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Standard

Dynamic Response Testing of Process Control Instrumentation



The International Society for Measurement and Control

ISA-S26 — Dynamic Response Testing of Process Control Instrumentation

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Foreword

This Foreword is included for informational purposes and is not part of Standard S26.

This revision to the earlier series of ISA Recommended Practices has been prepared as a continuing part of the service of ISA toward a goal of uniformity in the field of instrumentation. To continue to be of service to those organizations and individuals who use it, this document should not be static. The Society welcomes all comments and criticism; address letters to the Standards and Practices Board Secretary, ISA, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, North Carolina 27709, telephone 919-549-5411.

This document is an integration of four parts covering general recommendations for dynamic response testing, techniques for devices with pneumatic output signals, techniques for devices with electric output signals, and techniques for closed loop actuators for final control elements. The original editions were published in 1957, 1960, and 1961. The revisions providing pulse testing techniques, completed in 1966, have been added to the basic sine wave and step testing techniques. New or altered material is indicated by a vertical bar beside the text or drawing.

This composite ISA Standard was prepared by the Dynamic Response Testing Committee (SP26), established in 1956 with F. H. Winterkamp as Chairman. C. E. Ryker became Chairman in 1962. The purpose of this committee has been to establish guidelines for the successful application of dynamic response testing techniques to modern instruments and process lines. This subject has developed considerable interest among scientists and engineers concerned with accurate and efficient information from instrumental testing. The recommendations in this document are up-to-date with respect to the equipment commercially available to perform this type of testing.

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1 Purpose

This ISA Standard constitutes a series recommending dynamic test procedures for measurement and control equipment for production processes.

With the continuing development and application of dynamic analysis to systems engineering, dynamic response test data are becoming an increasingly important part of overall performance data. Proper use of this standard should result in:

- a) Data that will characterize dynamic performance in a uniform comparable manner,
- b) data of value for control systems design as well as for performance characterization, and
- c) a maximum amount of useful data per testing dollar.

2 Scope

This ISA Standard establishes the basis for dynamic response testing of measurement and control equipment with pneumatic output and electric output and for closed loop actuators for externally actuated control valves and other final control elements. General recommendations applicable to all dynamic response testing and a brief glossary, defining terms as used in this standard, are also included. Tabular format is used to simplify application in the laboratory by those familiar with dynamic response testing. A minimum of discussion and descriptive material precedes the tabulation of recommended tests. Methods for sine wave, step, and pulse-type signals are included.

Final control elements take many forms, and the actuators may be powered and signalled pneumatically, electrically, or in combination. Externally actuated valves for controlling flow are most common in the process industries, but the final control element can be a controlled volume pump, motor speed control, or many others.

It would, of course, be desirable to have a system which relates the flow response of a control valve or a variable speed pump to the input signal of the closed loop actuator. It was the committee's feeling that it would not be practical to require this.

For the purpose of this ISA Standard, all final control elements will be considered as having an input signal and an output motion or rotation and no distinction will be made between power media.

3 Factors to be considered in dynamic response testing

3.1 Use of data

The application of dynamic response test data can be generally divided into two categories:

- 1) characterization of a control or measuring device.
- 2) control system design.

Non-specific designations such as *flat response* or *good response* should not be used in interpreting dynamic response test data for measurement and control devices. Such terms, which are borrowed from audio work, are not applicable in the control field. It is recommended that data be taken and presented according to the appropriate sections of this standard and that the performance be judged only in the light of requirements for a specific application. For example, a device whose dynamic response is too slow for one application might be ideal for another where undesirable high frequency noise signals are present.

3.2 Interaction

A control system usually consists of a number of elements. Each element has one or more input and output signals. Two elements are said to be interacting when the relation between input and output of one element is affected by changing the characteristics of the other element. In studying dynamic response of a control system, elements which interact are often considered as a unit. It is important to note that interaction is not necessarily mutual.

An example of interacting elements is a pneumatic transmitter and the pneumatic tubing which is attached to it. The response of the transmitter (measured at the point where the tubing is attached) for a given input disturbance depends upon the amount of tubing attached. In the usual case the greater the amount of tubing, the slower the response. This system could be made non-interacting by placing a booster relay between the transmitter and the tubing. Then the speed of response of the transmitter would be virtually independent of the amount of tubing attached to the booster.

