SIEMENS

Tests for induction motors
This documentation pertains to
Factories NMA and RHF

Reference Manual

# Tests for asynchronous motors

## SIMOTICS

Type 1L, 1M, 1P, 1R, 1S, 1N

Edition 02/2020

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| | |
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## Legal information

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|---|
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|---|
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|---|
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|---|
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# 1 Introduction

The system test facility in Nuremberg, Germany

The test field in Ruhstorf, Germany

This document describes the preconditions for carrying out tests on induction motors in our Nuremberg-Vogelweiherstrasse and Ruhstorf factories. The fulfillment of these preconditions is the basis for achieving the smoothest possible testing process and maximum possible customer satisfaction.

The following induction motor tests are described:

- Routine tests and inspections which are part of the normal production process
- Tests that are offered as standard
- Tests during production

---

**Note**

If the scope of testing and inspection cannot fulfill all customer requirements, please consult your Siemens sales advisor at head office.

---

# 2 General scope of services

A variable-speed drive can include the following components:

- Induction motor, synchronous motor or PEM motor with or without speed encoder
- SINAMICS drives
- Drive transformer
- Cooling unit for water-cooled drives
- Small PLCs with drive functionality.

The factory offers adapted test systems adapted to address such systems.

---

**Note**

Contact your sales person if additional components must be taken into account for your particular project.

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## Scope of services offered

Unless otherwise stated in the quotation, the scope of tests ordered includes all activities, equipment, materials and expendables required.

Additional activities, services and provisions - for example, the use of third-party converters - must be coordinated well in advance.

The deadline and testing period stated, and the quoted cost, can be met only if all the test and inspection procedures are **clarified in detail in advance**. Due to the high capacity utilization of the associated equipment, it might not be possible to carry out individual inspections and tests that are requested late if the planned test is already in progress.

If you have received specific requirements from your customer, please send these as soon as possible – with the necessary key data – to the system test facility.

## Test equipment

Siemens ensures the availability of the equipment required for the agreed tests and inspections, including test couplings for load runs.

Customer couplings, coupling dummies and coupling jigs for non-cylindrical shaft extensions are excluded.

## Sequence of a customer acceptance

A customer acceptance test is generally executed in the sequence:

1. Installation and commissioning of the components before the customer arrives.
2. Kickoff with presentation of the test schedule and discussion of individual steps in the acceptance test workflow.
3. Execution of the tests according to the test schedule
4. Discussion of the test results
5. Preparation of test documentation for the customer.
   The test documentation is created before or after the customer leaves depending on the scope of testing and the time schedule.

## Components provided by customer

Components provided by the customer must be available in plenty of time so that tests can be carried out on time. The factory has no access to components, which are not part of the scope of supply of PD LD. This also applies to components ordered from other Siemens' Groups. The technical data for these components is required at the latest eight weeks before the start of the acceptance test, e.g.:

- Dimensions
- Weights
- Energy Requirement
- Interfaces

## See also

Testing equipment capacity (Page 13)

## 2.1 Testing equipment capacity

The technical data of the test systems and equipment are listed in the following tables. If this available capacity does not meet your requirements, please consult your Siemens sales person. The following options are available:

- Equivalent loading and substitution techniques and mathematical calculation of projected performance data
- The machine(s) can be tested in the Berlin plant

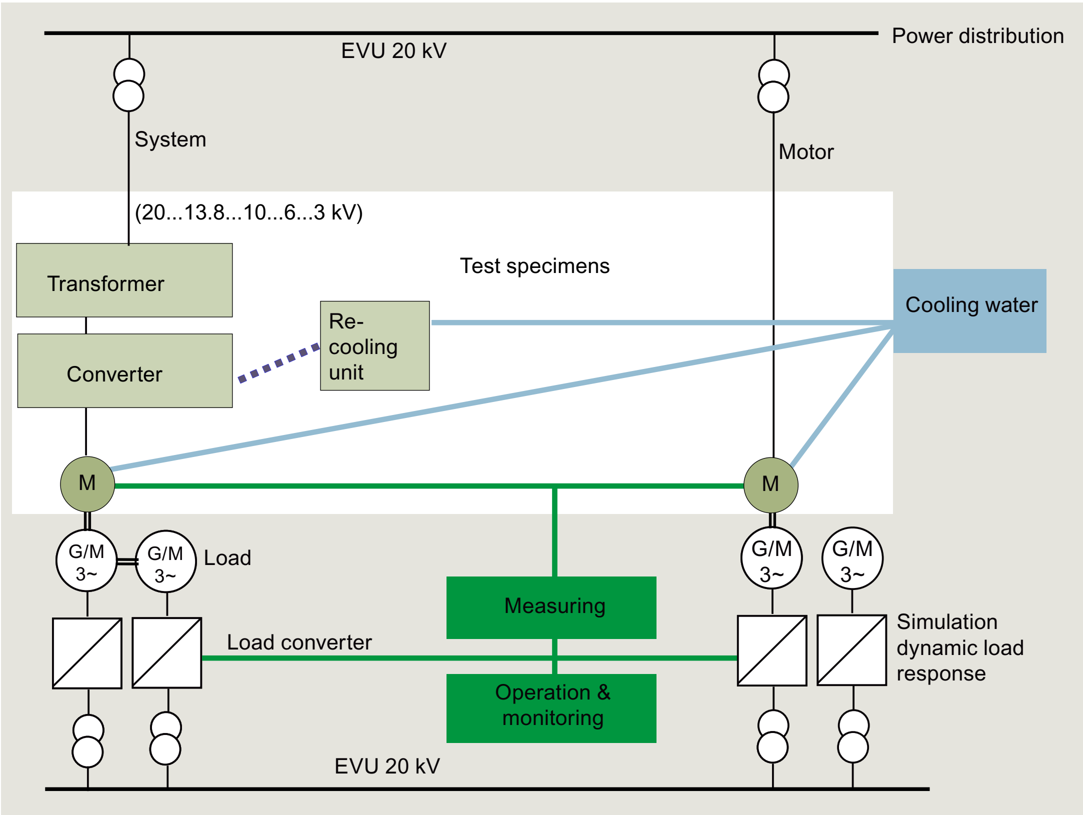



Figure 2-1 Example: Overview diagram of a test configuration

### Options available in our Nuremberg factory

Table 2-1 Load capabilities

| Speed<br>1 rpm | Torque<br>Nm | Power<br>kW | Max. shaft height<br>mm |
|---|---|---|---|
| 0 ... 1500<br>1500 ... 2100 | 31830 max. | 0 ... 5000<br>5000 max. | 710<br>710 |
| 0 ... 3000<br>3000 ... 4200 | 15915 max. | 0 ... 5000<br>5000 max. | 710<br>710 |

| | | | |
|---|---|---|---|
| 0 ... 600<br>600 ... 800 | 79577 max. | 0 ... 5000<br>5000 max. | 1100<br>1100 |
| 0 ... 6000<br>6000 ... 8000 | 1591 max. | 0 ... 1000<br>1000 max. | 500<br>500 |

Table 2-2 Power supplies

| **Type** | **Voltage**<br>kV | **Levels**<br>% | **Power**<br>kVA or kW |
|---|---|---|---|
| Direct | 20 | | |
| Medium-voltage transformer | 1.73 / 3 / 3.4 / 6<br>5 / 10 / 13.8 | ±13<br>±13 | 6000<br>6000 |
| Medium-voltage transformer | 1.73 / 3 / 3.4 / 6<br>5 / 10 | -9 / +16<br>-9 / +16 | 3600<br>3600 |
| Low-voltage transformer | Up to 0.7 | | 3150 |
| SINAMICS LV converter | 0.7 | | 4500 |

## Options available in our Ruhstorf factory

| | |
|---|---|
| Shaft height / mm | Max. 1000 |
| Torque / Nm | Max. 45 000 |
| Power / kW | Max. 4800 |
| Frequency / Hz | 30 ... 60 |

| **Voltage levels / V** | **Current / A** |
|---|---|
| 15000 | Max. 220 |
| 11000 | Max. 330 |
| 6600 | Max. 570 |
| 3000 | Max. 1000 |
| 1000 | Max. 3200 |

Special features:

- Testing submersible motors in water tanks that can be heated
- Load noise measurements in an acoustic measuring chamber up to approximately 3 MW - or a machine weight of up to 16 tons
- System tests with drive components from all of the usual manufacturers
- Tests performed according to customer specifications, especially in the oil and gas industry

## Instrumentation

When requested, with the test, persons witnessing the test are provided with a list of the measuring equipment and devices.

## 2.2 Tests and inspections as part of the production process

### Transformers

The transformer manufacturer carries out routine checks on the transformer according to IEC 76 / VDE 0532. The following is checked/tested:

- Insulation test
- Vector group
- Transformation ratio
- Resistances
- No-load test
- Short-circuit test

### Converter

The routine test for converters include the following:

- Visual inspection
- High-voltage insulation test according to EN 60146-1 and EN 50178
- Function test, e.g. auxiliary voltages, software, firmware
- U/f test

Options that have been ordered are taken into consideration for the specified tests. Where relevant, individual tests will also be performed for specific options.

### Motors

The routine test for motors in accordance with IEC / EN 60034-1 includes the following:

- Determining the stator winding resistance
- Testing the insulation resistance of the stator winding
- No-load tests
- Short-circuit test
- Phase sequence and direction of rotation
- Testing optional built-on/mounted equipment
- Withstand voltage test

---

**Note**

**No inspection/testing of converter**

None of the tests specified for the transformers and motors will be performed on the converter. The factory certificates for components supplied by LD will be discussed with the customer at the kickoff presentation.

---

Converters and motors are already subject to a routine test by the manufacturer as part of the quality assurance program. Consequently, the routine test is not repeated for the acceptance test, unless it has been explicitly ordered.

**Note**

Test documents are created automatically and so not signed.

## 2.3 Function tests for the line supply according to IEC, IEEE, NEMA

The machine is subjected to a comprehensive **function test** . The machine in the context of the system capacity is operated with the rated data for this type and all machine-specific characteristic data determined.

The function test is performed in accordance with IEC/EN 60034-1/-29, based on ANSI/ NEMA MG-1 and IEEE 112 method A, B, B1 or E1.

Optionally, function tests are performed in the presence of the customer. Certain function tests in no-load operation are obligatory, and are always performed. IEC 60034-1 links them with a routine test.

### Routine test

The routine test is necessary to check the correct functioning of a machine. Reference variables are provided by a motor of the same type, which was subject to comprehensive function tests ("type test").

Reference variables are available for 50 Hz and 60 Hz in certain voltage versions for each motor type. The variables measured during a routine test are converted over to the voltage and frequency of the reference variables and then compared.

The machine is released if the converted measured variables lie within the tolerance range. In the event of deviations outside the tolerance level, the cause of this is determined in a separate investigation and, if necessary, rectified. The results of the routine test are summarized in the routine test certificate.

| Routine test | Order codes | |
|---|---|---|
| | Without the customer present | With the customer present |
| • Measurement of the insulation resistance $R_{isol}$<br>• DC resistance test of the stator winding<br>• Testing of accessories, integrated and mounted components<br>• Agreement between the direction of rotation and terminal designations<br>• Vibration severity measurement [2]<br>• No-load test ($P_0 + I_0$)<br>• Short-circuit test<br>• Shaft voltage measurement [3]<br>• Surge voltage test [4]<br>• Surge pulse measurement [5]<br>• High-voltage test<br>• Voltage test of the main insulation while the windings are being produced | F00[1] | F01 |

[1] F00 is part of the scope of the standard test.

[2] Not included in the minimum scope of the routine test according to IEC 60034-1; however, it is still performed.

[3] Only carried out for motors with non-insulated bearings.

[4] If a surge voltage test has already been carried out, 80 % of the test voltage is used for testing.

[5] Only for motors with roller bearings and measuring nipple

## Function tests under load (combination test F82 / F83)

You can individually ordered the following function tests, but also as combination test with order codes F82 (without the customer being present) or F83 (with the customer present).

| Function tests under load | Order codes | |
|---|---|---|
| | Without the customer present (F82) | With the customer present (F83) |
| Temperature rise test under load | F04 | F05 |
| Recording the no-load characteristic and determining iron (core) and no-load losses (no load operation) | F14 | F15 |
| Plotting the short-circuit characteristic and calculating the short-circuit losses | F16 | F17 |

| | | |
|---|---|---|
| Recording the load characteristic | F18 | F19 |
| Calculating the efficiency from the individual losses [6] | F20 | F21 |

[6] "Calculating the efficiency from the individual losses" (F20/F21) can only be ordered in conjunction with "Temperature rise test under load" (F04/F05), "Recording the no-load characteristic and determining the iron (core) and no-load losses" (F14/F15) and "Recording the load characteristic" (F18/F19).

## Additional tests

The following additional tests can be individually ordered.

| **Function tests** | **Order codes** | |
|---|---|---|
| | **Without the customer present** | **With the customer present** |
| "tan δ" loss factor measurement on single coils | F22 | F23 |
| Loss factor measurement "tan δ" on the installed stator winding in the test bay | F26 | F27 [8] |
| Noise measurement (no-load operation) | F28 | F29 |
| Measuring the cooling air flow (no-load operation) | F30 | F31 |
| Plotting the current and torque characteristics using a dynamometer (load) | F34 | F35 |
| Calculation of moment of inertia using the coast-down method | F36 | F37 |
| Overspeed test | F38 | F39 |
| Sealed Winding Conformance Test according to NEMA | F42 | F43 |
| Partial-discharge measurement | F46 | F47 [8] |
| Measurement of locked-rotor torque and locked-rotor current | F52 | F53 |
| Measuring the insulation resistance and polarization index | F54 | F55 |
| Vibration analysis (no-load operation) | F58 | F59 |
| Impulse or AC voltage test on two single coils | F60 | F61 |
| Noise analysis (no-load operation) | F62 | F63 |
| Journal bearing inspection | - | F67 |
| Runout measurement [7] | - | F71 |

[7] Is always measured when producing machines with journal bearings with shaft vibration measuring systems.

[8] Only on request in our Ruhstorf factory.

# 2.4 Function tests for machines connected directly to the line supply according to API 541

Optionally, the machine is subject to a comprehensive **function test according to API 541** .

## Routine test according to API

The following tests are part of the routine tests according to API. You can order the tests as "Required", "Witnessed" or "Observed".

| Function tests of the routine test | Order codes | | |
|---|---|---|---|
| | Re-quired | Wit-nessed | Ob-served |
| • Calculation of the short-circuit current [1]<br>• DC resistance test of the stator winding<br>• Testing of accessories, integrated and mounted components<br>• Agreement between the direction of rotation and terminal designations<br>• Bearing temperature rise test<br>• Vibration severity measurement after a temperature rise test under load [2]<br>• No-load test ($P_0$ + $I_0$)<br>• Short-circuit test<br>• Shaft voltage measurement [3]<br>• Withstand voltage test on stator winding [4]<br>• Measuring the insulation resistance and polarization index<br>• Visual journal bearing inspection after the electrical tests<br>• Bearing insulation measurement [5]<br>• Air gap measurement [5]<br>• Slow roll measurement | F100 | F101 | F102 |

[1] The calculation is made in the order processing phase when generating the electrical documentation.

[2] For machines with journal bearings equipped with shaft vibration measuring systems, the runout is measured while the rotor is being produced.

[3] Only carried out for motors with non-insulated bearings.

[4] If a surge voltage test has already been carried out, then 80 % of the test voltage is used for testing.

[5] These tests are part of the quality assurance process.

## Complete Test according to API (F154, F155, F156)

The tests of the complete test can be ordered individually and also as combination test using order code F154 ("Required"), F155 ("Witnessed") or F156 ("Observed").

| Tests included in the "Complete Test" | Order codes | |
|---|---|---|
| | Without the customer present (F154) | With the customer present (F155, F156) |
| Plotting the no-load characteristic and calculating the iron and no load losses | F14 | F15 |
| Temperature rise test under load | F04 | F05 |
| Vibration measurementunder load [6] | - | - |
| Plotting the short-circuit characteristic and calculating the short-circuit losses | F16 | F17 |
| Recording the load characteristic under load | F18 | F19 |
| Calculating the efficiency from the individual losses according to IEC 60034-2-1 / IEEE 112 [7] | F20 | F21 |
| Recording the current and torque characteristics using a dynamometer under load | F34 | F35 |
| Noise measurement according to IEC under no load conditions | F28 | F29 |

[6] Vibration acceptance values only for no load operation.

[7] "Calculating the efficiency from the individual losses" (F20/F21) can only be ordered in conjunction with "Temperature rise test under load" (F04/F05), "Recording the no-load characteristic and determining the iron (core) and no-load losses" (F14/F15) and "Recording the load characteristic" (F18/F19).

## Tests according to API during production

You can order the tests as "Required", "Witnessed" or "Observed".

| Tests according to API during production | Order codes | | |
|---|---|---|---|
| | Required | Witnessed | Observed |
| Surge Comparison Test | F120 | F121 | F122 |
| Component Balance | F126 | - | - |
| Final Balance | F129 | F130 | F131 |
| Stator Inspection Prior to VPI | F139 | F140 | F141 |
| Final Assembly Running Clearances / Final rotating assembly clearance data storage | F172 | - | - |
| Runout measurement with acceptance | - | F71 | - |
| Special surge test of coils | F123 | F124 | F125 |
| Stator Core Test | F117 | F118 | F119 |
| Residual Unbalance Verification Test | F132 | F133 | F134 |
| Sealed Winding Comformance Test according to NEMA | F142 | F143 | F144 |
| Overspeed Test | - | - | F138 |

| | | | |
|---|---|---|---|
| Bearing Dimensional & Alignment Checks Before Tests | F148 | F149 | F150 |
| Bearing Dimensional & Alignment Checks After Tests | F160 | F161[1] | F162[1] |

[1] Only on request in our Ruhstorf factory.

## Additional tests according to API

You can optionally order additional tests according to API

| Function tests | Order codes | | |
|---|---|---|---|
| | **Re-quired** | **Wit-nessed** | **Ob-served** |
| Final Inspection | - | F03 | - |
| Design Review | F103 | - | - |
| Coordination Meeting | - | F104 | - |
| Lateral Critical Speed Analysis | F105 | - | - |
| Shop inspection | F106 | - | - |
| Submit Test procedures 6 weeks before Tests | F107 | - | - |
| Inspection for Cleanliness | F108 | F109 | F110 |
| Heat exchanger performance verification test TEWAC [8] | F111 | F112 | F113 |
| Demonstrate Accuracy of Test Equipment | F114 | F115 | F116 |
| Running Test with Coupling Half / Vibration Test with Coupling Half under no-load conditions | F135 | F136 | F137 |
| Power Factor Tip-Up Test [9] | F145 | F146[11] | F147[11] |
| Vibration Recording | F151 | F152 | F153 |
| Sound pressure level test | F157 | F158 | F159 |
| Unbalance Response | F166 | F167 | F168 |
| Bearing Housing Natural Frequency Test | F169 | F170 | F171 |
| Hydrostatic Test | F175 | - | - |
| Certified data prior to shipment | F176 | - | - |
| All required test and inspection equipment | F177 | - | - |
| Rated Rotor Temperature Vibration Test under load [10] | F191 | F192 | F193 |
| Material inspections | | | |
| • Radiographic Test Parts | F178 | - | - |
| • Ultrasonic Test Parts | F181 | - | - |
| • Ultrasonic Inspection of Shaft Forging | F184 | - | - |
| • Magnetic Particle Test Parts | F185 | F186 | F187 |
| • Liquid Penetrant Test Parts | F188 | F189 | F190 |

[8] Only together with "Complete Test", and under test facility/test field conditions

[9] Equivalent to F26

[10] Individual tests are part of the Complete Test and do not have to be ordered in addition to the Complete Test.

[11] Only on request in our Ruhstorf factory.

## 2.5 API 541: 4th versus 5th Edition

The paragraphs of API 541 differ between the 4th und 5th editions.

| Test | API 4th edition | API 5th edition |
|---|---|---|
| Routine Test | 4.3.2 | 6.3.2 |
| Coordination Meeting | - | 8.2 |
| Design Review | 6.2.1.4 | 8.4 |
| Torsional Analysis | 2.4.6.2.4 | 4.4.6.2.2 |
| Lateral Critical Speed Analysis | 2.4.6.2.1 | 4.4.6.2.1 / 8.6.2b |
| Shop Inspection | 4.1.1 | - |
| Submit Test Procedures 6 Weeks Before Tests | 4.3.1.5 | 6.3.1.4 |
| Inspection for Cleanliness | 4.2.3.2 / 4.2.3.3 | 6.2.3.3 |
| Observance of Assembly / Dismantling | 4.3.1.1 | - |
| Demonstrate Accuracy of Test Equipment | 4.3.1.14 | 6.3.1.15 |
| Stator Core Test | 4.3.4.1 | 6.3.4.1 |
| Surge Comparison Test | 4.3.4.2 | 6.3.4.2 |
| Special Surge Test of Coils | 4.3.4.2.1 | 6.3.4.2.1 |
| Component Balance | 2.4.6.3.1 | - |
| Final Balance | 4.3.1.6.1 | - |
| Residual Unbalance Verification Test | 2.4.6.3.6 / 6.2.5.1a | 4.4.6.3.4 |
| Balance Check with Half Coupling | 2.4.6.3.3 | - |
| Running Tests with Coupling Half / Vibration Test with Coupling Half | 2.4.6.3.3 / 4.3.1.6 | 4.4.9.4 / 6.3.1.5 |
| Stator Inspection Prior to VPI | 4.3.4.5 | 6.3.4.5 |
| Sealed Winding Conformance Test | 4.3.4.4 | 6.3.4.4 |
| Power Factor Tip-Up Test | 4.3.4.3 | 6.3.4.3 |
| Partial Discharge test | - | 6.3.4.6) |
| Bearing Dimensional & Alignment Checks Before Tests | 4.3.2.1j | 6.3.2.1k |
| Vibration Recording | 4.3.3.12 | - |
| Purchaser supplied vibration monitoring / recording | - | 6.3.3.7 |
| Complete Test | 4.3.5.1.1 | 6.3.5.1.1 |
| • Efficiency | 4.3.5.1.1a | 6.3.5.1.1 |
| • Locked Rotor | 4.3.5.1.1b | 6.3.5.1.1 |
| • Heat Run | 4.3.5.1.1e | 6.3.5.1.1 |
| • Sound Pressure Level Test | 4.3.5.1.1g | 6.3.5.1.1 |
| Bearing Dimensional & Alignment Checks After Tests | 4.3.2.1k | 6.3.2.1l |
| DC High-Potential Test | 4.3.5.1.2 | 6.3.5.1.2 |
| Unbalance Response Test | 4.3.5.3 | 6.3.5.3 |
| Bearing Housing Natural Frequency Tests | 4.3.5.4 | 6.3.5.4.1 |
| Heat exchanger performance verification test TEWAC | - | 6.3.5.5 |
| Overspeed test | - | 6.3.5.6 / 4.1.5 |

| Test | API 4th edition | API 5th edition |
|---|---|---|
| Final Assembly Running Clearances / Final rotating assembly clearance data storage | 4.2.1.1e | 6.2.1.1e |
| Material Inspection | 4.2.2 | 6.2.2 |
| • Radiographic Test Parts | 4.2.2.2 | 6.2.2.2 |
| • Ultrasonic Test Parts | 4.2.2.3 | 6.2.2.3.2 |
| • Ultrasonic Inspection of Shaft Forging | 4.2.2.3.1 | 4.4.5.1.8 / 6.2.3.1 |
| • Magnetic Particle Test Parts | 4.2.2.4. | 6.2.2.4 |
| • Liquid Penetrant Test Parts | 4.2.2.5. | 6.2.2.5 |
| • Hydrostatic test | - | 6.2.2.6 |
| Rated Rotor Temperature Vibration Test | 4.3.5.2.1 | 6.3.5.2.1 |
| Bearing Inspection After Tests | 4.3.2.1i | 6.3.2.1j |
| Certified data prior to shipment | - | 8.6.2a |
| All required test and inspection equipment | - | 6.1.4 |

## 2.6 Function tests with converter

| Function tests with converter | Order codes | |
|---|---|---|
| | Without the customer present | With the customer present |
| Function test with test field converter | F74 | F75 |
| System test with the customer's converter | - | F97 |

### See also

Function test at the test field converter (Page 121)

System test for variable-speed drives (Page 29)

## 2.7 Tests carried out on explosion-protected motors

Electrical machines are used in the widest range of designs and power ratings in hazardous zones. As a result of the many motor versions, when testing and certifying there are an extremely wide range of requirements relating to explosion protection. The basic requirements relating to electrical machines are specified in the series of IEC / EN 60034-1 standards. Additional requirements for various types of protection are described in the series of IEC / EN 60079-ff standards.

