International Standard ISO 7626/1

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Vibration and shock — Experimental determination of mechanical mobility — Part 1: Basic definitions and transducers

Vibrations et chocs — Détermination expérimentale de la mobilité mécanique — Partie 1: Définitions fondamentales et transducteurs

First edition — 1986-08-15

UDC 534.1.08 **Ref. No. ISO 7626/1-1986 (E)**

Descriptors : vibration, mechanical shock, structures, buildings, machinery, tests, vibration tests, determination, mobility, test equipment, transducers, specifications, calibration, data representation.

Price based on 23 pages

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 7626/1 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Contents

This page intentionally left blank

Vibration and shock — Experimental determination of mechanical mobility — Part 1 : Basic definitions and transducers

0 Introduction

0.1 General introduction to ISO 7626 on mobility measurement

Dynamic characteristics of structures can be determined as a function of frequency from mobility measurements or measurements of the related frequency-response functions, known as accelerance and dynamic compliance. Each of these frequency-response functions is the phasor of the motion response at a point on a structure due to a unit force (or moment) excitation. The magnitude and the phase of these functions are frequency-dependent.

Accelerance and dynamic compliance differ from mobility only in that the motion response is expressed in terms of acceleration or displacement, respectively, instead of in terms of velocity. In order to simplify the various parts of ISO 7626, only the term "mobility" will be used. It is understood that all test procedures and requirements described are also applicable to the determination of accelerance and dynamic compliance.

Typical applications for mobility measurements are for

a) predicting the dynamic response of structures to known or assumed input excitation;

b) determining the modal properties of a structure (natural frequencies, mode shapes and damping ratios);

c) predicting the dynamic interaction of interconnected structures;

d) checking the validity and improving the accuracy of mathematical models and structures;

e) determining dynamic properties (i.e. the complex modulus of elasticity) of materials in pure or composite forms.

For some applications, a complete description of the dynamic characteristics may be required using measurements of translational forces and motions along three mutually perpendicular axes as well as measurements of moments and rotational motions about these three axes. This set of measurements results in a 6×6 mobility matrix for each location of interest. For N locations on a structure, the system thus has an overall mobility matrix of size $6N \times 6N$.

For most practical applications, it is not necessary to know the entire $6N \times 6N$ matrix. Often it is sufficient to measure the driving-point mobility and a few transfer mobilities by exciting with a force at a single point in a single direction and measuring the translational response motions at key points on the structure. In other applications, only rotational mobilities may be of interest.

In order to simplify the use of the various parts of ISO 7626 in the various mobility measurement tasks encountered in practice, ISO 7626 will be published as a set of five separate parts.

ISO 7626/1 (this part of ISO 7626) covers basic definitions and transducers. The information given in this part of ISO 7626 is common to most mobility measurement tasks.

ISO 7626/2 covers mobility measurements using single-point translational excitation with an attached exciter.

ISO 7626/3 covers mobility measurements using single-point rotational excitation with an attached exciter. This information is primarily intended for rotor system rotational resonance predictions.

ISO 7626/4 covers measurements of the entire mobility matrix using attached exciters. This includes the translational, rotational and combination terms required for the 6×6 matrix for each location on the structure.

ISO 7626/5 covers mobility measurements using impact excitation with an exciter which is not attached to the structure.

Mechanical mobility is defined as the frequency-response function formed by the ratio of the phasor of the translational or rotational response velocity to the phasor of the applied force or moment excitation. If the response is measured with an accelerometer, conversion to velocity is required to obtain the mobility. Alternatively, the ratio of acceleration to force, know as accelerance, may be used to characterize a structure. In other cases, dynamic compliance, the ratio of displacement to force, may be used.

NOTE — Historically, frequency-response functions of structures have often been expressed in terms of the reciprocal of one of the above-named dynamic characteristics. The arithmetic reciprocal of mechanical mobility has often been called mechanical impedance. It should be noted, however, that this is misleading because the arithmetic reciprocal of mobility does not, in general, represent any of the elements of the impedance matrix of a structure. This point is elaborated upon in annex A.

