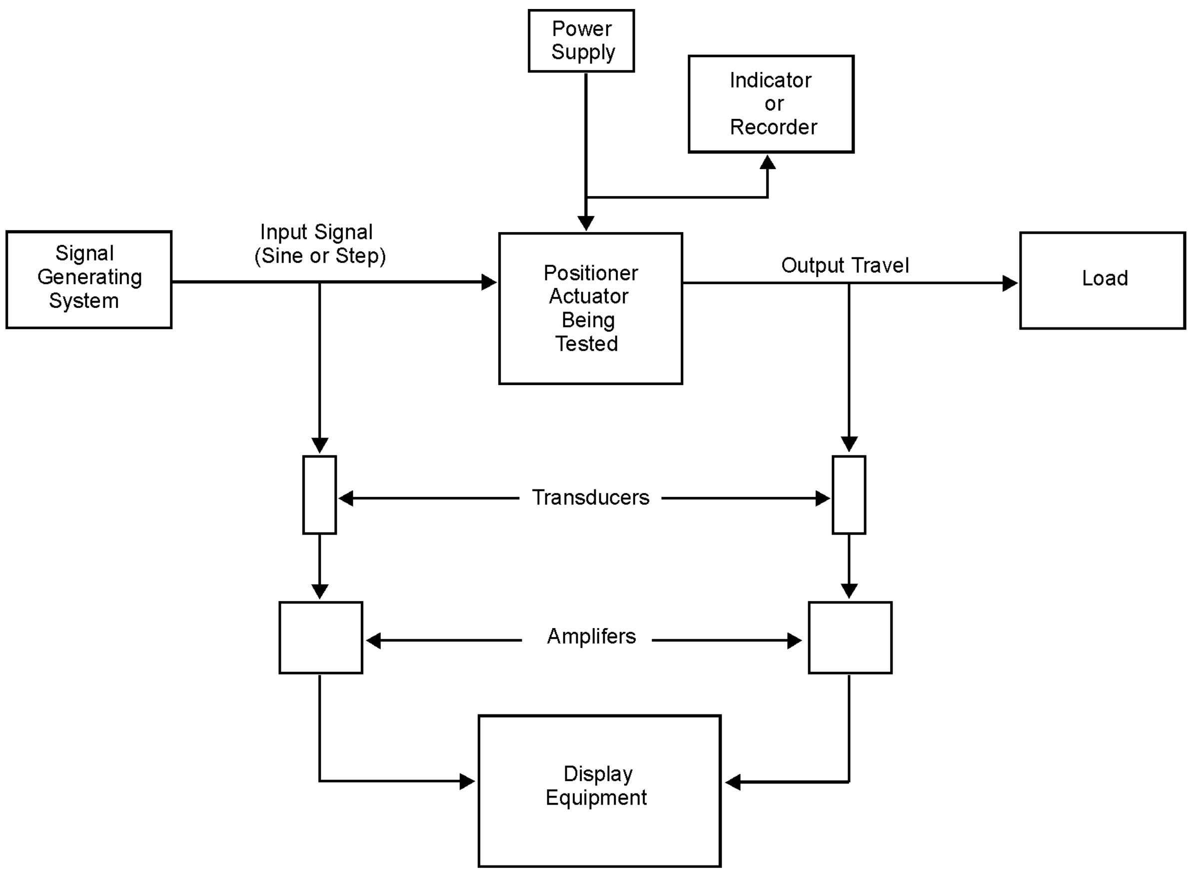


Figure 12 — Schematic of simple dynamic response test system

6.3 Influence of test conditions

Many factors influence the dynamic response of a control device. It is therefore important that the test conditions, such as ambient temperature and pressure, be reported for use in later analyses.

6.3.1 Input signal amplitude (sine wave)

One of the initial problems in establishing test conditions is that of determining an appropriate test signal amplitude. The value selected for the input amplitude can affect the shape of the frequency response curve because very few actual positioner/actuators are really linear. Most positioner/actuators are subject to two amplitude-dependent nonlinear effects: dead band and saturation.

Dead band is usually the result of static friction or mechanical lost motion in the actuator or is the basic threshold of some element in the positioner. Figure 13 illustrates the nonlinearity, dead band, and its effect on output amplitude. If the test amplitude is below the dead band value (input amplitude A1), the gain of the device is zero. If the test is conducted at input amplitude A2, the gain is somewhat lower than for an ideal linear element. Once the amplitude is appreciably greater than the dead band, the dead band's existence has little effect.