The mechanical version of the machine is the basis for certifying explosion-protected drives. The approval is summarized in the form of a mechanical test report. The test report includes results of the various tests according to the standards listed above, e.g. material properties of the individual components, IP degree of protection test, ... . The test report is generally accepted by a testing body. At the time of the type test, the acceptance has normally been completed.

Only the aspects of the electrical-pneumatic measurements are discussed in the following chapter.

The type of protection defines which aspects of explosion protection are tested at the machine. The type of protection is reflected in the Ex marking:

- A machine with "Increased safety "eb"" type of protection is tested to ensure that the appropriate temperature class is complied with. This means, in normal operation, or in the case of a locked rotor, it is not permissible that the defined temperature limits are exceeded at any part of the machine.
- A machine with "Increased safety "ec"" type of protection is tested to ensure that the appropriate temperature class is complied with. Contrary to type of protection "eb", compliance is only tested under normal operating conditions.
- Machines with type of protection "Pressurized enclosure "p"" are subject to specific pneumatic tests. Based on a thermal test, it is verified that the appropriate temperature class is complied with outside the pressurized enclosure.
- A machine with "flameproof enclosure "db"" type of protection is tested to ensure that the appropriate temperature class is complied with under normal operating conditions.

### 2.7.1 Temperature rise test under load for all types of protection

The temperature rise test under load is most important test for all types of protection. During the test, the temperature class of the complete machine is verified. The following is tested: Compliance with the upper temperature limits for the winding, seals, cable and conductor branches/connections, maximum operating temperature for mounted devices etc.

- 
  Motors destined for Zone 1 - with the following types of protection - are tested as standard.
  - "Device protection provided by pressurized enclosure "p""
  - "Increased safety "e""
  - "Flameproof enclosure "d""
- Motors destined for Zone 2 – with the following types of protection - are optionally tested.
  - "Increased safety "ec""

### 2.7.2 Pneumatic routine test

The following tests are part of the routine test for motors, type of protection "device protection provided by pressurized enclosure "p"".

- Leakage loss measurement at motors, type of protection "device protection provided by pressurized enclosure "p"" (Page 61)
- Pressure distribution measurement at motors, type of protection "device protection provided by pressurized enclosure "p"". (Page 62)
- Flow rate measurement and adjusting the pressurized system (Page 63)

### 2.7.3 Type tests for explosion-protected machines with type of protection "device protection provided by pressurized enclosure "p""

#### 2.7.3.1 Pneumatic type test

The following is tested for each new electrical design of motors with type of protection "device protection provided by pressurized enclosure "p"":

- The level of leakage at the maximum operating pressure is measured.
  Leakage loss measurement at motors, type of protection "device protection provided by pressurized enclosure "p"" (Page 61)
- When purging with the set flow rate, the pressure in the enclosure must not fall below the minimum pressure level.

- At all measurement locations, it is not permissible that the minimum pressure falls below a value of 50 Pa.
  Pressure distribution measurement at motors, type of protection "device protection provided by pressurized enclosure "p"". (Page 62)
- The parameters of the pressurizing system must correspond to the EU type examination certificate regarding the following data:
  - Purge time
  - Purge volumes
  - Differential pressure at the start of purging
  - Maximum and minimum pressure
  - ...

  Flow rate measurement and adjusting the pressurized system (Page 63)

### 2.7.3.2 Purging and dilution test as part of the type test

For motors with type of protection "device protection provided by pressurized enclosure "p"", the minimum purge rate and minimum purging time are defined as part of the type test. These values are dependent on the type of construction and cooling method. The maximum gas concentrations according to IEC / EN 60079-2 Appendix A.2 apply as test criteria.

The purging and dilution test is carried out by the certification body, e.g. Physikalisch-Technischen Bundesanstalt (PTB) corresponding to the restrictions and corresponding to IEC / EN 60079-2 Annex A.

## 2.8 System test for variable-speed drives

### 2.8.1 System tests for safety and reliability

For a system test, complete drive systems are installed on the test stand. Once systems have been tested in this way, they operate extremely safely and reliably in processing and manufacturing industries.

The load simulation in the system test bays check/test the interaction between all the system's components, e.g.:

- Motors
- Converter
- Gear unit
- Brakes
- All other drive components

The following is examined here:

- Standard operating ranges, e.g.
  - 4-Quadrant operation
  - Dynamic and regenerative braking
  - Undervoltage and overvoltage monitoring
  - Temperature rise in braking resistors
- Extreme operating situations and faults, e.g.:
  - Abrupt load change
  - Load shedding
  - Shock load

### 2.8.2 System test

The basis for a system test is generally a temperature rise test under load. All other listed tests are supplements to the temperature rise test under load. If your customer has specified something else, then please contact your sales person.

The following sequence is only an example; on a case-for-case basis, the sequence and scope of the system test is defined together with the customer.

### Temperature rise test under load during the system test

1. Recording the electric data of the motor in a cold state
   – Stator winding resistance
   – Stator winding insulation resistance (optional)
2. The machine coupled to the load machine (dynamometer) is if possible operated with the converter at rated speed and rated torque until it reaches its steady-state temperature, i.e. the motor temperature changes by less than 2 K within one hour. If a speed range is specified, then the speed at which the highest temperature rise is expected is selected. For example, the following parameters are continuously recorded during the measurement:
   – Primary current, primary voltage, primary power and primary power factor of the transformer (if one is being used)
   – Converter output frequency
   – Motor current, motor voltage
   – Motor speed
   – Torque and power at the motor shaft
   – Motor enclosure temperature (optional)
   – Motor winding temperature
     The winding temperature is only measured if there is a winding Pt100.
   – Motor bearing temperature
   – For machines with air/water cooler, which are equipped with Pt100 elements at the air intake and discharge, then these temperatures are also recorded.
3. Measuring the winding temperatures
   – The resistance when warm is measured.
   – The cooling-down curve is recorded by measuring the stator winding resistance. The average motor temperature rise at the instant of shutdown is derived from this curve.

## 2.8.3 Tests on explosion-protected systems

There are various requirements laid down in standards for drive systems, which must be used in hazardous zones.

| | "Increased safety" | "Flameproof enclosure" | "Pressurized enclosure" | "Non-sparking" |
|---|---|---|---|---|
| | EN 60079-0 | | | |
| **Standards** | **EN 60079-7** | **EN 60079-1** | **EN 60079-2** | **EN 60079-7** |
| **System test required?** | Yes | No | No | Yes or an alternative calculation |
| **Certification with individual converter?** | Required | Not required | Not required | Required |
| **Type of certification** | EU type examination certificate of the nominated body, e.g. PTB | | | EU declaration of conformity |

### 2.8.4 Possible scope of a system test

A part of these tests are already included in the manufacturing process and are carried out within the framework of the quality assurance program. These tests are no longer performed for the acceptance test unless they have been explicitly ordered.

Tests that you can order for system acceptance - in addition to the temperature rise test under load - are listed in the following. The time required for these must be taken into consideration for the system acceptance tests.

#### Load points and determining the system efficiency

1. Temperature rise test under load
2. The following parameters are measured at different speeds at each load point:
   - Primary current, primary voltage, primary power and primary power factor of the transformer (if one is being used)
   - Converter output frequency
   - Motor current, motor voltage
   - Motor speed
   - Torque and power at the motor shaft
3. The overall system efficiency is then calculated from this data.

#### Measurement of harmonics

1. This measurement is either made at the input terminals of the converter power unit or at the primary side of the converter transformer (if one is being used).

   **Note**

   The measured values are only valid for the line supply conditions in the test bay at the time of the measurement. These values do not necessarily apply at the customer site.

#### HV insulation test/insulation test

The high-voltage test/insulation test is already part of the routine test for motor and converter.

The work required to prepare, conduct and retest the converter cannot be practically included in the time required for the system test. During the system test, it is not possible to additionally test the converter insulation. The high voltage test at the converter must be separately ordered, and this is conducted before the system acceptance test.

#### Function test of the drive system

Key functions of the drive system are verified during this test.

- EMERGENCY STOP
- Individual, selected remote operation signals are tested
- Individual, selected fault and alarm messages/signals are tested

- Circuit breakers are manually opened to simulate failure of auxiliary systems

### Visual inspection

- Visual inspection of the converter and motor
- Where relevant, visual inspection of the transformer

### Noise measurement at the motor

1. The motor is operated at the converter and at rated speed without any load.
2. The sound pressure level of the machine is recorded at defined measuring points. The sound pressure level is calculated on an A-weighted basis.

### Vibration test at the motor

1. The motor is operated at the converter and at rated speed without any load.
2. The vibration velocities are measured for the rated voltage and frequency at the bearing housing.
3. For journal bearings, the shaft vibration is also measured if the appropriate transducer is mounted.

## 2.8.5 Component test

The system components are individually tested before the system test (F97).

| Component | Tests |
|---|---|
| **Transformer**<br>(according to IEC 76 / VDE 0532) | • Insulation test (applied and induced high-voltage)<br>• Vector group<br>• Transformation ratio<br>• Resistances<br>• No-load measurements<br>• Short-circuit test |

| | |
|---|---|
| **Converter** | • High-voltage insulation test according to EN 60146-1 and EN 50178<br>• Visual inspection<br>• Function inspection (auxiliary supplies, software, firmware)<br>• U/f test |
| **Motor ***<br>(according to IEC 34-1) | • Determining the stator winding resistance<br>• Stator insulation test<br>• No-load measurements<br>• Short-circuit measurements<br>• Phase sequence<br>• Testing optional built-on/mounted equipment |

* For F74/F75, only the motor is checked.

### 2.8.6 Important ordering information

In the order, state in plain text whether a **system acceptance test** is required, witnessed by the customer or somebody that the customer mandates to do this.

**Example**

- Definition of the system to be tested, e.g. system acceptance test for a high-voltage motor and a SINAMICS GM drive system with 2500 kW rating, including transformer
  The catalog data of all components is required, e.g. ordering data (=MRPD)
- The scope of the system acceptance test, e.g. temperature rise test under load and definition of the load points

Based on this data, a test plan is drawn-up and sent to the orderer.

### 2.8.7 Time required

This information is only intended to provide you with a rough idea regarding the time required. The actual time required depends on the configuration and the test scope.

| | Preparing for the acceptance test | Conducting | Disassembling the system | Ordering deadlines |
|---|---|---|---|---|
| Low voltage | 2 ... 3 days | 1 ... 2 days | 1 ... 2 days | At least four months before the accept-ance date |
| Medium voltage | 1 ... 2 weeks | 2 ... 3 days | 1 ... 3 days | |

# Tests

# 3

## 3.1 Routine test

Each motor is subject to a routine test according to IEC 60034-1. Additional checks and tests are performed within the scope of quality assurance. The sequence of the subsequently described tests is random and is not fixed.

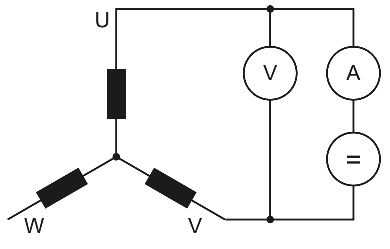
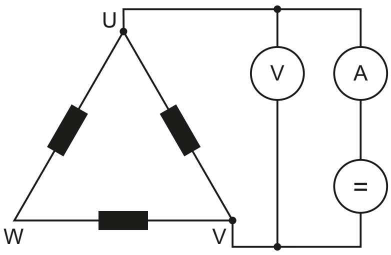
### 3.1.1 Direct-current resistance test of the stator winding

#### Fundamentals

The DC resistance test is used to check the stator winding. If a temperature rise test under load has been ordered, then this test is also used to determine the average (mean) winding temperature. It is checked that the internal specifications for the DC winding resistance and the winding design are complied with.

### Test procedure

1. The DC resistance between the two phases is measured using an ohmmeter.

| | |
|---|---|
|  |  |
| Star connection | Delta connection |

2. This measurement is repeated for all phase combinations.
3. The measured values are scaled to a 20 °C reference temperature.

### Result

The directly measured DC resistances, scaled to 20 °C, are listed in the test report. The measured values displayed are compared with the specified target values.

The test is successfully completed if the measured values remain within the tolerance specifications. The measured values and test results are documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.1.2 No-load test

#### Fundamentals

The no-load losses and the no-load current are determined at rated voltage and rated speed.

#### Test procedure

1. The resistance when cold is measured.
2. The motor is operated at rated speed and rated voltage. The no-load losses are recorded. The values of the measuring points are documented in the test report.

#### Result

The no-load losses at the measuring point and at 100 % rated voltage are compared with the internal test specifications. The test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.1.3 Short-circuit test

#### Fundamentals

The short-circuit test is used to check the rotor, the rotor winding and the current symmetry.

#### Test procedure

1. With the rotor mechanically locked, the motor is fed with a variable voltage at the rated frequency and the stator current measured. The voltage amplitude at the motor (short-circuit voltage) is varied until the rated current is obtained.
2. Alternatively, the direction of rotation is reversed while the motor is operating; the stator current is measured at the zero crossover.

The measured values are listed in the form of a table in the measurement report.

#### Result

The short-circuit voltage is compared with the internal test specifications and the current symmetry is monitored in the various phases. The successful test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.1.4 Agreement between the direction of rotation and terminal designations

#### Fundamentals

Checking that the terminal designation and the direction of rotation match ensures that the direction of rotation of a correctly commissioned motor corresponds to what has been specified.

#### Test procedure

1. The designations on the mains supply cables and terminals are checked. When viewed from the drive side, the direction of rotation is defined as follows:
   – L1 L2 L3 at U V W produces a clockwise direction of rotation.
   – L1 L2 L3 at V U W produces a counter-clockwise direction of rotation.
2. The motor is connected corresponding to the specified direction of rotation.
3. The direction of rotation is then checked when the motor starts.

#### Result

The test is successfully completed if the direction of rotation matches what has been specified. The test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.1.5 Withstand voltage test

#### Fundamentals

With the withstand voltage test, the winding insulation of the active components under voltage are tested with respect to ground potential and also with respect to one another. These active components include, for example individual winding phases, temperature sensors, anti-condensation heating etc.

#### Test procedure

1. The test voltage is applied between the winding phases and between winding phase and ground potential.
   The duration of the withstand voltage test is 1 min. The amplitude of the withstand voltage at the various tested motor parts is specified in the measurement report.

#### Result

The successful completion of the test is confirmed in the measurement report. The test values are documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.1.6 "Soft Foot test" according to API 541

#### Fundamentals

- API 4th edition 4.3.1.15
- API 5th edition 6.3.1.16

For all vibration tests (shaft and housing vibration), the motor must be mounted and clamped to a test grating, completely free from any distortion. The test can only be completed on type IM B3 motors and is completed at a standstill.

The "Soft Foot Test" is used to determine whether the motor is mounted and installed to measure vibrations in accordance with the requirements.

### Test procedure

1. The machine is positioned on the test grating.
2. A feeler gauge is used to test how much underlay is required for a uniform placement of all machine feet. The measured differences between the machine feet are compensated using shims.
3. The machine is attached to the test frame with all its feet. The mounting is attached in close proximity to the relevant foot. The clamping elements should be positioned as horizontally as possible and cover slightly more than half the foot width or depth on the surface of the foot.
4. The fastening at each foot is loosened individually. The degree of the remaining distortion of the machine is then measured. The distortion must not exceed a limit value. The result is documented internally.

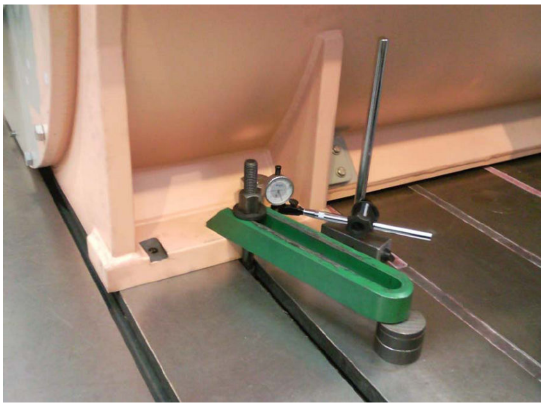


Figure 3-1 Soft Foot Test

### Result

The machine is installed and mounted according to the requirements of "Soft Foot".

## 3.1.7 Vibration severity measurement

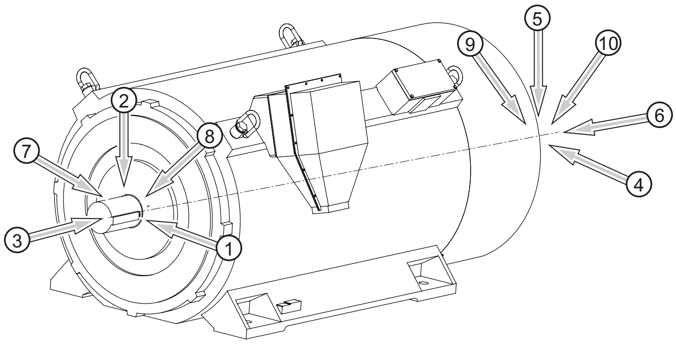
### Fundamentals

The vibration severity measurement is conducted according to IEC / EN 60034-14.

The vibration severity limits must be complied with to prevent damage to parts of the plant and system and the motor itself as a result of increased levels of vibration.

## Test procedure

After the bearings have been run in, the vibration speeds at the rated voltage and rated frequency are measured in the horizontal, vertical and axial direction to the bearing housings at the DE and NDE.




| Measuring points | DE | NDE |
|---|---|---|
| Horizontal | ① | ④ |
| Vertical | ② | ⑤ |
| Axial | ③ | ⑥ |
| + 45° | ⑦ | ⑨ |
| - 45° | ⑧ | ⑩ |

Figure 3-2 Vibration severity measuring points and directions for bearing housing vibration

For journal bearings, at measuring points ⑦ to ⑩ the shaft vibration is also measured if the appropriate transducer is mounted.

## Result

The results of the vibration severity measurement are compared with the specifications in IEC / EN 60034-14 and are documented together with the operating conditions in a 3.1 certificate, or if a customer acceptance test has been ordered, in a 3.2 certificate.

## 3.1.8 Vibration severity measurement according to API 541

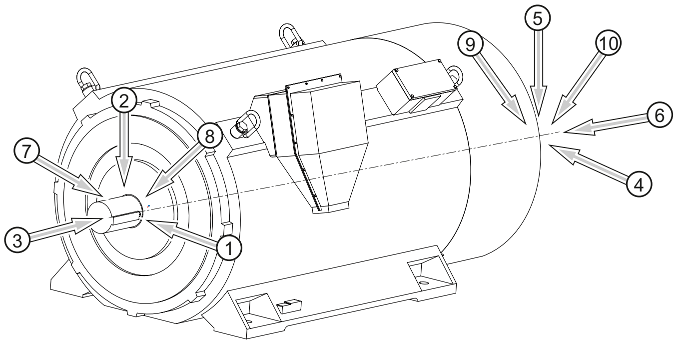
### Fundamentals

- API 4th edition: 4.3.3.2
- API 5th edition: 6.3.3.4

The vibration limit values according to API 541 are only applicable for machines, whose bearings have reached their steady-state operating temperature. This is the reason that before every vibration measurement, a bearing temperature rise test (Page 59) is conducted.

Bearing housing vibration is measured in the horizontal, vertical and axial directions at the bearing housing of roller and journal bearings.

For motors with journal bearings, shaft vibration is measured in the radial direction using contactless eddy current pickups if measuring pickups are mounted or have been prepared. If there are no shaft vibration pickups, only the vibration of the bearing housing is measured.




| Measuring points | DE | NDE |
|---|---|---|
| Horizontal | ① | ④ |
| Vertical | ② | ⑤ |
| Axial | ③ | ⑥ |
| + 45° | ⑦ | ⑨ |
| - 45° | ⑧ | ⑩ |

Bearing housing vibration levels for roller bearings ①...⑥, shaft vibration levels for journal bearings ⑦ to ⑩

Figure 3-3 Vibration severity measuring equipment

### Test equipment

Vibration pickups and measuring signal transducers mounted on the motor are used if they are compatible with the equipment in the test bay. Alternatively, sensors available in the test bay are used. The test bay sensors fulfill the accuracy requirements laid down by API 670.

Vibration levels are recorded using a data acquisition system, and analyzed. The data acquisition system complies with all criteria laid down in API 541 4th edition 4.3.3.7 or 5th edition 6.3.3.7.

For example, the "Dynamic Signal Processing Instrument" ADRE 408 DSPi is used together with the "Sxp" software platform.


Figure 3-4 ADRE 408 DSPi

After prior consultation, customers can use their own measuring technology to acquire data. In this case, the following topics are coordinated together with the customer:

- List of all used measuring instruments.
- List of all measurements to be performed using customer instrumentation. This means that the time frame can be estimated.

- The measuring instrumentation must comply with the local safety regulations; for example, the measuring cables must be long enough so that the measurement can be performed outside the hazardous area.
- The instrumentation must be compatible with the test setup.

**Note**

Siemens (the test bay) must be informed of this at least four weeks before the start of testing.

## Test procedure

1. A bearing temperature-rise run is performed.
2. The radial and axial vibration, voltage, frequency and the bearing temperature are recorded. The measurement takes at least 15 minutes.