Mobility test data cannot be used directly as part of an impedance model of the structure. In order to achieve compatibility of the data and the model, the impedance matrix of the model shall be converted to mobility or vice-versa (see clause A.3 for limitations).

0.2 Introduction to this part of ISO 7626

Before carrying out mobility measurements, it is necessary to evaluate the characteristics of the force and response transducers to be used in order to ensure that accurate amplitude and phase information can be obtained over the entire frequency range of interest.

This part of ISO 7626 is primarily a guide for the selection, calibration and evaluation of the transducers and instruments for their suitability in making mobility measurements.

1 Scope and field of application

This part of ISO 7626 provides basic definitions with comments and identifies the calibration tests, environmental tests and physical measurements necessary to determine the suitability of impedance heads, force transducers and response transducers for use in measuring mechanical mobility.

This part of ISO 7626 is limited to information which is basic to various types of driving point and transfer mobility, accelerance and dynamic compliance measurements. Blocked impedance (see 4.3) measurements are not dealt with.

NOTE — Procedures for carrying out mobility measurements in various circumstances will be dealt with in ISO 7626/2, ISO 7626/3, ISO 7626/4 and ISO 7626/5.

2 References

ISO 2041, *Vibration and shock — Vocabulary.*

ISO 4865, *Vibration and shock — Methods for analysis and presentation of data.* 1)

ISO 5347, *Vibration and shock — Methods of calibration of vibration and shock pickups.* 1)

IEC Publication 263, *Scales and sizes for plotting frequency characteristics and polar diagrams.*

3 Symbols and units

Symbol	Quantity	SI unit
a	Acceleration	m/s^2
a_i/F_j	Accelerance	m/(N·s^2)
E	Transducer output	V
f	Frequency	Hz
F	Force	N
k	Stiffness	N/m
m	Mass	kg
S	Sensitivity	V/units of input variable
v	Velocity	m/s
x	Displacement	m
x_i/F_j	Dynamic compliance	m/N
Y_{ij}	Mobility	m/(N·s)
Z	Free impedance	N·s/m
Z_{ij}	Blocked impedance	N·s/m

4 Definitions

For the general terms and their definitions used in this part of ISO 7626, see ISO 2041. Several of the more important definitions used in the measurement and presentation of mechanical mobility data are listed below to emphasize their use in this part of ISO 7626.

4.1 frequency-response function: The frequency dependent ratio of the motion-response phasor to the phasor of the excitation force.

NOTES

1 Frequency-response functions are properties of linear dynamic systems which do not depend on the type of excitation function. Excitation can be harmonic, random or transient functions of time. The test results obtained with one type of excitation can thus be used for predicting the response of the system to any other type of excitation. Phasors and their equivalents for random and transient excitation are discussed in annex B.

2 Linearity of the system is a condition which, in practice, will be met only approximately, depending on the type of system and on the magnitude of the input. Care has to be taken to avoid non-linear effects, particularly when applying impulse excitation. Structures which are known to be non-linear (e.g. certain riveted structures) should not be tested with impulse excitation and great care is required when using random excitation for testing such structures.

1) At present at the stage of draft.

3 Motion may be expressed in terms of either velocity, acceleration or displacement; the corresponding frequency-response function designations are mobility, accelerance and dynamic compliance, respectively.

4.2 mobility, Y_{ij}: The frequency-response function formed by the ratio of the velocity-response phasor at point i to the excitation force phasor at point j, with all other measurement points on the structure allowed to respond freely without any constraints other than those constraints which represent the normal support of the structure in its intended application. A typical graph is given in figure 1.

NOTES

1 The velocity response can be either translational or rotational, and the excitation force can be either a rectilinear force or a moment.

2 If the velocity response measured is a translational one and if the excitation force applied is a rectilinear one, the mobility term should be expressed in metres per newton second in the SI system.

