CD/K/030:2009
ICS 23.080

EAST AFRICAN STANDARD

Pumps — Rotodynamic pumps — Circulation pumps having a rated power input not exceeding 200 W for heating installations and domestic hot water installations — Part 2: Noise test code (vibro-acoustics) for measuring structure- and fluid-borne noise

EAST AFRICAN COMMUNITY

First Edition 2010

Foreword

Development of the East African Standards has been necessitated by the need for harmonizing requirements governing quality of products and services in East Africa. It is envisaged that through harmonized standardization, trade barriers which are encountered when goods and services are exchanged within the Community will be removed.

In order to meet the above objectives, the EAC Partner States have enacted an East African Standardization, Quality Assurance, Metrology and Test Act, 2006 (EAC SQMT Act, 2006) to make provisions for ensuring standardization, quality assurance, metrology and testing of products produced or originating in a third country and traded in the Community in order to facilitate industrial development and trade as well as helping to protect the health and safety of society and the environment in the Community.

East African Standards are formulated in accordance with the procedures established by the East African Standards Committee. The East African Standards Committee is established under the provisions of Article 4 of the EAC SQMT Act, 2006. The Committee is composed of representatives of the National Standards Bodies in Partner States, together with the representatives from the private sectors and consumer organizations. Draft East African Standards are circulated to stakeholders through the National Standards Bodies in the Partner States. The comments received are discussed and incorporated before finalization of standards, in accordance with the procedures of the Community.

Article 15(1) of the EAC SQMT Act, 2006 provides that "Within six months of the declaration of an East African Standard, the Partner States shall adopt, without deviation from the approved text of the standard, the East African Standard as a national standard and withdraw any existing national standard with similar scope and purpose".

East African Standards are subject to review, to keep pace with technological advances. Users of the East African Standards are therefore expected to ensure that they always have the latest versions of the standards they are implementing.

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Introduction

This part of CD/K/044:2009 covers the measurement of fluid and structure-borne noise as induced by small circulation pumps. It has been prepared in response to the need of having uniform procedures as requirements for noise levels especially in residential housing. The issue of airborne noise is covered by other standards.

In the preparation of this East African Standard, the following source was consulted extensively:

BS EN 1151-2:2006, *Pumps — Rotodynamic pumps — Circulation pumps having a rated power input not exceeding 200 W for heating installations and domestic hot water installations — Part 2: Noise test code (vibro-acoustics) for measuring structure- and fluid-borne noise*

Assistance derived from this source and others inadvertently not mentioned is hereby acknowledged.

Pumps — Rotodynamic pumps — Circulation pumps having a rated power input not exceeding 200 W for heating installations and domestic hot water installations — Part 2: Noise test code (vibro-acoustics) for measuring structure- and fluid-borne noise

1 Scope

This part of CD/K/044:2009 specifies a test code for the vibro-acoustic characterisation of circulation pumps as defined in CD/K/044-1:2009, and is limited to circulation pumps with threaded connections of 1 ½ inch. The test code comprises the test rig, the measurement method and the test conditions.

The characterization principle is based on measuring the structure-borne and the fluid-borne power; transmitted respectively by vibration and pressure fluctuations in the pipe connected to a circulation pump.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

CD/K/044-1:2009, *Pumps — Rotodynamic pumps — Circulation pumps having a rated power input not exceeding 200 W for heating installations and domestic hot water installations — Part 1: Non-automatic circulation pumps, requirements, testing, marking*

ISO 2016, *Capillary solder fittings for copper tubes — Assembly dimensions and tests*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in CD/K/044-1:2009 and the following apply.

3.1
fluid-borne intensity
I_{fb}
time averaged rate of flow of the acoustic energy per cross section of fluid transmitted lengthways the straight pipe by internal pressure fluctuations

NOTE 1 Its sign can be positive or negative indicating the sense of energy propagation.

NOTE 2 Fluid-borne intensity is expressed in W/m^2.

3.2
fluid-borne power
P_{fb}
net acoustic power emitted by a source of pressure fluctuations in the connected straight pipe (circulation pumps)

NOTE 1 Fluid-borne power is always positive.

NOTE 2 Fluid-borne power is expressed in W.

3.3
structure-borne intensity
I_{sb}

time averaged rate of flow of the vibrational energy per unit of length transmitted lengthways the straight pipe by vibration

NOTE 1 Its sign can be positive or negative indicating the sense of energy propagation.

NOTE 2 I_{sb} is an average of the structure borne intensity over the pipe wall thickness and is therefore expressed in W/m.

3.4
structure-borne power

F_{sb}

net vibration power emitted by a source of vibration in the connected straight pipe (circulation pumps)

NOTE 1 Structure-borne power is always positive.

NOTE 2 Structure-borne power is expressed in W.

3.5
coefficient of fluid-borne energy reflection

R_{fb}

ratio between the net fluid-borne power reflected by pipework discontinuities and the net fluid borne power emitted in a straight pipe by a pump (circulation pumps)

NOTE 1 Pipework discontinuities covers bends, obstructions, section changes, pipe fixations etc.