## Result

The maximum value of the vibration variable, measured during the motor test run, is compared with the limit value.

The test is successfully completed if the limit values are not exceeded. The results are displayed in the form of a trend plot. As documentation of the test result, a 3.1 certificate is issued, or for acceptance tests witnessed by the customer, a 3.2 certificate is issued.

### Bearing housing vibration

At speeds above 1000 rpm, the bearing housing vibration limit is 2.54 mm/s (0-p).

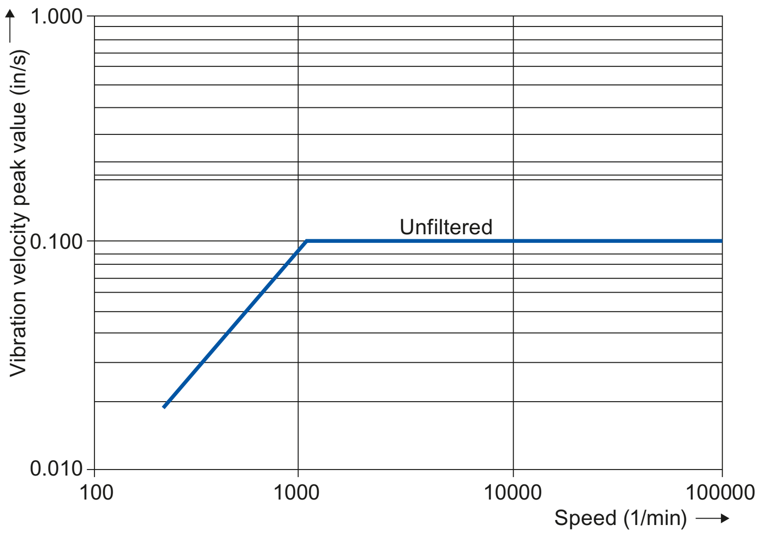



Figure 3-5 Limit values for the vibration velocity of the bearing housing

### Shaft vibration

At speeds up to 5300 rpm, the shaft vibration limit is 38.1 mm/s (p-p).

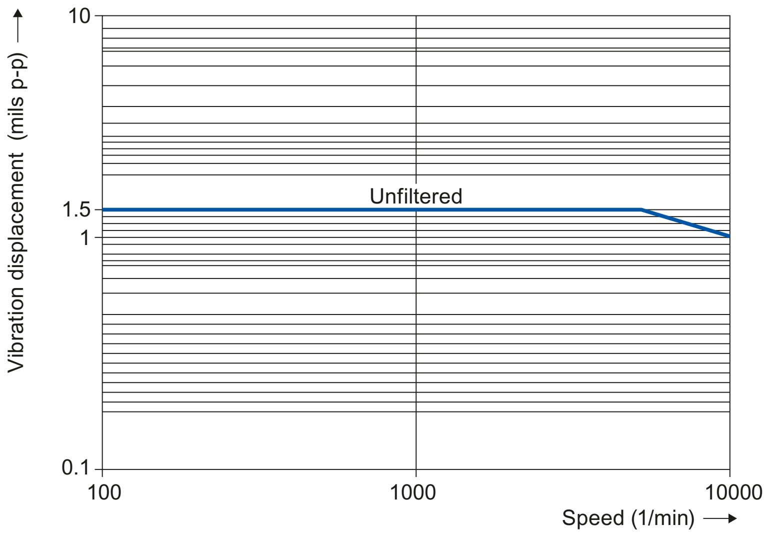



Figure 3-6 Limit values for shaft vibration

## Result

The maximum value of the vibration variable, measured during the motor test run, is compared with the limit value.

The test is successfully completed if the limit values are not exceeded. The results are displayed in the form of a trend plot. As documentation of the test result, a 3.1 certificate is issued, or for acceptance tests witnessed by the customer, a 3.2 certificate is issued.

### Bearing housing vibration

At speeds above 1000 rpm, the bearing housing vibration limit is 2.54 mm/s (0-p). Limit values for other speeds are calculated using the following formula:

$$2,5 * \frac{N}{1000 \text{ mm/s}} \ \text{0-p}$$

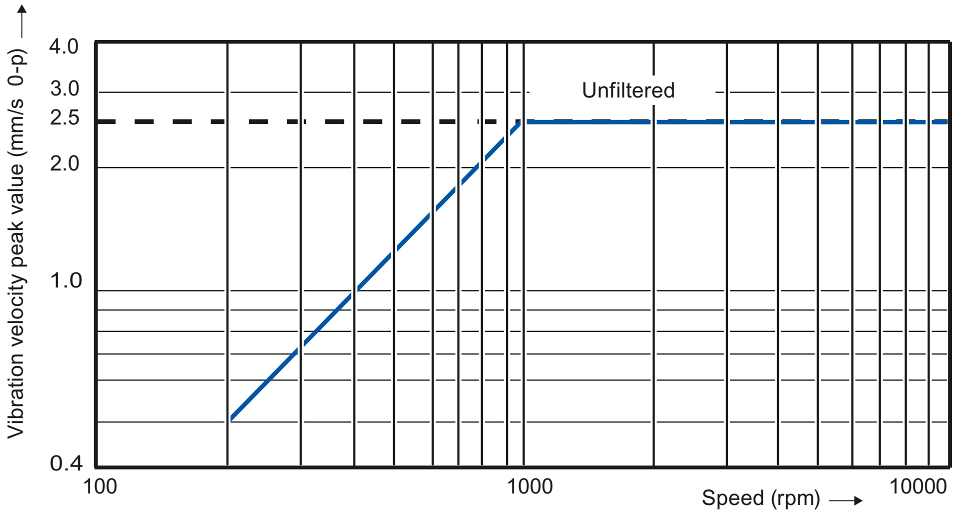



Figure 3-7 Limit values for the vibration velocity of the bearing housing

**Shaft vibration**

At speeds up to 5300 rpm, the shaft vibration limit is 38.1 mm/s (p-p). Limit values for other speeds are calculated using the following formula:

$$25{,}4 * \sqrt{\frac{12{,}000}{N}}\ \mu m\ p\text{-}p$$

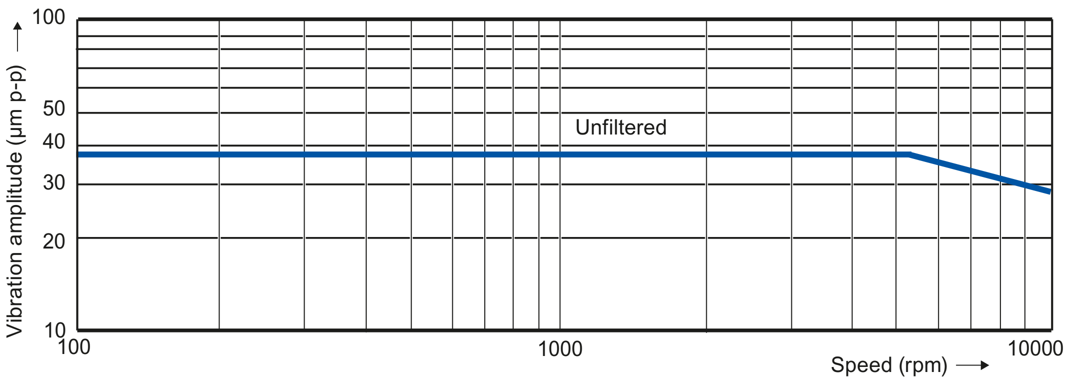



Figure 3-8 Limit values for shaft vibration

## 3.1.9 Vibration severity measurement for "Complete Test" or for "Rated Rotor Temperature Vibration Test"

**Fundamentals**

- API 4th edition: 4.3.5.2.1
- API 5th edition: 6.3.5.2.1

The vibration severity measurement is part of the "Complete Test" and corresponds to the "Rated Rotor Temperature Vibration Test" according to API (Page 39).

The motor is mounted on steel blocks to adapt the motor shaft height to the dynamometer. This type of mounting does **not** correspond to "Soft Feet" mounting. Coupling the motor to the load can result in changes to the vibrational behavior. This is mainly caused by components that are required for the coupling, e.g.

- Test coupling
- Multiple-disk couplings for two-pole motors – or an articulated shaft for motors with four poles and higher
- Gearbox and dynamometer

This additional vibration is specific to the test bay and for customers is available in another form and magnitude at the installation site.

Depending on the test field equipment and the power range, deviations from what is specified in API can occur. These deviations are communicated and coordinated with the customer in advance.

## Test procedure

1. A temperature rise test under load is performed.
2. The motor is shut down.
3. The machine is quickly decoupled and the tested coupling is removed.
4. The machine is rigidly mounted corresponding to the "Soft Foot test".
5. Bearing housing and the relative shaft vibration is measured under no load at the rated voltage and rated frequency.

## Result

**Only the vibration values, which are measured according to Point 5, are used to evaluate the measurement.**

The measured values and test result are documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

**NOTICE**

**Overall vibration**

In accordance with API 4th edition 4.3.3.9, the motor vibrations are measured over the entire duration of the temperature rise test under load:

- Figure Limit values for the vibration velocity of the bearing housing (Page 41)
- Figure Limit values for shaft vibration (Page 42)

The overall vibration, as the sum of these vibration components, can **exceed** the value laid down in API 541.

### See also

Vibration severity measurement according to API 541 (Page 39)

| NOTICE |
|---|
| **Overall vibration** |
| In accordance with API 5th edition 6.3.3.1.1.e, the motor vibrations are measured over the entire duration of the temperature rise test under load:<br>• Figure Limit values for the vibration velocity of the bearing housing (Page 43)<br>• Figure Limit values for shaft vibration (Page 43) |
| The overall vibration, as the sum of these vibration components, can **exceed** the value laid down in API 541. |

### See also

Vibration severity measurement according to API 541 (Page 39)

## 3.1.10 Testing of accessories, integrated and mounted components

#### Fundamentals

The function of accessories as well as installed and mounted components is checked and ensured.

### Test procedure

1. For temperature sensors integrated in the windings and for anti-condensation heating systems, the resistance and the temperature are measured. After this, the insulation resistance is determined corresponding to Table (Page 48). The voltage test is with respect to ground potential with 1500 V~.
2. For temperature sensors for bearing and air temperatures, the resistance and the insulation resistance are measured.
3. Other accessories – such as vibration sensors and pulse encoders – are tested, if required, corresponding to the particular Operating Instructions.

### Result

If the accessories, installed and mounted components match the specifications, then the test is successfully completed. The test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### See also

Measuring the insulation resistance (Page 46)

## 3.1.11 Measuring the insulation resistance

### Fundamentals

The tests essentially correlate with the recommendations of IEEE 43-2013. While assembling the machines, tests are carried out at the components or at the complete machine in the scope of the routine or type test – and during the product lifecycle within the scope of checking the condition of the insulation as part of a diagnostics routine.

The insulation state of the winding insulation and the electrically insulated mounted and installed components are tested with respect to ground. If required, the insulation state is also checked with respect to one another to ensure that the defined minimum requirements are complied with.

As a consequence, in addition to the withstand voltage test, it has been proven that the winding insulation has been perfectly implemented and functions as it should with respect to ground.

The insulation resistance is measured at the stator winding or at the complete machine. The resistance of the winding insulation is measured with respect to ground or the winding phases and winding elements. The insulation resistance is a measure for the insulating property (dielectric strength) of the insulation of live components with respect to ground or with respect to one another.

Measuring the insulation resistance allows the following conclusions to be drawn:

- The specified production processes have been complied with, e.g. hardening of the resin impregnation
- Absorption of moisture, moisture content of the insulation
- Conductive pollution/dirt on the surfaces, e.g. creepage paths
- Age-related changes, e.g. the formation of creepage paths

The measurement results are influenced by the following factors:

- Machine size regarding the stator winding
- Insulation design
- Materials used

The following table shows the insulated components of a machine – and the tests and measuring voltages preferably to be applied. The measuring voltages can vary slightly across factories.

Table 3-1 DC test voltages to the rated motor voltages to determine the winding insulation resistance

<table>
<tr><th rowspan="2">Rated voltage $U_B$ of the motor in V</th><th colspan="3">DC test voltage in V</th></tr>
<tr><th>IEEE 43</th><th>API 541 4 th</th><th>API 5 th</th></tr>
<tr><td>$U_B$ < 1000</td><td>500</td><td rowspan="2">1000</td><td>500</td></tr>
<tr><td>1000 ≤ $U_B$ ≤ 2299</td><td rowspan="2">500 ... 1000</td><td rowspan="2">1000</td></tr>
<tr><td>2300 ≤ $U_B$ ≤ 2500</td><td rowspan="2">2500</td></tr>
<tr><td>2501 ≤ $U_B$ ≤ 3999</td><td rowspan="2">1000 ... 2500</td><td rowspan="2">2500</td></tr>
<tr><td>4000 ≤ $U_B$ ≤ 5000</td><td rowspan="3">5000</td></tr>
<tr><td>5001 ≤ $U_B$ ≤ 12000</td><td>2500 ... 5000</td><td rowspan="2">5000</td></tr>
<tr><td>$U_B$ > 12000</td><td>5000 ... 10 000</td></tr>
</table>

Table 3-2 DC test voltages to determine the insulation resistance of parts and components that are either installed or mounted

| Insulated component | DC test voltages in V |
|---|---|
| Winding temperature sensors | 500 ... 1000 |
| Anti-condensation heating to ground/to the winding $U_N$ to 1000 V | 500 |
| Insulated bearings | 100 ... 250 |
| Other insulated components | 500 |

The resistance of the winding insulation is measured with respect to ground potential. If the neutral point is accessible or open, then the insulation resistance of the winding phases or the winding elements with respect to one another is measured.

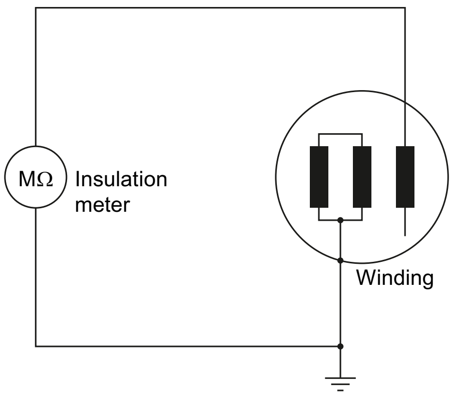



Figure 3-9 Circuit diagram of the insulation measurement

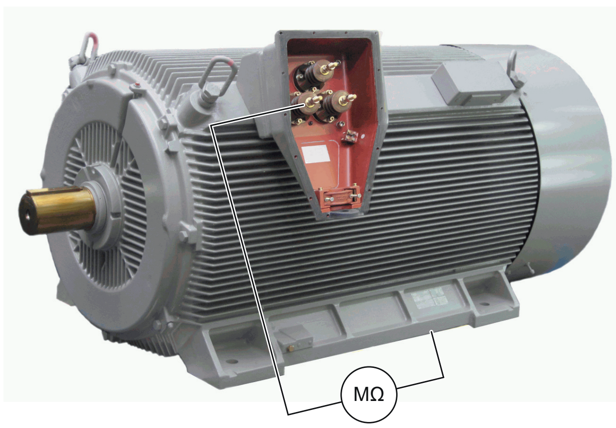



Figure 3-10 Measuring the insulation resistance of the winding

For windings and mounted & installed components, minimum insulation resistances for new and operationally aged windings are defined according to the following table.

Table 3-3 Minimum value for the insulation resistance

| Insulated component | Minimum values for operationally-aged machines in MΩ | | | Minimum values for new machines in MΩ | |
|---|---|---|---|---|---|
| | IEEE 43-2000 | | Siemens / Large Drives | | |
| | 40 °C | 25 °C | 25 °C | 40 °C | 25 °C |
| Stator winding $U_N$ < 1000 V * | 5 | 20 | 20 | 25 | 100 |
| Stator winding $U_N$ ≥ 1000 V | 100 | 300 | 300 | 500 | 1500 |
| Winding temperature sensor to ground | - | - | 500 | - | 2500 |
| Anti-condensation heating to ground | - | - | 1 | - | 5 |
| Anti-condensation heating to winding $U_N$ up to 1000 V | - | - | 20 | - | 100 |
| Insulated bearings | - | - | 1 | - | 1 |
| Other insulated components | - | - | 100 | - | 500 |

* The values apply for the complete winding with respect to ground. Twice the minimum values apply to the measurement of individual phases

The minimum values for the insulation resistance of new insulation/windings are valid for the measuring voltages specified in the table.

The minimum values apply for the following conditions:

- Measuring temperature of 25 °C ±5 °C or 40 °C ±5 °C
- Relative humidity up to 70 %

For different measurement and/or object temperatures, the measured values are converted to a reference temperature of preferably 40 °C using the following equations from IEEE 43.

$R_C = K_T \cdot R_T$

| | |
|---|---|
| $R_C$ | Insulation resistance converted to a 40 °C reference temperature |
| $K_T$ | Temperature coefficient |
| $R_T$ | Measured insulation resistance for measurement/object temperature T |

The temperature coefficient $K_T$ is calculated as follows:

$K_T = 0.5^{(40-T)/10}$

| | |
|---|---|
| 40 | Reference temperature |
| 10 | Halving / doubling of the insulation resistance with 10 K |
| T | Measurement/object temperature |

### Test equipment

The measurement is taken with an insulation meter or a highly stable DC source and a µA meter.

### Test procedure

The test is performed before the machine is switched on for the first time. The insulation resistance is preferably determined at the voltages specified in the table above. For large machines, the winding phases are preferably measured individually. In this case, an accessible and open neutral point is required.

1. The measurement is made between the winding and ground. Windings, integrated winding temperature sensors and possibly other mounted and installed components are connected to ground.
2. The measuring voltages correspond to the table above or to the applicable specification.
   - For the type test, the values are read off after 1 min.
   - For the routine test, the test is ended when the minimum value is reached.
3. After completion of the measurement, the windings are discharged.

### Result

For windings and mounted & installed components, minimum insulation resistances are defined according to the table above. The test is successfully completed if these values are reached. A lower insulation resistance can be obtained at higher air humidities or higher temperatures.

The test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## 3.1.12 Measurement of the polarization index

#### Fundamentals

Measurement is preferably carried out corresponding to the recommendations of IEEE 43-2013 (see Table 3-3 Minimum value for the insulation resistance (Page 48)) – or according to what is laid down in the applicable specification.

The polarization index (PI) indicates the time-dependent polarization processes in the insulation. The polarization index is formed from the time characteristic of the insulation resistance or the insulation currents. The polarization index indicates the moisture content and degree of pollution/dirt of the winding insulation.

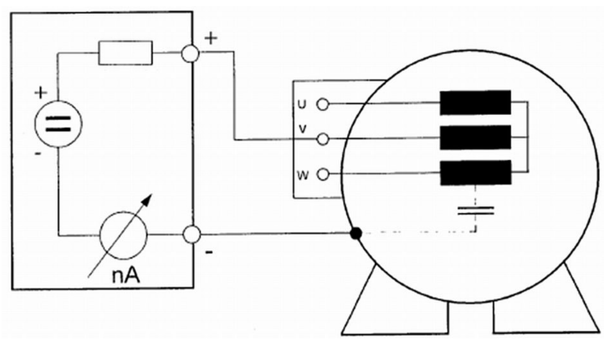



Figure 3-11 Circuit diagram for the measurement of the polarization index

**Test equipment**

- Insulation meter with a highly stable DC current source and a µA meter
- Insulation meter with integrated automatic determination of the polarization index

## Procedure when testing the winding

1. Just the same as for the insulation resistance measurement, the measuring device is connected between the winding and/or winding element/phase to be measured and ground (laminated core, enclosure, shaft for rotor windings).
2. When automatically determining the polarization index, the measurement is performed in the "Polarization index" mode. The required measuring voltage is set corresponding to Table 3-3 Minimum value for the insulation resistance (Page 48) or the specification that applies.
3. The polarization index is calculated from the ratio between the measured insulation resistance after 10 min and after 1 min – or the inverse ratio of the currents. For devices where the polarization index is automatically determined, the polarization index is automatically displayed after a measuring time of 10 min.

## Result

The measured values must, as a minimum, correspond to the requirements shown in the first line of the Table 3-3 Minimum value for the insulation resistance (Page 48). For lower PI values, the overall diagnostic data of the winding is included in the evaluation along with the possibly required measures.

The measured values are assessed using the following table.

| $R_{(10\ min)}$ / $R_{(1\ min)}$ | Assessment |
|---|---|
| ≥2 | • Insulation in good condition |
| <2 | • Insulation resistance >5 GΩ → test successfully completed and OK (API 4th Edition/IEEE 43)<br>• Insulation resistance >100 GΩ → test successfully completed and OK (API 5th Edition) |

The measured values and test results are documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## See also

Measuring the insulation resistance (Page 46)

According to API, the polarization index is measured **before** and **after** the high-voltage test.

## 3.1.13 Shaft voltage measurement

### Fundamentals

The shaft voltage is measured. Excessively high shaft voltages can cause arcing across the film of grease or oil on the bearings. Circulating currents can result, which damage the bearings.

**Note**

- According to IEC, the shaft voltage is only measured if none of the bearings are insulated.
- According to API, the shaft voltage is also measured if the bearings are insulated.

### Test procedure

1. The measurement is made between the shaft ends.

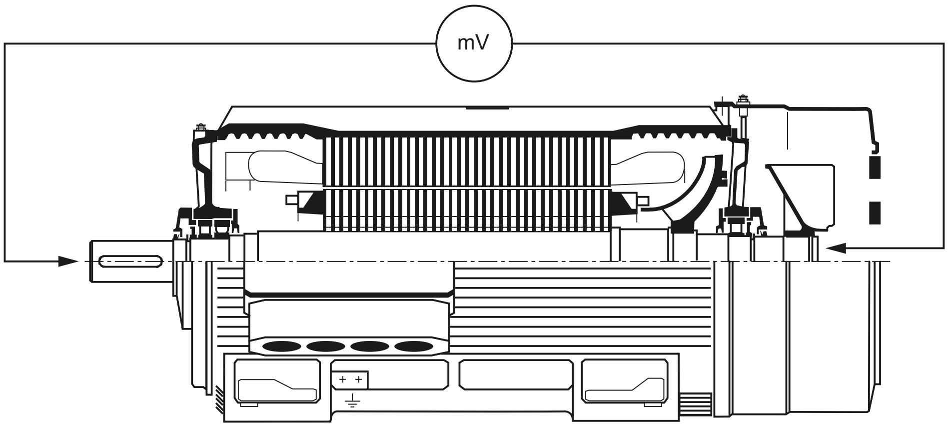



Figure 3-12 Shaft voltage measurement

### Result

If the limits according to the test plan are exceeded, then a bearing (non-drive end) is insulated.

The measured values and test result are documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## 3.1.14 Bearing insulation measurement according to API 541

### Fundamentals

Excessively high shaft voltages can cause arcing across the film of grease or oil on the bearings. Circulating currents can result, which damage the bearings. The bearing insulation resistance measurement checks as to whether the electrical insulation is high enough to prevent circulating currents.