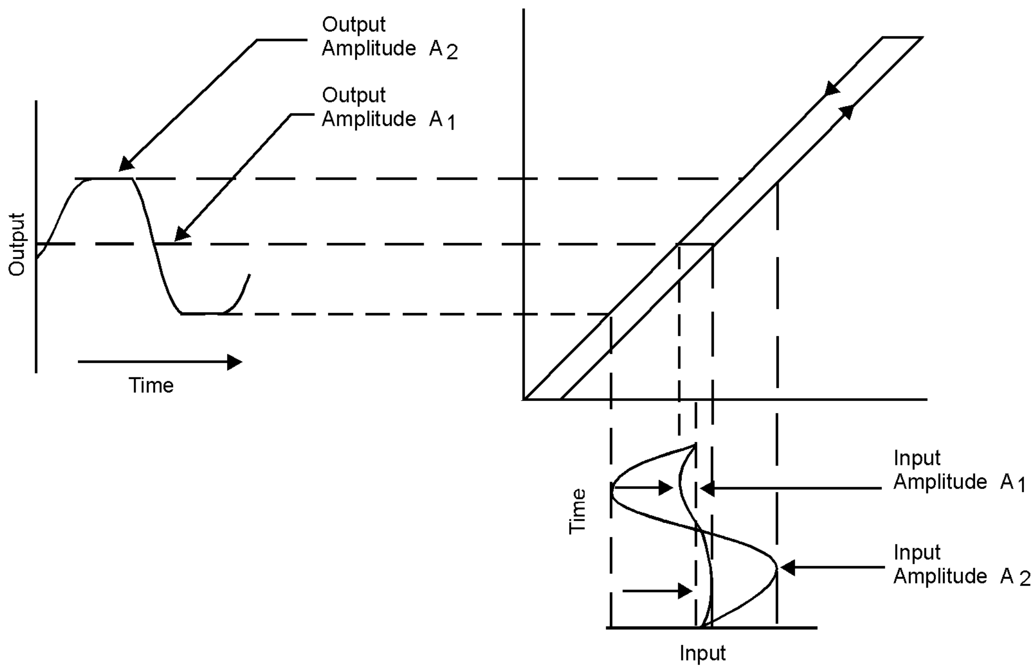


Figure 13 — Steady-state characteristic of element exhibiting dead band and effect on output

Saturation occurs when the test amplitude is large enough to cause some element to reach the limit of its output. Two types of saturation limit the maximum input amplitude that can be employed and still obtain valid results. The first of these saturation limits is position saturation, the effect of which is obvious from Figure 14. If a frequency response test is conducted with the input amplitude shown, the gain will be lower than if the device were linear or if the input amplitude were decreased until the input remained in the linear range of values.

The second type of saturation is called velocity saturation. If the mean level were selected as mid-range and if the input amplitude were selected as 50 percent of input span, it would seem that a device with a characteristic such as that in Figure 14 could be tested with no difficulty. At very low frequencies, there is no problem. But the physical limitation on the velocity that can be achieved by the mechanical elements will cause saturation at higher frequencies. As the frequency increases, the input amplitude that will cause saturation decreases. Therefore, for valid results, the input amplitude must not be large enough to cause either position or velocity saturation.

