
**Ships and marine technology —
Verification method for portable power
measurement using a strain gauge**

Titre manque

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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).

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This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 2, *Marine environment protection*.

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.

Ships and marine technology — Verification method for portable power measurement using a strain gauge

1 Scope

This document specifies a procedure for the verification of portable power measurement equipment using a strain gauge in the laboratory.

The power measurement equipment verified in accordance with this document can be used on merchant ships.

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 15016:2015, *Ships and marine technology — Guidelines for the assessment of speed and power performance by analysis of speed trial data*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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

strain gauge

gauge used to measure the strain on an object

Note 1 to entry: As the object is deformed it causes a change in electrical resistance. This change in resistance, usually measured using a Wheatstone bridge, is related to the strain by the quantity known as the gauge factor.

3.2

shaft power meter verification equipment

equipment designed to provide a real torque, produced by a torque arm weighted with a known exact mass, to the torque measurement device

3.3

portable power measurement equipment

equipment temporarily installed on the ship and operated during a sea trial to measure the power delivered to the propeller by the engine and transmission systems, as opposed to the fixed-type shaft power measurement equipment, if installed

4 Composition of the shaft power meter verification equipment

4.1 General

The verification equipment is composed of a torque arm, a weight surface plate, a torque arm axis, a shaft, a torque sensor, a weight and an RPM (revolutions per minute) generator. See [Figure 1](#). The real torque is generated by weights with known exact mass, attached to a torque arm of known length which is attached to the shaft.

Shaft torque shall be measured by means of a verified permanent torque sensor or strain gauges on the shaft.

4.2 Torque generator and RPM generator

4.2.1 General

Torque and RPM are needed for calculating the shaft power output. The ship's power output can be simulated by multiplying the RPM, which are generated by an RPM generator, generating exact RPM, and the torque which is generated by a torque generator.