4.3 blocked impedance, Z_{ij}: The frequency-response function formed by the ratio of the phasor of the blocking or driving-point force response at point i to the phasor of the applied excitation velocity at point j, with all other measurement points on the structure "blocked" (i.e. constrained to have zero velocity). All forces and moments required to constrain fully all points of interest on the structure shall be measured in order to obtain a valid blocked impedance matrix. Blocked impedance measurements (see [13]) are, therefore, seldom made and are not dealt with in the various parts of ISO 7626.

NOTES

1 Any changes in the number of measurement points or their location will change the blocked impedances at all measurement points.

2 The primary usefulness of blocked impedance is in the mathematical modelling of a structure using lumped mass, stiffness and damping elements or finite element techniques. When combining or comparing such mathematical models with experimental mobility data, it is necessary to convert the analytical blocked impedance matrix into a mobility matrix, or vice versa, as discussed in annex A.

4.4 free impedance: The ratio of the applied excitation force phasor to the resulting velocity phasor, with all other connection points of the system free (i.e. having zero restraining forces). Free impedance is the arithmetic reciprocal of a single element of the mobility matrix, as defined in 4.2.

NOTES

1 Historically, no distinction has often been made between blocked impedance and free impedance. Caution should, therefore, be exercised in interpreting published data.

2 While experimentally determined free impedances could be assembled into a matrix, this matrix would be quite different from the blocked impedance matrix resulting from mathematical modelling of the structure and, therefore, would not conform to the requirements discussed in annex A for using mechanical impedance in an overall theoretical analysis of the system.

4.5 Other frequency-response functions related to mobility

There are several other structural response ratios which are sometimes used instead of mechanical mobility. These are summarized in table 1.

Careful note should be taken of the comments on each type of ratio. Typical magnitude graphs for accelerance and for dynamic compliance, corresponding to the mobility graph shown in figure 1, are shown in figures 2 and 3, respectively.

Table 1 — Equivalent definitions to be used for various kinds of measured frequency response functions related to mechanical mobility

	Motion expressed as velocity	Motion expressed as acceleration	Motion expressed as displacement
Term	Mobility	Accelerance	Dynamic compliance
Symbol	$Y_{ij} = v_i/F_j$	a_i/F_j	x_i/F_j
Unit	m/(N·s)	$m/(N \cdot s^2) = kg^{-1}$	m/N
Boundary conditions	$F_k = 0 ; k \neq j$	$F_k = 0 ; k \neq j$	$F_k = 0 ; k \neq j$
See figure	1	2	3
Comment	Boundary conditions are easy to achieve experimentally		
Term	Blocked impedance	Blocked effective mass	Dynamic stiffness
Symbol	$Z_{ij} = F_i/v_j$	F_i/a_j	F_i/x_j
Unit	(N·s)/m	$(N \cdot s^2)/m = kg$	N/m
Boundary conditions	$v_k = 0 ; k \neq j$	$a_k = 0 ; k \neq j$	$x_k = 0 ; k \neq j$
Comment	Boundary conditions are very difficult or impossible to achieve experimentally		
Term	Free impedance	Effective mass (free effective mass)	Free dynamic stiffness
Symbol	$F_j/v_i = \frac{1}{Y_{ij}}$	F_j/a_i	F_j/x_i
Unit	(N·s)/m	$(N \cdot s^2)/m = kg$	N/m
Boundary conditions	$F_k = 0 ; k \neq j$	$F_k = 0 ; k \neq j$	$F_k = 0 ; k \neq j$
Comment	Boundary conditions are easy to achieve, but results shall be used with great caution in system modelling		

NOTES

1 Dynamic compliance is called "receptance" by several authors.

2 Accelerance has, regrettably, been called "inertance" in some publications. This term is not a standard term and should be avoided because it is in conflict with the common definition of "acoustic inertance" and also contrary to the implication carried by the term "inertance".

4.6 frequency range of interest: Span, in hertz, from the lowest frequency to the highest frequency at which mobility data are to be obtained in a given test series.