3.3 Nonlinearity

Nonlinearity can have a profound effect on the dynamic response of a device, particularly in causing large variations in performance with changes in output load or input signal size. Some common types of nonlinearities are dead spot, friction, hysteresis, velocity limiting, saturation, exponential measurements, and valve characteristics. Nonlinearity not only causes distortion of the signal shape, but also may result in additional phase shift and attenuation.

3.4 Power supply to device being tested

The performance of the power supply system used for the device under test can exert considerable influence on the dynamic test results. A power supply that is adequate for static calibration may be totally inadequate for the large power demands that can occur when high frequency input signals are used. It is common practice for vendors to specify the energy level to be used, but only in the electrical field is it common practice to specify a degree of regulation also.

Since these tests are to characterize devices in a uniform, comparable manner, it is recommended that the energy level specified by the vendor be used, and that the power supply be capable of regulating to $\pm 2\%$ of this level at all test conditions. It is extremely important to check this regulation immediately at the power input connection of the device being tested because in pneumatic and hydraulic work unexpected, large supply line drops can occur during high frequency tests.

3.5 Test signals

This ISA Standard outlines methods for obtaining two types of dynamic data. The first are data that can be used for mathematical analysis, for graphical solution of control problems and for characterization of dynamic performance. These data can be obtained by use of either sine-wave or pulse-type forcing functions. The second type of dynamic data provides a qualitative evaluation of the nonlinearity of the device under test and are obtained by use of step tests.

The choice of whether to use sine-wave or pulse-type forcing functions is a matter of convenience and is left to the discretion of the person performing the test. Either type forcing function when used as outlined in this standard, will yield the same information. The committee is in agreement that the pulse method provides a marginal advantage over the sine-wave method for obtaining dynamic data of instrument components. However, the pulse method does offer distinct advantages when the generation of sinusoidal input signals for a given device is difficult. The committee feels the greatest potential use of the pulse method is not on certain instrument components but on plant process equipment and processes themselves. The scope of this standard is limited to instrument components.

This Standard is organized in a manner that, it is hoped, will be convenient to the user. All references to sine wave and step tests appear before all reference to pulse tests. Redundancy has been kept to a minimum.

3.6 Qualifications of personnel performing tests

This ISA Standard, as stated in the Purpose, is designed to present standardized procedures for performing dynamic tests. It is not the intent of the committee that this document be used as a textbook or instruction sheets but that it serve as a guide for use by personnel trained in the field of dynamic analysis.

4 Recommended tests — sine wave and step

4.1 Input signals

It is recommended that sine wave and step input signals be used with various output loads.

Sine wave test data are most generally useful for mathematical analysis, for graphical solution of control problems, and for characterization of dynamic performance.

In order to arrive at a practical number of recommended tests, the number of output load and input signal configurations must be minimized. This could result in nonlinearities being unnoticed. To permit a qualitative evaluation of the nonlinearity of the device under test, step tests are recommended.

It is realized that the total data from both the recommended step and sine wave tests will not suffice to describe nonlinearity in the device being tested quantitatively. However, this standard is a practical compromise which will give actual data useful for most applications, and a qualitative indication of the effect of unusually large signals or loads.

Sine wave and step tests shown in [Figure 1](#) below are recommended. The input span referred to here is that input signal that will drive the output signal through its full range.