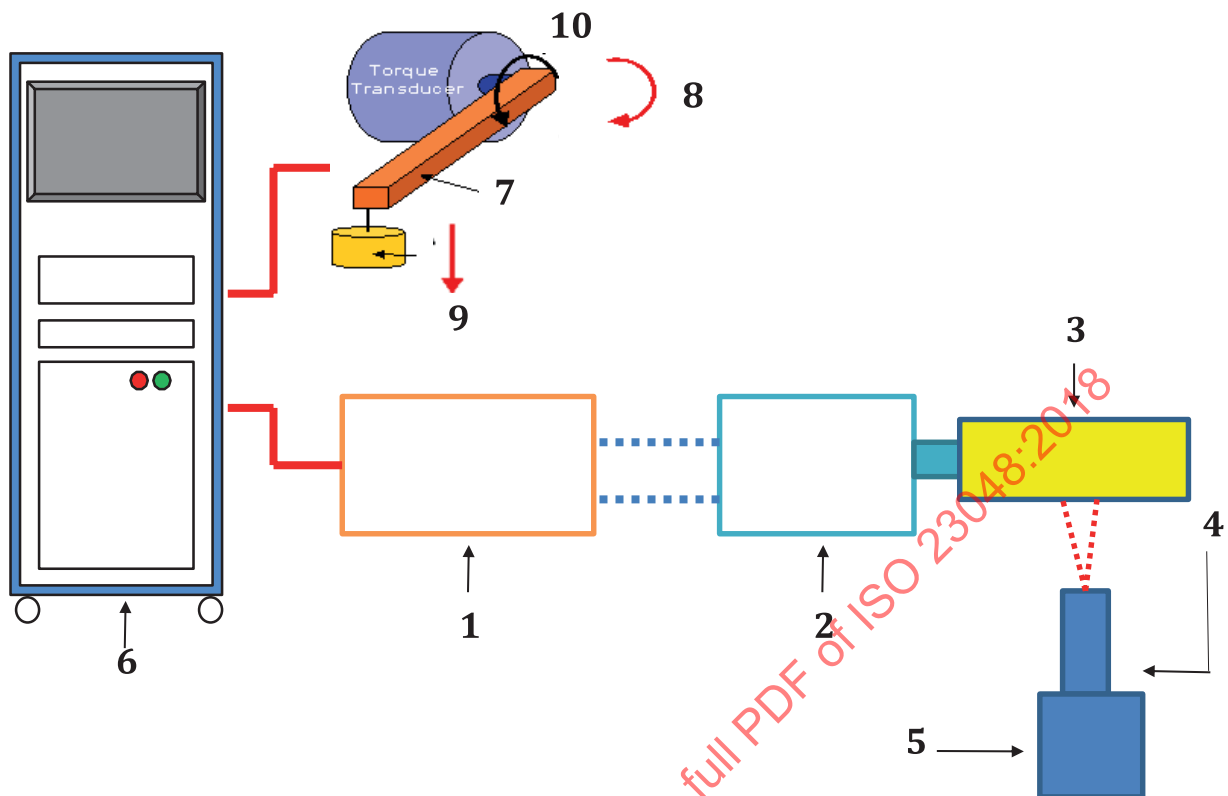
4.2.2 Torque generator

Torque is applied to the shaft by a torque generator using weights with exact mass and a torque arm with exact length, see [Figure 2](#). Weight shall be corrected and calibrated accurately.

The shaft material properties of the torque generator shall be stated in a test report in accordance with ISO 15016:2015, 6.1.

4.2.3 RPM generator

- a) The RPM generator is composed of a body of revolution, which can be controlled from 0 RPM to 1 RPM, and a tacho sensor which measures the number of revolutions.
- b) The RPM generator shall control the RPM precisely. It shall be designed to attach to the various types of tacho sensors to be linked with the shaft power device.
- c) The RPM generator shall be capable of displaying the current RPM status data. The RPM error rate shall be recorded in the test report as specified in [Annex C](#).
- d) The RPM generator should be calibrated by a facility meeting ISO/IEC 17025. If it is not, it should be verified by a calibrated tachometer.
- e) The engine RPM generator shall be included for exact verification of the shaft power meter as shown in [Figure 1](#).
- f) The RPM error rate shall be measured at least five times for each of the RPM testing conditions.



Key

- 1 motor precise control system
- 2 precise servo meter
- 3 rotating shaft
- 4 tachometer
- 5 shaft power verification simulator (SW)
- 6 control and data processing unit
- 7 torque arm
- 8 torque
- 9 weight
- 10 moment

Figure 1 — Composition of the verification equipment

5 Guidelines for installation and verification test

5.1 General

The verification equipment shall be designed to enable a comparison with the output of the portable shaft power meter by generating torque and RPM.

When the weights are installed to the torque arm, the specimen shaft is twisted by the torque and this torque is measured by the shaft power verification equipment.

The torque can be verified by a torque arm weighted with a known exact mass and exact length. The shaft power meter can be verified by comparing the output values with the verification equipment. It is possible to verify whether the torque output measured by the torque sensor is equal to the calculated values or not.

Measured values of the verification equipment torque sensor are the standard values.

Final power (kW) of the shaft power meter for the ship's engine can be verified when RPM data is provided by the RPM generator.

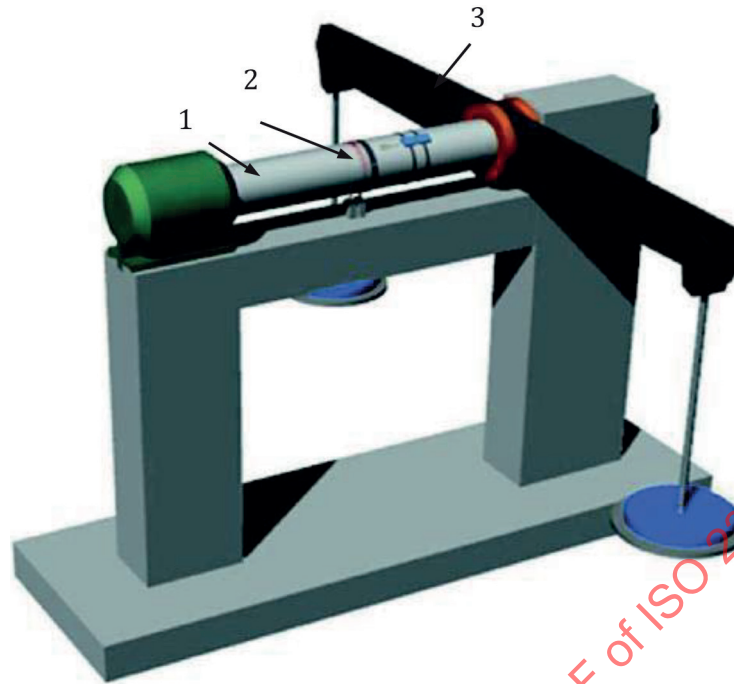
NOTE The verification equipment is designed for the portable torque meter; however, this equipment can verify other types of shaft power meters by agreement between manufacturers and purchasers.