NOTE 2 This coefficient is always positive and is non-dimensional.

3.6
coefficient of structure-borne energy reflection

R_{sb}

ratio between the net structure-borne power reflected by pipework discontinuities and the net structure borne power emitted in a straight pipe by a pump (circulation pumps)

NOTE 1 Pipework discontinuities covers bends, obstructions, section changes, pipe fixations etc.

NOTE 2 This coefficient is always positive and is non-dimensional.

3.7
fluid-borne power level

L_{wtb}

logarithmic measure of the fluid-borne power emitted in the straight pipe by a source (circulation pumps)

3.8
structure-borne power level

L_{Wsb}

logarithmic measure of the structure-borne power emitted in the straight pipe by a source (circulation pumps)

3.9
steady state temperature

period of time during which the variation of temperature on the motor and on the body of the circulation pump is contained between limits specified by the manufacturer

4 Test rig

4.1 General

The fluid- and structure-borne powers are determined from measurement data acquired from the test rig.

Components and assembly of the test-rig are described below. To get repeatable and reproducible results of the measurements, it is essential to use a rig, which is in accordance with or corresponds to all specifications and assembly advice given here.

4.2 Main components of test rig

The test rig is illustrated in Figure 1 and its main components are given in Table 1.

Table 1 — Main components of test rig

No.	Component	Purpose
1	Circulation pump	Test object: source of pressure pulsation and vibration.
2	Vibration measurement pipe	Acquisition of vibration data allowing the determination of the structure-borne power.
3	Solid anechoic termination	Device absorbing structure-borne power.
4	Pressure pulsation measurement pipe	Acquisition of pressure fluctuation data allowing the determination of the fluid-borne power.
5	Liquid anechoic termination	Device absorbing fluid-borne power.
6	Water tank	Acoustical isolation of the regulation valve.
7	Pressure vessel	Device equalizing the system pressure.
8	Flow meter	Measurement of flow rate
9	Regulation valve	Flow rate regulation
10	Pipe supports	Connecting devices of pipework with frame.
11	Frame	Metal structure.

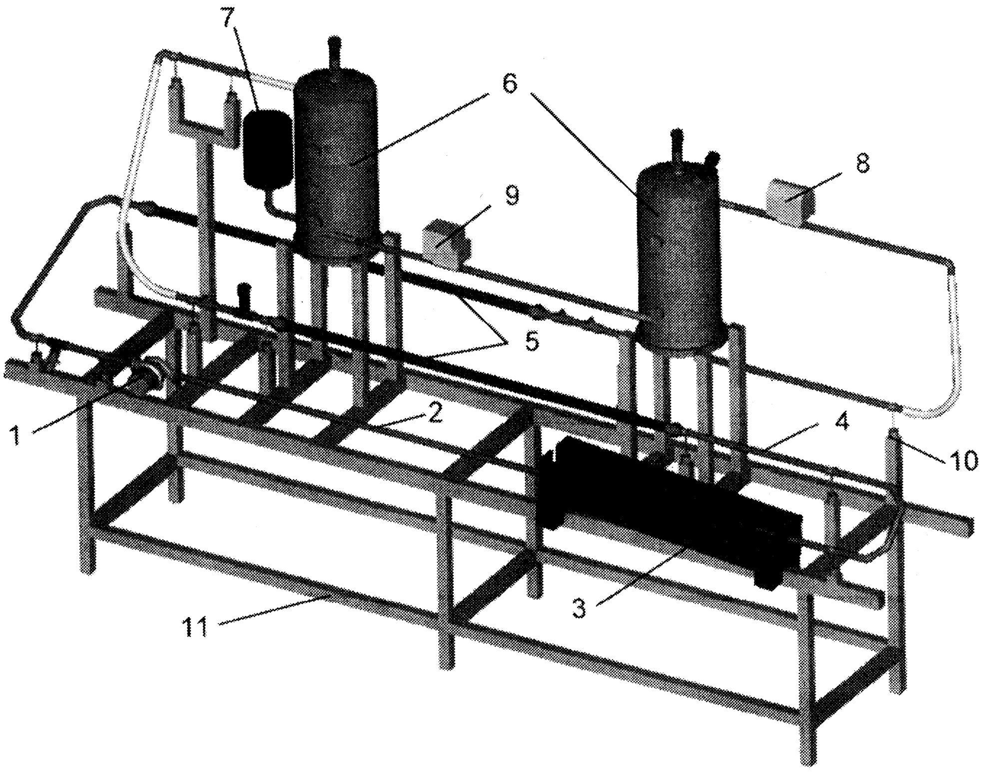

Figure 1 — Test rig

4.3 Specification of test rig components

Table 2 provides the necessary overview of the specified components of the test rig.

