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**Planning for functional performance  
testing for building commissioning —**

Part 1:

**Secondary hydronic pump, system and  
associated controls**

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ISO copyright office  
CP 401 • Ch. de Blandonnet 8  
CH-1214 Vernier, Geneva  
Phone: +41 22 749 01 11  
Fax: +41 22 749 09 47  
Email: [copyright@iso.org](mailto:copyright@iso.org)  
Website: [www.iso.org](http://www.iso.org)

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## 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. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 205, *Building environment design*.

A list of all parts in the ISO 19455 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

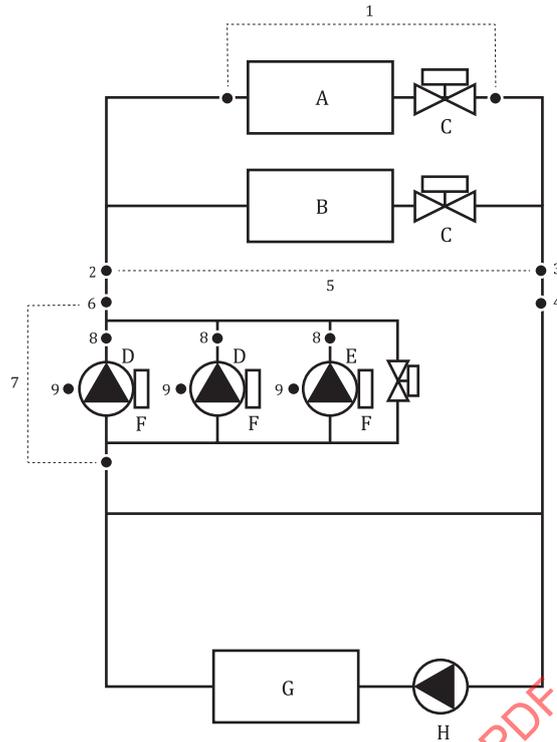
## Introduction

This document gives a methodology of planning for functional performance testing of secondary hydronic pump, system and associated controls for building commissioning, and has been prepared for building designers, i.e. architects, environmental designers and building system designers, as well as building clients, contractors, commissioning providers, government officials, and academic staff.

The aim of this document is to assist the building designers in applying a commissioning plan and a commissioning test, which are defined in ISO 16813. In order to achieve effective energy saving in building equipment systems that consume a large amount of energy, it is important not only to introduce energy efficient technologies to the system but also to verify their functional performance by tests and adjustments after the completion whether the system works properly according to its design intent. This document makes it possible to verify performance of secondary hydronic pump, system and associated controls with clear and specific processes.

As well as the intended usage for heating, ventilation and air conditioning (HVAC) systems, the secondary hydronic pump system targeted by this document is described in [Figure 1](#).

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**Key**

- |   |                            |   |  |
|---|----------------------------|---|--|
| A | farthest air handling unit | 1 | $dP_{w\_AHU}$ : end-pressure difference (in Pa)                          |
| B | air handling units         | 2 | $T_{w\_AHUin}$ : inlet water temperature of air handling units (in °C)   |
| C | valve                      | 3 | $T_{w\_AHUout}$ : outlet water temperature of air handling units (in °C) |
| D | secondary hydronic pumps   | 4 | $V_{w\_AHUout}$ : water flow rate of air handling units (in kg/s)        |
| E | reserve hydronic pumps     | 5 | $Q_{w\_AHU}$ : amount of heat exchanged in air handling units (in kW)    |
| F | inverter                   | 6 | $P_{w\_PSout}$ : supply-side pressure (in Pa)                            |
| G | heat source equipment      | 7 | $dP_{w\_PS}$ : pump pressure difference (in Pa)                          |
| H | primary hydronic pump      | 8 | $V_{w\_PS}$ : water flow rate of each secondary hydronic pump (in kg/s)  |
|   |                            | 9 | $E_{PS}$ : energy consumption of each secondary hydronic pump (in kW)    |

**Figure 1 — Secondary hydronic pump system targeted by this document**

# Planning for functional performance testing for building commissioning —

## Part 1: Secondary hydronic pump, system and associated controls

### 1 Scope

This document specifies a planning method for functional performance testing (FPT). This document is applicable to the planning of the FPT during the design phase of new buildings and retrofit projects, which is defined in ISO 16813.