5 Basic requirements for force- and motion-measurement transducers

5.1 General

The basic characteristics of all measurement transducers which are important in acquiring adequate mobility data are as follows:

a) Transducers shall have sufficient sensitivity and low noise in order to obtain a signal-to-noise ratio of the measurement chain which is adequate to cover the dynamic range of the mobility of the structure. Since lightly damped structures require a larger dynamic range than structures with considerable damping, transducer noise is of particular concern when testing lightly damped structures.

b) If the frequency-response function of the measurement transducer is not compensated by suitable signal processing, the natural frequency of the response transducer shall be far enough below or above the frequency range of interest that no unacceptable phase shift will occur.

c) Transducer sensivity shall be stable with time and have negligible d.c. drift.

d) Transducers shall be insensitive to extraneous environmental effects, such as temperature, humidity, magnetic fields, electrical fields, acoustical fields, strain and cross-axis inputs.

e) Transducer mass and rotational inertia shall be small so as to avoid dynamic loading of the structure under test, or at least small enough so that a correction can be made for the loading.

Low susceptibility of the measurement system to the effects of electrical ground loops and other extraneous signals is also important.

5.2 Requirements for motion-measurement transducers

Although motion-measurement transducers require the characteristics outlined in 5.1, certain of these characteristics are more important than others. Motion transducers used in mechanical mobility measurements are most commonly accelerometers; however, displacement or velocity transducers are sometimes used. The major characteristics to be considered in transducer selection are outlined in 5.2.1 to 5.2.4.

5.2.1 The motion transducer should be of lightweight (or non-contacting) design so as to minimize structural loading of the structure under test.

5.2.2 The attachment of the transducer to the structure under test should be stiff in the direction of the primary measurement axis of the transducer.

5.2.3 The attachment should have a sufficiently small contact area to prevent stiffening or damping of the structure by the transducer or its mounting fixture.

5.2.4 When applying impulse excitation, zero drift of piezoelectric accelerometers due to the pyro-electric effect is likely to occur and this will limit the accuracy of the measurement at low frequencies. Other types of motion transducers (e.g. piezoresistive, electrodynamic or some shear type piezoelectronic accelerometers) can provide the solution to this problem.

5.3 Requirements for force-measurement transducers

Some of the characteristics outlined in 5.1 are more important than others in the selection of a force-measurement transducer to be used for mechanical mobility measurements. Since compromises in design have to be made, the items outlined in 5.3.1 to 5.3.3 shall be considered as being of prime importance.

5.3.1 The effective end mass (mass between the force-sensing element of the transducer and the structure) should be small enough to minimize extraneous inertial signals related to such mass. (See 8.4 for further details.)

5.3.2 The stiffness of the force transducer and its components should be selected so that no resonances involving this stiffness occur within the frequency range of interest. As a compromise, the effect of such resonances on the signal from the force-sensing element should be compensated for by suitable signal processing.

5.3.3 The static preload shall be adequate for the range of excitation forces required by the test application. Transducers with built-in preload are available to minimize this problem.

5.4 Requirements for impedance heads and attachments to the structure under test

A device which combines an accelerometer and a force transducer in one assembly for the purpose of mobility measurement is traditionally called an "impedance head". The design is a compromise based on the characteristics outlined in 5.2 and 5.3. However, certain characteristics of prime importance, given in 5.4.1 to 5.4.4, should be borne in mind.

5.4.1 The total compliance between the structure and the internal accelerometer should be small, because a large compliance will cause errors in acceleration measurements.

NOTE — The total compliance is the sum of the attachment compliance and the internal compliance of the impedance head. The attachment compliance includes the localized "die effect" compliance of the structure under test. The total compliance can be measured as described in annex C.

5.4.2 The effective end mass (mass between the force-sensing element of the transducer and the structure) should be small in relation to the free effective mass of the structure under test.

5.4.3 The moment of inertia of the impedance head, relative to an axis in the plane of attachment, should be small enough to minimize structural loading due to rotational motion about that axis.