### Test equipment

An insulation resistance measuring device is used as the test device.

### Test procedure

Production internally carries out the measurement.

- For rolling bearings, the insulation resistance at the enclosure is measured using a test voltage of 100 V or 250 V, for example. The measurement is carried out after assembling the insulated bearing before attaching the bearing shield.
- The insulation resistance of journal bearings is measured after the installation of the shaft vibration sensors.

### Result

The test has been successfully completed if the measured resistance of the bearing insulation is at least 1 MΩ. The test result is documented internally. It is **not possible** that the customer witnesses this test.

## 3.1.15 Air gap measurement

#### Fundamentals

Checking the air gap checks as to whether the electrical and mechanical specifications have been complied with.

---

**Note**

This test involves an indirect measurement: The air gap is calculated based on the difference between the measured internal stator diameter and the measured external rotor diameter.

---

### Calculation

The calculation is carried out and documented by production.

### Result

The calculation is documented internally. A report is generated if requested by the customer (optional order). It is **not possible** that the customer witnesses this test.

## 3.1.16 Runout measurement with acceptance

#### Fundamentals

For this measurement, the mechanical and electrical Runout of the complete rotor is determined in accordance with API 4.3.3.1.

The "Runout" is all of the metallurgical inhomogeneities in the shaft surface, local remaining magnetism and mechanical irregularity of a shaft that are not generated by vibrations. Measuring the Runout is only possible for motors that have been designed and built for contactless measurement of the shaft vibration levels. The Runout value is measured in µm.

### Runout measuring procedure

1. Electrical and mechanical Runout are measured in the balancing machine in so-called V-prisms with a contactless pickup (transducer) and a dial gauge at the center of the measuring track on the shaft over one complete revolution (360°). The following values are measured for each measuring track:
   – The mechanical Runout is measured using a probe.
   – The total Runout is measured as a total of the mechanical and electrical runout using an eddy current pickup.
2. The measurement is repeated if the start and end values of the measurement series are not this same.

### Result

On the measuring surface for the radial vibration monitoring, the combined electrical and mechanical Runout value must not exceed the following values:

- The values specified in IEC 60034-14
- In accordance with API 541, 25 % of the maximum permissible peak-to-peak value of the shaft vibration.

### See also

Vibration severity measurement according to API 541 (Page 39)

## 3.1.17 Slow Roll measurement according to API 541

#### Fundamentals

The Slow Roll measurement in the complete machine serves as a comparative measurement for the runout measurement of the rotor. The result allows a quantitative assessment of the total shaft vibration in operation to be made. Only machines with journal bearings are tested, and with sensors for the shaft vibration measurement.

### Test procedure

1. At the complete machine, the shaft vibration is measured while machine coasts down with an axially fixed rotor in the speed range from 300 rpm to 200 rpm.

### Result

The maximum value of the shaft vibration values constitutes 30 % of the maximum permissible peak-to-peak value of the shaft vibration.

The measured values and test results are documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### See also

Vibration severity measurement according to API 541 (Page 39)

## 3.1.18 Surge Comparison Test

#### Fundamentals

- API 4th edition: 4.3.4.2
- API 5th edition: 6.3.4.2

The winding test corresponds to the coil comparison test according to API ("Surge Comparison Test").

The test ensures that the coils, used for the winding, have the required withstand voltage between the winding turns or layers.

The winding turns and layers are tested with the impulse voltage. With the impulse voltage, with a rise time in the vicinity of < 1 µs, generated by discharging a capacitor, the coil impedance generates a voltage drop across the coil being tested. The voltage is approximately linearly distributed over the winding turns within the coil. The winding turn or layer voltage obtained is approximately the impulse voltage applied across the coil divided by the winding turns/number of layers of the coil.

The test can also be carried out on complete windings. As a result of the non-uniform voltage distribution and the higher cost for fault detection and location, this test is mainly used during the production of round wire windings and when diagnosing winding problems in the service environment.

### Test procedure

The test is carried out after inserting the coils in the laminated core before connecting up the individual coils.

1. The impulse voltage is connected to one end of the coil, and the other end of the coil is connected to the ground potential of the impulse generator. Generally, the laminated core is not grounded, to reduce the voltage at the main insulation of the coils.
2. Depending on the test equipment being used, either two coils are simultaneously tested in a comparative test or, at one coil a reference voltage characteristic is recorded. This is then saved and used as a basis to compare the other coils to be tested.
3. All of the winding coils are tested using the specified voltage. Each coil is tested with a minimum of five voltage impulses. The voltage amplitude depends on the machine type (coil design). This can be identified by reviewing the relevant winding data taken from the test plan.

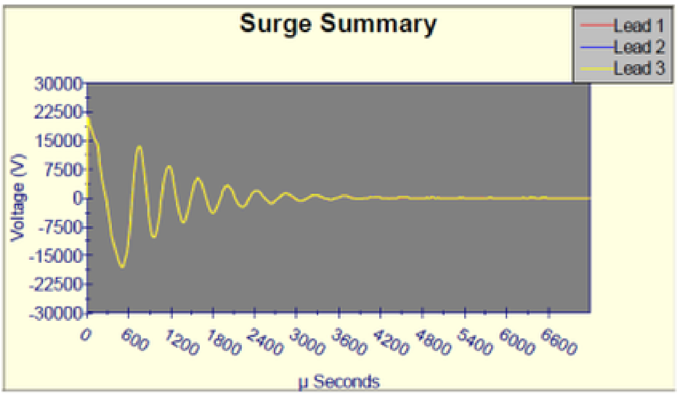



Figure 3-13 Example of a voltage characteristic

For amplitude or frequency deviations from the reference signal or between two signals with respect to one another, which exceed the tolerance range, the cause is clarified. Depending on the fault profile, additional tests may be required. The fault is resolved or the coil involved is replaced.

### Result

The test has been successfully completed if the voltage characteristics are congruent in the defined tolerance range; this means that there are no significant deviations with respect to the reference signal or between one another.

A successfully completed test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## 3.1.19 High-voltage test

### Fundamentals

As part of the routine test, the high-voltage test is carried out according to IEC 60034-1 with $2 \cdot U_N$ + 1000 V~ 50 Hz for 1 min. The winding with respect to ground and, if possible, also the phases are tested with respect to one another.

The test ensures the minimum withstand voltage of the winding insulation with respect to ground (enclosure, laminated core) - and where relevant, the winding phases with respect to one another. This method is also called "power-frequency withstand voltage test".

### Test procedure

1. The test voltage is applied at rated voltages from > 1 kV between the winding and ground, and if possible, also between the winding phases.
   The test voltage must be at the line frequency and should be a sinusoidal is possible.
2. The test voltage is maintained for 1 minutes. It is not permissible that any arcing or sparking occurs.

When checking the machine/winding again, e.g. within the context of the type or acceptance test, only 80 % of the test voltage is applied, corresponding to what is laid down in the standard.

For machines with rated voltages of > 6 kV, a DC voltage test at 1.7x of the rms value of the test AC voltage can be alternatively used if high rating AC voltage test equipment is not available.

### Result

The value of the test voltage is documented in the routine test certificate or in the acceptance test certificate. This test is always successful, as faulty windings are withdrawn from the system.

A successfully completed test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## 3.1.20 Voltage test of the main installation while the windings are being produced

#### Fundamentals

After the coils have been inserted in the laminated core, and before impregnating the windings, the insulation of the winding to ground potential (laminated core) is tested. If possible, the insulation between the winding phases is tested using high voltage. This tests that the main coil insulation has no faults.

#### Test equipment

High-voltage source with charging capacity for the winding size to be tested

### Test procedure

1. The coils are all connected with one another or per phase. This is realized depending on the point in time in production through the winding connection.
2. The high voltage is applied to the coils/winding and the laminated core grounded.
   For the inter-phase test, the phases that are not being tested are connected to ground potential (laminated core).

3. The voltage is increased from zero up to the target value and is maintained for at least 1 min. The amplitude of the test voltage depends on the insulation system being used and is defined internally.
4. The tested winding is then short-circuited, grounded and discharged.

### Result

The test has been successfully completed, if, within the test time, no sparking or arcing occurred, and the current did not significantly increase. In the case of a fault, the coil involved is localized and replaced, or a new insulation applied.

The test result is documented internally.

## 3.1.21 Shock pulse measurement

### Fundamentals

Structure-born transient noise is generated when the rolling elements roll on the raceway if the surfaces of the raceway and rolling elements are rough or damaged. This structure-born sound is propagated to the surrounding material, and is detected by an acceleration sensor (SPM transducer). The SPM probes convert these pulses into electrical impulses, whose amplitude is proportional to the shock velocity.

The following variables are measured:

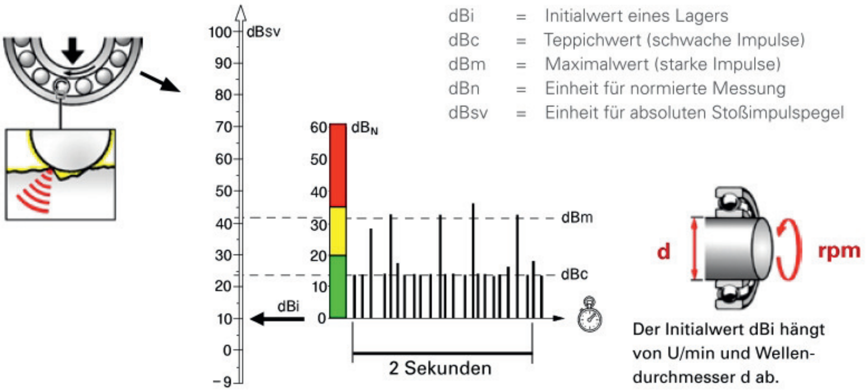
- Carpet value $dBc_{SV}$: The noise, i.e. the many small pulses, provides information about the lubricating film thickness in the load zone. An increasing trend indicates a reduction in the lubricating film thickness in the load zone.
- Maximum value $dBm_{SV}$: The highest pulse measured during the measuring time. Pulses such as these occur for significant damage or irregularities of the raceway or rolling elements.

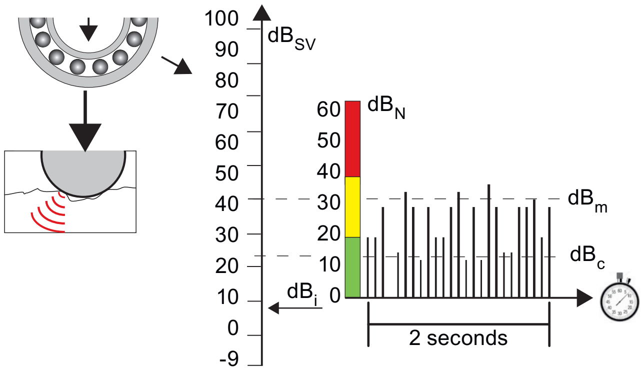
dB stands for decibels, c for Carpet, m for maximum, SV for "Shock Value" (not scaled).

A reliable statement about the condition of the roller bearings cannot be made after just one single measurement. To do this, several measured values, sensed at intervals during the operating time, are required. The trend characteristic of these measured values provides information about the change to the roller bearing and lubrication state - and the remaining service life.

Empirical values are defined for non-standardized shock pulses. These empirical values apply as acceptance criterion for the shock pulse measurement.

Customers can use the values from the shock pulse measurement in the routine test as reference value to identify pending bearing damage, if the measured values for $dB_{SV}$ are scaled.




Initial value $dB_i$ depends on $U_{min}$ and the shaft diameter. $dB_N$ is the unit for the scaled measurement.

### Test equipment

Surge impulse tester, e.g. T2000 from SPM Instrument

### Test procedure

1. The machine is mounted corresponding to its type of construction, and is operated, uncoupled under no-load conditions with its rated voltage and frequency.
2. The SPM probe is attached to an SPM nipple mounted at the motor. The measurement starts.
3. Values $dBc_{SV}$ and $dBm_{SV}$ are measured and documented.

### Result

The measured values displayed are compared with the specified target values. The test has been successfully completed if the measured values remain below the specified limits. The measured values and test result are documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## 3.1.22 Bearing temperature rise

#### Fundamentals

- API 4th edition: 4.3.2.1h
- API 5th edition: 6.3.2.1h

The bearing temperature rise test serves to prove that in no-load operation, the bearings do not leak, do not emit unusual noise or manifest increased vibration or temperature levels. The bearing temperature rise test is the initial basis for almost all vibration tests according to API.

With the exception of the "Unbalance Response Tests", the bearing temperature rise test is carried out before starting all additional no load vibration measurements described in API. Before the bearing temperature rise test, the motor is mounted on a solid foundation in accordance with "Soft Foot", as vibration is immediately measured at the end of the bearing temperature rise test.

### Test procedure

1. The machine is rigidly mounted corresponding to the "Soft Foot test".
2. The machine is operated under no load conditions until the bearing temperature stabilizes, and it is then operated for an additional hour at a constant bearing temperature. "Constant bearing temperature" means a maximum temperature change of 1 K/30 min.
3. The following temperatures are continuously recorded during the measurement:
   - Bearing temperature on the DE and NDE
   - Housing temperature
   - Ambient temperature
   - Additional installed and mounted temperature sensors
   - Only for journal bearings: Oil temperature, with oil input and outlet temperature as the reference temperature

### Result

The measured values are documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## 3.1.23 Bearing Inspection after Tests

#### Fundamentals

During the visual bearing inspection after the electrical tests, the following components of the journal bearing undergo a visual inspection for damage including dents, lead-in grooves, material displacements, etc.:

### Test procedure

After the electrical tests - and after the journal bearings have cooled down - the following components are visually inspected in production.

- Removed bearing shells
- Shaft bearings including the bearing shoulders
- Bearing seals

### Result

The report contains photos of the contact surfaces of the bearing shells and shaft bearings. The test result is documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

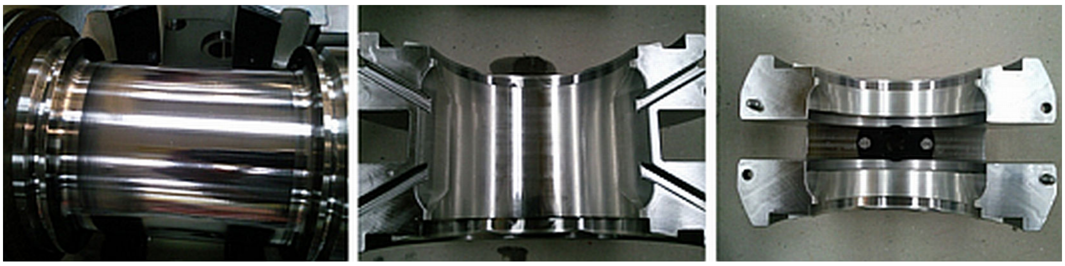


Figure 3-14 Example: Photograph of a journal bearing

## 3.1.24 Visual Bearing Checks After Tests

#### Fundamentals

- API 4th edition: 4.3.2.1i
- API 5th edition: 6.3.2.1j

During the visual bearing inspection a check is made to determine whether the wear pattern corresponds to at least 80 % of the possible contact surface of the rotor in the bearing shell.

The wear pattern is documented.

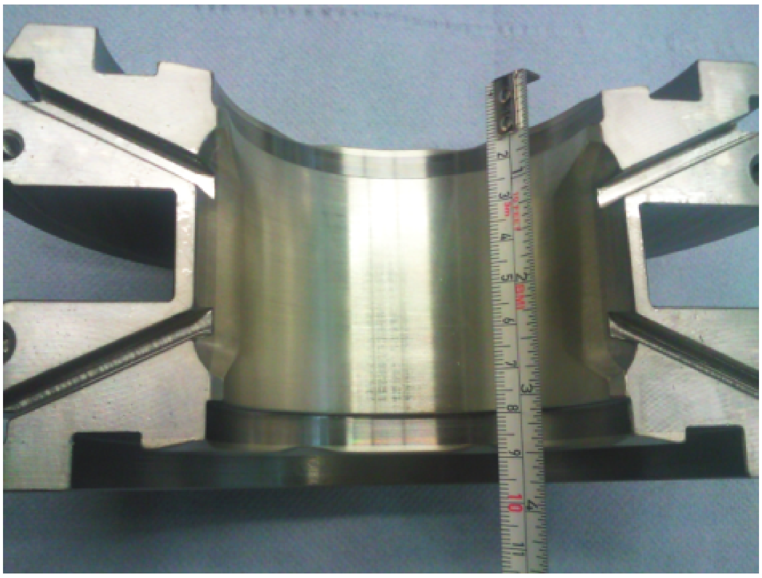


Figure 3-15 Wear pattern

Depending on the factory involved, the report also contains photos of the oil used during the electrical tests.

Figure 3-16 Photograph of the oil used

## 3.1.25 Leakage loss measurement at motors, type of protection "device protection provided by pressurized enclosure "p""

### Fundamentals

The test is conducted according to IEC / EN 60079-2 and the technical documentation of the pressurized system.

Using compressed air, the machine is tested to ensure that it has no leaks, and any leakage losses are measured.

**Test equipment**

- Manometer
- Pressurized air flow meter
- Thermometer

## Test procedure

The test is performed in the same standard way for all pressurized systems, independent of the manufacturer.

1. A compressed air connection with compressed air meter is connected at an access point on the motor enclosure.
2. The manometer is connected to the motor enclosure.
3. The pressurized system is closed and sealed. This therefore avoids leaks as a result of the pressurized system.
4. The pressure is increased to the operating pressure and maintained at this level.
   Measurements are made at the maximum speed and when the motor is stationary.
   The machine is investigated for any leaks once the operating pressure has been reached.
   - Acoustically by listening for a hissing noise
   - Optically using mist-generating or fog generating equipment
   - Sensory, for example a cold air flow in contact with the skin, e.g. back of your hand
   - Leaks are sealed.

   The amount of air fed in is measured over a defined period of time.
5. The ratio of standstill time to operating time is calculated based on the two measurements.
6. Optionally, when the motor is undergoing final checks before shipping, and after painting, leakage is again measured at standstill.
   To determine the final leakage in operation, the value last measured is multiplied by the calculated ratio of standstill time to operating time. This value is stamped on the motor rating plate.

## Result

An internal test report is generated.

## 3.1.26 Pressure distribution measurement at motors, type of protection "device protection provided by pressurized enclosure "p"".

**Fundamentals**

According to IEC / EN 60079-2, it is not permissible that the minimum pressure of 50 Pa inside the motor is fallen below. The minimum pressure at the monitoring location is determined using this measurement.

**Test equipment**

- Manometer
- Compressed air meter or flow rate measuring instrument
- Thermometer

## Test procedure

1. The pressure sensors are mounted on the motor at the specified measuring locations. The measuring locations differ between machine versions, and for example, are located in the bearing shield at the DE or NDE, the top-mounted cooler, terminal box etc.
2. Measurements are taken in the following operating states, and the pressure documented at the individual measuring locations:
   – For line operation
   - Motor operating at rated speed without the pressurized air supply connected
   - Motor operating at rated speed or maximum speed and operating pressure (optional)

   – For motors fed from converters (converter operation)
   - One series of measurements at the lower speed limit and one at the upper speed limit

As the pressure levels are measured at any value between the minimum and maximum pressure, the results are interpolated up or down to the minimum pressure at the monitoring location. The measured values are converted into relative pressure values. The reference pressure is the pressure outside the motor enclosure. For air-cooled motors with mounted cooler, the reference pressure is the back pressure in the cooler tubes.

## Result

The test result is documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## 3.1.27 Flow rate measurement and adjusting the pressurized system

**Fundamentals**

The test is conducted according to IEC / EN 60079-2 and the technical documentation of the pressurized system.

The air flow of the pressurized system is checked. The minimum flow of inert gas is necessary in order to guarantee safe operation.

**Test equipment**

- Manometer
- Compressed air meter or flow rate measuring instrument
- Thermometer

### Test procedure

1. The manometer is connected to the motor enclosure through the pressurized system to document the pressure inside the motor enclosure during purging.
2. The pressurized system is ready to function is connected to the pressurized air supply.
3. With the pressurized air supply connected, purging is started. The purge time is set to 5 min or an empirical value.
4. Using the purge air valve connected to the pressurizing system, the purge air quantity is increased until the required purge air quantity is reached at the purge air output. The purge airflow is adjusted to the purge quantity specified for the particular motor type.
5. The purge airflow is sensed at the output valve of the pressurized system. This is achieved with a tube, with a defined inner diameter, that is installed at the purge air output. The measuring device is adjusted to the inner diameter. The purge airflow is read out at the device and recorded.
6. Alternatively, the purge airflow is sensed at the input valve of the pressurized system at the pressurized air meter. The purge airflow is increased by the measured leakage losses and documented.
7. Depending on the pressurized system, the necessary operating parameters are checked and adjusted.

### Result

The test is successfully completed if the pressure inside the enclosure does not fall below the determined minimum pressure over the complete purge time.

The test result is documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### See also

Leakage loss measurement at motors, type of protection "device protection provided by pressurized enclosure "p"" (Page 61)

## 3.1.28 Leakage test for water-cooled motors

The water cooling is checked for leaks during production, and is confirmed with a 3.1 certificate.

For motors intended for marine applications, this test represents a hold point with the accepting organization being present. In this case, a 3.2 certificate is issued.

# 3.2 Additional tests

In the following you will find descriptions of tests that you can additionally order for an induction motor.

## 3.2.1 Mechanical tests

### 3.2.1.1 Overspeed test

**Fundamentals**

- API 5th edition 6.3.5.6, 4.1.5
- An overspeed test is not required according to IEC 60034-1. However, the overspeed test is performed when there is an agreement to do so. With the exception of pole-changing motors, IEC 60034-1 specifies 120 % of the highest safe operating speed of three-phase induction motors with squirrel cage rotor as speed to be used for the overspeed test.

The overspeed test is used to verify the mechanical strength of the rotor. The bearing housing and shaft vibrations are evaluated using this test. Increased vibration values can indicate possible permanent deformation of the rotor after the overspeed test.

At the same time, due to the operation at increased speed by the centrifugal force, a setting for all rotor parts such as winding, sheets, mounting parts, etc. can be achieved.

The motors are designed for rigid mounting according to EN 60034-14. Some designs require that the motor is mounted on rubber elements. Within the scope of customer acceptance tests, the centrifugal speed is determined, based on the rated speed.

**Note**

For safety reasons, for some special motor versions, the overspeed test can be monitored via a video camera from a separate room.

#### Test procedure

1. The motor is rigidly mounted or mounted on rubber elements.
2. The motor is accelerated to its rated speed.
   The vibration values are recorded. For journal bearing motors, if the appropriate equipment is available, in addition to bearing housing vibration, also the shaft vibration is monitored.
3. The motor is accelerated to its centrifugal speed.
   The overspeed field test is done under no load conditions and takes 2 min.
4. The motor is again accelerated to its rated speed.

5. According to IEC: The vibration values are measured.
6. According to API: The residual unbalance of the rotor (1x component) is vectorially calculated before and after the overspeed test. The change to this component must not exceed 10% of the specified vibration limit values.
   To determine the 1x vector change, the mean values are calculated from 1x amplitude and the phase value.

