INTERNATIONAL STANDARD

IEC 61685

First edition
2001-07

Ultrasonics –
Flow measurement systems –
Flow test object

Ultrasons –
Systèmes de mesure de débit –
Montage pour essai de débit

Reference number
IEC 61685:2001(E)

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

Consolidated editions

The IEC is now publishing consolidated versions of its publications. For example, edition numbers 1.0, 1.1 and 1.2 refer, respectively, to the base publication, the base publication incorporating amendment 1 and the base publication incorporating amendments 1 and 2.

Further information on IEC publications

The technical content of IEC publications is kept under constant review by the IEC, thus ensuring that the content reflects current technology. Information relating to this publication, including its validity, is available in the IEC Catalogue of publications (see below) in addition to new editions, amendments and corrigenda. Information on the subjects under consideration and work in progress undertaken by the technical committee which has prepared this publication, as well as the list of publications issued, is also available from the following:

- **IEC Web Site (www.iec.ch)**

- **Catalogue of IEC publications**

  The on-line catalogue on the IEC web site (www.iec.ch/catlg-e.htm) enables you to search by a variety of criteria including text searches, technical committees and date of publication. On-line information is also available on recently issued publications, withdrawn and replaced publications, as well as corrigenda.

- **IEC Just Published**

  This summary of recently issued publications (www.iec.ch/JP.htm) is also available by email. Please contact the Customer Service Centre (see below) for further information.

- **Customer Service Centre**

  If you have any questions regarding this publication or need further assistance, please contact the Customer Service Centre:

Email: custserv@iec.ch
Tel: +41 22 919 02 11
Fax: +41 22 919 03 00

INTERNATIONAL STANDARD

IEC 61685

First edition
2001-07

Ultrasonics –
Flow measurement systems –
Flow test object

Ultrasons –
Systèmes de mesure de débit –
Montage pour essai de débit

International Electrotechnical Commission 3, rue de Varembé Geneva, Switzerland
Telefax: +41 22 919 0300 e-mail: inmail@iec.ch IEC web site http://www.iec.ch

Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE W

For price, see current catalogue

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ULTRASONICS – FLOW MEASUREMENT SYSTEMS –
FLOW TEST OBJECT

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

2) The formal decisions or agreements of the IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested National Committees.

3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.

4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.

5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.

6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 61685 has been prepared by IEC Technical Committee 87: Ultrasonics.

The text of this standard is based on the following documents:

FDIS	Report on voting
87/202/FDIS	87/208/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annexes A, C, D, E and F are for information only.

Annex B forms an integral part of this standard.

The committee has decided that the contents of this publication will remain unchanged until 2006. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

INTRODUCTION

The purpose of this International Standard is to establish a **flow Doppler test object** for the acceptance testing, quality assurance testing and clinical calibration of Doppler systems, working at a frequency between 2 MHz and 10 MHz. As the response of Doppler systems depends on the signal level and on the spectral contents of the signal, it is desirable to test some aspects of a Doppler system with a test object that mimics the *in vivo* situation. A **flow Doppler test object** is particularly useful for

– testing the influence of the size and the depth of the blood vessel on the signal recorded by a Doppler system;

– testing the response of a Doppler system with a spectrum of blood velocities typical of the *in vivo* situation.

This **flow test object** is not intended as a phantom mimicking clinical conditions.

The basis of this International Standard is given by IEC Technical Report 61206:1993 *Ultrasonics – Continuous Wave Doppler systems – Test procedures*. In annex A the position of this standard in relation to IEC 61206 and IEC 61895 is described. This standard only declares parameters that can be measured with the test object. Measurement methods are given in IEC 61206 and IEC 61895.

This International Standard deals only with the **flow Doppler test object** in a restricted sense, i.e. the section in which the ultrasonic measurements are performed. Where the whole of the set-up is meant, the phrase 'flow rig' is used. The prescriptions of this International Standard define the ultrasonic properties and the flow pattern in the measurement section of the flow test object. For other aspects of the flow rig (i.e. generating and measuring flows) standard engineering practice has to be followed.

The flow conditions are simplified as much as possible: a steady flow through a straight **tube** with a circular cross-section. Generalisation of the flow conditions to other geometries and time dependent flows is required in order to test some instrument functions. This generalisation is not undertaken in this International Standard.

In annex D, an example **flow Doppler test object** is described which complies with the requirements of this International Standard. Compliance with this International Standard can also be fulfilled by measuring the properties of the materials to be used, and complying with the values given in this International Standard.

In literature [1], [2] the nomenclature about the primary measurand of Doppler systems is confused. 'Doppler frequency' and 'velocity' occur on equal footing. In 'velocity' often a correction for **Doppler angle** has been included. To avoid this ambiguity, in this International Standard the term 'Doppler frequency' is preferred. In case a Doppler system is declared to measure velocity, it is intended that measured values are converted to Doppler frequency, using **acoustic working frequency** and, if applicable, **Doppler angle**.