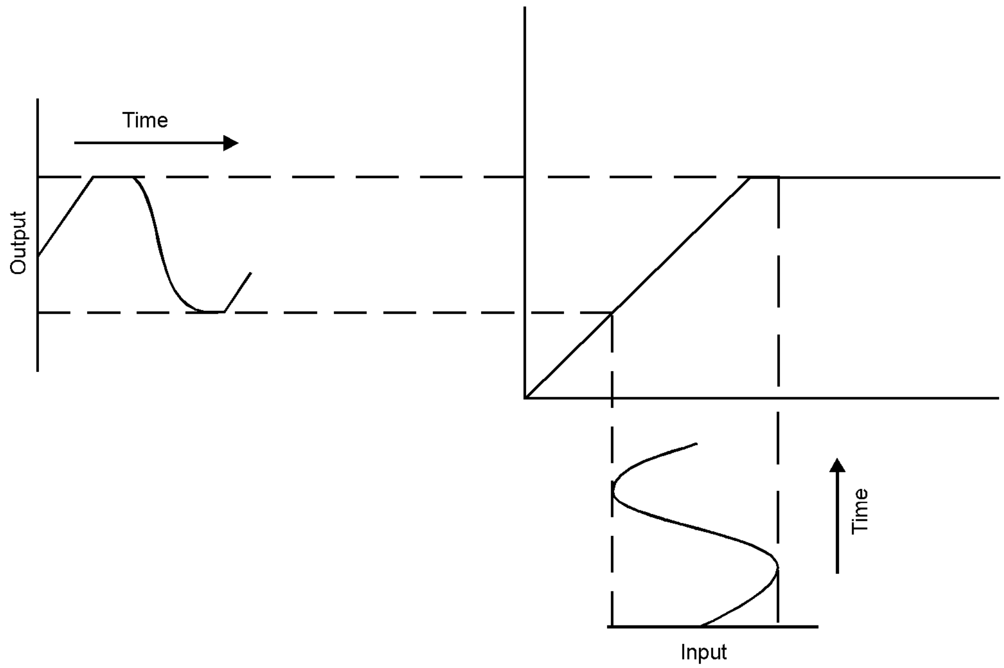


Figure 14 — Steady-state characteristic of element exhibiting saturation and effect on output

The test amplitude for positioner/actuators should be ± 5 percent of rated span unless saturation is encountered, in which case a ± 1/2 percent signal should be attempted; and, if this is impractical, then any intermediate amplitude may be used (see Figure 15).

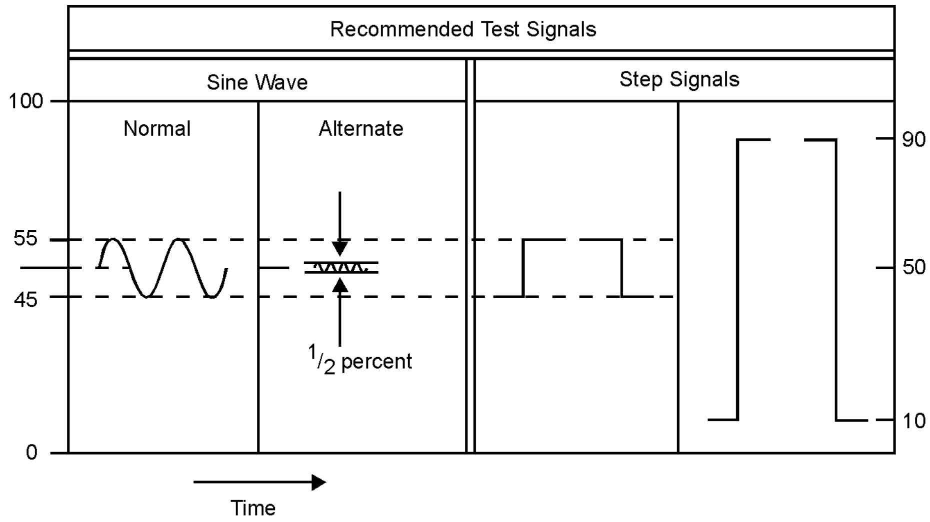


Figure 15 — Recommended test signals

6.3.2 Input signal amplitude (step)

The following step input signals should be used (in percentage of rated input span) for the step response tests (see Figure 15):

a) 45 to 55 percent

b) 55 to 45 percent

c) 10 to 90 percent

d) 90 to 10 percent

6.3.3 Pneumatic supply to positioner

The performance of the pneumatic supply system used for the positioner/actuator under test can exert considerable influence on the dynamic test results. A supply that is adequate for static calibration may be totally inadequate for the large demands that can occur when high-frequency input signals are used.

The supply must be capable of regulating to ± 2 percent of the supply pressure level recommended by the manufacturer, measured at the supply connection of the positioner being tested. Large supply-line pressure fluctuations can occur during tests at high frequencies; therefore, a volume tank added between the regulator and the positioner is recommended. If regulator and volume tanks are used, they should be adjacent to the positioner, and their use shall be noted in the report. Also, the degree of regulation shall be noted in the report. Supply regulator, volume tank, and associated piping details (including elbows and fittings) shall be noted on the data sheet.

6.3.4 Actuator load

The test setup and actuator load should be clearly described in the test report. The actuator should be coupled to the control valve or other final control element as required for the test.

6.3.4.1 Control valve load — frequency response testing

Frequency response tests should be performed with the valve body open to atmosphere and the packing tightened "finger-tight."

6.3.4.2 Control valve load — step response testing

Step response tests should be conducted with the packing tightened as required to hold a test pressure equal to the nominal working pressure for the valve. If it is not convenient to pressurize the valve to establish the packing load, the packing should be tightened to its intended stops (as in the case of spring-loaded packing) or to a static friction force equal to 60 pounds per inch of valve stem diameter.