NOTE — Further guidelines for avoiding loading of the structure under test by the attachment of impedance heads will be given in ISO 7626/2.

5.4.4 In the design of an impedance head, care is required to avoid cross-sensitivity of the acceleration transducer to the applied force.

6 Calibration

Calibrations fall into three categories:

a) operational calibration of the combined measurement and analysis system;

b) basic transducer calibrations;

c) supplementary transducer calibrations.

6.1 Operational calibrations

Operational calibrations of the combined measurement and analysis system shall be carried out at the beginning and end of each measurement series (and at intermediate times, as required). Detailed procedures will be covered in the relevant parts of ISO 7626 pertaining to the various types of mobility measurements, as outlined in clause 0.

Combined system calibrations are easier to perform, more accurate and in wider use than the basic calibrations discussed in clause 7. These system calibrations are achieved by driving, in free space, a known free mass while the acceleration and force channel gains are set at the values that will be used in later measurements. The ratio output shall follow the appropriate mass line on the resulting mobility graph. If any difficulties are experienced in combined system calibrations, basic calibrations should be carried out.

The accuracy of the frequency scale of the response graph or other data output should always be checked during the operational calibration.

NOTES

1 An example of the resulting mobility graph, showing the effect of the impedance head attachment compliance, is shown in annex C.

2 It is usually unnecessary to perform a phase-shift calibration provided that the accelerometers, force transducers and amplifiers are selected to have nearly flat response throughout the frequency range used for mobility measurements, and the accelerometer is of a low damping design. However, it is good practice to display the phase angle between the force transducer and accelerometer outputs on a phase meter and record any deviations from the proper phase angle between the force transducer and accelerometer outputs while carrying out the operational calibration.

6.2 Basic and supplementary transducer calibrations

The basic and supplementary calibrations (see table 2) are intended for determining the suitability of the transducers for mobility measurements. Piezoelectric transducers are very frequently used. If other types of transducers are used, the procedures may have to be modified to determine the suitability of such transducers.

Transducers exhibiting changes in basic or supplementary calibrations should not be used if the changes are unacceptable, as indicated in the appropriate clauses in this part of ISO 7626.

Table 2 — Summary of transducer calibrations and tests

Calibration or test	Accelerometer		Force transducer	
	Basic	Supplementary	Basic	Supplementary
Sensitivity	7.2.1		7.2.2	
Electrical impedance	7.3		7.3	
Dimensions		8.2		8.2
Mass		8.3		8.3
Effective end mass				8.4
Transducer compliance				8.5
Polarity		8.6		8.6
Frequency response		8.7.1		8.7.2
Linearity		8.8.1		8.8.2
Temperature sensitivity		8.9.1 and 8.9.2		8.9.1 and 8.9.2
Transverse sensitivity		8.9.4		
Strain sensitivity		8.9.5		

Transducers intended for use with specific amplifiers or signal conditioners should have the calibration performed under the conditions of intended use. For example, piezoelectric force transducers, impedance heads and accelerometers are intended for use with either charge amplifiers or high impedance voltage amplifiers and should be calibrated with the intended amplifier. For these transducers, the capacitance of the cables used between transducer and amplifier is important and the transducers should be calibrated together with the intended cable. Other types of transducers should be calibrated with their intended signal conditioning devices in accordance with the manufacturer's specifications for electrical excitation, special terminating impedance, etc.

When calibrating force transducers and impedance heads, special care should be taken to use mounting conditions similar to those specified by the manufacturer. Flatness of the mounting plate and proper torquing of the attaching screws is important. A thin film of oil or grease or wax between the transducer and the mounting surface may increase transducer coupling and rigidity for use at high frequencies. If special fixtures are used, every effort should be made to carry out force transducer calibrations using a mechanical arrangement closely resembling that to be used during the mobility measurement.