5.2 Installation guidelines

The verification equipment can be designed as given in Table 1, however other types of equipment designs can be applied by agreement between manufacturers and purchasers, see [Annex B](#).

Table 1 — Installation guidelines

Name	Use	Guidelines
Torque sensor	Sensor to measure torque values at specimen shaft	Comparing and analysing the output values installed in the test shaft and suggesting the standard value allows verification of the shaft power meter.
Shaft	Shaft for verification test	4.2.2 shall be followed for the shaft property of the shear modules.
Torque arm	Mechanism for transferring the torque moment by weight to the test specimen shaft	Distance between rotation pivot point of torque arm and acting point of weighting shall be 1 m for the sake of convenient calculation of moment of rotation and torsional rigidity.
Weight	Device for generating artificial torque	Predictable standard torque is generated by weight with exact mass.
RPM generator	Device for generating RPM	It shall be designed to equip the tacho sensor of shaft power equipment and precisely control the RPM.

**Key**

- 1 shaft
- 2 shaft angle of distortion sensor
- 3 torque arm
- 4 weight surface plate

Figure 2 — Torque generator**6 Test procedure**

- a) Install the shaft power meter to the shaft of the verification equipment in accordance with [A.2](#).
- b) Test the strain gauge to ensure it is attached correctly in accordance with [A.2](#) d).
- c) Put weight in surface plate and generate torque.
- d) Compare the installed shaft power meter values and the shaft power values by the verification equipment, and record the error rate of these compared values.
- e) Compare the number of revolutions generated by the RPM generator and measured output data and calibrated tachometer and record the error rate of these compared values.

7 Test report

The results of the verification test shall be reported in the form specified in [Annex C](#).

8 Verification

If the torque given by the torque generator is correctly indicated, the power measurement equipment is deemed to have correct performance of shaft power measurement.

Annex A (normative)

Installation and verification method — Strain gauge

A.1 Principle of the measurement test

A.1.1 Measurement of shaft distortion

The strain gauge is one of the portable type power measurement methods. It is a micro displacement detective sensor, usually made of metal, which changes its electric resistance as its length expands or contracts. The strain gauge is usually able to detect changes in electric resistance as small as $1/1\,000\,000\ \Omega$. The change in electric resistance can be converted to stress intensity using appropriate formulas and conversion factors.

Each position of point A and B is changed to point A' and B' when the rotation moment affects the shaft. Position changes are different because A point is weighted by a propeller, so the position difference would be made as much as Y values.

These position differences eventually transform the strain gauge, which is adhered solidly to the shaft and changes the resistance values of the strain gauge.

A.1.2 Measurement of shaft speed

Shaft speed is measured by a tacho sensor. An analog pulse signal is changed to a digital signal by a data acquisition device (DAQ).

A.1.3 Measurement of shaft power

Shaft power can be measured by calculating the distortion and shaft speed.

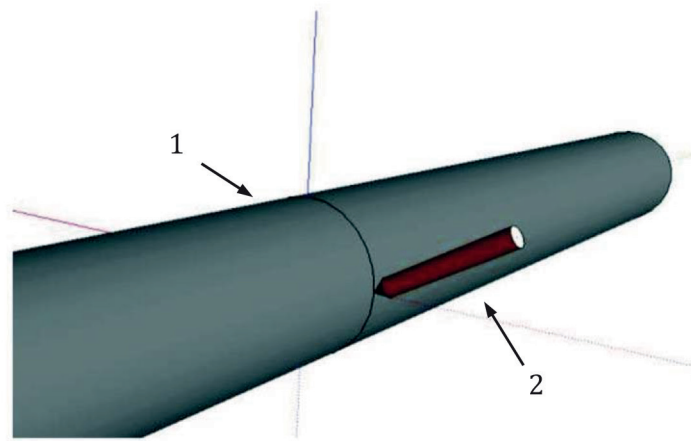
A.2 Performance requirements for installation of strain gauge shaft power meter

All strain gauges have their own factors, and these values are provided by a strain gauge manufacturer.