6.3.4.3 Other final control elements

Both frequency response tests and step response tests should be conducted with the actuator coupled to the final control element (such as variable speed drive or electrical rheostat), and the loads should represent those of the normal operation as closely as possible.

6.4 Test equipment

The following specifications outline the requirements for the test equipment to furnish current, voltage, or pneumatic signals as required and for the recording equipment.

6.4.1 Signal-generating system

6.4.1.1 Sine wave generation

The sine wave-generating device should be capable of generating sine wave frequencies from 0.001 Hz to one decade beyond the frequency response of the positioner/actuator.

The sine wave generator must be capable of producing a given frequency with a period of variation (A, B, and C in Figure 16) between any two cycles of not more than ± 2 percent. The input signal at the positioner must account for electrical or pneumatic nonlinearities, taking into account any transducers, wiring, or piping, and shall produce a sine wave whose distortion shall not exceed 25 percent total harmonic distortion, measured at the input to the positioner. The level of distortion shall be noted in the report.

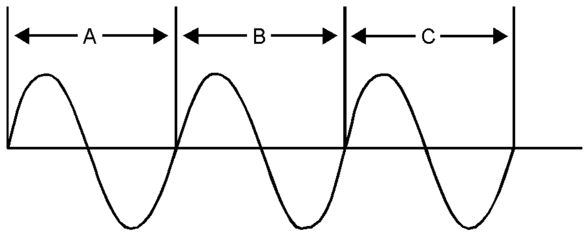


Figure 16 — Period variation

6.4.1.2 Step signal generation

The step input signal should not overshoot to a value greater than 105 percent of the final value and should rise to 95 percent of its final value within 5 percent or less of the time required for the output of the device under test to rise to 95 percent of its final value. The method of obtaining this step response shall be noted in the report.

6.4.2 Display equipment

Any display or recording equipment used to record the results of the test shall simultaneously record both input and output signals. It shall be capable of displaying both amplitude and phase shift changes in the output as the input signal changes. It is recommended, but not required, that a time-based record be made of all data so that any desired verification may be made of the data.

6.4.3 Test equipment performance

The recommended transducer/amplifier/display equipment system performance follows:

a) Signal amplitude: ± 1 dB from 0.0001 Hz to maximum frequency of test;

b) Phase shift: less than 5° from 0.001 Hz to maximum frequency of test; and

c) Dynamic response: The test equipment dynamic response criteria should hold over a frequency range one decade beyond the frequency where the positioner/actuator response exceeds ±3 dB or a 45° phase shift. Any deviation should be reported.

6.5 Test procedures

The following procedures are recommended. Any variation must be noted in the report.

6.5.1 Static calibration

The positioner/actuator and the test equipment should be allowed sufficient time to stabilize prior to starting the tests. The positioner/actuator should be set up and calibrated in accordance with the manufacturer's instructions. The overall test system should be statically calibrated with an independent standard meter on the actual input and output signals. The display equipment reading is thus known accurately at the start of the test. If drift is a problem, the calibration should be repeated periodically.

6.5.2 Preliminary frequency sweep

A frequency sweep at amplitudes of ± 5 percent of rated span, ± 1/2 percent, or intermediate amplitudes can be used to determine the proper test amplitude and the range of test frequencies. The supply regulation can be determined while operating at the selected amplitude. Selection of test frequencies can also be determined to provide small increments between critical data points and to avoid abrupt changes in the phase or magnitude curves. A general rule is to use at least 20 test frequencies for three decades of frequency.

6.5.3 Data correlation

Interpretation of the display equipment information is generally straightforward, except when the output sine wave is quite distorted. In this case, it is recommended that phase shift be determined as shown in Figure 17. When precise results are desired, the normalized gain and phase shift may be obtained by a Fourier analysis of the output wave. Modem sinusoidal frequency analyzers are capable of performing the Fourier analysis on the output signal and automatically computing the gain and phase relationships, based on the fundamental harmonic. Procedures for Fourier analysis are given in many standard reference works. The use of Lissajous figures can be helpful in obtaining accurate phase shift data where distortion is a problem.