This document establishes how to design building environmental systems when the FPT is being carried out. This document defines the following:

- what kind of information regarding the system is required (for example, design documents, drawings and product specifications);
- what kind of data should be measured (though concrete measurement techniques are not specified in this document);
- how the measured data is analysed.

Such clear definition of the FPT makes it possible for building designers to prepare and plan for FPT throughout the design process.

This document specifies an FPT method for secondary hydronic pump, system and associated controls in heating, ventilation and air conditioning (HVAC) systems.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

ISO 16813, *Building environment design — Indoor environment — General principles*

ISO 16484-1, *Building automation and control systems (BACS) — Part 1: Project specification and implementation*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 16813, ISO 16484-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

**3.1**  
**basis of design**  
**BoD**

document that bridges the objectives conveyed in the *owner project requirements* (3.5) and the contract documents (construction drawings and project specifications) which records through narrative, lists and calculations, the technical concepts, performance, assumptions, decisions, and product selections that fulfil the requirements of the owner project requirements

**3.2**  
**building control system**

measures taken to ensure the system operates in accordance with the specified conditions

**3.3**  
**commissioning**

quality-focused process for enhancing the delivery of a project which focuses upon verifying and documenting that all of the commissioned systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the *owner project requirements* (3.5)

**3.4**  
**design document**

written description of the essential factors of every design stage, to be retained for future reference

**3.5**  
**owner project requirement**  
**OPR**

written document that details the ideas, concepts, and criteria that are required by the owner and outlines the requirements upon which the pre-design, design and construction phases are executed

**3.6**  
**function performance testing**  
**FPT**

testing process to demonstrate the correct installation and operation of each component, system, and associated controls in accordance with the *owner project requirements* (3.5)

**3.7**  
**supply-side pressure**

hydraulic pressure of pump outlet

Note 1 to entry: This is illustrated in [Figure 1](#).

**3.8**  
**pump pressure difference**

hydraulic pressure difference between pump inlet and outlet

Note 1 to entry: This is illustrated in [Figure 1](#).

**3.9**  
**end-pressure difference**

hydraulic pressure difference between inlet and outlet of the farthest air handling unit

Note 1 to entry: This is illustrated in [Figure 1](#).

**3.10**  
**multiple-unit pump staging control**

number of operating pumps, which changes according to the water flow rate of air handling units or the amount of heat exchanged in air handling units

Note 1 to entry: The water flow rate of air handling units and the amount of heat exchanged in air handling units are illustrated in [Figure 1](#).

**3.11****rotation speed control with constant delivery pressure**

rotation speed of pumps is changed with inverters according to *supply-side pressure* (3.7) or *pump pressure difference* (3.8) with the set point of the supply-side water pressure or the pump pressure difference being constant

Note 1 to entry: The supply-side pressure and the pump pressure difference are illustrated in [Figure 1](#).

**3.12****rotation speed control with variable delivery pressure**

rotation speed of pumps is changed with inverters according to *supply-side pressure* (3.7) or *pump pressure difference* (3.8) with the set point of the supply-side water pressure or the pump pressure difference being variable according to the *end-pressure difference* (3.9)

Note 1 to entry: The supply-side pressure and the pump pressure difference are illustrated in [Figure 1](#).

**4 Planning for functional performance testing****4.1 Design of secondary hydronic pump system**

Building designers determine the required function and performance of secondary hydronic pump, system and associated controls according to the owner project requirements (OPR). The requirement shall be written in the basis of design (BoD). The secondary hydronic pump control systems targeted in this document are listed in [Table 1](#). This document assumes that there are multiple pumps in the secondary hydronic pump system:

- Type A: rotation speed control with constant delivery pressure.
  - Type A1) rotation speed of pumps is changed with inverters according to supply-side pressure. The set point of the supply-side pressure is constant.
  - Type A2) rotation speed of pumps is changed with inverters according to pump pressure difference. The set point of the pump pressure difference is constant.
- Type B: rotation speed control with variable delivery pressure.
  - Type B1) rotation speed of pumps is changed with inverters according to supply-side pressure. The set point of the supply-side pressure is variable according to the end-pressure difference.
  - Type B2) rotation speed of pumps is changed with inverters according to pump pressure difference. The set point of the pump pressure difference is variable according to the end-pressure difference.