Table 2 — Specification of components

Ref.	Component/Part	Qty.	Specification/Remark
1	**Circulation pump**		
1	Pump housing	1	According to CD/K/044-1:2009
2	Washer	2	Non absorbing fibre type
2	**Vibration measurement pipe**		
1	Pipe		Usual commercial, Copper, ext. diam. approx. 28 mm, wall thickness 0.9 mm - 1 mm
2	Union nut	2	Usual commercial
3	Insert	2	Usual commercial, soldered conn. diam. approx 28 mm
4	Accelerometer	4	Calibration according to 4.8
3	**Solid anechoic termination**		Propagation index curve according to 4.9
1	Sand box	1	Wood or plastic, wall thickness approx. 10 mm
2	Pipe cover	1	Usual commercial, plastic foam, wall thickness 10 mm
3	Sand	10kg	Fine grain 30 um - 300 um, medium grain size 130 urn
4	**Pressure pulsation measurement pipe**		
1	Bend	4	Copper, diam. approx. 28 mm, Form A according to ISO 2016
2	Pipe		Copper, ext. diam. approx. 28 mm, wall thickness 0.9 mm - 1 mm usual commercial
3	Sensor adapter	2	Welding socket piece for flush mounted sensor
4	Pressure transducer	2	Calibration according to 4.8
5	**Liquid anechoic termination**		Propagation index curve ace. To 4.9
1	Terminator	2	Length 1580 mm, diam. approx. 30 mm
2	Pipe connection	4	Union, usual commercial, inox steel
6	**Water tank**		
1	Tank	2	Non-corrosive, volume approx. 50 l
2	Support	8	Connection to frame, screw fixed
3	Intermediate connection	1	Usual commercial stainless steel or copper, ext. diam. approx. 28 mm
4	Pipe connection	2	Flexible tube
7	**Pressure vessel**	1	
1	Membrane or pressure tank		Usual commercial
8	**Flow meter**		
1	Flow meter	1	According to 5.1.2.1 of CD/K/044-1:2009
9	**Regulation valve**		
1	Valve	1	Usual commercial
10	**Pipe support**		
1	Support bar		
2	Clip		
3	Rubber insert		
11	**Frame**		
1	Profile		Massive or hollow, iron or aluminium
12	**Miscellaneous**		
	Inlet/outlet valve		
	Manometer		
	Air separator		
	Shut-off valve		

NOTE The test rig may be equipped with additional elements, which are necessary for the trouble-free operation of the water circuit. Such parts shall be installed (in flow direction) behind the 1st and in front of the 2nd liquid anechoic terminator. No additional element exceeding the specified parts is allowed in the remaining test loop area where the measurements take place between and including the fluid anechoic terminations.