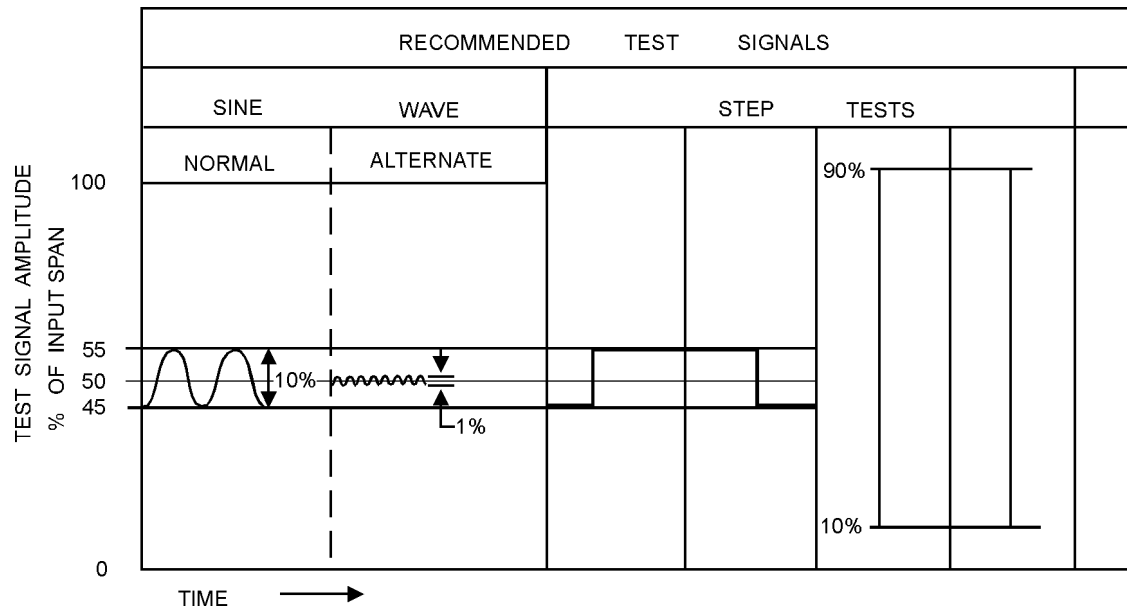


Figure 1 — Recommended test signals

4.1.1 Sine wave input signals

It is recommended that a sine wave input signal be used whose peak-to-peak magnitude is 10 percent of the actual input signal span of the device being tested. The sine wave should have the arithmetical midpoint of the input signal span as its center. The input span preferred is that span which will drive the output signal through its full range. Qualifications of the recommendation are discussed in the later documents.

The test should start at a frequency low enough that the magnitude of the output sine wave essentially equals that of the steady state output for the same input and there is essentially no phase shift between them (except if the device has pure integral or derivative functions). The frequency should be increased until the magnitude of the output sine wave is 10 percent or less of the output signal at zero frequency or the phase lag is 300° . Generally speaking, a response test should cover a frequency span of at least three decades.

Care should be taken to vary the frequency in small enough increments to describe abrupt changes in the response curve.

4.1.2 Step input signals

It is recommended that the following step input signals be used (in percent of actual input span):

- 1) 45 to 55
- 2) 55 to 45
- 3) 10 to 90
- 4) 90 to 10

4.2 Loading

The load presented to the output of the device has a very significant effect on dynamic performance (see [Section 3.2](#)). In selecting loadings to be used, two factors must be considered:

- 1) The loadings should be as representative of actual field conditions as possible, not only to make the data useful for system design, but to permit realistic characterization of the element.
- 2) The number of tests should be kept to a minimum.

Detailed load configurations for the various tests are specified below.