**4.2 Data acquisition**

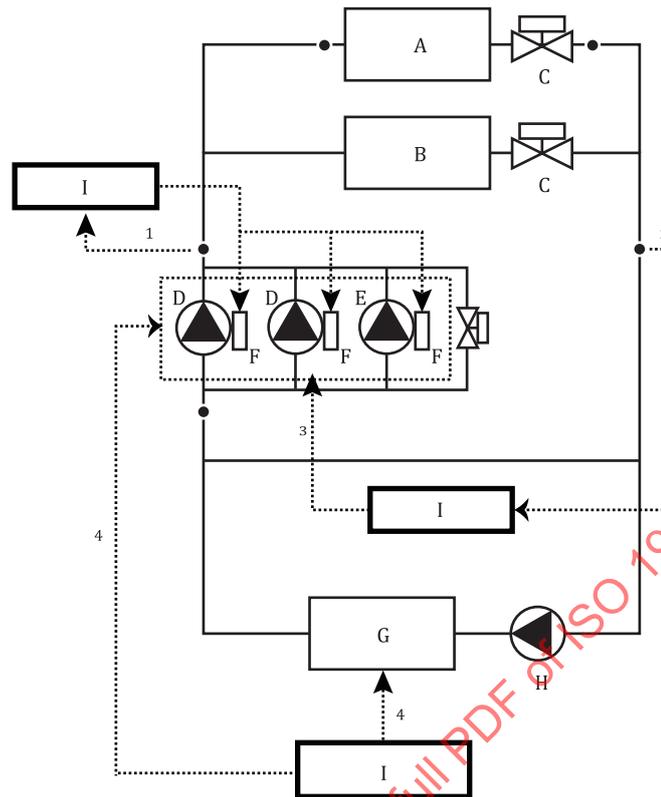
The required data for the functional performance testing is shown in [Table 2](#). In order to measure these data, the adequate sensors shall be deployed. For new building projects, the required data could be obtained from the building control system. For retrofit projects, the required data could be obtained from the existing building control system or measured by installing temporary data loggers. [Annex A](#) gives an example of data acquisition planning.

**Table 1 — Targeted secondary hydronic pump control systems**

Control system type	Multi-unit pump staging control	Rotation speed control				Schematic diagram
		Constant supply-side pressure	Constant pump pressure difference	Variable supply-side pressure	Variable pump pressure difference	
Type A1	✓	✓				<a href="#">Figure 2</a>
Type A2	✓		✓			<a href="#">Figure 3</a>
Type B1	✓			✓		<a href="#">Figure 4</a>
Type B2	✓				✓	<a href="#">Figure 5</a>

**Table 2 — Required data for the testing described in [Clause 5](#)**

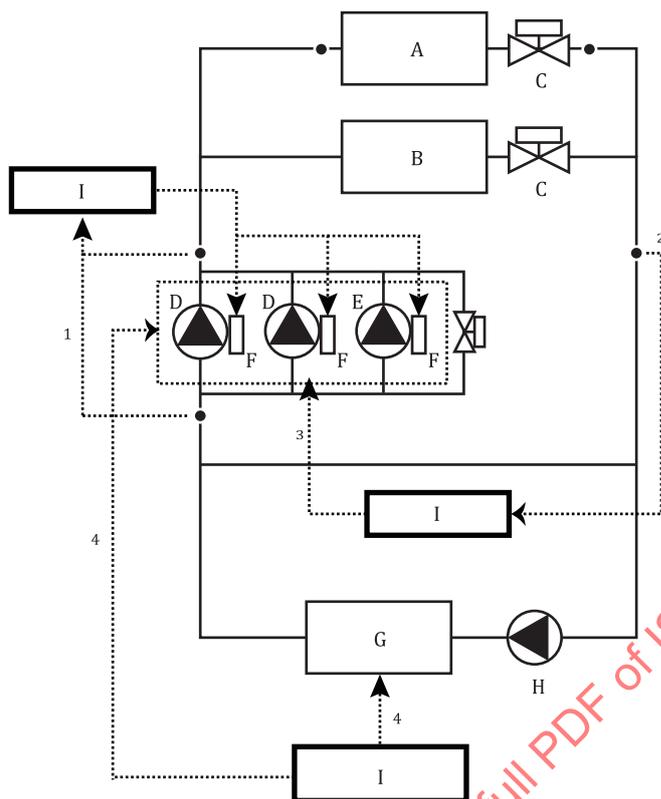
Testing method	Required data						
	Water flow rate of air handling units	Amount of heat exchange in air handling units	Water flow rate of pump	Energy consumption of pump	Electric current or inverter frequency of pump	Supply-side pressure	Pump pressure difference
Test 1 described in <a href="#">5.2</a>	✓ <sup>a</sup>	✓ <sup>a</sup>		✓ <sup>b</sup>	✓ <sup>b</sup>		
Test 2 described in <a href="#">5.3</a>			✓			✓	
Test 3 described in <a href="#">5.3</a>			✓				✓
Test 4 described in <a href="#">5.4</a>			✓	✓			
<sup>a</sup> Measure either of them. <sup>b</sup> Measure either of them.							