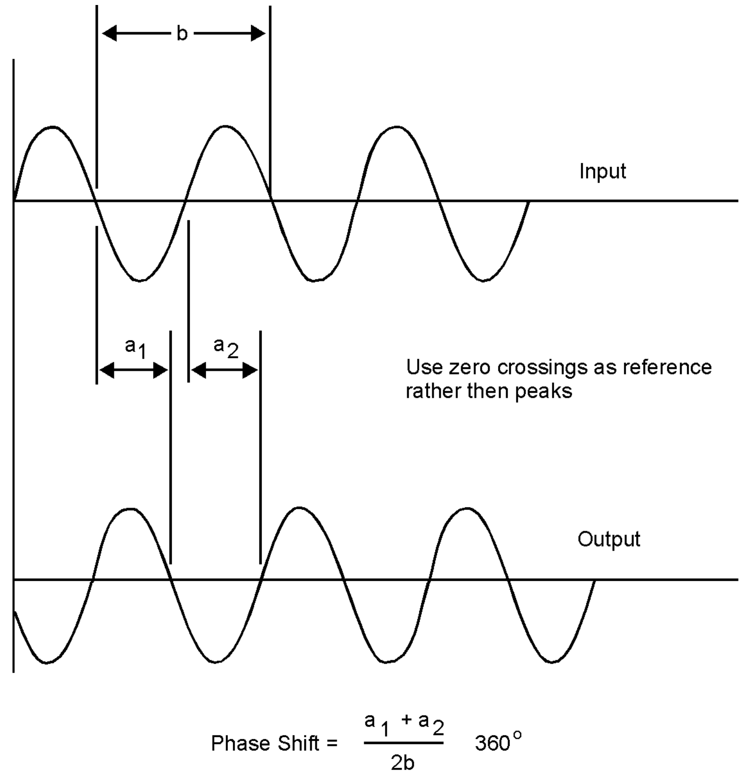


Figure 17 — Determination of phase shift for distorted output

7 Presentation of test results

A summary of all test results and supporting information shall be presented as outlined below.

7.1 Supporting information

The following supporting information shall be included in the presentation of test results. Additionally, any other conditions affecting the test results (such as deviations from the recommended environmental conditions) shall be reported:

a) Description of positioner tested, including model number, serial number, and whether it is single- or double-acting;

b) Description of actuator used in test, including model number, serial number, whether single- or double-acting, nominal effective area, volume(s) at 0 and 100 percent travel (on both sides of double-acting) and spring rate;

c) Description of test setup (including location of positioner feedback connection), supply regulators, volume tanks, and instrument tubing size and lengths;

d) List of test equipment used;

e) Output data: range, mean travel (percent span), and location of output transducer connection;

f) Input data: range, amplitude (percent span), and location of input signal transducer connection;

g) Static gain of positioner/actuator;

h) Supply pressure and medium;

i) Friction load — static;

j) Inertia load — dynamic (all moving parts); and

k) Date, location of tests, and names of persons conducting tests and reducing data.

7.2 Static behavior test results

The results of the tests listed below shall be reported where applicable. The results shall be expressed in the units described in the respective procedures.

a) Accuracy

b) Dead band

c) Drift, point

d) Hysteresis

e) Conformity

f) Repeatability

g) Supply pressure influence

h) Ambient temperature influence

i) Mounting position

j) Humidity effect

k) Vibration influence

l) Electromagnetic susceptibility

m) Normal mode interference influence

n) Common mode interference influence

o) Overrange effect

p) Shock effect

q) Supply flow capacity

r) Exhaust flow capacity

s) Flow gain

t) Steady-state power medium consumption

u) Locked-stem pressure gain

v) Life test effects

7.3 Dynamic behavior test results

7.3.1 Sine wave test data

The frequency response data shall be presented as a plot of the phase shift and logarithm of the normalized gain, each plotted against the logarithm of the test signal frequency (Bode diagram). The logarithm of the gain shall be displayed on linear coordinates.

The method of plotting the logarithm of the gain is to use the relationship

$$\mathrm{dB} = 20 \log_{10}(M)$$

where dB is the normalized gain in decibels, and M is the normalized (dimensionless) gain — that is, the gain at any frequency divided by the static gain — and is dimensionless.

Phase shift in degrees should be identified by a plus (+) sign when the output leads the input, and by a minus (–) sign when the output lags the input.

7.3.2 Step test data

Step test data shall be presented on linear coordinate paper, with input and output signal magnitudes expressed in percent of their steady-state changes plotted on the vertical scale (which may be suppressed to bring out detail) and elapsed time units plotted on the horizontal scale.

In all step test plots, the input signal shall be plotted with a dashed or broken line and the output signal with a solid line. It is important to choose a time axis such that dead time and deviations from a true step input can be seen clearly. Since the step tests consist of a given step upset "upward" and the same size step signal "downward," these companion tests should be presented on the same graph.

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