Dimensions in mm

Key
1 Circulation pump

2 Vibration measurement pipe

3 Adjustable solid anechoic termination

4 Pressure pulsation measurement pipe

5 Liquid anechoic termination

6 Water tank

7 Pressure vessel

8 Flowmeter

9 Regulation valve

10 Pipe support

A and B: Arrays of accelerometer

C and D: Pressure pulsation transducer

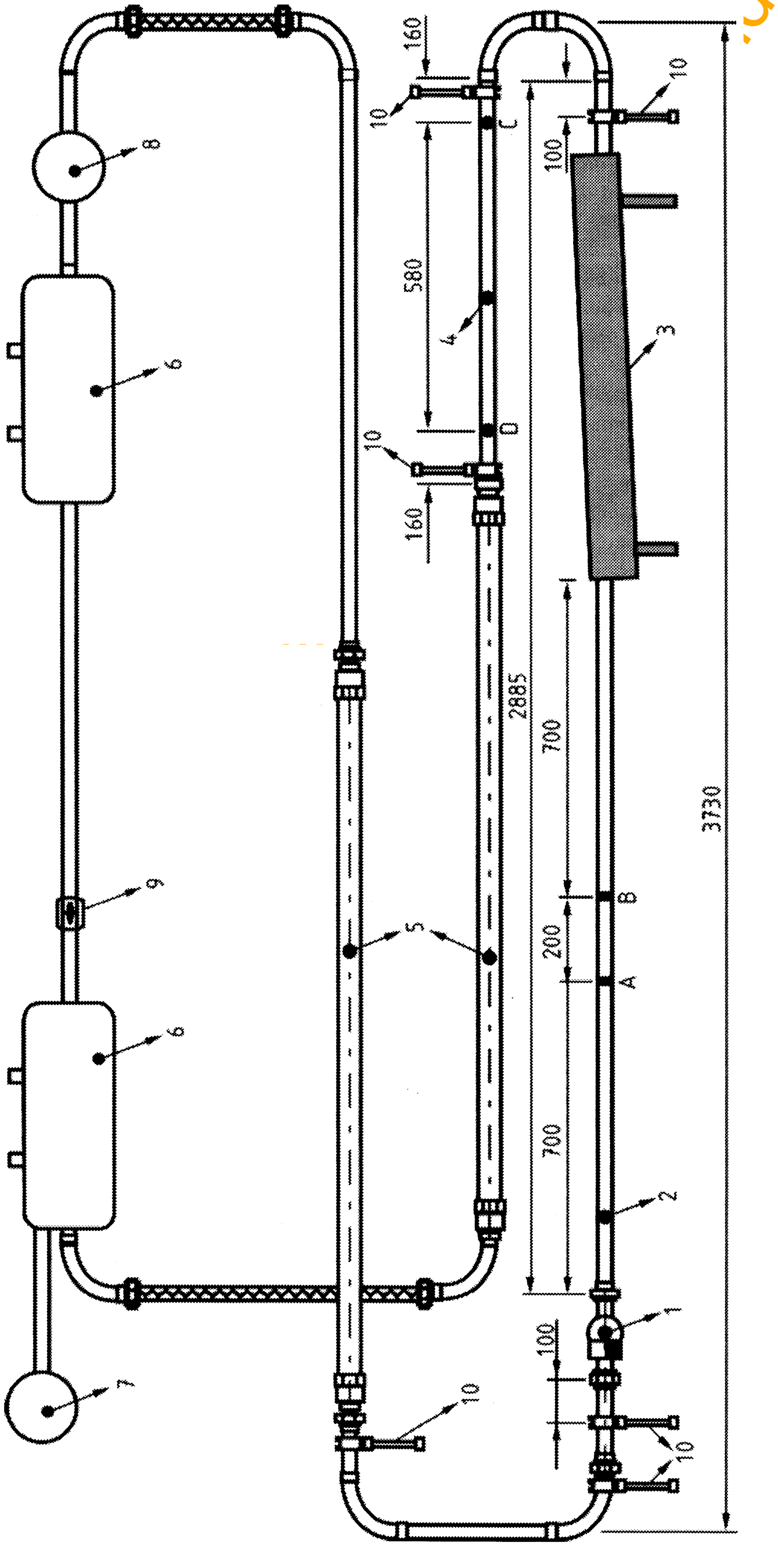

Figure 2 — Test rig dimensions

4.4 Assembly

All components shall be mounted free of remaining tensions. Standard sealing means like Teflon [1] bands may be used for pipe connections if not otherwise specified.

Torques of screws of fittings and pipe connections must meet the supplier's specifications.

The lengths of the support bars (Ref. 10.01) carrying the pipe sections for data acquisition and connecting them with the frame shall be adjusted for equalized load distribution.

No contact between walls of the sand box and pipe is allowed.

4.5 Foundation

The test rig shall be established on rigid (concrete) ground. The reacting forces between frame columns and floor shall be adjusted carefully. To avoid tensions in the frame structure it is recommended to use adjustable elements or screws with or without damping elements for equalized loads of all carrying columns.

4.6 Qualifications

After completion the rig has to withstand a pressure test of 4 bar overpressure without leakage. The typical hydraulic losses of the pipe loop shall not exceed 2 m at a flow of 2 m^3 /h.
A booster pump between the tanks is allowed.

4.7 Instrumentation

4.7.1 Measurement of pressure fluctuations

Two sensors of pressure fluctuations shall be flush mounted as shown in Figure 3 at points C and D (see Figure 2) on the pressure pulsation measurement pipe.

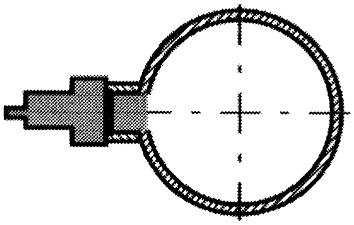

Figure 3 — Flush mounted sensor

4.7.2 Measurement of vibration

Four accelerometers arranged in two arrays as shown in Figure 4 are to be mounted at cross-sections A and B (see Figure 2) on the vibration measurement pipe. The mass of each accelerometer should be lower than 5g.

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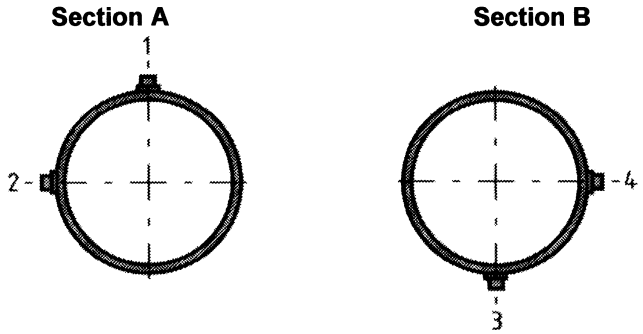
[1] Teflon is a suitable product available commercially. This information is given for the convenience of users of this International Standard and does not constitute an endorsement by CEN of this product.



Key
1 Position of accelerometer 1
2 Position of accelerometer 2
3 Position of accelerometer 3
4 Position of accelerometer 4

Figure 4 — Arrangement of accelerometers

4.8 Calibration

4.8.1 Accelerometers

It is recommended to use lightweight accelerometers the mass of which is not greater than 5 g, and having a high sensitivity (100mV/g).

4.8.2 Pressure transducers

It is recommended to use dynamic pressure transducers, with a high sensitivity (15 pC/bar) and compensation for vibration.