**Key**

- |   |                            |   |                                       |
|---|----------------------------|---|---------------------------------------|
| A | farthest air handling unit | 1 | supply-side pressure                  |
| B | air handling units         | 2 | water flow rate of air handling units |
| C | valve                      | 3 | number of operating units             |
| D | secondary hydronic pumps   | 4 | on or off                             |
| E | reserve hydronic pumps     |   |                                       |
| F | inverter                   |   |                                       |
| G | heat source equipment      |   |                                       |
| H | primary hydronic pump      |   |                                       |
| I | building control system    |   |                                       |

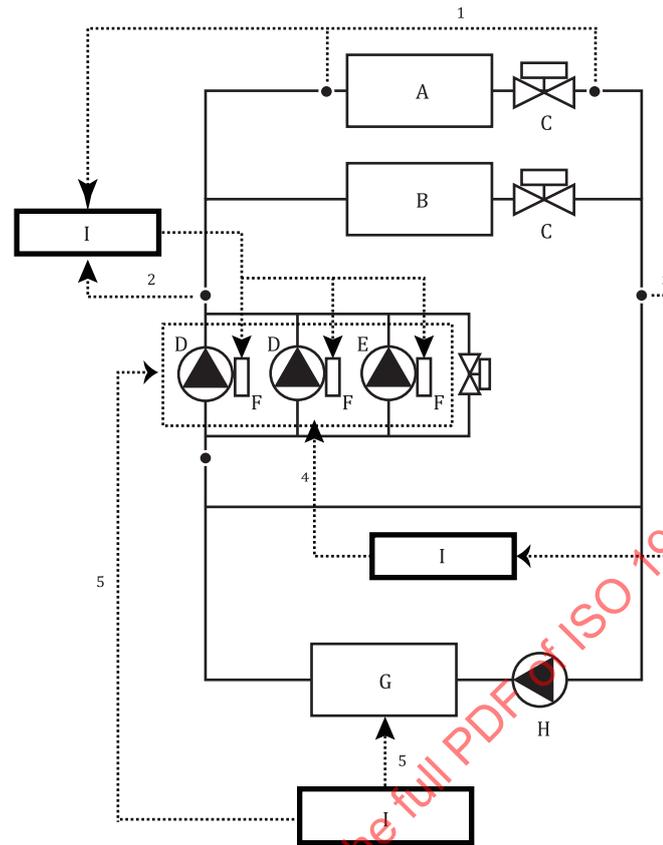
**Figure 2 — Secondary hydronic pump control systems (Type A1)**



**Key**

- |   |                            |   |                                       |
|---|----------------------------|---|---------------------------------------|
| A | farthest air handling unit | 1 | pump pressure difference              |
| B | air handling units         | 2 | water flow rate of air handling units |
| C | valve                      | 3 | number of operating units             |
| D | secondary hydronic pumps   | 4 | on or off                             |
| E | reserve hydronic pumps     |   |                                       |
| F | inverter                   |   |                                       |
| G | heat source equipment      |   |                                       |
| H | primary hydronic pump      |   |                                       |
| I | building control system    |   |                                       |