## Result

The overspeed test has been successfully completed if no inadmissible increase in the vibration values is measured. If the values or the vector changes to these values exceed the vibration limits, the customer must agree the further procedure with the manufacturer.

The overspeed and the duration of the overspeed test is noted in the test certificate. The test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.2.1.2 Component Balance

#### Fundamentals

API 4th edition: 2.4.6.3.1a

As a result of the optimized rotor design, two-pole motors operating above the critical speed, balancing at speeds less than the rated speed in two planes is permissible ("rigid balancing"). "Rigid balancing" is therefore carried out instead of what is laid down in API, which specifies balancing in three planes at the rated speed.

The components for the motors are already balanced when purchased. A balancing report for these components is not available.

### 3.2.1.3 Residual Unbalance Verification Test

#### Fundamentals

- API 4th edition: 2.4.6.3.6 / 6.2.5.1a
- API 5th edition: 4.4.6.3.4

The precision of the balancing machine is checked with reference to a specific rotor. The test is performed after the normal balancing of the rotor to the corresponding balance quality (G = 0.63).

On the balanced rotors, a specific unbalance is created using test weights. The precision of the balancing machine is evaluated based on the measurement results of the rotor that has been consciously unbalanced in a specific way.

#### Test equipment

Balancing machine according to DIN ISO 1940-1

### Test procedure

1. The unbalancing weight is consecutively attached to the drive end and non-drive end at 0°, 60°, 120°, 180°, 240°, 300° and 0°. As a consequence, a total of seven balancing runs are made for each end.
2. A balancing run is made for each position of the unbalancing weight.
   For each position / angular degree of the unbalancing weight, the amplitude and phase angle of the unbalance are output and the resulting unbalance calculated. The resulting unbalance is compared with the maximum permissible residual unbalance.

### Result

If the resulting unbalance is less than or equal to the maximum permissible residual unbalance, then the test has been successfully completed.

The successful test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### See also

Vibration severity measurement according to API 541 (Page 39)

## 3.2.1.4 Final Assembly Running Clearances / Final rotating assembly clearance data storage

#### Fundamentals

- API 4th edition: 4.2.1.1e
- API 5th edition: 6.2.1.1e

The test ensures that for safe operation there is sufficient clearance between the rotating components and the stationary, non-rotating components. The test is performed during assembly, and comprises several parts:

- Air gap
- Distance between shaft fans and air guidance panels (if shaft fans are specified)
- For journal bearings: geometrical axial play
- For journal bearings, and if specified: Bearing clearance

The test is always performed internally without the customer being present; it is not documented unless specified otherwise.

## 3.2.1.5 Inspection for Cleanliness

#### Fundamentals

- API 4th edition: 4.2.3.2 / 4.2.3.3
- API 5th edition: 6.2.3.3

The cleanliness of the oil inlets and outlets at the journal bearings is checked. This prevents dirt from causing journal bearing damage.

## Test procedure

1. The cleanliness inspection is carried out immediately before installation.
2. Two to six locations on the oil connection pipes and instrumentation selected by the inspector are checked for a visual and tangible presence of foreign bodies such as lime, rust, metallic shavings and sand etc.

## Result

The test has been successfully completed if no dirt or pollution has been identified. When the customer witnesses the test, a 3.2 certificate is generated.

### 3.2.1.6 Bearing Dimensional & Alignment Checks Before Tests

#### Fundamentals

- API 4th edition: 4.3.2.1j
- API 5th edition: 6.3.2.1k

The visual inspection of the journal bearings and/or the measurement of the geometry proves the functionality **before** the electrical tests.

#### Test equipment

Depending on the specific factory, different test equipment is used, for example the following:

- Cordameter
- 3D measuring machine
- Measuring strips for gap measurement
- Camera
- ...

## Test procedure

1. The average bearing clearance between the shaft and bearing shell is determined.
   – The diameter of the shaft bearings is measured when the bearings are being manufactured.
   – The bore diameters of the bearing shells are measured during assembly. The measurement is carried out without customers present.
   – The average bearing clearance is calculated as half the difference between the bearing shell bore diameter and the shaft bearing position diameter. All values are documented internally; the average calculated bearing clearance is recorded in the test report.
2. The gap between the bearing shell and bearing housing is measured.
   Special measuring strips are used to determine the clearance. The selection of the measuring strips depends on the particular gap.
   – The measuring strips are placed on top of the upper bearing shell on both of the inclined surfaces.
   – The upper bearing housing is mounted. During this process, the measuring strips are crushed between the upper shell and upper bearing housing.
   – After removing the upper housing, the crushed measuring strips are compared to the relevant scale. The suitable strip specifies the existing gap dimension.

Figure 3-17 Example of measuring strips

3. The gap dimensions of the DE and NDE bearings are documented internally. The measured values and photographs are included in the test report.

## Result

The test result is documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.2.1.7 Bearing Dimensional & Alignment Checks After Tests

**Fundamentals**

- API 4th edition: 4.3.2.1k
- API 5th edition: 6.3.2.1l

Measuring the journal bearing geometry verifies the functionality **after** the electrical tests.

#### Test procedure

Once they have cooled down, the journal bearings are inspected after the electrical tests.

1. Half the difference between the diameter of the bearing shell bore and the diameter of the shaft bearing journal is used to determine the average bearing clearance. The diameters of the bearing journals on the shaft are taken from the previous measurement.
2. The bore diameters of the bearing shells are measured. The measurement is carried out without customers present.
3. The average bearing clearance is calculated.

#### Result

All values are documented internally; the average calculated bearing clearance is recorded in the test report. The test result is documented in a 3.1 certificate.

#### See also

Bearing Inspection after Tests (Page 60)

### 3.2.1.8 Vibration Recording

**Fundamentals**

- API 4th edition: 4.3.3.12
- API 5th edition: -

While the machine is operating at the maximum operating speed and the bearing temperature is stable (steady state temperature), the vibration amplitudes are evaluated at frequencies other than the rotational frequency. This range lies between 25 % of the rotational frequency and four times the line frequency. You can find the limit values in the API 4th edition here:

- Figure 3-5 Limit values for the vibration velocity of the bearing housing (Page 41)
- Figure 3-6 Limit values for shaft vibration (Page 42)

### Test procedure

1. The machine is rigidly mounted corresponding to the "Soft Foot test".
2. A bearing temperature rise run is performed.
3. The machine is operated under no load at the rated frequency and rated voltage. A frequency spectrum in the range from 25% of the rotational frequency to four times the line frequency is recorded.

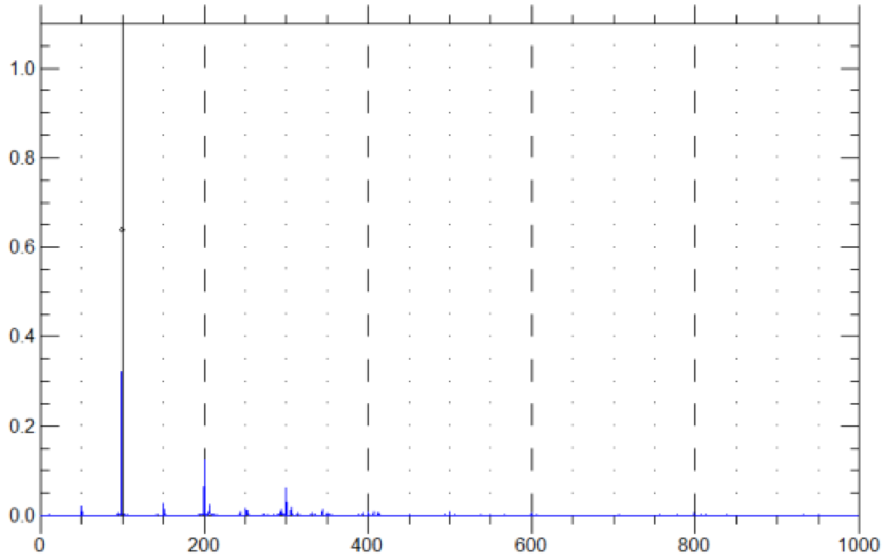



Figure 3-18 Example: Frequency spectrum of a two pole 50 Hz machine

### Result

If specified, the customer is provided with an electronic data record of the vibration analysis.

### See also

Bearing temperature rise (Page 59)

Vibration severity measurement according to API 541 (Page 39)

## 3.2.1.9 Vibration analysis

### Fundamentals

IEC / EN 60034-14

A vibration analysis shows the vibration behavior of the machine over the complete speed control range.

From the vibration values recorded, for a two pole motor, a beat frequency can be identified, for example. The resonant frequency can also be determined from the acceleration and coast down test, as well as the balance state of the installed rotor.

A frequency spectrum is created, which represents vibration in the range from 0 up to 1000 Hz.

### Test equipment

Vibration analyzing systems, e.g. ADRE 408 DSPi / Sxp or comparable

### Calculations

For machines, which manifest a beat frequency response, vibration variable $x_{rms}$ is calculated using the following equation:

$$X_{eff} = \sqrt{\frac{X_{max}^2 + X_{min}^2}{2}}$$

## Test procedure

All of the measured values are continually recorded. For the vibration analysis when operated from a converter, the operating point is selected, which is specified on the rating plate as operating point.

1. Run-up: Depending on the actual version, the motor is accelerated using a motor-generator set up to range between 1.05 and 1.2x rated speed with constant magnetization.
2. Vibration measurement in no-load operation at rated voltage and rated frequency for 15 minutes. The above mentioned formula is applied if a beat frequency response is identified.
   Measurement is shown as trend plot, specifying the overall vibration value; 1X and 2X components are shown with respect to time. In addition, an FFT spectrum is generated in the range from 0 to 1000 Hz from the measured data.
3. Coast down in a no-voltage state starting from 1.05x to 1.2x rated speed.
   Measurements 1 and 3 are shown as overall vibration value, 1X and 2X components are shown with respect to the motor speed ("BODE plot").

## Result

The measured values are compared with the target values, and specified in the test certificate. As documentation of the test result, a 3.1 certificate is issued, or for acceptance tests witnessed by the customer, a 3.2 certificate is issued.

## 3.2.1.10 Running/Vibration Tests with Coupling Half

### Fundamentals

- API 4th edition: 2.4.6.3.3 / 4.3.1.6.2
- API 5th edition: 4.4.9.4 / 6.3.1.5

The vibration response of the machine with balanced customer coupling is determined.

---

**Note**

**Coupling**

The customer must provide the coupling or an equivalent coupling on time, otherwise the test cannot be conducted.

The customer is responsible for the coupling quality.

---

## Test procedure

1. The machine is rigidly mounted corresponding to the "Soft Foot test".
2. The axial fixing system is mounted for machines with journal bearing. This is required because the rotor is no longer maintained at the axial magnetic center following the voltage reduction.
3. A bearing temperature-rise run is performed until a constant bearing temperature is maintained. The motor is then operated for a further hour at a constant temperature.
4. Vibration measurement at no-load and rated frequency and 25% of the rated voltage.
   - The 1x filtered bearing housing and shaft vibrations are measured.
   - For the mean value generation, five values of the 1x amplitude and the phase value for the measuring report are recorded.
5. The customer's coupling is mounted after the motor comes to a standstill.
6. A bearing temperature-rise run is performed until a constant bearing temperature is maintained. The motor is then operated for a further hour at a constant temperature.
7. The vibration measurement is repeated at 25 % of the rated voltage.
   - The 1x filtered bearing housing and shaft vibrations are measured.
   - For the mean value generation, five values of the 1x amplitude and the phase value for the measuring report are recorded.
   - The vectorial absolute value change of the vibration between the tests is documented in the measuring report with and without coupling.
8. The vibration measurement is repeated in no-load operation at the rated frequency and at the rated voltage. The vibrations are recorded as a complete set of measured data with all sensors.
   In addition to the overall vibration, the amplitude is documented with the associated phase angle for 1x and 2x component in the measuring report.

The vibration values with and without customer coupling are documented.

## Result

If the values or the vector changes to these values exceed the vibration limits, the customer must agree the further procedure with the manufacturer.

The test is documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## See also

"Soft Foot test" according to API 541 (Page 37)

### 3.2.1.11 Unbalance Response Test

#### Fundamentals

- API 4th edition: 4.3.5.3
- API 5th edition: 6.3.5.3

API 541 specifies the unbalance response test and defines the limit values for shaft vibration levels.

The unbalance response test verifies that all of the critical speeds have a minimum safety margin of 15 % from the rated speed or from the permissible speed control range and also to determine that the rotor does not manifest any excessively high vibration levels when it passes through the first critical speed.

The unbalance response test is also used to localize the first critical speed. The position of the first critical speed is also influenced by the weight of the coupling. This is the reason that this test is performed with the customers coupling if this is available.

Only motors equipped with journal bearings can be tested, where the balancing planes are accessible. This is the reason that the test is not possible for motors with flameproof enclosure.

## Test procedure

1. The machine is rigidly mounted corresponding to the "Soft Foot test".
2. Known balance weights are attached in phase with one another at the DE and NDE system balancing plates.
3. In no-load operation, the motor is brought up to 120 % of the rated speed and then runs without any power.
4. After each coast down, the balancing weights are shifted through 90°. The measurement is repeated for 90°, 180° and 270°.

## Result

The test has been successfully completed if the limit values for the range ± 15 % are maintained – and the rated speed and limit values are maintained for the remaining range.

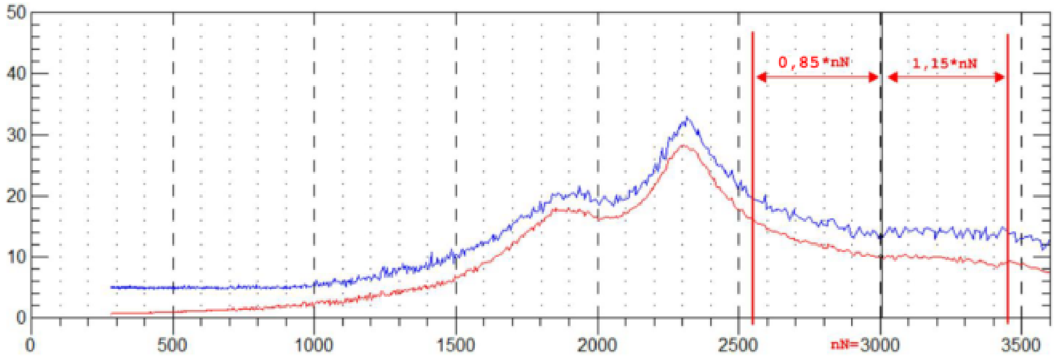



Figure 3-19 Example: Measurement result of dynamic unbalance test

The successful test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## See also

Vibration severity measurement according to API 541 (Page 39)

## 3.2.1.12 Bearing Housing Natural Frequency Tests

### Fundamentals

- API 4th edition: 4.3.5.4
- API 5th edition: 6.3.5.4.1

Motor components, such as the bearing housing, rotor, motor enclosure etc., together form a system that is capable of vibration at various natural frequencies, depending on the component being considered, such as the bearing housing, motor enclosure etc. The natural frequencies of the components decoupled from one another (i.e. separately considered) are different than those for the assembled motor. As a consequence, the resonant frequencies of these components are determined at a completely assembled machine; in this case only the natural frequency of the bearing housing.

According to API 541 4.3.1.4, a motor without a terminal box is considered a completely assembled machine.

The most important excitation sources for the bearing housing vibration of a motor include the rotor rotational frequency, and especially for two-pole machines, twice the line frequency. If one of these exciting frequencies coincides with the resonant frequency of the bearing housing in the mounted state, then excessive vibration levels are manifested at the bearing housing. This test indicates the resonant frequency of the motor bearing housing.

## Test procedure

1. The machine is rigidly mounted corresponding to the "Soft Foot test".
2. Motors with journal bearings: The rotor must rotate slowly in order to bring it into a defined state. To do this, the motor is operated in the speed range from 200 up to 300 rpm.
3. Motors with roller bearings: The rotor does not have to rotate.
4. Using a hammer, bearing housing vibration is excited in the directions to be measured (horizontal, vertical and axial).
   The vibration is recorded, analyzed and the natural frequency determined.

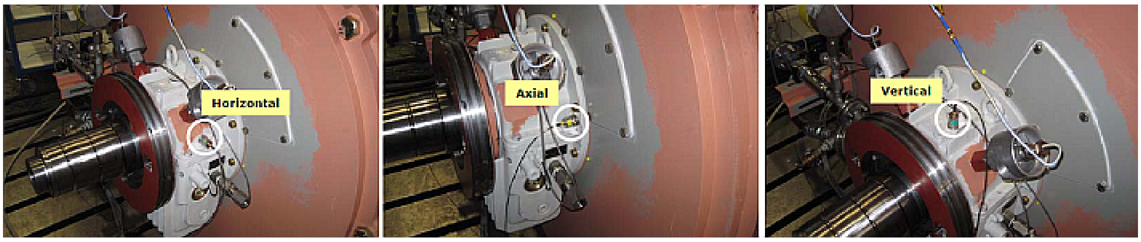



Figure 3-20 Positioning the pickups at DE

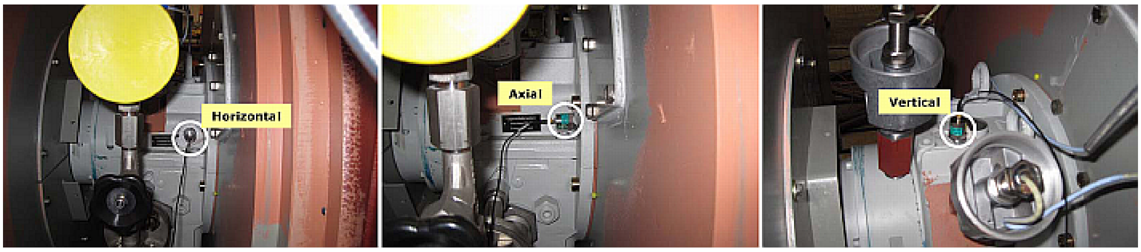



Figure 3-21 Positioning the pickups at NDE

The measured values are displayed in a plot for the frequency range from 0 to 400% of the line frequency.

If bearing housing resonance is determined, which coincides with the rotor rotational frequency or twice the line frequency, then the appropriate countermeasures are defined together with the customer.

## Result

The successful test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## See also

"Soft Foot test" according to API 541 (Page 37)

Runout measurement with acceptance (Page 52)

### 3.2.1.13 Visual inspection

#### Fundamentals

The visual inspection verifies that the order specifications are complied with.

### Test procedure

The visual inspection together with the customer – or with the company accepting the equipment – is carried out using the motor that has been completely painted and the appropriate labels attached.

The visual inspection includes the following steps:

- The outside of the motor is inspected and assessed.
- The instrumentation is explained based on the electrical/mechanical documentation and dimension drawing.
- The customer or the company accepting the motor on the customer's behalf can check the outer dimensions.
- Digital photographs are made that clearly document the situation.

---

**Note**

- The terminal box and auxiliary terminal boxes are not opened.
- Test reports are not handed over and discussed.
- It is possible that the motor is already mounted on a shipping pallet.
- A rotor holding brace can already be attached, i.e. the shaft face cannot be seen.

---

### Result

A paint thickness measuring report is generated. The test result is documented in a 3.2 certificate.

### 3.2.1.14 Paint thickness measurement

#### Fundamentals

The measurement is performed according to DIN EN ISO 2064. The paint film thickness measurement serves to verify the agreed film thickness, and is performed without the customer being present. When ordered, every film thickness is individually measured and documented.

#### Test equipment

A dry paint film thickness measuring instrument that is suitable for ferritic and non-ferritic surfaces. The measuring instrument works according to the following methods:

- Magnetic process according to DIN EN ISO 2178
- Eddy current process according to DIN EN ISO 2360

## Test procedure

At defined measuring points on the machine, the thickness of the applied paint film is measured five times. The average value of the paint film thickness is calculated.

The measurement locations specified in the following are not available or not possible at all motors.

1. Housing (top); for fin cooling: Power cable duct
2. Housing (at the side)
3. Foot or flange
4. Terminal box cover
5. Fan cover or air intake cowl
6. Bearing shield
7. Anti-friction bearing cover or journal bearing housing
8. Upper part of the enclosure underside
9. Upper part of the enclosure top
10. Upper part of the enclosure front face on the drive end, for IM V1 on the non-drive end
11. Upper part of the enclosure side
12. Protective cover (top)
13. The paint film thickness measurement protocol shows the measuring points and the measured layer thicknesses are entered with their average values.

## Result

The test result is documented in a 3.1 certificate.

### 3.2.1.15 Heat exchanger performance verification test TEWAC

**Basis for testing**

- API 6.3.3.5

The test establishes whether the TEWAC heat exchanger has been adequately designed to cool the air in the motor. Inadequate cooling impairs motor performance. TEWAC stands for "Totally Enclosed Water to Air Cooled".

The test can only be carried out under test facility/test field conditions regarding the cooling water supply.

## Test procedure

1. The cooling water supply is connected.
2. The cooling water is set to nominal flow, temperature and pressure on the water supply, where possible.
3. A temperature rise test under load is performed.

### Result

The test is passed if no leaks or pressure losses occur for at least 30 minutes and the specified heat dissipation is achieved. The test result is documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.2.1.16 Hydrostatic test

The compressive strength of the air-to-water heat exchanger is confirmed by a 3.1 certificate from the manufacturer. The air-to-water heat exchanger can also be tested underwater using air as a test medium, and documented accordingly.

## 3.2.2 Electrical tests

### 3.2.2.1 Testing the temperature limits of components in explosion-protected motors

#### Fundamentals

- IEC / EN 60079-0; -1; -2; -7
- PTB test regulations, Volume 3: "Test and certification in accordance with Directive 2014/34/EU for explosion-protected drives".

The temperature limits of the various materials and/or components used in the machine are tested corresponding to the thermal properties. If necessary, the test is carried out corresponding to the specified temperature classes. It is not permissible that the limit values are exceeded.

#### Test equipment

- Thermo elements or resistor sensors
- Handheld thermometer

## Test procedure

1. A temperature rise test under load is performed.
2. The temperature values are documented at the defined measurement locations according to IEC / EN 60079-0 and the appropriate test rules & regulations of the PTB.
3. All measured values are interpolated up to the maximum ambient temperature and rated values - and compared with the limit values of IEC / EN 60079-0; it is not permissible that the limit values are exceeded.

| Measurement location according to the temperature class | Maximum surface temperature |
|---|---|
| T1 | 450 °C |
| T2 | 300 °C |
| T3 | 200 °C |
| T4 | 135 °C |
| T5 | 100 °C |
| T6 | 85 °C |

| Measurement location | Maximum surface temperature | |
|---|---|---|
| | Normal, undisturbed operation | Overload/fault |
| Cable entry ② | 70 °C<br>>70 °C ① | 80 °C<br>>80 °C① |
| Conductor branch ② | 80 °C<br>>80 °C① | 95 °C<br>>95 °C① |
| Seals, non-metallic parts of the enclosure | Corresponding to the certification documentation | |

① With notification label according to IEC / EN 60079-0 on heat resistant cable or cable entry with temperature data

② The limit values listed in the table are appropriately reduced when using cables or cable entries with lower temperature resistance.