4.3 Load configurations

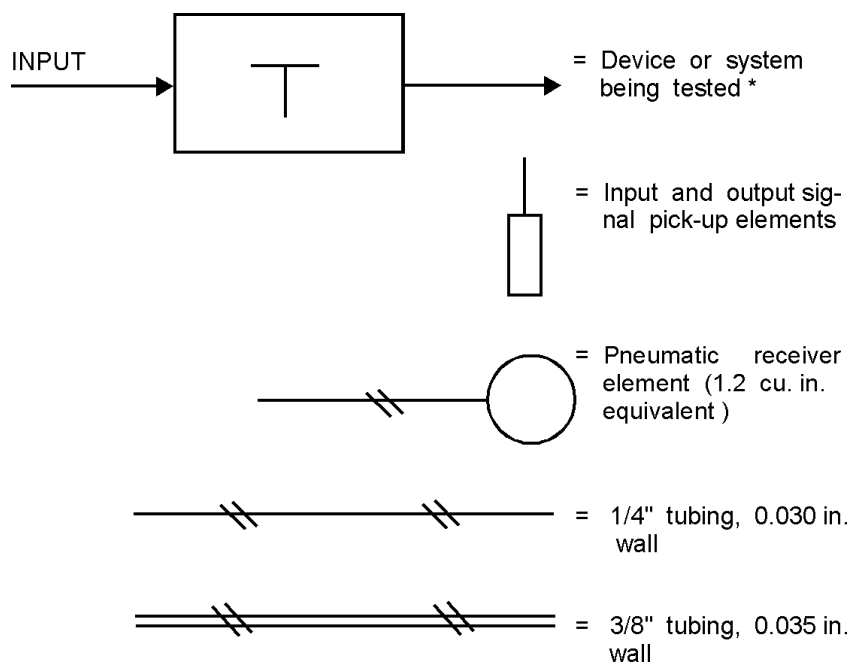
4.3.1 Pneumatic

Five standard load configurations are recommended in Figures 2-6. It should be noted that the recommended location of the pick-off point before the load will result in data which give the response of the device or system *alone* when coupled to the given load. To get the over-all response, it is necessary to combine the device or system response with that of the load. (See references 1-8 for dynamic response of pneumatic signal tubing.) Fewer load configurations are needed to describe typical field installations when this pick-off point location is used, than when the device or system and load are tested as a unit. For example, there can be several typical field piping configurations which appear the same to a transmitter, even though the over-all response, including load, of these installations might be quite different. The effect of the load on the response of the device or system only, when tested as recommended, reaches a limiting value as the load gets greater. For example, there is usually a difference in the system or device response if the load is changed from ten to fifty feet of one-quarter-inch tubing, but experience indicates little difference between the response curves for the device or system alone when the load is changed from 100 feet of one-quarter-inch tubing and a volume to 200 feet of one-quarter-inch tubing (see [Section 4.2](#)). To avoid restrictions due to flattened tubing, minimum coil diameter for one-quarter-inch copper tubing should be 16 inches; for 3/8-inch tubing, 30 inches.

The following symbols, used to illustrate typical load configurations, are consistent with ISA Standard S5.1(Y32.20).*

*ANSI accepted Standard Y32.20

Load configurations for pneumatic devices



*If the device being tested is a controller, the automatic-manual switch or cutoff relay should be included as part of the controller and the controller should be piped for bumpless transfer.

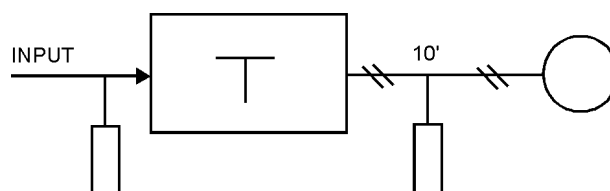


Figure 2 — Configuration A

If manufacturer's recommended minimum is more than 10 ft., use this minimum to prevent instability. This test will then give data for the smallest load the device or system can handle. This configuration represents a typical close-coupled pneumatic device such as a field transmitter and a controller with no long branch lines.

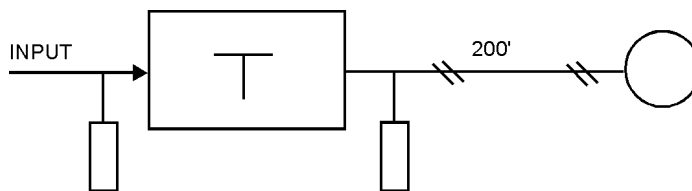


Figure 3 — Configuration B

This load looks like a long transmission line to the transmitter, or a short transmission line with a long branch. The response at the transmitter is the same for either case. In using the data for a field installation, it will be necessary to add the effects of the particular load used. Experience indicates that longer transmission lines will not significantly affect the response at the transmitter.

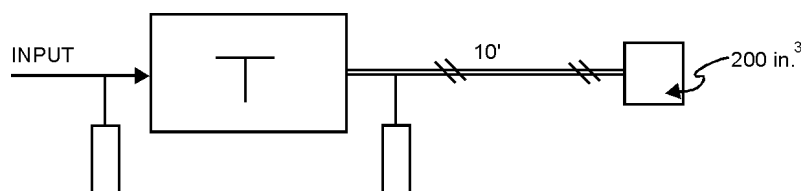


Figure 4 — Configuration C

This configuration represents the case of a large load such as a diaphragm motor. It was not felt that another test with longer tubing and this large load was needed since a booster or positioner would normally be interposed if dynamic response was critical. Also, experience indicates that this load is large enough that increasing it by lengthening the tubing will not have a significant effect on the response at the instrument.