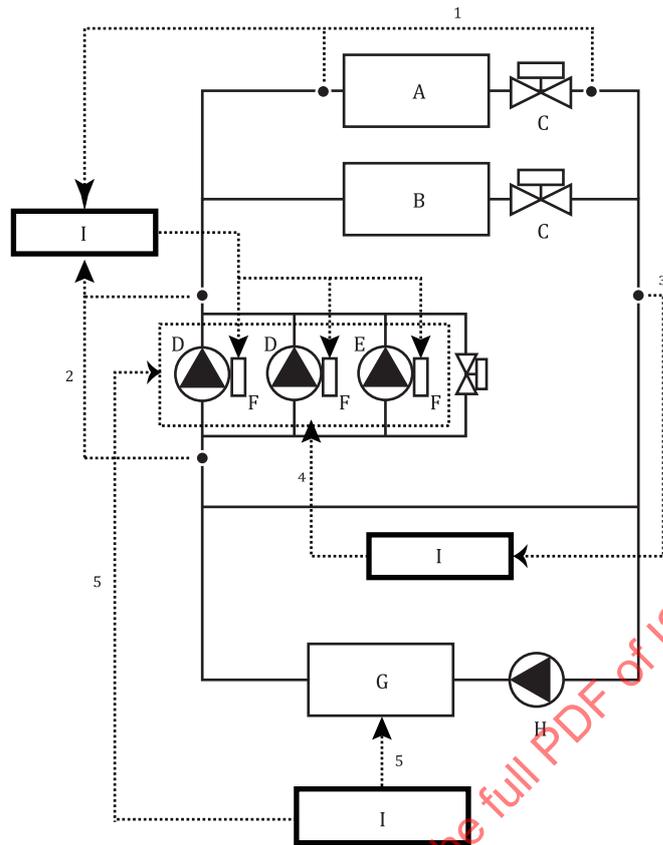
**Figure 3 — Secondary hydronic pump control systems (Type A2)**



**Key**

- |   |                            |   |                                       |
|---|----------------------------|---|---------------------------------------|
| A | farthest air handling unit | 1 | end-pressure difference               |
| B | air handling units         | 2 | supply-side pressure                  |
| C | valve                      | 3 | water flow rate of air handling units |
| D | secondary hydronic pumps   | 4 | number of operating units             |
| E | reserve hydronic pumps     | 5 | on or off                             |
| F | inverter                   |   |                                       |
| G | heat source equipment      |   |                                       |
| H | primary hydronic pump      |   |                                       |
| I | building control system    |   |                                       |

**Figure 4 — Secondary hydronic pump control systems (Type B1)**



**Key**

- |   |                            |   |                                       |
|---|----------------------------|---|---------------------------------------|
| A | farthest air handling unit | 1 | end-pressure difference               |
| B | air handling units         | 2 | pump pressure difference              |
| C | valve                      | 3 | water flow rate of air handling units |
| D | secondary hydronic pumps   | 4 | number of operating units             |
| E | reserve hydronic pumps     | 5 | on or off                             |
| F | inverter                   |   |                                       |
| G | heat source equipment      |   |                                       |
| H | primary hydronic pump      |   |                                       |
| I | building control system    |   |                                       |

**Figure 5 — Secondary hydronic pump control systems (type B2)**

## 5 Functional performance testing method

### 5.1 General

Functional performance testing for secondary hydronic pump, system and associated controls consists of the four tests listed in [Table 3](#):

- Test 1) – Testing for verifying relationship between water flow rate and number of operating units.
- Test 2) – Testing for verifying relationship between water flow rate and supply-side pressure.
- Test 3) – Testing for verifying relationship between water flow rate and pump pressure difference.
- Test 4) – Testing for verifying relationship between water flow rate and energy consumption.

NOTE It is not necessary to carry out all the tests listed in [Table 3](#). It is important to decide which test to conduct for each project depending on the OPR or commissioning cost.

**Table 3 — Functional performance testing methods**

Test Method	Target	Purpose	Control system types			
			A1	A2	B1	B2
Test 1	Relationship between water flow rate and number of operating units	To verify the function of multiple-unit pump staging control	✓	✓	✓	✓
Test 2	Relationship between water flow rate and supply-side water pressure	To verify the function of rotation speed control	✓		✓	
Test 3	Relationship between water flow rate and pump pressure difference	To verify the function of rotation speed control		✓		✓
Test 4	Relationship between water flow rate and energy consumption	To verify the energy performance of the secondary hydronic pump system	✓	✓	✓	✓

## 5.2 Testing method for verifying relationship between water flow rate and number of operating units (test 1)

### 5.2.1 General

This testing method aims to verify the function of the multiple-unit pump staging control. This test assumes that there are multiple pumps in the targeted secondary hydronic pump system.

