

STANDARD

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**A Guide for the Dynamic
Calibration of Pressure Transducers**

Approved 21 November 2002

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A Guide for the Dynamic Calibration of Pressure Transducers

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Contents

Acknowledgments from the current ISA SP37.16 Subcommittee	9
Introduction	11
1 Scope.....	13
2 Purpose.....	13
3 Table of symbols.....	13
4 Transducer properties.....	13
4.1 Underdamped second-order systems	14
4.2 General transducer properties.....	19
4.3 Properties in the frequency domain.....	20
4.4 Properties in the time domain.....	20
5 Dynamic pressure generators	22
5.1 Shock tube.....	22
5.2 Shockless pressure-step generators.....	27
5.3 Pulse generators	28
5.4 Periodic pressure function generators (sinusoidal pressure generators).....	29
6 Measurement of transducer properties.....	33
6.1 Sensitivity	33
6.2 Amplitude response.....	33
6.3 Phase response.....	35
6.4 Resonant frequency	36
6.5 Ringing frequency.....	36
6.6 Damping ratio	36
6.7 Rise time.....	37
6.8 Overshoot	38
7 Transducer interfaces.....	38

7.1	Mounting, strain effects	38
7.2	Cavities and passages	39
7.3	Temperature effects	40
7.4	Acceleration effects	42
8	Electronic considerations.....	43
8.1	Noise.....	43
8.2	Cabling	44
8.3	Voltage amplifier.....	45
8.4	Charge amplifier	46
9	Data acquisition and analysis	47
9.1	Digital oscilloscope or recorder	47
9.2	Data analysis	48
10	Reporting test results	48
10.1	Test conditions	48
10.2	Results and discussion.....	49
11	References.....	49

Acknowledgments from the current ISA SP37.16 Subcommittee

This document has a long history. Originally published by the American Society of Mechanical Engineers as A Guide for the Dynamic Calibration of Pressure Transducers, this document been an ANSI Standard since 1972. The theory, including the physics and mathematics of dynamic calibration, is timeless, but the further development of technology has caused changes in some of the methods described in the original document.

In 1996, the ASME handed the document over to the ISA. ISA's SP37.16 Subcommittee on Pressure Transducers began editing the document in 1997, in order to update the methods and references while leaving the timeless aspects alone. The result is ISA-37.16.01-2002, A Guide for the Dynamic Calibration of Pressure Transducers.

The following SP37.16 Subcommittee members are recognized because of the major involvement they had with the current revision of this document, and more importantly because of the role they might serve as reference sources in any future updates: Patrick Walter, Jim Lally, and Bob Goodemote. However, this does not lessen the contributions of the entire committee in this effort.

As stated in the original abstract: "While not intended as a step-by-step procedure, this document does contain specific examples and suggested methods for the determination of items of interest in the calibration of dynamic pressure transducers."

It is quite likely that in a very short period of time, another subcommittee will edit this document to reflect current technologies and techniques available.

Lawrence Whitby
SP 37.16 Subcommittee Chair

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Introduction

The state of art of dynamic pressure calibration and pressure sensor technology has significantly advanced since the original publication of this document in 1972 (Reference 56). The ASME standard documents early attempts to develop dynamic pressure calibration methods, some of which never evolved further into successful technology. Most of the calibration devices described in this document were uniquely engineered at individual laboratories to meet their specific measurement needs. However, today, some of these devices have evolved into commercially available products.

The need to measure "nonsteady" dynamic pressure became very important after WW-II during the rapid development of jet aircraft and aerospace technology. Investigations of turbulence associated with launch, shock waves upon re-entry, sonic boom, rocket combustion stability, air blast (References 67, 68), and the dynamics involved with weapons testing were significant measurement challenges. Investigations in these and other areas have necessitated faithful measurement of pressure variations at frequencies from near zero to the neighborhood of 10^6 Hertz (Hz). The degree of accuracy with which these measurements must be made varies widely throughout the technical community, as does the use made of information derived from such measurements. Often there are other complicating factors, such as severe environmental effects, which must be considered, if meaningful information is to be obtained. When considering the measurement problem, the investigator must first determine the dynamic characteristics of the pressure transducer. It is toward the satisfaction of this basic requirement that this document is directed.

Dynamic pressure calibration at the time this document was originally authored was difficult because of the limitation of dynamic pressure calibration sources available. Dynamic calibrators were simply not commercially available. Since then, substantial improvement has been made in the state-of-the-art of both dynamic pressure calibrators and high-frequency pressure transducers to meet many current measurement requirements for amplitude, frequency, and accuracy. Most of the dynamic calibrators available today incorporating fast-acting valves yield dynamic pressure amplitudes that are independently established. Others use a pressure transducer as a "transfer" standard that the transducer being calibrated is compared against (References 56, 57).

Although the user's requirement for information concerning a transducer's response characteristics has been as varied as the test methods used to obtain the data, current commercial calibrators and digital data acquisition systems have helped to obtain more accurate information. Unfortunately there have been many instances where worthwhile data have gone unused because of the manner in which they were presented. Test reports lacking adequately defined terms, test conditions, or other supporting information convey little more than misunderstanding to the reader.