- a) A strain gauge shall be installed on the intermediate part of the shaft. However, do not install it on the flange or bearing.
- b) Glue is normally used to firmly attach the strain gauge to the shaft. Before gluing the strain gauge, clean the shaft with a rust preventative oil and thoroughly remove the oil using a tissue or liquid (100 % acetone). Shaft temperature shall be kept steady at room temperature in order to glue the strain gauge well, especially in cold weather.
- c) The strain gauge shall be installed within $\pm 1,5$ angle ranges in accordance with [A.3](#).
- d) The strain gauge shall be firmly attached to the shaft and checked for its consistency of attachment. The E output shall be lower than $\pm 0,5\ \text{mV/V}$ when the engine is stopped and, during this condition, no change in the output shall occur even when pressure is applied to the top of the sensor.

A.3 Strain gauge installation method

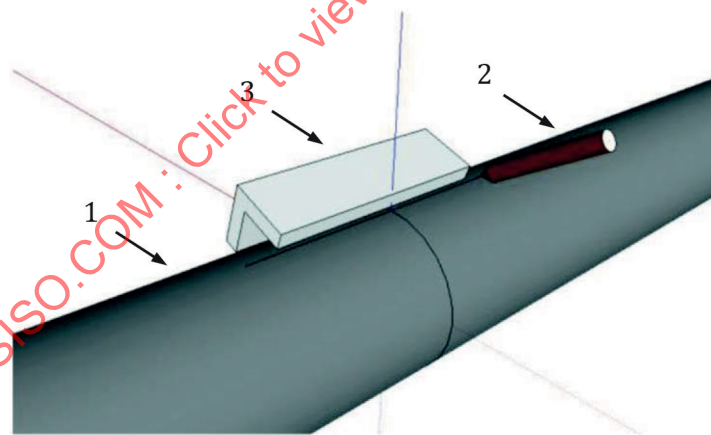
The strain gauge shall be installed within $\pm 1,5$ angle ranges to follow the procedure below.

**Key**

- 1 shaft
- 2 pen

Figure A.1 — Strain gauge installation

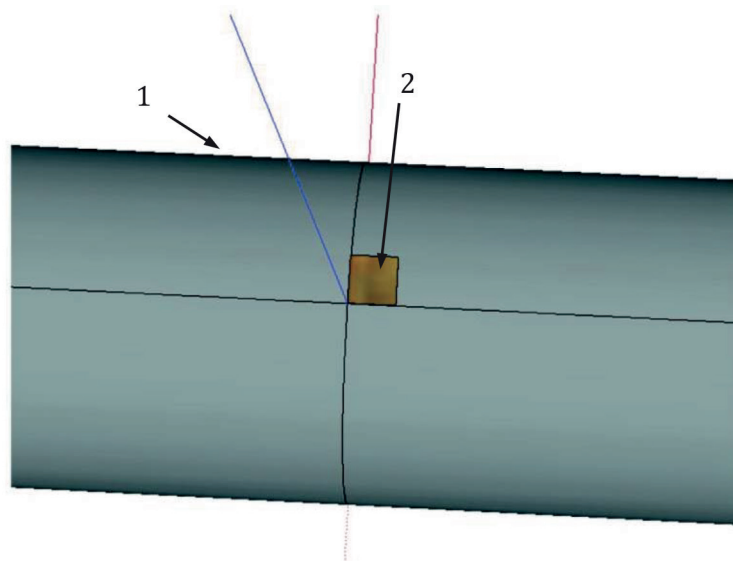
- a) Attach the tip of the pen to the shaft and fix the body of the pen.
- b) Rotate the shaft using the turning gear.
- c) The pen draws a vertical line onto the shaft.

**Key**

- 1 shaft
- 2 pen
- 3 angle ruler

Figure A.2 — Strain gauge installation (2)

- d) Hold the angle ruler onto the shaft and draw a line.
- e) Draw a horizontal line on the shaft using the pen.
- f) This creates an intersection point on the shaft.



Key

- 1 shaft
- 2 strain gauge

Figure A.3 — Strain gauge installation (3)

- g) Attach the corner of the sensor to the intersection point on the shaft using a special glue.

Annex B

(informative)

Shaft power measurement — Strain gauge (portable type)

B.1 Device composition

B.1.1 Strain gauge

The change in electric resistance can be converted to stress intensity using appropriate formulas and conversion factors.