7 Basic piezoelectric transducer calibrations

7.1 General

All basic calibrations and tests listed in table 2 shall be carried out by the manufacturer on each transducer and the results shall be recorded in the documentation supplied with the transducer. All basic calibrations should be repeated periodically by the user (or by a commercial calibration laboratory, if the user does not have adequate calibration facilities).

The recommended time interval for repeating basic calibrations and tests is 1 year. In addition, calibrations such as sensitivity should be repeated more frequently, particularly if the transducer is subjected to conditions which may change its sensitivity.

7.2 Sensitivity

7.2.1 Accelerometer sensitivity

Sensitivity of accelerometers and the accelerometer portion of impedance heads shall be determined by using the comparison method. Calibration shall be carried out by mounting the accelerometer on a suitable shaker equipped with a reference accelerometer previously calibrated by or referenced to an absolute calibration. The calibration amplitude should be within the range encountered in actual mobility measurements, generally between 1,0 and 100 m/s^2.

The sensitivity calibration should be carried out at a single frequency, generally 80 Hz.

NOTE — A different frequency may be used, if 80 Hz is outside the operating frequency range of the transducer or if another frequency is more suitable for the particular transducer design or experimental application of the transducer.

For accelerometers designed to be used with a charge amplifier, accelerometer sensitivity shall be expressed in picocoulombs per metre per second squared [$pC/(m/s^2)$]. For accelerometers designed to be used with a voltage amplifier and for accelerometers with a built-in charge amplifier or impedance transformer, accelerometer sensitivity shall be expressed in volts per metre per second squared [$V/(m/s^2)$].

NOTE — Since the output signal of the charge or voltage amplifier associated with the accelerometer is always a voltage, the resultant acceleration channel sensitivity should always be expressed in volts per metre per second squared [$V/(m/s^2)$]. In general, the acceleration channel sensitivity is determined from the knowledge of the separate sensitivities of the accelerometer and the amplifier; in cases where precise mobility measurements are required, the accelerometer and the amplifier to be used with the accelerometer should be calibrated together in order to obtain the acceleration channel sensitivity directly.

7.2.2 Force-transducer sensitivity

Force transducers and the force section of impedance heads shall be calibrated using a mass-loading technique.

The sensitivity calibration shall be carried out by mounting the force transducer on a suitable shaker using the rated preloading torque recommended by the manufacturer. The force transducer shall be vibrated at a controlled acceleration amplitude, a_0, with only a reference accelerometer attached to its opposite face. The force transducer amplifier voltage output, E_0, and the applied acceleration, a_0, shall be measured. A loading mass, m, shall then be attached to the opposite face of the force transducer without changing the amplifier gain settings. The voltage output, E_M, shall be measured with the shaker input adjusted so that the applied acceleration, a, has exactly the same amplitude as before (that is $a = a_0$). The sensitivity of the force channel, S_f, is then given by the following equation:

$$S_f = \frac{E_M - E_0}{(m + m_1 + m_2 + m_3)a - (m_1 + m_2 + m_3)a_0} \quad \ldots (1)$$

where

m is the loading mass;

m_1 is the mass of the reference accelerometer;

m_2 is the effective mass of the bolt;

m_3 is the effective end mass of the force transducer.

All the masses are expressed in kilograms and the acceleration shall be expressed in metres per second squared. As $(m_1 + m_2 + m_3)a_0 = (m_1 + m_2 + m_3)a$, because $a_0 = a$, equation (1) becomes

$$S_f = \frac{E_M - E_0}{ma} \quad \ldots (2)$$

NOTE — For force transducers which have not been pre-assembled, extreme care should be taken to ensure that the mounted preload does not change from application to application, since sensitivity and calibration depend on transducer preload.

Equation (2) gives the sensitivity of the force channel (i.e. the transducer/amplifier combination) in volts per newton. The sensitivity of the force transducer alone can be deduced from equation (2) and the sensitivity of the amplifier used.

For force transducers designed to be used with a charge amplifier, force-transducer sensitivity shall be expressed in picocoulombs per newton. For force transducers designed to be used with a voltage amplifier, force-transducer sensitivity shall be expressed in volts per newton.