The intent of this document is to provide documentation for current techniques and to identify possible pitfalls associated with the dynamic calibration of pressure transducers. The results of providing such a document to the technical community will be a better understanding of the basic problems as well as more effective communication between workers in the field.

This document is not a step-by-step procedure that can be followed without fail to the absolute truth in pressure measurements. Neither is it an attempt to discuss in detail all of the factors that affect the accuracy of pressure measurements, e.g., environmental effects, signal transmission, or recording techniques. References to applicable documents concerning such problems are contained herein, and Reference 74 deals specifically with the measurement/data acquisition/data utilization process. This document concentrates on the factors that directly affect dynamic response, such as adapters and mechanical attachments physically a part of, or relatively inseparable from the transducer, and electronic equipment that, in practical use, is required for the operation of the transducer. The description of equipment and techniques appearing in this document will be limited to their use as directly related to dynamic pressure calibration.

The clauses of this document are divided into three groups. The first, consisting of Clauses 4, 5, and 6, discusses the significant transducer properties, dynamic pressure sources available, and the use of sources to determine the desired transducer properties. The second group, consisting of Clauses 7 and 8, deals with the problems of transducer installation and the immediate electronic signal conditioning necessary to obtain a satisfactory output signal. The final group, consisting of Clauses 9 and 10, indicates data-recording methods and recommends procedures for reporting test results.

Although this document focuses primarily on pressure levels above acoustic, it is worth noting that ¼ inch precision condenser microphones, in compliance with IEC 61094-1 (Reference 78), also have been successfully used for dynamic pressure measurements on jet aircraft, rocket engines, and other aerospace applications. For dynamic calibration, the open-circuit sensitivity and the frequency response are normally obtained by a precision acoustical calibration system (Reference 51) using a pistophone (Reference 52) for the open-circuit sensitivity, and the electrostatic-actuator method for the frequency response. An acoustical calibrator (Reference 53) meeting the requirements of IEC 942 (1988) Class 1 may also be used to calibrate the open-circuit sensitivity.

This document is inconsistent in the use of the word calibration in reference to dynamic testing of pressure transducers. It should be understood that calibration as used in this document and others (Reference 1) means a test during which known values of measurand are applied to a transducer, and corresponding output readings are recorded. The degree of accuracy associated with these dynamic tests is generally lower, and the manner in which the results are used is generally less rigorous than in the conventional and more easily controllable field of static pressure calibration.

In preparing this Guide in 1972, the original ANSI B88 Subcommittee on Pressure had considered the various testing and reporting techniques before recommending specific practices. This present document represents the first step in the accomplishment of the Subcommittee's assignment, which was to develop or approve standards for the dynamic calibration of pressure transducers in order to improve the quality of dynamic calibrations.

1 Scope

This standard covers dynamic pressure transducers, which are, primarily “those” used in measurements.

2 Purpose

This standard establishes guidelines for the preferred techniques and practices in the calibration of dynamic pressure transducers.

3 Table of symbols

a	gas speed of sound	RC	time constant of R-C circuit
A_e	outlet orifice area	t_s	settling time
\hat{A}_e	maximum exit area	Δt_s	shock-wave transit time
A_i	inlet orifice area	t_r	rise time, transducer
A_r	amplification factor	T	temperature
c	damping	v	chamber volume
d	diameter	V	voltage or volume
f	frequency	ΔV	peak incremental voltage
k	spring constant	\hat{V}	peak voltage for any cycle
K	steady-state sensitivity	\bar{V}	average voltage
l	piston position	V_p	peak-output voltage
L	length of cylindrical passage	V_s	shock-wave velocity
m	mass	∞	modulation factor
M_s	shock wave Mach number	γ	ratio of specific heats of constant pressure and volume
N	number of oscillations	η	constant
$\frac{OUT(s)}{IN(s)}$	transfer function	ζ	damping ratio
p	pressure	λ	wavelength
p_s	stagnation pressure of supply gas	τ	rise time, input
p_a	absolute pressure	ω	frequency in radians per second
ΔP	pressure change	ω_d	ringing frequency
p_o	equilibrium pressure	ω_o	natural frequency
\bar{p}	average chamber pressure	ω_r	resonant frequency

4 Transducer properties

The transducer properties or characteristics of interest to a user will depend to a large extent on the application involved. This clause defines and discusses some of the properties most often required. These properties sometimes can be described in terms of the “transient” response of the device to a step input, or in terms of its “steady-state” response to sine-wave excitation, or both.

In defining transducer properties related to dynamic response, the transducer's transfer function provides valuable information. The transfer function is the ratio of output to input (expressed in the frequency domain), and forms the basis for the frequency response parameters. Once the transfer function is known, the input vs. time for any output can be determined. These topics have been treated by those working in the fields of servomechanisms and network theory, where it is often necessary to describe