B.1.2 Frequency transducer

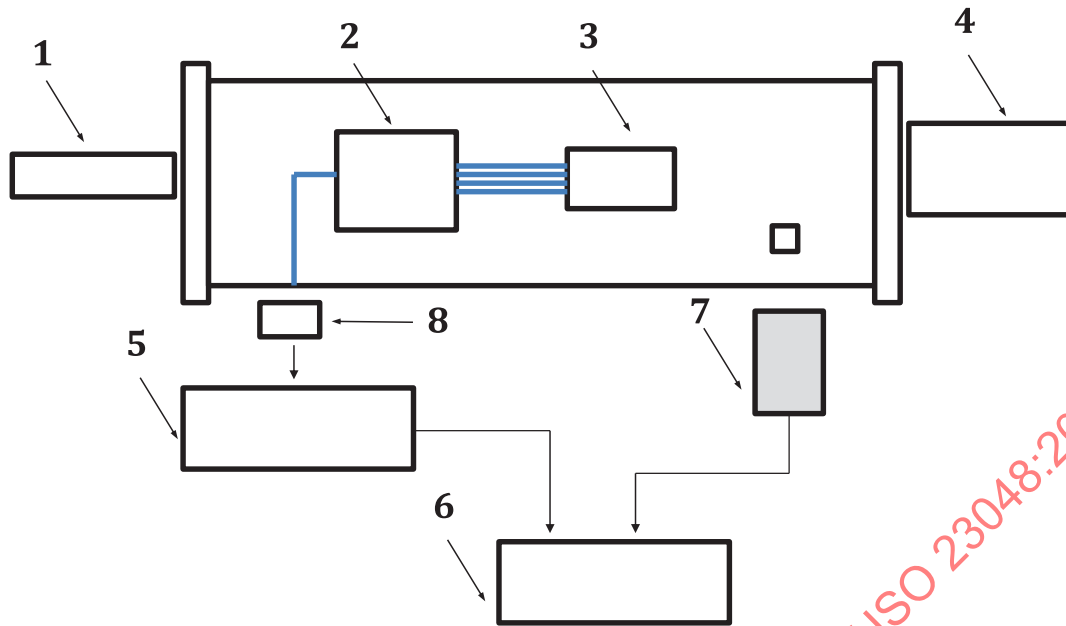
The frequency transducer is fixed to the propeller shaft and it generates frequency through the vibrator after receiving the strain gauge resistance value from deformation.

B.1.3 Tele-metric receiver

The tele-metric receiver is a device for detecting the antenna's frequency signal with shaft and delivers the frequency signal to the terminal board. It also calculates the exact RPM in accordance with the rotation of a metal pole with shaft.

B.1.4 Electric measurement device

Torque values are decided on pre-recorded information (shaft material and diameter) and frequency signal from tele-metric receiver. The operation is also worked by the keyboard and all of the parameters are displayed as four digital lines. See [Figure B.1](#)