## Result

The test result is documented in a 3.1 certificate – or in the case that the customer witnessed the acceptance test, in a 3.2 certificate.

### 3.2.2.2 Short-circuit temperature rise test for motors with type of protection "Ex eb"

#### Fundamentals

- IEC / EN 60079-7
- PTB test regulations, Volume 3: "Test and certification in accordance with Directive 2014/34/EU for explosion-protected drives".

Machines of the "Ex eb" type of protection are suitable for use in Zone 1, and are therefore assigned to Category 2. Category 2 states that also for common operating faults, protection is to be provided (locked rotor).

For explosion protection, as critical fault situation, it is assumed that the motor has reached its final operating temperature after many hours of operation at rated load under unfavorable cooling conditions, and that the rotor is locked as a result of a fault. The results from continuous operation and the short-circuit temperature rise are evaluated and the $t_E$ time (locked rotor time) determined.

If at all possible, the short-circuit temperature rise test is carried out at the rated voltage. The duration of the test is defined based on the machine size and type of construction.

---

**Note**

The test is carried out within the scope of a type test, and cannot be ordered.

---

**Test equipment**

- Supply equipment: Transformer with supply at the rated frequency
- Locking equipment for rotors, e.g. a starting torque test stand
- Temperature measuring equipment
- Fast plotter

## Test procedure

The short-circuit temperature rise test is carried out twice as minimum: in various rotor positions or in both directions of rotation.

1. According to the directives of the nominated body, e.g. the Physikalisch Technischen Bundesanstalt (PTB), the rotor is equipped with thermo elements. During the test, the temperature values are recorded using a temperature plotter.
2. The winding resistance when cold is measured.
3. The motor is switched on. The electrical values are documented.
   - 5 seconds after switch on
   - Shortly before switching off
4. After the machine has been switched off, the winding resistance when warm is measured. This determines the average winding temperature rise reached during the short-circuit temperature rise test.
5. Together with the results of other temperature rise tests performed under load, the $t_E$ time (locked rotor time) is determined.

All of the measurement results form the basis for certification issued by the nominated body.

## Result

The measurement is internally documented.

### 3.2.2.3 "tan δ" loss factor measurement on single coils

**Fundamentals**

The dielectric losses in the main insulation (slot part of the coil with respect to ground) are determined at the individual coils.

The coils are manufactured in the same production processes from the same material batches as the winding of the machine itself. Impregnation is carried out in slot models, whose slot dimensions correspond to the laminated core slots and in the same impregnation process as the winding itself.

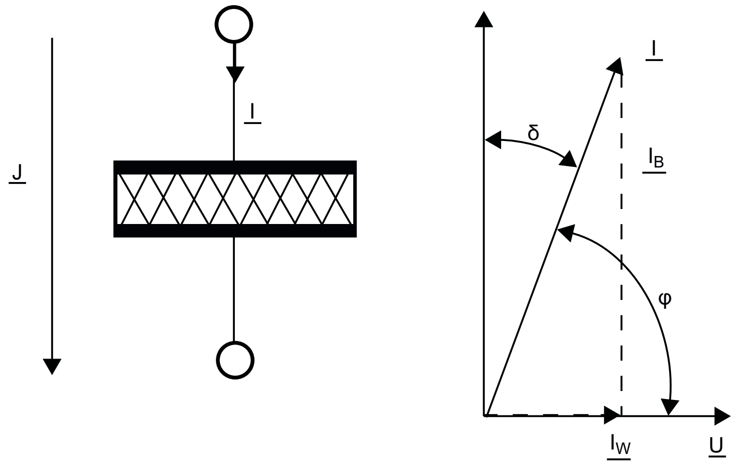



Figure 3-22 Definition of the loss factor tan δ

The loss factor is defined as the ratio between the active and reactive current:

$\tan \delta = I_W / I_B$

When carry out measurements at individual coils, the influence of edge fields and the ohmic electric field strength distribution (potential grading) can be essentially eliminated using shield electrodes. This allows the state of the slot insulation alone to be assessed.

**Test equipment**

A classic Schering measuring bridge or another electronic measuring system is used to measure the loss factor. The measuring circuit for an electronic measuring system and the test object with shield electrodes (coil side or bar) is shown in the following sketch. More information is available in IEC 60034-27-3.

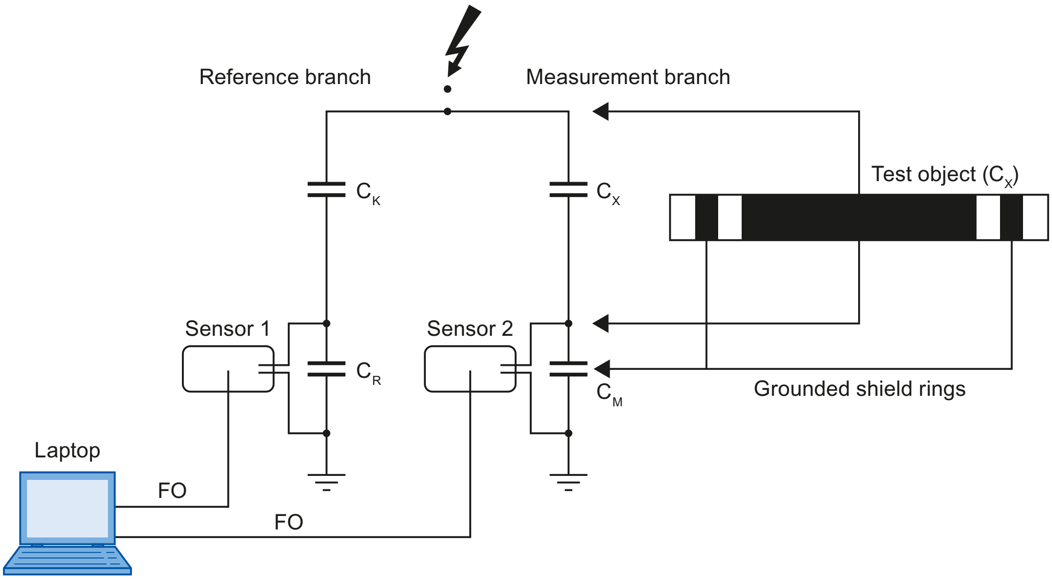



Figure 3-23 Sketch showing the principle: Loss factor measurement at single coils

## Test procedure

1. For coils, the two coil sides (upper or lower coil side) are separately measured and evaluated.
   A 50 Hz AC voltage is used for the test with an increment of $\Delta U = 0.2\ U_N$ – starting with $0.2\ U_N$ to $1.2\ U_N$.
2. Alternatively, for electronic measuring systems, a continuous measurement is possible with the appropriate evaluation in $0.2\ U_N$ steps.
3. The characteristic values, defined in the table, are generated from the measured loss factor.

| Characteristic values | Formula | Limit |
|---|---|---|
| Initial value at $0.2\ U_N$ | $\tan \delta_{0.2}$ | $20 \cdot 10^{-3}$ |
| Maximum rise per $0.2\ U_N$ | $\Delta\tan \delta_{max} / 0.2\ U_N$ | $5 \cdot 10^{-3}$ |
| Average initial increase between $0.6\ U_N$ and $0.2\ U_N$ | $\tan \delta_{0.6} - \tan \delta_{0.2}$ | $5 \cdot 10^{-3}$ |

## Result

The characteristic values must, as a minimum, comply with the requirements laid down in IEC 60034-27-3 or the associated specification.

### 3.2.2.4 Loss factor and capacitance measurement on the complete winding or machine

#### Fundamentals

The test corresponds to the "Power Factor Tip-Up Test" according to API. At the complete winding or machine, the dielectric losses in the main insulation (winding with respect to ground) of the high voltage windings are determined.

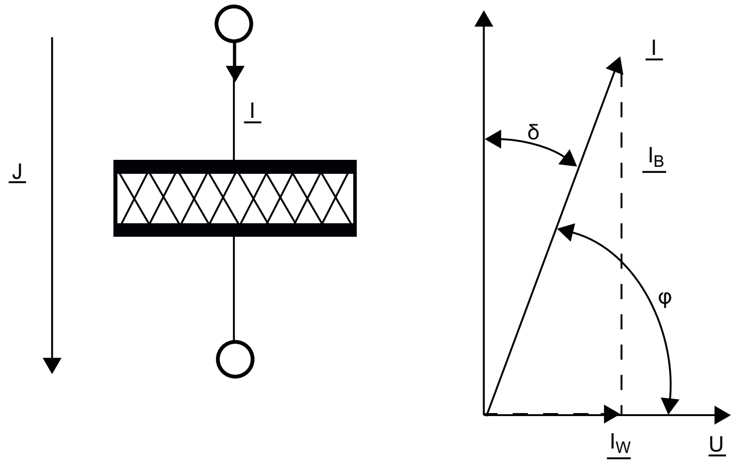



Figure 3-24 Definition of the loss factor tan δ

The loss factor is defined as the ratio between the active and reactive current:

$\tan \delta = I_W / I_B$

The loss factor measurement is a summarizing measurement; this means that all dielectric losses are measured, including the losses of the edge fields and the electric field strength distribution (overhang corona shielding). The influence of edge fields and electric field strength distribution (overhang corona shielding) decreases with increasing laminated core length.

The overall losses are made up as follows:

- Transmission losses in the dielectric, essentially independent of the voltage
- Cable losses at the surface (electric field strength distribution (overhang corona shielding), pollution/dirt). The electric field strength distribution (overhang corona shielding) losses increase with increasing voltage.
- Losses caused by partial discharge in voids or gaps. These losses depend on the voltage.

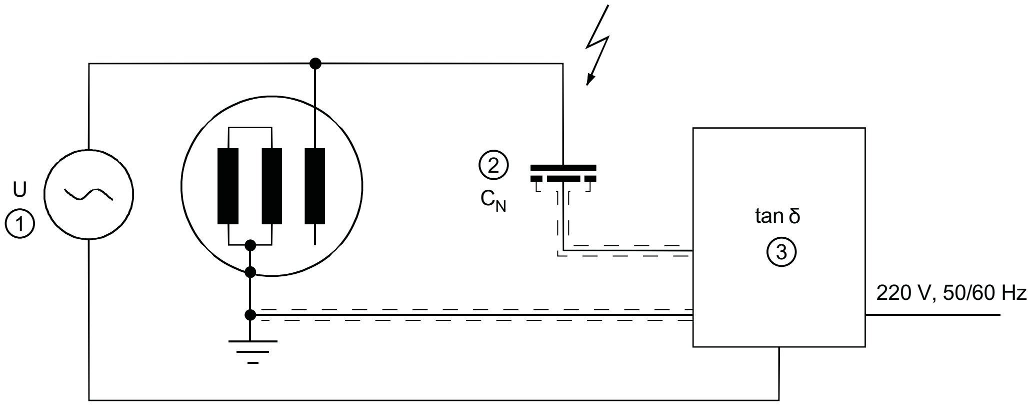
These losses can indicate the state of the overall insulation.

#### Test equipment

The measuring methods and requirements relating to winding insulation of rotating electrical machinery are described in Standards DIN EN 50209, IEC 60894 and IEC 60034-27-3

The classic Schering measuring bridge or electronic measuring systems is used. Alternatively, measuring circuits to measure grounded test objects (machine in the test bay) are used. A detailed description can be found in IEC 60034-27-3.

The following block diagram shows the loss factor measurement using a Schering bridge and grounded machine.




① Test voltage
② Standard capacitor
③ Measuring bridge

Figure 3-25 Loss factor measurement of complete windings or machines

## Measuring procedure

- Accessible and open neutral point: The voltage-dependent capacitance and loss factor values are measured from 0.2 $U_N$ to 1.2 $U_N$ in 0.2 $U_N$ steps.
  - At the complete winding U+V+W
  - Optionally, at the individual phases U, V, W
- The machine enclosure and the winding phases that are not being measured are grounded.
- With the neutral point closed, the complete winding is measured with respect to the housing (ground).

## Result

In addition to the dielectric itself, the loss factor also depends on the machine size and specific design features such as how the overhang corona shielding is implemented. Limit values for loss factor parameters of windings are not specified in the standards. If loss factor measurements at the winding are requested, the results are purely of an informative nature. For instance, they are used as reference when making measurements to diagnose the state of windings based on their dielectric properties.

---

**Note**

Limit values mean that individual agreements have to be made with customers on a case-for-case basis.

---

The loss factor characteristic over a voltage range from 0.2 up to 1.2 $U_N$ and the parameters determined from it, defined in the following, are specified.

### 3.2.2.5 Power Factor Tip-Up Test

#### Fundamentals

- API 4th edition: 4.3.4.3
- API 5th edition: 6.3.4.3

The loss factor measurement corresponds to test "Loss factor and capacitance measurement on the complete winding or machine (Page 83)".

The successful completion of the test is confirmed in a 3.1 certificate.

### 3.2.2.6 Stator Core Test

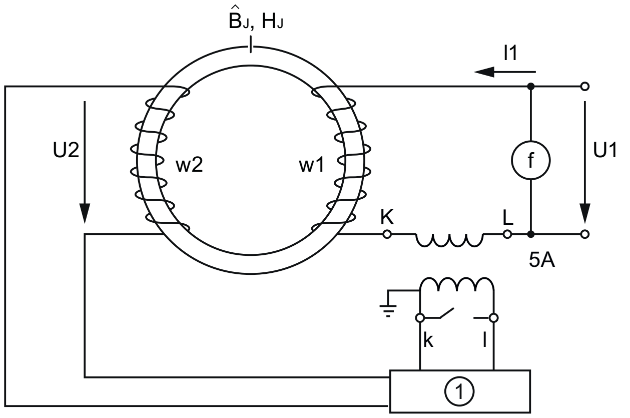
#### Fundamentals

- API 4th edition: 4.3.4.1
- API 5th edition: 6.3.4.1

During the "ring core magnetization" test, closed, ring-shaped material samples, yokes or unwound or wound stators of electrical machines, in which a magnetic field is generated in a tangential direction, are examined. Hereinafter, these parts are referred to as "yoke".

Defects of the laminated core insulation can cause eddy currents that can result in an excessive increase of the sheet temperature (hotspots). Hot spots can cause coil faults.

During the test, the characteristic magnetization characteristic B = f(H) or the specific no-load losses $v_{FE}$ = f(B) are optionally recorded. To a certain extent, the insulation of the laminations can be checked against each other by magnetizing the laminated stator core. Faults are detected that cause an inadmissible local temperature rise of the stator core.




| | | | |
|---|---|---|---|
| f | Excitation frequency | $w_1$ | Number of excitation windings |
| $U_1$ | Excitation voltage | $w_2$ | Number of measurement windings |
| $U_2$ | Measuring voltage | $P_w$ | Active power |
| $I_1$ | Excitation current | $B_J$ | Maximum yoke induction |
| ① | Wattmeter 7KB 4306 | Values I, $U_2$, $P_w$, cos φ are displayed on the Wattmeter. | |

Figure 3-26 Example of a test setup

The test is executed by applying a defined induction in the laminated core by attaching coils similar to a transformer winding.

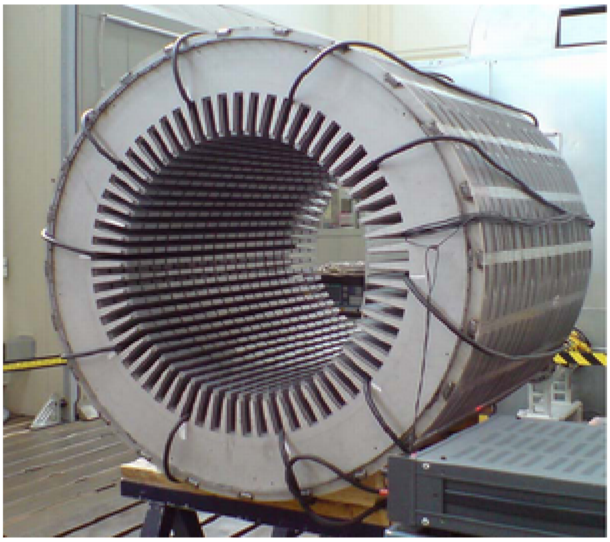


Figure 3-27 Stator

## Test procedure

1. The cables for the specified excitation winding with number of turns $w_1$ are placed along the shortest path around the laminated core. The cables can also wind around the housing. The windings are distributed as evenly as possible around the circumference. The measurement winding with number of turns $w_2$ is optionally placed in a groove around the yoke of the laminated stator core and between the laminated core and pressure plate. The winding is placed on the back of the laminated core and the remainder of the cable is twisted.
2. The voltage is increased at the test coils until the ring core is almost magnetized to its nominal induction level. As a consequence, the laminated stator core temperature increases.
3. During the 30-minute measuring period, the temperature rise is continuously monitored using a heat imaging camera.

4. Thermal images of the hot spots are recorded at various points in time to document how the temperature changes.

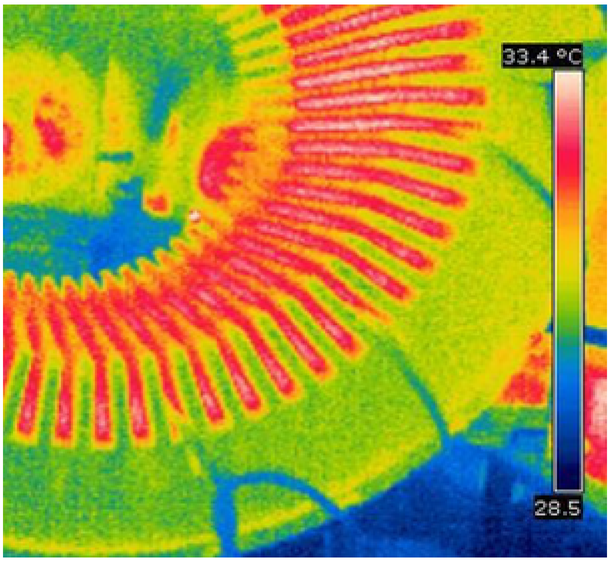



Figure 3-28 Example of a heat image

5. A magnetization characteristic to determine the specific core losses with a continuously increasing magnetization of the ring core is optionally recorded.

## Result

In comparison with other machines, differences can be identified and can be analyzed if necessary. The successful test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.2.2.7 Special Surge Test of Coils

**Fundamentals**

- API 4th edition: 4.3.4.2.1
- API 5th edition: 6.3.4.2.1
- IEC 60034-15

The pulse withstand capability of the inter-turn/layer and main insulation of the winding is verified at two separately manufactured individual coils. The coils are manufactured in the same production processes from the same material batches as the winding of the machine itself. Impregnation is carried out in slot modules, whose slot dimensions correspond to the laminated core slots and in the same impregnation process as the winding itself.

The surge voltage test is carried out in two different test circuits:

- Test of the main insulation (= slot area and electric field strength distribution (overhang corona shielding))
- Test of the inter-turn and layer insulation (= insulation between the conductors)

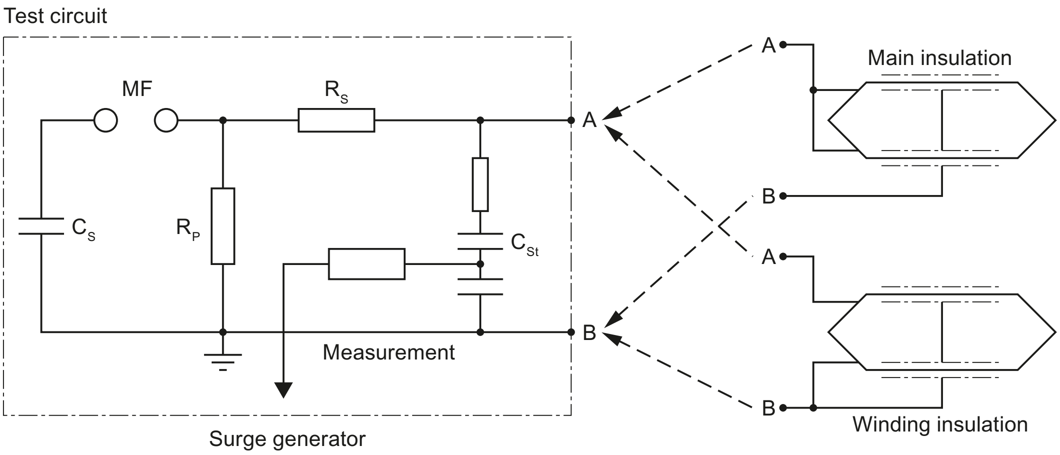



Figure 3-29 Surge voltage test block diagram

The requirements and criteria according to IEC 60034-15 are applied as standard. Requirements going beyond this, e.g. as a result of customer specifications, must be agreed on a case-for-case basis.

Table 3-4 Test criteria according to IEC 60034-15

| Test | Amplitude | Rise time | Time to half value | Number of pulses |
|---|---|---|---|---|
| Main insulation | $\hat{U}_{main} = 4 \cdot U_N + 5$ kV | 1.2 µs ±30 % | 50 µs ±20 % | 5 |
| Inter-turn/layer insulation | $\hat{U}_{coil} = 0.65 \cdot \hat{U}_{main}$ | 0.2 ± 0.1 µs up to $U_P$ = 35 kV<br>0.2 +0.3/-0.1 µs from $U_P$ > 35 kV | - | 5 |

The values depend on the coil and test circuit impedance, and typically lie between 5 and 10 µs.

Table 3-5 Test criteria according to API 541 5th Edition

| Test | Amplitude/ Test voltage | Rise time | Time to half value | Number of pulses |
|---|---|---|---|---|
| Partial discharge measurement only for coils with overhang corona shielding | $\sqrt{3} \cdot U_N$ | n.a. | n.a. | n.a. |
| Main insulation | 5.0 pu | 1.2 µs | 50 µs | 3 |
| Winding insulation | 2.0 pu / 3.5 pu | 0.1 ... 0.2 µs * | n.a. | At least 1 pulse per minute |
| Breakdown test/ puncture test of the winding insulation | The voltage is increased in 5 kV steps | 0.1 ... 0.2 µs | n.a. | 1 |

* This value is dependent on the coil and can deviate from the values listed here

According to IEEE 522 6.2, the pu (per unit) is calculated as follows:

$$1\ \text{pu} = \sqrt{\frac{2}{3}}\ U_{LL}$$

### Test procedure

1. The voltage is increased, starting from approx. 50 % of the test voltage amplitude to be applied up to the specified impulse withstand voltage in steps of approx. 3 kV. Three voltage surges (pulses) are applied per voltage stage.
2. For the impulse withstand voltage, as a minimum, the voltage impulses are applied corresponding to the relevant table.
3. For tests according to the API 5th Edition - or optionally according to IEC 60034-15 - after the main insulation test, the test voltage is increased step-by-step until either the strength of the main insulation or the clearance in air breaks down ("Breakdown Test").