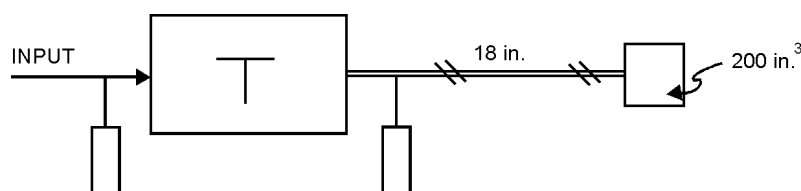


Figure 5 — Configuration D

This configuration represents the case of a close-coupled large load such as would be seen by a device intended primarily to deliver pneumatic power such as a booster or positioner.

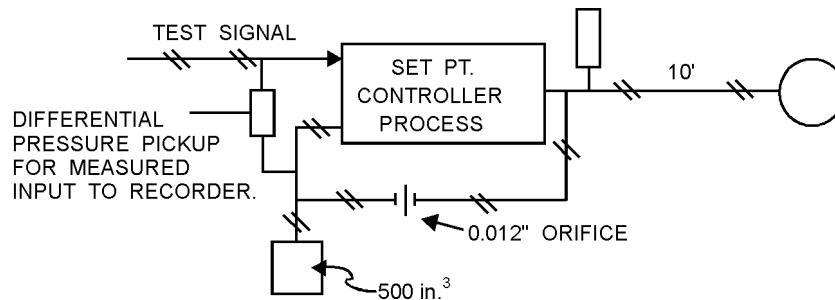


Figure 6 — Configuration E

This configuration is used to test the reset function in a pneumatic controller. The controller feedback connection should be hooked up in a normal way, in addition to the connections shown above. It is possible to make dynamic tests of controller reset functions with an open loop hookup, but it requires meticulous care and very stable test signals. For this reason, the above hookup, with a feedback loop to stabilize the controller, is recommended. The restriction and volume provide sufficient time delay to permit the effects of the reset circuit to be seen. (See the section on Integral or Reset Action and reference 17.)

4.3.2 Electrical

Devices designed for a specific receiving element or load, such as commercial electronic control systems, should be tested with the actual element they would normally use as the load. Equivalent resistive loads should be used only if the element thus replaced would present a purely resistive load to the unit under test.

A special load configuration is recommended for the optional dynamic test of controller reset or integral action.

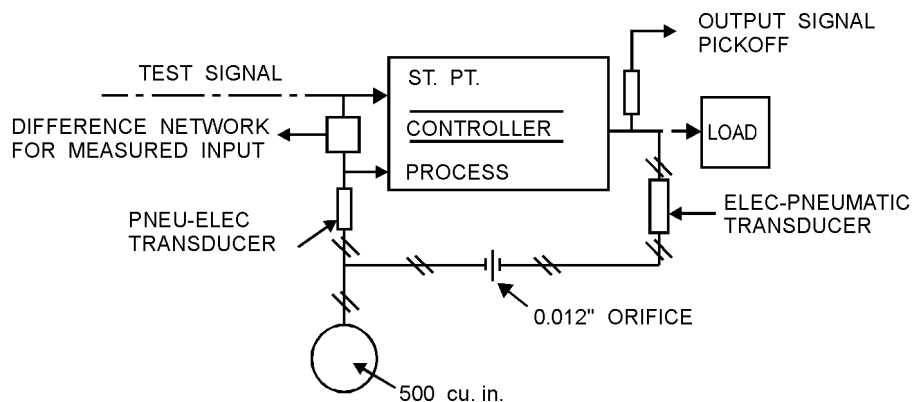


Figure 7 — Test configuration for reset function

The configuration of Figure 7 is used to test the reset function in an electronic controller. The controller feedback connection should be hooked up in a normal way, in addition to the connections shown above. It is possible to make dynamic tests of controller reset functions with an open loop hookup, but it requires meticulous care and very stable test signals. For this reason, the above hookup, with a feedback loop to stabilize the controller, is recommended. The restriction and volume provide sufficient time delay to permit the effects of the reset circuit to be seen.