ULTRASONICS – FLOW MEASUREMENT SYSTEMS – FLOW TEST OBJECT

1 Scope

This International Standard specifies parameters for a **flow Doppler test object** representing a blood vessel of known diameter at a certain depth in human tissue, carrying a steady flow.

This International Standard establishes a **flow Doppler test object** which can be used to assess various aspects of the performance of Doppler diagnostic equipment.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 61206:1993, *Ultrasonics – Continuous-wave Doppler systems – Test procedures*

IEC 61102:1991, *Measurement and characterisation of ultrasonic fields using hydrophones in the frequency range 0,5 MHz to 15 MHz*

IEC 61895:1999, *Ultrasonics – Pulsed Doppler diagnostic systems – Test procedures to determine performance*

3 Definitions

For the purposes of this International Standard, the following definitions apply:

3.1
–3 dB Doppler frequency
frequency at which the power per unit frequency in the Doppler spectrum is half (–3 dB) of the maximum value

3.2
–3 dB sample volume
volume of a region in space for which the Doppler system gives a response to a point Doppler target that is above –3 dB from the maximal response, taking account of the effects of both transmission and reception

Unit: cubic millimetre, mm^3

3.3
–3 dB sample volume length
largest dimension of the **–3 dB sample volume** in the direction of the beam alignment axis (see 3.5 of IEC 61102)

Unit: millimetre, mm

3.4
–3 dB sample volume width
largest value of the dimension of the **–3 dB sample volume** along an axis which is perpendicular to the beam alignment axis. In case the Doppler system has a scan plane, the axes are taken in the scan plane and perpendicular to the scan plane

Unit: millimetre, mm

3.5
acoustic-working frequency
frequency of an acoustic signal based on the output observed by a hydrophone placed in an acoustic field: it is the arithmetic mean of the two frequencies at which the amplitude of the acoustic pressure spectrum is 3 dB below the peak amplitude

[conforms to 3.4.2 of IEC 61102]

Unit: hertz, Hz

3.6
aliasing
false indication of signal frequency as a result of sampling at too low a frequency

NOTE The threshold for **aliasing** depends on pulse repetition frequency and a possible base line shift.

3.7
average frequency of the Doppler spectrum
parameter estimated by clinical Doppler systems for the short-time average in a Doppler spectrum, ignoring the contributions from noise

NOTE The **average frequency of the Doppler spectrum** is generally determined for a small time interval, typically 2 ms to 20 ms).

Unit: hertz, Hz

3.8
axial response range
depth range in tissue over which a signal from a specific target plus noise is at least 3 dB above the noise level

[see 2.4.1 of IEC 61206]

Unit: millimetre, mm

3.9
blood-mimicking fluid (BMF)
fluid which simulates blood acoustically and is moved at a known flow rate through the **flow Doppler test object**

3.10
channel separation
ratio of the signal level in the signal channel corresponding to the movement in the test object (the desired output voltage) and the signal level in the opposite channel (the undesired output voltage)

NOTE **Channel separation** is to be quoted in decibels as twenty times the logarithm of the desired output to the undesired output voltage.

[see 2.6.1 of IEC 61206]

Unit: decibel, dB

3.11

colour display spatial resolution
minimum separation in space for which two separate moving point targets or line targets can be resolved

NOTE The **colour display spatial resolution** is measured in three directions: 1) along the beam alignment axis, 2) the direction perpendicular to the scan plane and 3) the direction in the scan plane perpendicular to the beam alignment axis.

Unit: millimetre, mm

3.12
dead zone boundary
boundary of the region close to the transducer in which the system is insensitive to movement

3.13
depth of measurement
distance from the surface of the **tissue-mimicking material** to the centre of the **tube**. In case various attenuating materials, not being **tissue-mimicking material** or **blood-mimicking material**, are present in the ultrasonic path, the **depth of measurement** is taken to be the equivalent distance in the **tissue-mimicking material**, from the surface of the **tissue-mimicking material** to the centre of the **tube**, over which the attenuation is the same as that in the actual path in the **flow Doppler test object**

(see also annex B)

Symbol: M

Unit: millimetre, mm

3.14
Doppler angle

acute angle between the Doppler beam axis used for the Doppler measurement and the axis of the **tube**

Symbol: θ

Unit: degree, °

3.15
Doppler angle error
difference between the measurement of the **Doppler angle** and its true value

Unit: degree, °

3.16
Doppler frequency –3 dB response range
frequency region in the Doppler spectrum around the frequency where power per unit frequency is maximal, which is delimited by the nearest **–3 dB Doppler frequencies**

Unit: hertz, Hz

NOTE The Doppler frequency response range at another signal level may be used in an analogous way.

3.17
Doppler frequency non-linearity error
largest frequency deviation of a data point from the least squares fitted line through the origin in a plot of Doppler frequency versus observed velocity over the **Doppler frequency –3 dB response range**

[see 2.3.2 of IEC 61206]

Unit: hertz, Hz

3.18
Doppler frequency response
Doppler signal level (in dB) as a function of Doppler frequency

3.19
dynamic range
ratio (in decibels) between the largest Doppler signal which can be processed by the system without generating spurious outputs and the smallest Doppler signal which can be detected

NOTE **Dynamic range** is a measure of the ratio between the maximum allowable signal from clutter and the minimum signal level at which flow can be detected.