### Result

At the specified impulse withstand voltages, it is not permissible that there is any arcing across the main or inter-turn insulation. Every surge voltage value is documented during the test. The curve is graphically depicted in order to guarantee that deviations in the curve form, which could indicate faults, can be detected as the voltage increases.

The successful test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate. It contains the test results and the voltage curve forms as graphical representation.

## 3.2.2.8 Partial discharge test

#### Fundamentals

- API 5th edition: 6.3.4.6
- The measurement is in conformance with IEC 60034-27-1

Using the partial discharge measurement, electrical discharges in voids (gas pockets) inside the insulation or at transitional surfaces, e.g. at insulation surfaces, can be detected. In contrast to the integrating loss factor measurement, the partial-discharge measurement is differential in character. This means that it can identify limited local weak points on the insulation.

This test measures the apparent single pulse charges q in a wide-band frequency range as a function of the amplitude of the applied AC voltage. The most important recorded values include the partial-discharge inception voltage, the maximum pulse charge at the phase voltage $U_N/\sqrt{3}$ (operating voltage of the winding with respect to ground) and rated voltage $U_N$. The phase distribution, frequency and polarity of the discharges can also be measured. This provides additional information regarding the source and significance of the discharge.

In conjunction with other diagnostic measurements and, where possible, trend monitoring, this testing technique allows the insulation condition to be evaluated.

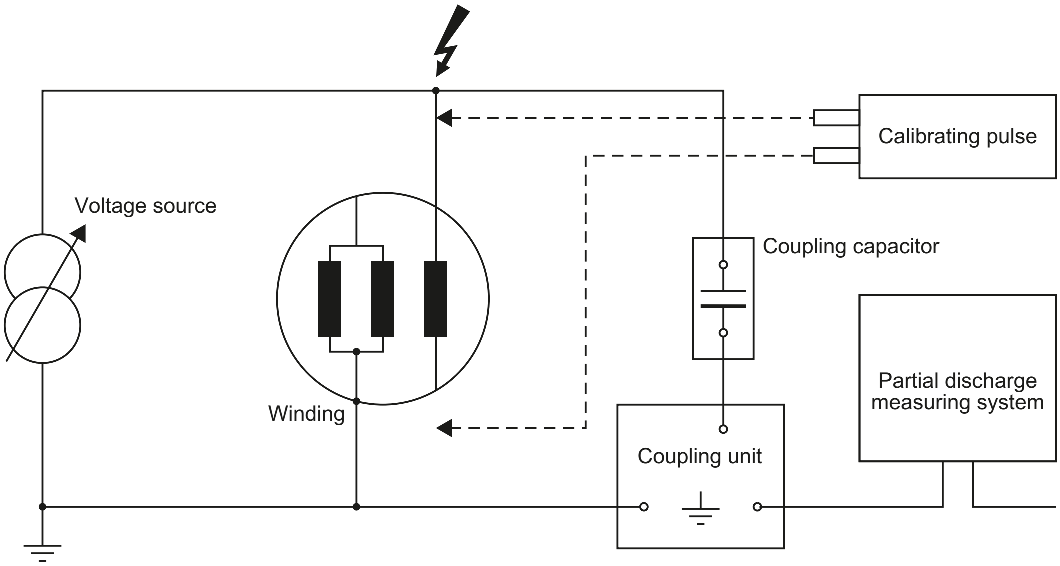



Figure 3-30 Measuring circuit for the partial discharge measurement

- Broad-band partial discharge measuring system compliant with IEC 60270
- Controllable voltage source

## Measuring procedure

1. The partial discharges are measured for an increasing as well as decreasing test voltage between 0 and $U_N$, optionally up to 1.2 $U_N$.
2. All partial discharge events are saved with the correct phase, time, amplitude and polarity and analyzed by software.
3. Essential results:
   - Maximum apparent single pulse charges as a function of the voltage (Q(U) curves)
   - Partial discharge pattern (in-phase amplitudes and frequencies of the partial discharges)
   - Amplitude-specific frequency distribution of the partial discharges
4. Wherever possible, the measurement is recorded for the entire winding U+V+W. Phases U, V, W are optionally recorded.
   If the neutral point is accessible, the values for X, Y, Z and X + Y + Z are recorded.
5. The partial discharge parameters are visualized and documented.

## Result

Presently, there are no limit values listed in the standards. Requirements from customer specifications must be agreed on a case-for-case basis. The results can be subsequently used as reference to diagnose the winding condition. In order that the measurement results can be compared, measuring systems and a defined measuring circuit with essentially identical parameters are required.

The successful completion of the test is confirmed in a 3.1 certificate.

### 3.2.2.9 Recording the no-load characteristic and calculating losses separately

#### Fundamentals

The no-load characteristic is used to determine the iron and friction losses of the motor.

The no-load characteristic is recorded after stabilization of the no-load losses. The no-load losses are considered to have stabilized as follows:

- When the recorded no-load power of two consecutive measurements taken on a cold machine at an interval of 30 min changes by a maximum of 3%.
- When the no-load test is carried out immediately after the load test.

## Test procedure

#### Measuring the no-load characteristic

1. The winding resistance of the cold motor is measured.
2. Variables $U_0$, $I_0$, $P_0$ are measured at a constant frequency for eight voltage values in the range from 110 % up to 30 % $U_N$ in a descending order.
3. The no-load characteristic is generated by entering $P_k$ and $I_0$ with respect to $U_0^2$.

The constant losses $P_k$ are the no-load losses, adjusted by the no-load winding losses ($P_{S0}$), with the winding resistance of the cold machine (R) and no-load current ($I_0$).

$$P_k = P_0 - P_{S0}$$

$$P_{s0} = 1.5 \cdot I_0^2 \cdot R$$

The constant losses are the sum of the friction and windage losses ($P_{fw}$) and the iron losses ($P_{fe}$).

### Separating the losses

1. The **friction losses** $P_{fw}$ are determined from the no-load characteristic by extrapolating the $P_k$ graph to voltage 0 V.

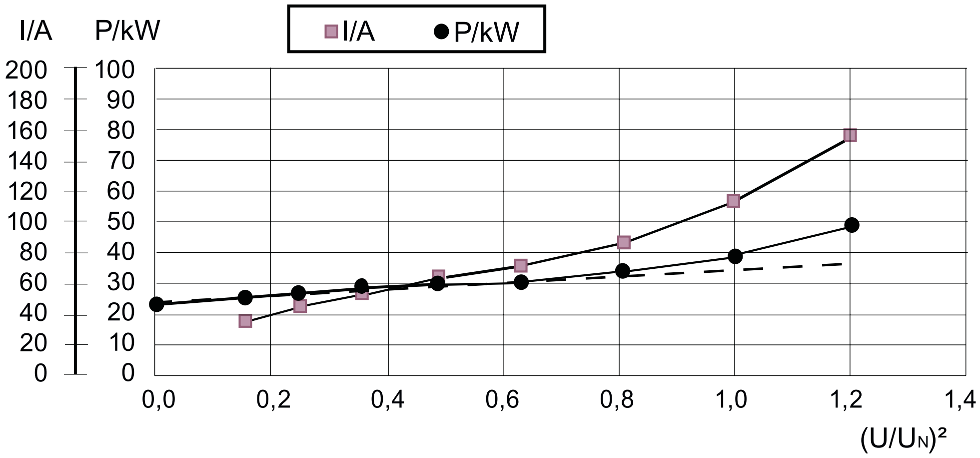



Figure 3-31 Determining the friction losses from the no-load characteristic

2. **Iron losses** $P_{fe} = P_0 - P_{S0} - P_{fw}$ at the rated operating point are determined from the no-load characteristic, at the voltage reduced by the ohmic voltage drop in the primary winding $U_i$.

$$U_i = \sqrt{\left(U-\frac{\sqrt{3}}{2}\cdot I\cdot R\cdot\cos\varphi\right)^2+\left(\frac{\sqrt{3}}{2}\, I\cdot R\cdot\sin\varphi\right)^2}$$

## Result

The results of the test are confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.2.2.10 Recording the short-circuit characteristic and short-circuit losses

#### Fundamentals

The short-circuit characteristic is recorded to check the rotor, the rotor winding and the current symmetry.

## Test procedure

1. With the rotor mechanically locked, the motor is fed with a variable voltage at the rated frequency. The voltage amplitude (short-circuit voltage) is varied until the specified values for the stator currents are obtained.
2. As standard, three measurement points are recorded at 50 %, 100 % and 160 % rated current.
   The short-circuit voltage is compared with the internal test specifications and the current symmetry is monitored in the various phases.
   Additional statements regarding the starting torque and starting current (inrush current) can be made based on the results of the short-circuit characteristic.

## Result

The measured values are listed in the form of a table in the measurement report. The successful test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## See also

Short-circuit test (Page 36)

### 3.2.2.11 Plotting the load characteristic

**Fundamentals**

The load characteristic is required to determine the load-dependent losses. It represents characteristic data of the machine under various load conditions. Based on the load characteristic (operating diagram), information can be obtained regarding the operating points in subsequent operation.

A load characteristic, where conclusive comments can be made, must be recorded with the motor in the warm state after a temperature rise test under load. If the load characteristic (option F18/F19) was ordered without temperature rise test (option F04/F05) then it is recorded with the motor in the cold state.

## Test procedure

The test is carried out with the motor in an operationally warm condition if the temperature rise test under load (option F04/F05) was ordered. If a temperature rise test under load was not ordered, then the load characteristic is recorded with the motor in the cold condition.

The measurement starts with the highest load point and ends with the lowest.

Variables U, I, $P_1$, R, n, f, T are recorded for each load point.

1. The resistance is measured before recording the first load point. This resistance is used for all load points.
2. The machine is loaded at six load points in the range from 25 % up to 150 % $P_N$.
   - Four load points, evenly distributed in the range between 25 % and 100 % $P_N$ are recorded.
   - Two load points are recorded at 110 % and at 125 % $P_N$.

According to the standard, resistance R is measured before the highest load point and after the lowest load point.

- As resistance for 100 % $P_N$ and higher load points, the value that was determined before the highest load point applies.
- As resistance for load points below 100 % $P_N$, that value should apply, which was determined before the highest and after the lowest load point at 25 % $P_N$ under the assumption of a linear characteristic between these two points.

Generally, the load test is carried out so fast (<5 min) that the influence of the low temperature change – that takes place while recording the load characteristic – has very little impact on the resistance. The low temperature change is as a result of the large thermal time constant of the motor. This applies to all SIMOTICS HV and SIMOTICS TN motors.

For this reason, in deviation to the standard but favorable to the customer, the measured resistance from the highest load point can be used for all load points.

## Result

The load characteristic with data regarding cos φ, I and n is generated from the measured values. The result is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

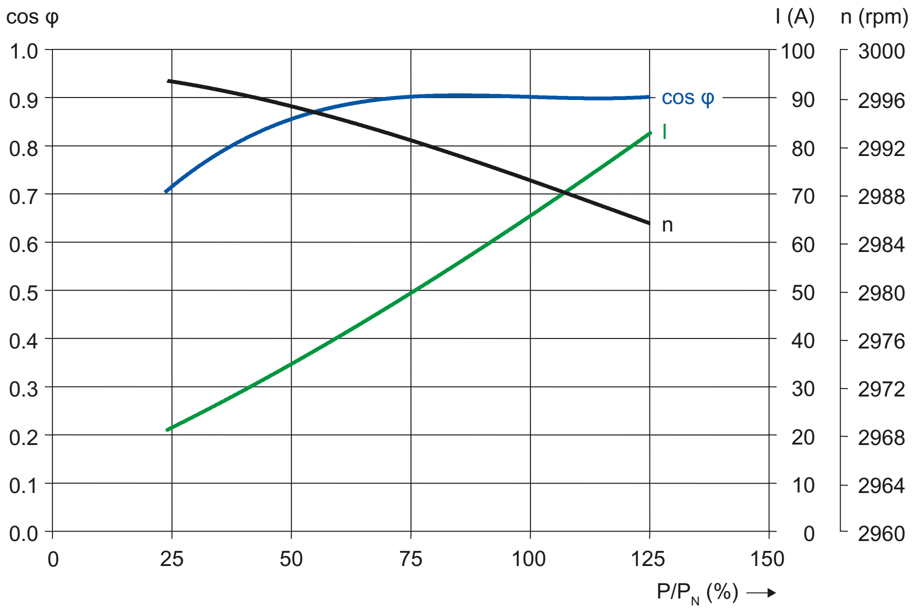



Figure 3-32 Example of a load characteristic

## See also

Calculating the efficiency from the individual losses (Page 99)

### 3.2.2.12 Recording the starting torque and current

#### Fundamentals

Checking the locked-rotor current and the starting torque checks whether the motor starting behavior complies with what has been specified.

---

**Note**

As an alternative to the test procedure described here, the values can also be determined from the short-circuit characteristic.

---

## Test procedure

1. The motor is coupled with the dynamometer and a torque measuring shaft and is fed with the rated voltage at 50 / 60 Hz.
2. The dynamometer is controlled at zero speed so that the starting torque generated by the motor is measured at the torque measuring shaft. The locked-rotor current is also measured in the stator feeder cable.
   The average values from the three measuring points provides the starting torque and the locked-rotor current at the rated voltage.
3. If the motor cannot be tested at the rated voltage, then the current and torques are measured at the highest possible voltage and additional lower voltages. The locked-rotor current and starting torque are then extrapolated up to the rated voltage.

## Result

The measured values and the locked-rotor torque and current calculated from these values are documented in the measurement report. The test has been successfully completed if the locked-rotor current and starting torque are within the specified tolerances.

The successful test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## See also

Recording the current and torque characteristics using a dynamometer (Page 98)

### 3.2.2.13 Recording the current and torque characteristics using a dynamometer

#### Fundamentals

This test should provide a conclusive statement regarding the acceleration performance of a machine. By comparing the motor characteristic and the expected load torque characteristic curve, the accelerating torque (excess torque) is determined. The excess torque is defined as the difference between the motor torque and the load torque of the driven machine. This can be used to verify correct acceleration of the entire machine unit.

## Test procedure

1. The motor is coupled with the dynamometer and a torque measuring shaft and is fed with the rated voltage at 50 / 60 Hz.
2. The dynamometer is controlled at various speeds between zero and synchronous speed. The torque generated by the motor and the current in the stator cable are measured at the various speeds.
   The acceleration characteristic is obtained from these measuring points.

If, for system-related reasons, the motor cannot be tested at the rated voltage, then the acceleration characteristic is recorded at the highest possible voltage, and then subsequently extrapolated to the rated voltage. The prerequisites in this case is that the starting torque test is carried out at the same voltage and is extrapolated up to the rated voltage.

The measured variables are documented in the measurement report and extrapolated up to the rated voltage. Current and torque with respect to the speed are entered in a diagram. The highest measured value in the torque characteristic corresponds to the breakdown torque, the lowest measured value, the pull-up torque.

## Alternatively: Test procedure according to IEEE 112

The torque-speed characteristic is the relationship between the torque and speed of the motor in the range from 0 speed up to synchronous speed. Starting torque and motor breakdown torque are determined from the diagram.

The torque-speed characteristic is determined from the speed change, as the torque available is proportional to the speed change.

## Result

The test has been successfully completed if the breakdown torque and the pull-up torque remain within the specified tolerance. The successful test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## See also

Recording the starting torque and current (Page 97)

### 3.2.2.14 Calculating the efficiency from the individual losses

#### Fundamentals

It is conducted in compliance with the following standards:

- IEC 60034-2-1: Individual loss method
- IEEE 112: Method B ($P_{LL}$ measured) or method E1 ($P_{LL}$ assumed)

---

**Note**

**Ordering options**

The following options for calculating the efficiency from the individual losses are required, and must be ordered in addition to F20/F21:

- Temperature-rise test under load (F04/F05)
- Recording the no-load characteristic and determining the iron (core) and no-load losses (F14/F15)
- Recording the load characteristic (F18/F19)

---

**Note**

The following text includes formula symbols and statements from IEC 60034-2-1. The definition of the symbols can be taken from this standard. As a result of the analogous approach, this description is also applicable for methods B and E1 from IEEE 112.

---

## Test procedure

1. The winding resistance of the cold motor is measured.
2. A temperature rise test under load is performed. The following variables are recorded at the end of the temperature-rise test under load:
   $P_N$, $I_N$, $U_N$, s, f, $\theta_c$, $\theta_N$, $R_N$

3. The load characteristic is recorded with the motor in a warm operating condition. The measurement starts with the highest load point and ends with the lowest. Variables U, I, $P_1$, R, n, f, T are recorded for each load point.
   – The resistance is measured before recording the first load point. This resistance is used for all load points.
   – The machine is loaded at six load points in the range from 25 % up to 150 % $P_N$.
     - Four load points, evenly distributed in the range between 25 % and 100 % $P_N$ are recorded.
     - Two load points are recorded at 110 % and at 125 % $P_N$.

   According to the standard, resistance R is measured at the highest load point and after the lowest load point.
   – As resistance for 100 % $P_N$ and higher load points, the value that was determined before the highest load point applies.
   – As resistance for load points below 100 % $P_N$, that value should apply, which was determined before the highest and after the lowest load point at 25 % $P_N$ under the assumption of a linear characteristic between these two points.
     Generally, the load test is quickly performed (<5 min). The low temperature change that occurs while recording the load characteristic plays a secondary role on the resistance. The low temperature change results from the high thermal time constant of SIMOTICS HV and SIMOTICS TN motors.
4. The motor is decoupled from the dynamometer.
5. The no-load characteristic is recorded with the motor in a warm operating condition.
   – Variables $U_0$, $I_0$, $P_0$ are measured at a constant frequency for eight voltage values in descending order in the range from 110 % down to 30 % $U_N$.
   – The no-load characteristic is generated by entering $P_k$ and $I_0$ with respect to $U_0^2$. Constant losses $P_k$ are described in the following.
6. The efficiency is calculated.

## Calculating the efficiency

The efficiency is defined as follows:

$$\eta = P_2 / P_1$$

The difference $P_1 - P_2$ is the total power loss $P_t$. The power loss $P_T$ is made up of the individual losses:

$$P_t = P_k + P_s + P_r + P_{LL}$$

These include constant losses ($P_k$), load-dependent stator winding losses ($P_s$), rotor winding losses ($P_r$), supplementary losses ($P_{LL}$).

### Constant losses $P_k$

The constant losses $P_k$ are the no-load losses, adjusted by the no-load winding losses ($P_{S0}$), with the winding resistance of the cold machine (R) and no-load current ($I_0$):

$$P_k = P_0 - P_{S0}$$

$$P_{s0} = 1.5 \cdot I_0^2 \cdot R$$

$P_k$ is the sum of the friction and windage losses ($P_{fw}$) and the iron losses ($P_{fe}$).

- The **friction losses** $P_{fw}$ are determined from the no-load characteristic by extrapolating the $P_k$ graph to voltage 0 V.

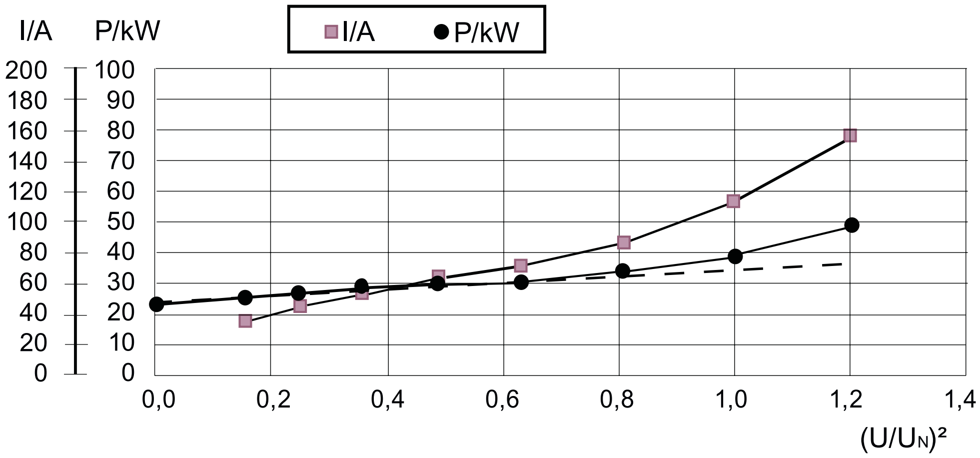



Figure 3-33 Determining the friction losses from the no-load characteristic

- The **iron losses** at the required load point are determined from the no-load characteristic at the voltage reduced by the ohmic voltage drop in the primary winding $U_i$:

$$P_{fe} = P_0 - P_{s0} - P_{fw}$$

$$U_i = \sqrt{\left(U - \frac{\sqrt{3}}{2} \cdot I \cdot R \cdot \cos\varphi\right)^2 + \left(\frac{\sqrt{3}}{2} I \cdot R \cdot \sin\varphi\right)^2}$$

### Load-dependent stator winding losses $P_s$

The stator winding losses, which are not corrected to the reference coolant temperature, are determined for each load point with the values for current I and winding resistance R associated with the specific load point.

$$P_s = 1.5 \cdot I^2 \cdot R$$

The temperature of the coolant is taken into account for each load point using factor $k_\theta$:

$$P_{s,\theta} = P_s \cdot k_\theta$$

$$k_\theta = (235 + \theta_w + 25 - \theta_c) / (235 + \theta_w)$$

### Rotor winding losses $P_r$

The rotor winding losses $P_r$, which are not corrected to the reference coolant temperature, are determined for each load point:

$$P_r = (P_1 - P_s - P_{fe}) \cdot s$$

The following equation is used to correct them to the reference coolant temperature:

$$P_{r,\theta} = (P_1 - P_{s,\theta} - P_{fe}) \cdot s_\theta$$

Here, $s_\theta = s \cdot k_\theta$ is the slip, corrected to a reference temperature of 25 °C.

### Load-dependent supplementary losses - $P_{LL}$ measured

The residual (secondary) losses $P_{Lr}$ are determined for every load point from the load characteristic according to the following equation:

$P_{Lr} = P_1 – P_2 - P_{S,\theta} - P_{r,\theta} - P_{fe} – P_{fw}$

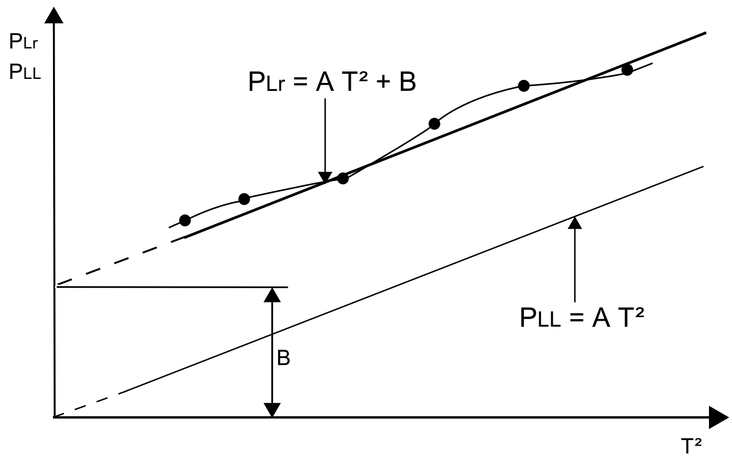
$P_2 = 2\pi \cdot T \cdot n$

The residual losses are entered over the square of the associated torque. An approximation function is applied through the points that have been determined:

$P_{Lr} = A \cdot T^2 + B$

By shifting this function in parallel through –B at the coordinate origin, a function is obtained to determine the load-dependent supplementary losses for each load point with torque M.