4.8.3 Calibration of accelerometers and pressure transducers

The calibration of the instruments shall be done at least once a year. The following criteria should be satisfied:

- Phase angle between 2 pressure transducers should be inferior to ± 1°.
- Amplitude difference between 2 pressure transducers should be inferior to ±5 %.

4.9 Propagation factors

The typical propagation coefficients for solid anechoic termination (S.A.T) and liquid anechoic termination (L.A.T) are as shown in Figures 5 and 6.

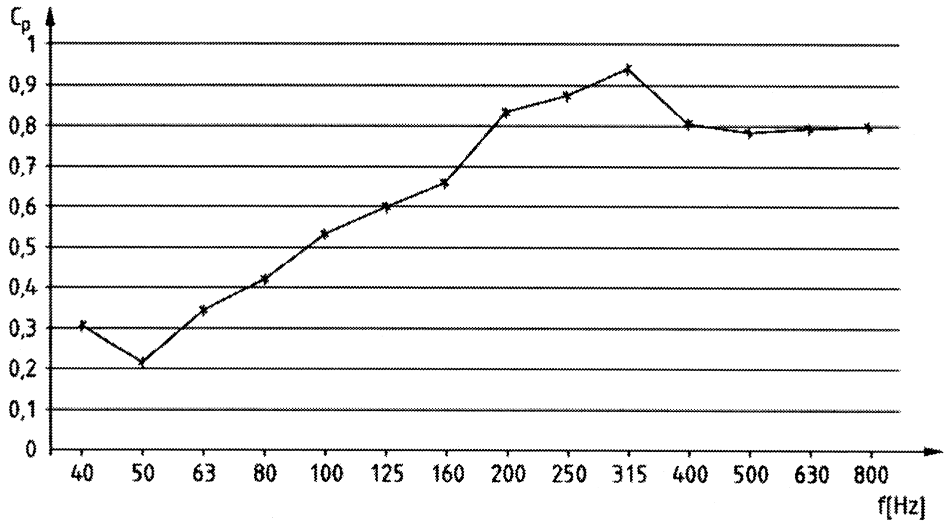


Figure 5 — Propagation coefficients (vibration) for solid anechoic termination (S.A.T.)

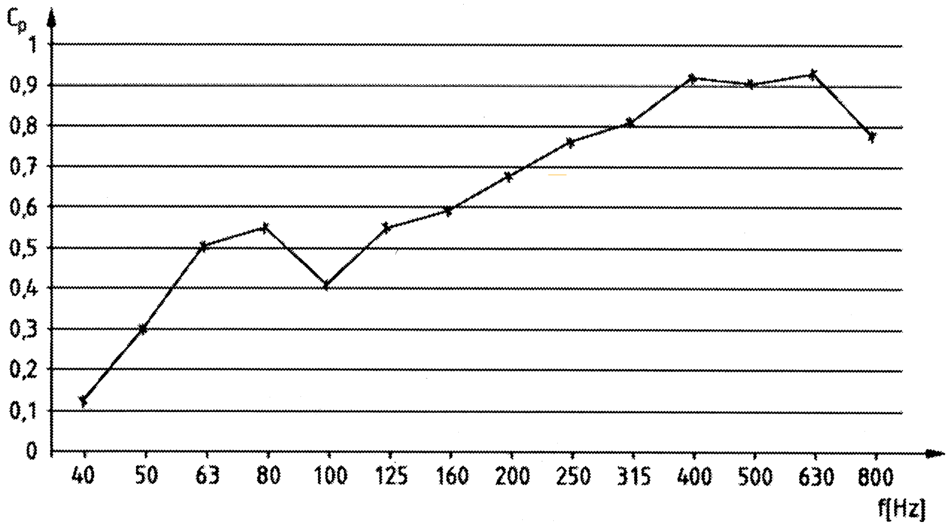


Figure 6 — Propagation coefficient (pulsation) for liquid anechoic termination (L.A.T.)

5 Installation and operation of the tested pump

5.1 Installation of the pump

The outlet of a circulation pump to be tested shall be connected to the vibration measurement pipe. Non-absorbing fibre type joints shall be mounted on fittings of the pump, e.g. fibre gaskets.

If not specified by the supplier, a fastening torque of 5 Nm shall be applied to fitting of screw connections of the pump.

The test rig shall be filled with water and completely degassed as well as the pump.

5.2 Operating parameters

Nominal values shall be according to 6.2 of CD/K/044-1:2009 except for the flow rate which shall be at maximum speed and in the point where the product of the flow rate and the head reaches the maximum value (see CD/K/044-1:2009, Figure 1.a, point 1).

5.3 Initial operation time

The initial operation time covers the period of time between the instant of switching on the pump and the instant of the first measurement. This initial operation is required for:

- complete degassing of the test rig and the pump;
- achievement of the established operating regime according to parameters given in 5.2;
- achievement of the steady state of temperature of a tested pump.