Unit: decibel, dB

3.20
fixed target effect on sensitivity
change in Doppler output level (in decibels) when a strongly reflecting stationary structure (a perfect reflector, see 2.3.3.2 of IEC 61206) is brought into the Doppler beam

Unit: decibel, dB

3.21
flow Doppler test object
physical model of blood flowing within a vessel that is embedded in soft tissue. The object is composed of **tissue-mimicking material** through which **blood-mimicking material** is caused to flow

3.22
frequency to colour translation table
table which describes the way in which Doppler frequencies are mapped to colours for display

3.23
highest detectable Doppler frequency
Doppler frequency corresponding to the highest **observed velocity** which can be determined unambiguously (without **aliasing**)

Unit: hertz, Hz

3.24
inner diameter
inner diameter of the **tube** through which the **blood-mimicking fluid** flows

Symbol: D

Unit: millimetre, mm

3.25
inlet length
distance over which the **tube** must have a uniform cross-section in order to ensure that a well defined velocity distribution develops which is independent of the flow conditions at the entry of the **tube**

Symbol: L

Unit: millimetre, mm

3.26
intrinsic spectral broadening
width of the frequency region over which the spectral intensity is above –3 dB from its maximal value, when the Doppler system observes a moving target having a single velocity

Unit: hertz, Hz

3.27
lowest detectable Doppler frequency
Doppler frequency corresponding to the lowest **observed velocity** which can be distinguished from noise

Unit: hertz, Hz

3.28
maximum frequency of the Doppler spectrum
parameter estimated by a Doppler system for the highest occurring frequency in a Doppler spectrum, ignoring the contributions from noise

NOTE 1 The **maximum frequency of the Doppler spectrum** corresponds to the highest velocity occurring in the sample volume at a certain time.

NOTE 2 Clinical Doppler systems generally determine the **maximum frequency of the Doppler spectrum** for a small time interval (typically 2 ms to 20 ms).

Unit: hertz, Hz

3.29
observed velocity
component of the velocity of a scatterer that is directed towards or away from the transducers

[definition 1.3.10 of IEC 61206]

3.30
parabolic velocity profile
axisymmetrical flow distribution in a cross-section of the **tube**, in which the velocity decreases in proportion to the square of the distance from the **tube**'s axis, and the velocity at the **tube** wall is zero

3.31
penetration depth
maximum depth in **tissue-mimicking material** from which a Doppler signal can be detected from noise

Unit: millimetre, mm

3.32
sample volume position error
difference between the centre of the sample volume on the image and its true position

Unit: millimetre, mm

3.33
tissue-mimicking material (TMM)
material whose pertinent ultrasonic properties (sound velocity, attenuation and scattering) are similar to those of soft tissue

3.34
tube
conduit which carries the **blood-mimicking fluid (BMF)** flow

NOTE The word **tube** also applies to the case of a hole in the **tissue-mimicking material**.

3.35
volume flow measurement error
100 times the absolute value of the difference between the Doppler measurement of a particular volume flow rate and its true value, divided by the true value

NOTE The **volume flow measurement error** has a sign and is reported as a percentage.

3.36
wall thickness
thickness of the wall of the **tube**

NOTE In the case of a hole in the **tissue-mimicking material**, the value of the wall thickness is zero.

Symbol: w

Unit: millimetre, mm

3.37
working distance
distance between the transducer and a specific target in **tissue-mimicking material** when the signal is maximal

Unit: millimetre, mm

3.38
zero-velocity noise level
r.m.s. voltage of the signal (in dB) on the Doppler output connector under the condition that the moving portion of the Doppler test object is stopped

Unit: decibel, dB

NOTE 1 Generally the **zero-velocity noise level** is the sum of the system noise level and the clutter noise level.

NOTE 2 **Zero-velocity noise level** is reported as dB with respect to 1 mV r.m.s.

4 List of symbols

c = velocity of sound

c_w = velocity of sound in the **wall** material

c_t = velocity of sound in the **tissue-mimicking material**

c_b = velocity of sound in the **blood-mimicking fluid**

D = **inner diameter of tube**

f = **acoustic-working frequency** of the investigated equipment

h = path length in **TMM**

L = **inlet length**

M = **depth of measurement** *

q = flow rate of **blood-mimicking fluid**

Re = Reynolds number *

v = local velocity of **blood-mimicking fluid**

v_{avg} = velocity averaged over the cross-section of the **tube** *

v_{max} = the highest velocity occurring in a cross-section of the **tube** *

w = **wall thickness** of **tube**

Z = characteristic acoustic impedance *

α = attenuation coefficient of sound

η = viscosity of a **blood-mimicking fluid**

θ = **Doppler angle**

ρ = density of material

σ = differential scattering cross-section in the backward direction per unit volume, also called backscatter coefficient

NOTE For quantities marked with an asterisk, formulae are given in annex B.