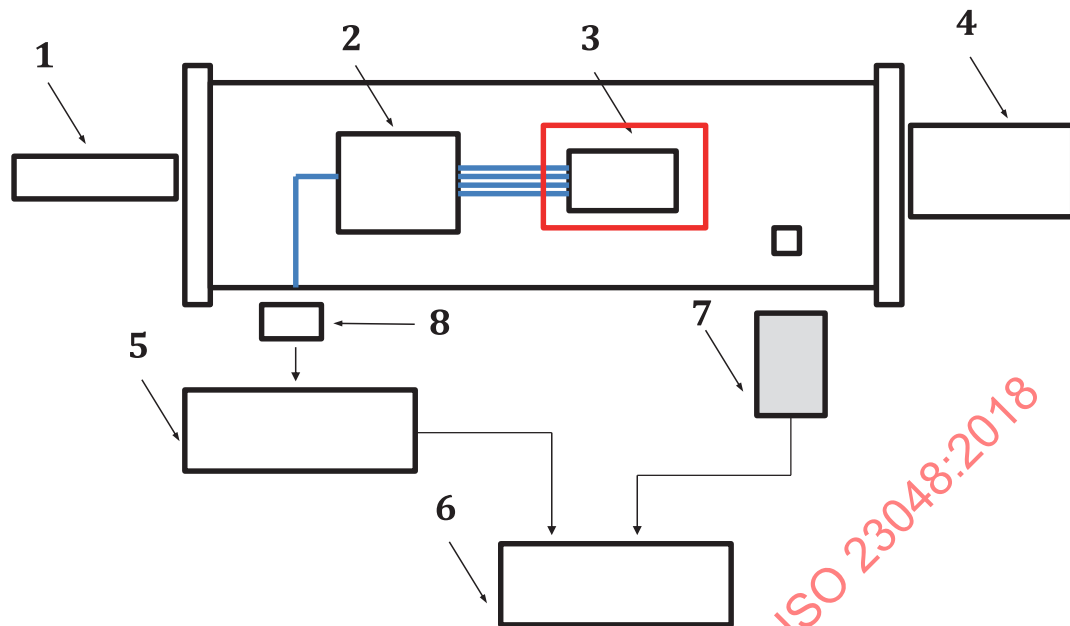
Key

- 1 propeller
- 2 transmitter ($\Delta V \rightarrow \Delta F$)
- 3 strain gauge
- 4 main engine
- 5 receiver ($\Delta F \rightarrow \Delta V$)
- 6 data acquisition & data analysis
- 7 tachometer (RPM)
- 8 antenna

Figure B.1 — Design composition of shaft power meter

B.2 Installation and verification procedure – Strain gauge (portable type)

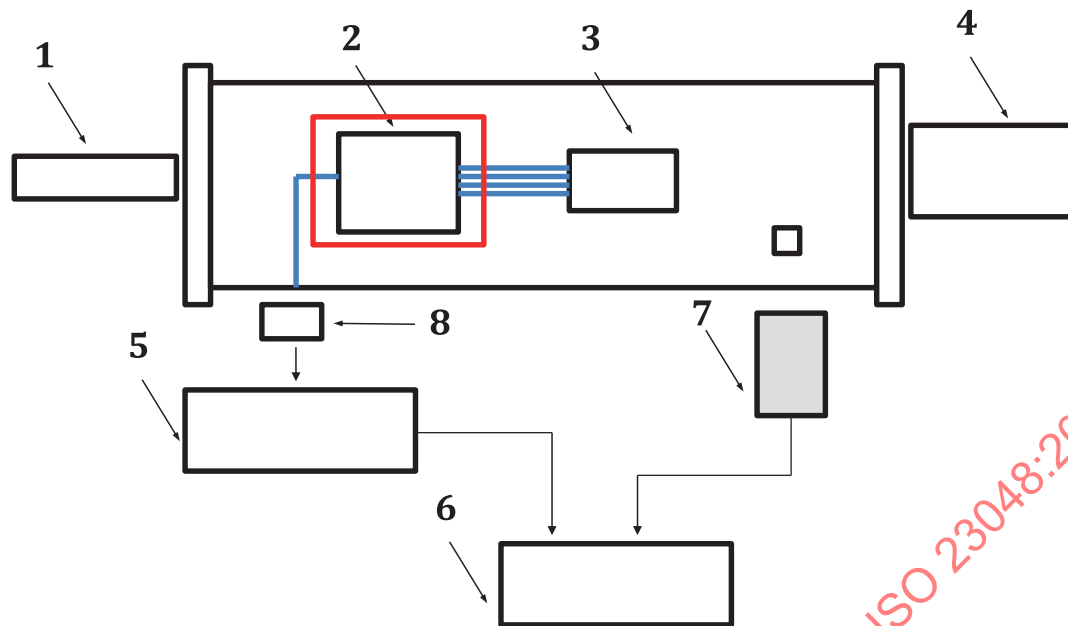
- a) Select the proper position for attaching the strain gauge, which is a device of the shaft power verification equipment. Next, polish the surface where the strain gauge is to be attached and attach the strain gauge. See Figure B.2.

**Key**

- 1 propeller
- 2 transmitter ($\Delta V \rightarrow \Delta F$)
- 3 strain gauge
- 4 main engine
- 5 receiver ($\Delta F \rightarrow \Delta V$)
- 6 data acquisition & data analysis
- 7 tachometer (RPM)
- 8 antenna

Figure B.2 — Specimen shaft for strain gauge attached to the shaft

- b) Connect the converter mounted on the shaft and the strain gauge attached to the shaft, and install the wireless transmitter to transmit the torque value data. See Figure B.3



Key

- 1 propeller
- 2 transmitter ($\Delta V \rightarrow \Delta F$)
- 3 strain gauge
- 4 main engine
- 5 receiver ($\Delta F \rightarrow \Delta V$)
- 6 data acquisition & data analysis
- 7 tachometer (RPM)
- 8 antenna

Figure B.3 — Installation of wireless converter

- c) The torque data received by the wireless transmitter is converted into digital value through a wireless converter that can be read by the measuring device and the device configured to be able to obtain the data. See Figure B.4