6 Factors influencing measurements

6.1 Electromagnetic surroundings

Surrounding equipment producing high electromagnetic fields can seriously parasitize measurements. The coexistence of such devices and the test rig in the same room shall be prevented.

6.2 Earth loops

Earth loops established through the cabling of sensors parasitize measurements in the set of discrete frequencies taking values at 50 Hz and its multiples. These parasites shall be minimised by a careful 1 realization of sensors cabling.

6.3 Vibration surroundings

A circulation pump being a low level vibration source, vibration measurements can be affected by any secondary vibration source of high level vibration. The co-existence of such sources and the test rig in the same room shall be prevented.

7 Determination of fluid- and structure-borne powers

7.1 Frequency range

The fluid- and structure-borne powers are determined in the frequency band between 35 Hz and 900 Hz.

NOTE Frequency response measurements with forced excitation at the pump may reveal problems in the low frequency area, when measuring structure-borne power, where the response may change significantly with only small changes in frequency of excitation. This means that the speed of the pump may very much influence the low frequency power flow below 100 Hz.

7.2 Measurement parameters

7.2.1 Pressure fluctuation measurement parameters

The pressure fluctuation measurement parameters are given in Table 3.

Table 3 — Pressure fluctuation measurement parameters

Parameter	Description	Unit
G_{CC}	narrow-band auto-power spectrum of the signal from the pressure transducer C 1)	Pa^2
G_{DD}	narrow-band auto-power spectrum of the signal from the pressure transducer D 1)	
G_{CD}	narrow-band cross-power spectrum between signals from pressure transducers C 1) and D 1) with the signal from the transducer C as reference 1)	
1) See Figure 2.		

7.2.2 Vibration measurement parameters

The vibration measurement parameters are given in Table 4.

Table 4 — Vibration measurement parameters

Parameter	**Description**	**Unit**
G11	narrow-band auto-power spectrum of the signal from the accelerometer 1 (array A) [1]	m^2/s^4
G22	narrow-band auto-power spectrum of the signal from the accelerometer 2 (array A) [1]	
G33	narrow-band auto-power spectrum of the signal from the accelerometer 3 (array B) [1]	
G44	narrow-band auto-power spectrum of the signal from the accelerometer 4 (array B) [1]	
G13	narrow-band cross-power spectrum between signals from accelerometers 1 and 3 with the signal from the accelerometer 1 as reference	
G24	narrow-band cross-power spectrum between signals from accelerometers 2 and 4 with the signal from the accelerometer 2 as reference	
[1] See Figures 2 and 4.		

7.3 Sense of power propagation

The sense of propagation of the structure- or the fluid-borne power is determined by means of the sign of the coefficient of the structure- or fluid-borne power propagation.

Positive signs of these coefficients indicate the sense of water flow in the vibration and pressure fluctuation measurement pipes - the sense of power propagation thus goes from the power source (i.e. the circulation pump) to the power receivers (i.e. anechoic terminations).

7.4 Fluid-borne power determination

7.4.1 General

In the frequency range of interest (see 7.1), the transfer of net acoustic power is achieved by means of plane waves propagating in the water inside the pipe.

7.4.2 Fluid-borne intensity

Determine the fluid-borne intensity, I_{fb} in W/m², by the equation:

$$I_{\mathrm{fb}} = \left(\frac{1}{\rho_{\mathrm{f}} c_{\mathrm{fb}}} \times \frac{\Im\{G_{\mathrm{CD}}\}}{\sin\left(2\pi f \frac{\delta_{\mathrm{CD}}}{c_{\mathrm{fb}}}\right)} \right) [\mathrm{W/m^2}] \qquad (1)$$

And calculate the coefficient of fluid-borne energy reflection, R_{fb}, by the equation.

$$R_{\mathrm{fb}} = \frac{G_{\mathrm{CC}} + G_{\mathrm{DD}} - 2\left[\Re\{G_{\mathrm{CD}}\}\cos\left(\frac{2\pi f \delta_{\mathrm{CD}}}{c_{\mathrm{fb}}}\right) - \Im\{G_{\mathrm{CD}}\}\sin\left(\frac{2\pi f \delta_{\mathrm{CD}}}{c_{\mathrm{fb}}}\right)\right]}{G_{\mathrm{CC}} + G_{\mathrm{DD}} - 2\left[\Re\{G_{\mathrm{CD}}\}\cos\left(\frac{2\pi f \delta_{\mathrm{CD}}}{c_{\mathrm{fb}}}\right) + \Im\{G_{\mathrm{CD}}\}\sin\left(\frac{2\pi f \delta_{\mathrm{CD}}}{c_{\mathrm{fb}}}\right)\right]} \qquad (2)$$

where:

G_{CD}	is the measured cross-power spectrum (see 7.2.1)
G_{CC}, G_{DD}	are the measured auto-power spectra (see 7.2.1)
$\Im\{\ \}$	is the designation of the imaginary part of the complex quantity between { }
$\Re\{\ \}$	is the designation of the real part of the complex quantity between { }
f	is the frequency in Hz

c_{fb} = 1188.6 m/s	is the propagation speed of plane waves in the water-filled pressure pulsation measurement pipe of dimension given in 4.3
δ_{CD}	is the spacing between the transducers C and D (see Figure 2)
ρ_{W}	is the mass density of the water