### 5.2.2 Step 1) Measurement of operational data

The following operational data shall be measured:

- water flow rate of air handling units (see [Figure 1](#));
  - when the number of operating pumps is changed according to the amount of heat exchanged in air handling units (see [Figure 1](#)), the heat amount shall be measured.
- energy consumption of each secondary hydronic pump (see [Figure 1](#));
  - when the measurement of the energy consumption is difficult, electric current of each pump or frequency of each inverter can be used.

### 5.2.3 Step 2) Calculation of number of operating pumps

The number of operating pumps shall be calculated using the measured energy consumption of each pump. When the measured energy consumption is larger than zero, the pump is judged to be in operation.

### 5.2.4 Step 3) Analysis of relationship between water flow rate and number of operation units

Using the operational data of water flow rate and number of operating pumps, a figure shall be drawn (see [Figure 6](#)), where the horizontal axis is the water flow rate and the vertical axis is the number of operating units.

### 5.2.5 Step 4) Clarification of the design specification

The control set points of the water flow rate when the number of pumps is changed (upper limit and lower limit) shall be added to the figure drawn in [5.2.4](#). In general, the set points are written in the design documents as shown in [Table 4](#).

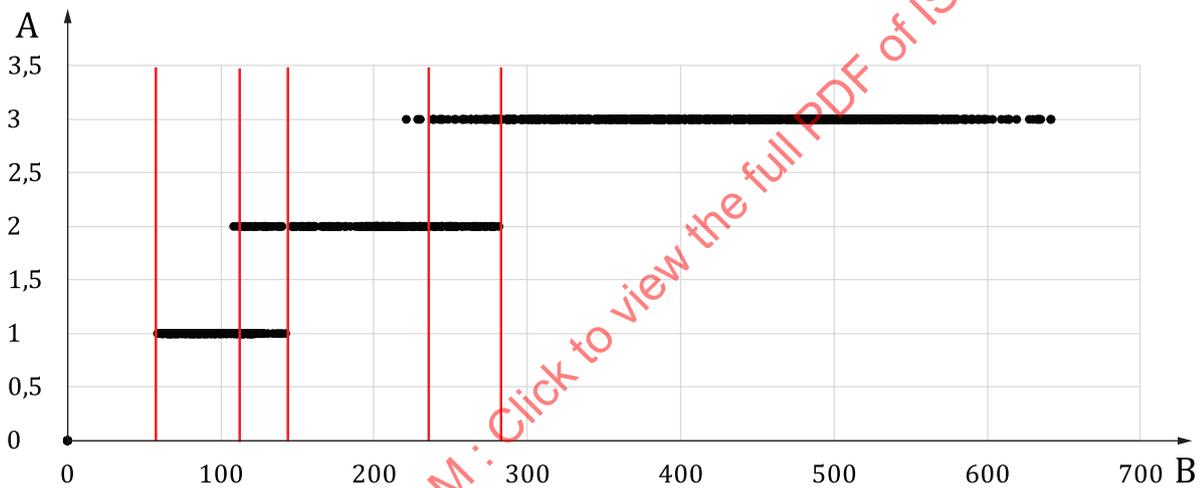
5.2.6 Step 5) Comparison with the design values

The measured water flow rates at which the pump operation number changes shall be compared with the design values (upper limit and lower limit). The followings especially need to be confirmed:

- whether the water flow rate for each number of operating units is not over the upper limit of the number of operating units;
- whether the water flow rate for each number of operating units is not below the lower limit of the number of operating units.

Table 4 — Example of the design set points of the multiple-unit pump staging control

Number of operating units	Lower limit of water flow rate	Upper limit of water flow rate
1 unit	60 m <sup>3</sup> /h	140 m <sup>3</sup> /h
2 units	120 m <sup>3</sup> /h	280 m <sup>3</sup> /h
3 units	240 m <sup>3</sup> /h	700 m <sup>3</sup> /h



Key  
 A number of operating units  
 B water flow rate (in kg/s)

Figure 6 — Example of the relationship between water flow rate and number of operation units

5.3 Testing method for verifying relationship between water flow rate and pressure (test 2, 3)

5.3.1 General

This testing method aims to verify the function of the rotation speed control system. When there are multiple pumps in the secondary pump system, this test shall be applied to each pump which has the rotation speed control system installed.

5.3.2 Step 1) Measurement of operational data

For each pump, the following operational data shall be measured:

- water flow rate of each secondary hydronic pump (see Figure 1);
- supply-side pressure (only for test 2) (see Figure 1);

- pump pressure difference (only for test 3) (see [Figure 1](#)).