NOTE — In cases where precise mobility measurements are required, the force transducer and the amplifier to be used with the force transducer should be calibrated together in order to obtain the total force channel sensitivity directly.

The method described is adequate only at frequencies below approximately one-fifth of the resonance frequency due to the effective mass of the system and the stiffness, k, of the force transducer. This resonance can be estimated by means of the following equation:

$$f_n = \frac{1}{2\pi}\left[\frac{k}{(m + m_1 + m_2 + m_3)}\right]^{1/2} \qquad \ldots (3)$$

where f_n is the resonance frequency of the mass-loaded transducer, in hertz.

7.2.3 Impedance-head sensitivity

The sensitivity of an impedance head can be obtained from the individual calibrations of the accelerometer and the force transducer performed using the methods given in 7.2.1 and 7.2.2, respectively. Field calibration of an impedance head usually consists of driving two or three differently sized free masses. This ensures that the impedance head can measure known mobilities over a wide range.

7.3 Electrical impedance

7.3.1 Transducer resistance and capacitance

The direct current resistance between the terminals of the transducer shall be measured by the manufacturer with a megohmmeter, using an applied voltage not exceeding 50 V.

The capacitance shall be measured with an impedance bridge, using an excitation voltage within the operating frequency range of the transducer. If the capacitance changes with frequency, the measurement shall be carried out at a minimum of two frequencies, including the frequency at which the reference sensitivity shall be determined. For transducers the capacitance of which does not change significantly with frequency, the measurement shall usually be carried out at 1 000 Hz.

Since the capacitance of some piezoelectric materials changes with temperature and voltage, the capacitance measurement shall be performed at room temperature (20 to 30 °C) and at an excitation voltage recommended by the transducer manufacturer. Variations due to temperature can be minimized by avoiding handling immediately before or during the capacitance measurements.

NOTE — For some transducers containing internal electronic components, the above impedance measurement operation may produce inaccurate results or possibly cause damage. In these cases, insertion methods should be used.

Resistance and capacitance measurements should be repeated at suitable time intervals (see 7.1). Since these measurements are generally not very accurate, only significant variations, compared to previous calibrations, shall be taken into account. For instance, if resistance and/or capacitance has changed by more than 5 %, the transducer should be further evaluated by performing all basic and supplementary calibrations or it should be repaired, as required.

7.3.2 Insulation resistance

The direct current resistances between all the terminals of the transducer and its mounting surface shall be measured and supplied as data by the manufacturer.

If the transducer is not of an isolated type, the manufacturer shall indicate the type of mounting needed to achieve isolation when using the transducer (see 5.1).

8 Supplementary calibrations

8.1 General

The supplementary calibrations and tests listed in table 2 shall be carried out by the manufacturer on samples of the transducers for each type manufactured. Furthermore, some of the supplementary calibrations and tests should be carried out by the user to determine the condition of a transducer which exhibits peculiar operating characteristics or changes in performance.

8.2 Dimensions

Pertinent dimensions, including height, width, length, diameter and dimensions of any mounting holes or studs, shall be given. The dimensions shall be provided in the form of an outline drawing. Descriptions of connectors, cable sizes and cable types shall also be provided.

8.3 Mass

The mass specified is the total mass of the transducer, excluding mounting studs and cables which do not form an integral part of the transducer.

8.4 Effective end mass of force transducers and impedance heads

The effective end mass of force transducers and impedance heads is the mass between the force-sensing elements and the specimen end of the transducer. This effective end mass should be included in the manufacturer's specifications. However, the user should be aware that the effective end mass is increased by the addition of the hardware used to attach the transducer to the structure under test and/or to preload the transducer. Thus, the total effective end mass is the sum of the manufacturer's effective end mass and the mass of the attaching hardware.

8.5 Compliance of impedance heads

The compliance of an impedance head is the compliance of that part of the assembly between the point of attachment to the structure and the internal accelerometer (see [10]).