7.4.3 Fluid-borne power

Calculate the fluid-borne power, P_{fb}, in W, by the equation:

$$P_{\text{fb}} = \frac{\pi d_i^2 I_{\text{fb}}}{4(1 - R_{\text{fb}})} \ \text{[W]} \qquad (3)$$

where:

d_{i}	is the internal diameter of the pipe (see 4.3);
I_{fb}	is the fluid-borne intensity as given by Equation (1);
R_{fb}	is the coefficient of fluid-borne energy reflection as given by Equation (2).

7.5 Structure-borne power determination

7.5.1 General

In the frequency range of interest (see 5.1), the transfer of net vibrational power is achieved by means of bending waves propagating in the pipe wall.

7.5.2 Structure-borne intensity

Calculate the structure-borne intensity, I_{sb} in W/m, by the equation:

$$I_{\text{sb}} = 2 \times K_{\text{sb}} \times \frac{\Im\{G_{13} + G_{24}\}}{16(\pi f)^4 \sin(k_{\text{sb}} \delta_{\text{AB}})} \ \text{[W/m]} \qquad (4)$$

and calculate the coefficient of structure-borne energy reflection by the equation:

$$R_{\text{sb}} = \frac{\sum_{i=1}^{4} G_{ll} + 2\left[\Re\{G_{13} + G_{24}\}\cos(k_{\text{sb}}\delta_{\text{AB}}) - \Im\{G_{13} + G_{24}\}\sin(k_{\text{sb}}\delta_{\text{AB}})\right]}{\sum_{i=1}^{4} G_{ll} + 2\left[\Re\{G_{13} + G_{24}\}\cos(k_{\text{sb}}\delta_{\text{AB}}) + \Im\{G_{13} + G_{24}\}\sin(k_{\text{sb}}\delta_{\text{AB}})\right]} \qquad (5)$$

where:

G_{13}, G_{24}	are the measured cross-power spectra (see 7.2.2)
G_{ll}, $l=1, \ldots, 4$	are the measured auto-power spectra (see 7.2.2)
$\Im\{\ \}$	is the designation of the imaginary part of the complex quantity between { }
$\Re\{\ \}$	is the designation of the real part of the complex quantity between { }
f	is the frequency in Hz
δ_{AB}	is the spacing between accelerometer arrays A and B (see Figure 2);
k_{sb}	is the bending wave number in m^{-1} (see Annex A);
K_{sb}	is the associated dimensional constant in Ws^4/m^3 (see Annex A).

7.5.3 Structure-borne power

Calculate the structure-borne power, P_{sb} in W, by the equation:

$$P_{\mathrm{sb}} = \frac{\pi(d_i + d_{\mathrm{e}})I_{\mathrm{sb}}}{2(1 - R_{\mathrm{sb}})} \text{ [W]} \qquad (6)$$

where:

d_{e}	is the external diameter of the pipe (see 4.3);
d_{i}	is the internal diameter of the pipe (see 4.3);
I_{sb}	is the structure-borne intensity as given by Equation (4);
R_{sb}	is the coefficient of structure-borne energy reflection as given by Equation (5).

7.6 Overall values of power

Overall fluid-(or structure-)borne power, in W, characterizing the test, is obtained by summing all spectral components of fluid-(or structure-)borne power in the frequency band of interest:

$$P_{\mathrm{fb}}^{\mathrm{tot}} = \sum_{f_n = f_0}^{f_1} P\mathrm{fb}(f_n) \text{ [W]} \qquad \begin{aligned} f_0 &= 35 \text{ Hz} \\ f_1 &= 900 \text{ Hz} \end{aligned}$$

$$P_{\mathrm{sb}}^{\mathrm{tot}} = \sum_{f_n = f_0}^{f_1} P_{\mathrm{sb}}(f_n) \text{ [W]} \qquad \begin{aligned} f_0 &= 35 \text{ Hz} \\ f_1 &= 900 \text{ Hz} \end{aligned}$$

NOTE The number of frequency lines and the type of weighting window used during data acquisition should be taken into account when processing the data.

7.7 Coefficients of energy propagation and power levels

7.7.1 Coefficient of fluid-borne energy propagation

Calculate the coefficient of fluid-borne energy propagation by the equation:

$$C_{\mathrm{fb}} = \left\{ \begin{array}{ll} 1 - R_{\mathrm{fb}} & \text{if } R_{\mathrm{fb}} \leq 1 \\ -1 + \dfrac{1}{R_{\mathrm{fb}}} & \text{otherwise} \end{array} \right\} \qquad (9)$$

NOTE C_{fb} is the complement of the coefficient of fluid-borne energy reflection. This coefficient is non-dimensional and limited in value ($-1 \leq C_{\mathrm{fb}} \leq 1$). Its sign indicates the sense of energy propagation. If this coefficient equals 0, there is no propagation of power lengthways the pipe.