### 5.3.3 Step 2) Analysis of relationship between water flow rate and pressure

Using the operational data of water flow rate and pressure, a figure shall be drawn (see [Figure 7](#)), where the horizontal axis is the water flow rate and the vertical axis is the pressure.

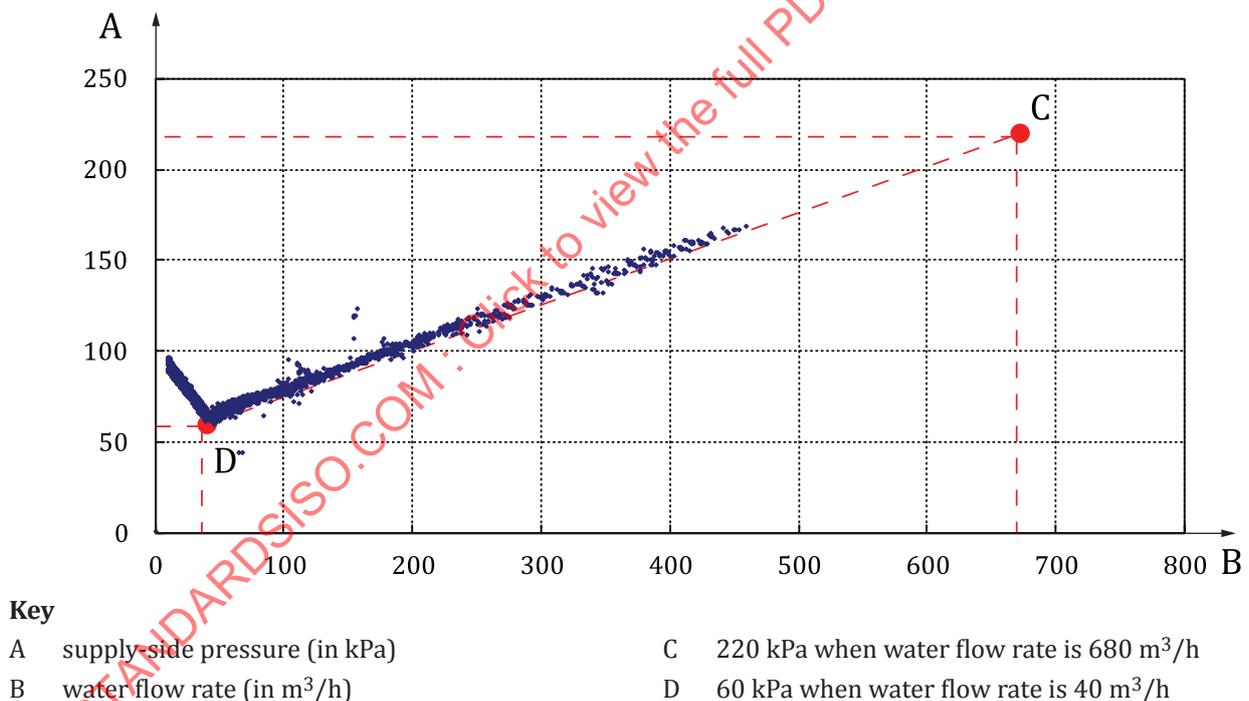
### 5.3.4 Step 3) Clarification of the design specification

When the targeted system has a rotation speed control with constant delivery pressure (the control system types is type A1 or A2), the control set point of the pressure shall be added to the figure drawn in [5.3.3](#). When the targeted system has a rotation speed control with variable delivery pressure, the control set points of maximum and minimum delivery pressure, and maximum and minimum water flow rate shall be added to the figure drawn in [5.3.3](#) as shown in [Figure 7](#). In general, the set points are written in the design documents.

### 5.3.5 Step 4) Comparison with the design values

The measured pump pressure shall be compared with the design value. The followings especially need to be confirmed:

- whether the difference between the measured and assumed pressure is below 10 %.



**Figure 7 — Example of the relationship between water flow rate and pressure (control system type B)**

## 5.4 Testing method for verifying relationship between water flow rate and energy consumption (test 4)

### 5.4.1 General

The testing method aims to verify the energy performance of the rotation speed control system. When there are multiple pumps in the secondary pump system, this test shall be applied to each secondary hydronic pump on which a rotation speed control is installed.