7.7.2 Coefficient of structure-borne energy propagation

Calculate the coefficient of structure-borne energy propagation by the equation:

$$C_{\mathrm{sb}} = \left\{ \begin{array}{ll} 1 - R_{\mathrm{sb}} & \text{if } R_{\mathrm{sb}} \leq 1 \\ -1 + \dfrac{1}{R_{\mathrm{sb}}} & \text{otherwise} \end{array} \right\} \qquad (10)$$

NOTE C_{sb} is the complement of the coefficient of structure-borne energy reflection. This coefficient is non-if dimensional and limited in value ($-1 \leq C_{\mathrm{sb}} \leq 1$). Its sign indicates the sense of energy propagation. If this coefficient equals 0, there is no propagation of power lengthways the pipe.

7.7.3 Fluid-borne power level

Calculate the fluid-borne power level by the equation:

$$L_{\mathrm{Wfb}} = 10\log\left(\frac{P_{\mathrm{fb}}}{P_0}\right) \quad [\mathrm{dB}] \tag{11}$$

where:

P_0 is the reference power (10^{-12} W)

7.7.4 Structure-borne power level

Calculate the structure-borne power level by the equation:

$$L_{\mathrm{Wsb}} = 10\log\left(\frac{P_{\mathrm{sb}}}{P_0}\right) \quad [\mathrm{dB}] \tag{12}$$

where:

P_0 is the reference power (10^{-12} W)

8 Information to be reported

The following vibro-acoustic information shall be compiled and recorded for measurements according to this part of EN 1151:

a) Level of total fluid-borne power;

b) Level of total structure-borne power;

c) 1/3-octave spectra of fluid-borne power level;

d) 1/3-octave spectra of structure-borne power level;

e) 1/3-octave spectra of coefficient of fluid-borne energy propagation;

f) 1/3-octave spectra of coefficient of structure-borne energy propagation;

NOTE The above is calculated from the Fast Fourier Transformation (FFT) analysis.

Annex A
(informative)

Bending wavenumber and intensity dimensional constant

Bending wavenumber k_{sb} and the associated dimensional constant K_{sb} needed to determine the structure-borne intensity by using Equation (4) both depend on the frequency. These quantities are obtained by solving the relation of dispersion for the fluid-filled pipe. For the vibration measurement pipe of prescribed dimensions (see 4.3) filled with water, both the bending wavenumber and the associated dimensional constant can be given in polynomial form:

$$k_{sb}(f) = \sum_{n=0}^{15} P_k(n) f^{n} \qquad \text{(A.1)}$$

$$k_{sb}(f) = \sum_{n=0}^{15} Q_k(n) f^{n} \qquad \text{(A.1)}$$

where:

k_{sb} is the bending wavenumber in m^{-1}

P_k(n) is the coefficient on nth order for wavenumber polynomial

Kab is the structure-borne intensity dimensional constant in Ws^4/m^3

Qk(n) is the coefficient on nth order for the associated dimensional constant polynomial

f is the frequency in Hz

The coefficients P_k(n) and Q_k(n) are given in the Table A.1.

Table A.1 — Coefficients P_k(n) and Q_k(n)

n	P_k(n)	Q_k(n)
0	9.191 531 730933632 × 10^{-1}	2.453630851 250 135 × 10^{6}
1	7.644 003 204 232 786 × 10^{-2}	-3.453686638310214 × 10^{5}
2	-8.550 458 718 746 952 × 10^{-4}	3.529 880 907 31 3 807 × 10^{4}
3	9.395 883 345 803 304 × 10^{-6}	6.500083821 268914 × 10^{2}
4	-7.592 454 346 606 851 × 10^{-8}	-2.51 7 623 922 1 39 443 × 10^{0}
5	4.435931 238145724 × 10^{-10}	1.137 477 695 843 318 × 10^{-2}
6	-1.893 892 534 428 029 × 10^{-12}	-4.263 277 267 379 334 × 10^{-5}
7	5.979 170 403 451 006 × 10^{-15}	1.243573041 487822 × 10^{-7}
8	-1.406556256150061 × 10^{-17}	-2.774257279426475 × 10^{-10}
9	2.469 612 247 609 014 × 10^{-20}	4.689566527408795 × 10^{-13}
10	-3.217980995719116 × 10^{-23}	-5.939275339140709 × 10^{-16}
11	3.064353525551 454 × 10^{-26}	5.532259814305975 × 10^{-19}
12	-2.069 860 566 521 089 × 10^{-29}	-3,671 640 122 946 185 × 10^{-22}
13	9.386 247 482 026 814 × 10^{-33}	1.641 266003553832 × 10^{-25}
14	-2.561 150 398 477 605 × 10^{-36}	-4.425 360 224 978 495 × 10^{-29}
15	3.176 743 706 757 041 × 10^{-40}	5.434 195 752 593 468 × 10^{-33}

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