$P_{LL} = A \cdot T^2$




● Measured values

A Gradient

Figure 3-34 Smoothing the residual loss data

The correlation coefficient as measure of the linear interrelationship between residual losses at the particular load points must have the following absolute value:

| | |
|---|---|
| IEC 60034-2-1 | ≥0.95 |
| IEEE 112 method B | ≥0.9 |

**Load-dependent supplementary losses - $P_{LL}$ assumed**

The load-dependent supplementary losses $P_{LL}$ can be assumed. Depending on the rated motor power, according to IEC 60034-2-1, the supplementary losses are obtained from the following equations:

- For 1 kW < $P_2$ < 10 000 kW, $P_{LL}$ is = $P_1 \cdot$ [0.025 - 0.005 log 10 ($P_2$/1 kW)]
- For $P_2 \geq$ 10 000 kW, $P_{LL}$ is = $P_1 \cdot$ 0.005
- According to IEEE 112 Method E1, the assumed supplementary losses are listed in the following table as a function of the rated motor power:

| Motor rated power [kW] | Assumed supplementary losses [%] |
|---|---|
| 1 ... 90 | 1.8 |
| 91 ... 375 | 1.5 |
| 376 ... 1850 | 1.2 |
| 1851 and more | 0.9 |

## Result

The result is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.2.2.15 Calculation of moment of inertia using the coast-down method

**Fundamentals**

The moment of inertia is required to calculate dynamic processes, for example:

- Acceleration times
- Torque oscillations
- Surge torques of a machine or a machine set.

The speed is measured over time for the coast-down method.

## Test procedure

1. The machine is accelerated to approximately 110% of the rated speed by increasing the frequency or via a coupled drive machine and is then shut down.
2. As the machine coasts down, the speed is recorded over time.

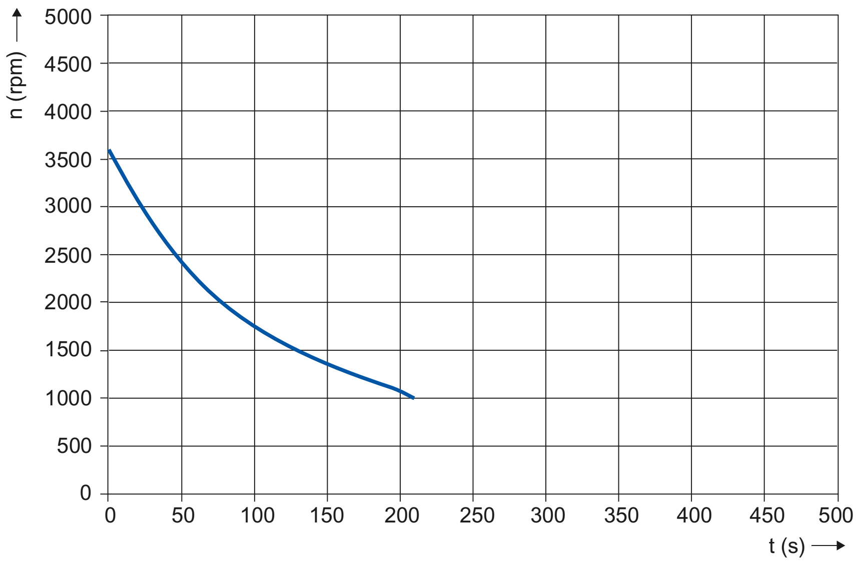



Figure 3-35 Example of a coast-down curve for speed over time

The moment of inertia is calculated based on the speed differentiation and the losses related to speed. The deceleration losses are calculated separately for the relevant speeds, usually at a no-load speed of $n_0$.

$$J = \frac{P_R(n_0)}{4 \cdot n_0} \cdot \left(\frac{60}{\pi}\right)^2 \cdot \frac{\Delta t}{\Delta n}$$

| | | |
|---|---|---|
| $J$ | = | Moment of inertia |
| $P_R$ $(n_0)$ | = | Friction losses at no-load speed |
| $n_0$ | = | No-load speed |

When coasting down with a coupled drive machine, the motor's moment of inertia is calculated by subtracting the moment of inertia from the drive machine.

## Result

The test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## See also

Recording the no-load characteristic and calculating losses separately (Page 92)

### 3.2.2.16 Sealed Winding Conformance Test

**Fundamentals**

- API 4th edition: 4.3.4.4
- API 5th edition: 6.3.4.4

Checking the winding insulation corresponds to the subsequently described "Testing the winding insulation (Page 105)".

### 3.2.2.17 Testing the winding insulation

**Fundamentals**

A rugged winding insulation with respect to humidity and moisture guarantees safe and reliable machine operation at the appropriate ambient conditions. Water with low surface tension is used to verify that the insulation is sealed according to NEMA MG1-2003, Part 20.18.2. As a result of their size, the stator laminated cores with winding are sprayed with water and are not completely immersed in water.

**Test equipment**

- Insulation resistance measuring instrument (500 V test voltage)
- High-voltage test instrument (AC, 50 Hz)

### Test procedure

1. The insulation resistance of the winding is measured at a voltage of 500 V. It is not permissible that the insulation resistance falls below 1500 MΩ.
2. The winding, especially the winding overhangs, are sprayed with water for 30 min. The water properties are adjusted to obtain a surface tension of 31 x $10^3$ mN/m.

Figure 3-36 Spraying the winding

3. The insulation resistance is measured for 10 minutes at a voltage of 500 V immediately after spraying. The minimum insulation resistance in MΩ must reach $5 \cdot U_N + 5$ ($U_N$ in kV).
4. The winding that is still wet is subject to an AC voltage test with $1.15 \cdot U_N$ for 1 min.
5. The insulation resistance is measured again for 1 min. The minimum insulation resistance in MΩ is also $5 \cdot U_N + 5$.
6. The stator laminated core with winding is cleaned and dried before it is used further.

### Result

The test has been successfully completed if the insulation resistance reaches the minimum values - and the AC test voltage is maintained during the test duration of 1 min.

All test results are recorded in a test certificate. The successful test is confirmed in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

## 3.2.3 Material Inspection

#### Fundamentals

- API 4th edition: 4.2.2
- API 5th edition: 6.2.2

The aim of the material inspections is the detection of material faults, such as cavities, cracks, pores, inclusions, etc – and to document the material quality. Material inspections are completed during production or are part of the incoming goods inspection.

The material inspections are completed on fully machined parts following the last relevant heat treatment for the material properties. Normally, the shaft or, for example, the weld joints on the the bar shaft are tested.

The test personnel are to be certified according to EN 473 to at least Level 1, the test supervision personnel to at least Level 2.

## See also

Radiographic Test Parts (Page 107)

Ultrasonic Test (Page 108)

Magnetic Particle Test Parts (Page 111)

Liquid Penetrant Test Parts (Page 112)

### 3.2.3.1 Radiographic Test Parts

#### Fundamentals

- API 4th edition: 4.2.2.2
- API 5th edition: 6.2.2.2
- ISO 5579 or EN 444 in test Class B. EN 12681 is applicable for radiographic testing of cast parts.

The permissible limits are specified in the drawing or in the test plan.

The X-ray test identifies internal flaws in the component that are not permissible. The test is carried out after the last heat treatment that is key to the material properties. The surfaces of the components to be checked must be free of impurities.

The number and size of the permissible faults within the respective acceptance levels to be observed - also "Quality levels" or "Quality classes" - are described as follows:

- Cast parts:
  - ASTM E 446 for cast steel
  - ASTM E 155 for aluminum and magnesium-cast parts
- Welded constructions:
  - ISO 6520-1 to classify any irregularities
  - ISO 5817 for appraisal groups for the irregularities
- Forged parts: Based on ASTM E 446

#### Test equipment

The following and additional test equipment can be used:

- X-ray device Isovolt 320 from the company Seifert. Voltage class 320 kV, max. ray flow 13 mA, focal spot 2 $mm^2$
- Microfocus rod anodeXWT-225-RAC made by X-RAY WorX GmbH voltage class 225 kV, max. tube current 1 mA, focused spot < 6 µm
- X-ray films in film classes C3 or C4 according to EN 584-1 with lead reinforcement films, i.e. front and back film, each with 0.02 mm lead
  The required image quality of the x-rays is to be documented with image quality test specimens to EN 462-1 to -5. The radiograph density is in the range that can be analyzed for test class A ≥ 2.0 and test class B ≥ 2.3.

### Test procedure

1. Each film is uniquely identified by lead numbers.
2. The film location on the component, if necessary, is added as a film location plan to the test report to enable a precise reconstruction of the images.
   - Overlapping zones are marked by attaching lead points.
   - X-rays after completed repairs are also marked with "R".
3. The components are x-rayed.

### Result

If requested, a test report in accordance with EN 444 is produced for each performed test.

## 3.2.3.2 Ultrasonic Test

#### Fundamentals

- API 4th edition: 4.2.2.3
- API 5th edition: 6.2.2.3.2

The ultrasonic test identifies internal flaws in the component that are not permissible.

A suitable coupling device is used for all ultrasonic tests. Distance and sensitivity adjustment, and the testing sequence are completed with the same coupling aid. The distance and sensitivity adjustment is carried out in accordance with EN 583-2. Displays that require registration must cover 20% of the height of the screen.

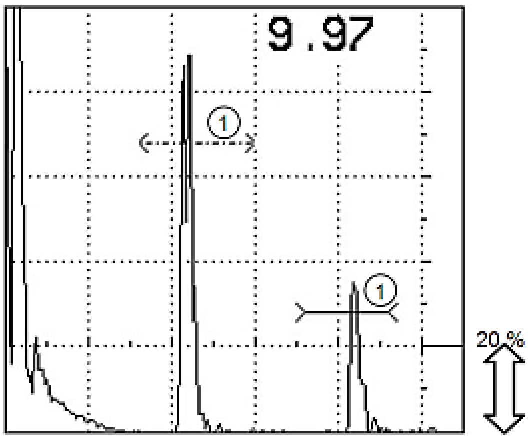



Figure 3-37 Example: Ultrasonic display in an A screen with flaw echoes ①

#### Test equipment

The test is carried out with test equipment in accordance with EN 12668-1 to -3.

The probes are selected depending on the material and diameter of the shaft blanks. The following ultrasonic probes are used:

Table 3-6 Ultrasonic probes

| Probe | Angle | Frequency | Diameter of the transducer |
|---|---|---|---|
| Vertical probe | 0° | 2 MHz | 10 mm or 24 mm |
| Vertical probe | 0° | 4 MHz | 10 mm or 24 mm |
| Vertical probes with separate transmitter and receiver (SE test probes) | 0° | 2 MHz | 10 mm or 24 mm |

### Result

A test report in accordance with EN 583-1 is created for each of the ultrasonic tests subsequently described.

### Ultrasonic test of rolled or forged shaft blanks

#### Fundamentals

The ultrasonic test is carried out according to EN 10308 and EN 10228-3. The test is performed on the shaft blank after the last heat treatment relevant for the material properties. The surface of the shaft blank must be free of scale; the quality of the surface must comply with the quality grade 3 according to EN 10228-3.

The DGS method is completed on the specimen, as part of the sensitivity adjustment. DGS means: D = distance, G = gain, S = replacement reflector size.

For this purpose, the provided DGS diagrams for the appropriate probes are used. A DGS diagram shows the echo amplitudes of the so-called circular disk reflectors of various diameters and of a large plane reflector (rear panel) as function of the distance.

## Test procedure

The test is carried out using the manual pulse-echo contact technique. During this process, the sample rate must not exceed 150 mm/s.

100% of the peripheral surface is checked, whereby the test paths overlap by at least 10% of the effective diameter of the probe. When scanning at only 180°, the same test area is also checked with a TR probe to record areas near the surface.

The registration limit corresponds to the permissible limit. The permissible limits apply to individual punctiform discontinuities and grouped discontinuities. Extended discontinuities are not permissible.

Table 3-7 Permissible limit depending on the shaft diameter

| Shaft diameter | Permissible limit |
|---|---|
| ≤ 150 mm | Flat bottom hole FBH = 2 mm |
| > 150 mm | Flat bottom hole FBH = 3 mm |

## Ultrasonic test of welded products

### Fundamentals

The ultrasonic testing of weld joints is carried out in accordance with ISO 17640. The test category is selected in accordance with the evaluation group specified in the drawing or the test plan according to ISO 5817.

## Test procedure

The test is carried out using the manual pulse-echo contact technique. During this process, the sample rate must not exceed 150 mm/s.

The permissible limits must be observed in accordance with ISO 11666.

Table 3-8 Permissible limit depending on the shaft diameter

| Shaft diameter | Permissible limit |
|---|---|
| ≤ 150 mm | Flat bottom hole FBH = 2 mm |
| > 150 mm | Flat bottom hole FBH = 3 mm |

## Ultrasonic testing of cast parts

### Fundamentals

The ultrasonic testing of cast parts is carried out in accordance with the following standards:

- EN 12680-1 for steel cast parts for general use
- EN 12680-2 for steel cast parts for highly stressed parts and components
- EN 12680-3 for castings made of cast iron with nodular graphite

The applicable quality grades are specified in the drawing or the test plan.

### Test procedure

1. The test is carried out using the manual pulse-echo contact technique. During this process, the sample rate must not exceed 150 mm/s.
   The applicable registration and permissible limits must be observed in accordance with EN 10228-3.

## 3.2.3.3 Magnetic Particle Test Parts

#### Fundamentals

- API 4th edition: 4.2.2.4
- API 5th edition: 6.2.2.4

The magnetic particle test is carried out according to ISO 9934-1 bis -3. EN 1369 applies to the magnetic particle test on ferromagnetic iron and steel cast parts.

The test identifies all possible inhomogeneities in the material. Combined magnetization is used to verify the inhomogeneities in all directions. The bare load locations of the cast iron enclosure are tested.

---

**Note**

Non-ferromagnetic layers up to 50 µm, such as non-destroyed, flat fixed color layers, do not influence the sensitivity of detection. The sensitivity of detection is verified for thicker layers.

---

The number and size of the permissible material faults within the respective acceptance levels to be observed - also "Quality levels" or "Quality classes" - are described as follows:

- Forged parts: EN 10228-1
- Welded constructions: ISO 23278
- Cast parts: Based on EN 10228-1

| Type | Damage | Quality class |
|---|---|---|
| I | Material separations | 1 |
| II | Shrinkage | 2 |
| III | Inclusions | 2 |
| IV | Scales and peeling | 1 |
| V | Porosity | 1 |
| VI | Welds | 1 |

#### Test equipment

The test solution used meets the requirements of ISO 9934-2. The test solution is a suspension made from fluorescent particles in a carrier liquid.

## Test procedure

Before starting the test, the entire test system is checked.

1. The surface is cleaned.
2. The test solution is applied before and during the magnetization of the component. The application of the test solution is terminated before switching off the magnetization.
3. The result is assessed. The evaluation conditions fulfill the requirements according to ISO 3059. All indications that cannot be clearly identified as false indications are classified and registered according to the requirements of the product standard:
   - Line-shaped: Length is greater than three times the width
   - Round: Length is equal to or less than three times the width
4. If agreed, the test specimen is demagnetized after the check, so that the agreed remaining field strength is reached. The parts are cleaned and anticorrosion protection applied.

## Result

The permissible limits are specified in the drawing or in the test plan. A report is to be produced for each test carried out pursuant to EN 9934-1 in German / English, if requested.

### 3.2.3.4 Liquid Penetrant Test Parts

#### Fundamentals

- API 4th edition: 4.2.2.5
- API 5th edition: 6.2.2.5
- ISO 3452-2 to -6 and EN 571-1

The liquid penetrant test identifies external flaws in the component surface for solid and spider shafts etc., which are not permissible. The test is carried out after the last heat treatment - that is key to the material properties - at the machined part. The surfaces must be of a condition that corresponds to the test purpose. They must be free of scale, spatter or other loose dirt. Scoring, scars, etc. that adversely affect the test result are not permissible.

The number and size of the permissible markingswithin the respective acceptance levels to be observed - also "Quality levels" or "Quality classes" - are described as follows:

- Forged parts: EN 10228-3
- Cast parts: EN 1371-1
- Welded constructions: ISO 23277

#### Test equipment

- Test equipment system II A d according to EN 571-1 1
- A fine-granular powder (chalk) in suspended solvents is used as developer. The capillary action in the own cavities causes the developer to remove the remaining penetrant from the fine cracks or cavities. This procedure is designated as developing an error display, in short, display.

### Test procedure

1. The test area is cleaned. It must be dry, clean and free of oil, grease and other any dirt.
2. The penetrant is applied by spraying, painting or dipping. The temperature of the test surfaces lies in the range between 5 °C to 50 °C.
   The penetration duration is 30 min. During this time it is ensured that the penetrant does not dry.
3. The penetrant is removed by rinsing, spraying or wiping with water. Sharp spraying is not permitted. Warm water may be used as long as the water temperature is not higher than 50° C.
4. Immediately after intermediate cleaning, the test surfaces are dried.
5. The developers are applied evenly by spraying immediately after drying. The test surfaces are kept vertical where possible; they are then covered evenly with developer.
   The development term matches the penetration term of 30 min. In exceptional cases, the development term may also be extended.
6. The result is evaluated after the developer has been applied or after it has dried. The relevant assessment of the displays for the evaluation is performed after expiration of the development duration.
7. After the last evaluation, the tested part must be cleaned if residues from the test equipment could impair its further use.

### Result

The permissible limits are specified in the drawing or in the test plan. A test report in accordance with EN 571-1 is created for each performed test.

## 3.2.4 Other tests

### 3.2.4.1 Coordination Meeting

#### Fundamentals

- API 5th edition 8.2

At the kickoff meeting ("Coordination Meeting") based on the confirmed ordering data, the implementation of all order-related components is discussed and checked. The date represents a hold point for the start of production.

#### Preconditions

- The order must have been entered into the factory.
- The technical clarification must have been completed. Only then can a date be defined for the kickoff meeting.

The group of participants is restricted as follows:

- Siemens customer, representative from the region and possibly representatives from additional partners in the supply chain (representatives from "Engineering, Procurement and Construction" (EPC), third party, end user)
- Internal Siemens engineering
- Manufacturer of the converter system

## Workflow

The following topics can be discussed:

- The region places an order with the factory, contact person in the factory, area of responsibility, responsibilities, documents and purchased parts, communication paths
- Required contractual data and data sheets according to API 541
- Factory data: Order number of the region, order number of the factory, order number of the motor (MLFB) - or where relevant - the TAG number of the motor
- Spare parts with the associated order numbers, list of recommended spare parts → Manual
- Comments and deviations to API 541 and project
- Speed-torque characteristic and moment of inertia of rotating parts → electrical documentation
- Schedule for transferring data for the production workflow, testing and shipping
- Production schedule, if one of the options B43, B44 or B45 was ordered.
- Quality management manual, ISO 9001 certification
- Operating conditions and corresponding restrictions relating to the motor → electrical and mechanical documentation
- Instrumentation, operating elements and additional motor interfaces → Information about the machine dimension drawing
- Applications, performance, operating parameters, piping and instrument flowchart for auxiliary systems → information on the machine dimension drawing
- Identification of components, which require a design review. It is possible that only certain information is available at this point in time, e.g. shaft design, motor dimension drawing, information about the machine dimension drawing, position data, geometry
- Inspection, test procedures and the appropriate acceptance criteria
- Additional technical points. The basis is the electrical and mechanical technical documentation and/or the machine manual and the test description.

### 3.2.4.2 "Design Review"

#### Fundamentals

- API 4th edition: 6.2.1.4
- API 5th edition: 8.4

Based on the confirmed ordering data, after the electrical and mechanical engineering process, an internal design review is carried out where the use of new order-related components is checked.

### 3.2.4.3 Submit Test Procedures 6 Weeks Before Tests

**Fundamentals**

- API 4th edition: 4.3.1.5
- API 5th edition: 6.3.1.4

Six weeks before the final electrical test, the customer receives an order-specific description of the tests that are conducted as standard for this motor and possible optional tests – and a function test plan if tests are to be conducted.

**List of documents and information**

The documents referred to in the following are supplied only when they are part of the contract or explicitly ordered.

1. Type of the test (electrical or mechanical)
2. Sequence of the tests
3. Schedule of the test sequence
4. Contractually agreed values:
   – Temperature rise
   – Vibration
   – Critical speeds
   – Efficiency
   – Noise
5. Alarm and trip values
6. For converter-supplied motors:
   – Base frequency at which the test is completed
   – Harmonic content
7. List of the measuring equipment used

---

**Note**

**Customer information**

Some of the content is dependent on information that the customer must provide, such as the coupling drawing for the lateral analysis. The test description can only be transferred in full when all of the content is available.

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**Note**

Empty test report forms are not handed out in advance.

---

**Additional documents**

- List of test measuring instruments and calibration process as separate document.
  The customer receives a list including the measuring device, type, and manufacturer, additional information at the time of the next calibration and registration number.

**Can be ordered separately**

Depending on the order, the customer will also receive the following:

- Rotor-dynamic calculations
  For these calculations, the customer must provide a drawing of the coupling on time.
- Drawings and parts lists for the spare parts list (option B38)
  A spare parts recommendation is only provided if it is specifically ordered.
- Calibration certificates for the measuring instruments at the machine.
  All of the existing data sheets, test certificates or calibration reports are sent to the customer assuming that they are available at the time.
  The operating instructions or the collection of certificates created after the delivery contains all of the documents. If information is required in the meantime, this is agreed with the customer.

### 3.2.4.4 Shop Inspection

**Fundamentals**

- API 4th edition: 4.1.1
- API 5th edition: -

With the shop inspection, customers have the opportunity of obtaining a general overview of the most important production areas.

---

**Note**

This preinspection does **not** constitute a witness test or a holding point in production. The customer cannot ask for production to be stopped following a pre-inspection.

If the customer requests order-related information or supplements to be taken into consideration, their feasibility will be checked. The customer will be informed about the result of this verification.

---

**Workflow**

Once the order has been clarified technically, the customer is invited to complete a general pre-inspection of the coil winding workshop, assembly and system test facility or test field. Other production areas are not included in the scope of the pre-inspection.

### 3.2.4.5 Demonstrate Accuracy of Test Equipment

#### Fundamentals

- API 4th edition: 4.3.1.14
- API 5th edition: 6.3.1.15

The customer receives full proof of the test configuration accuracy based on the calibration certificates.

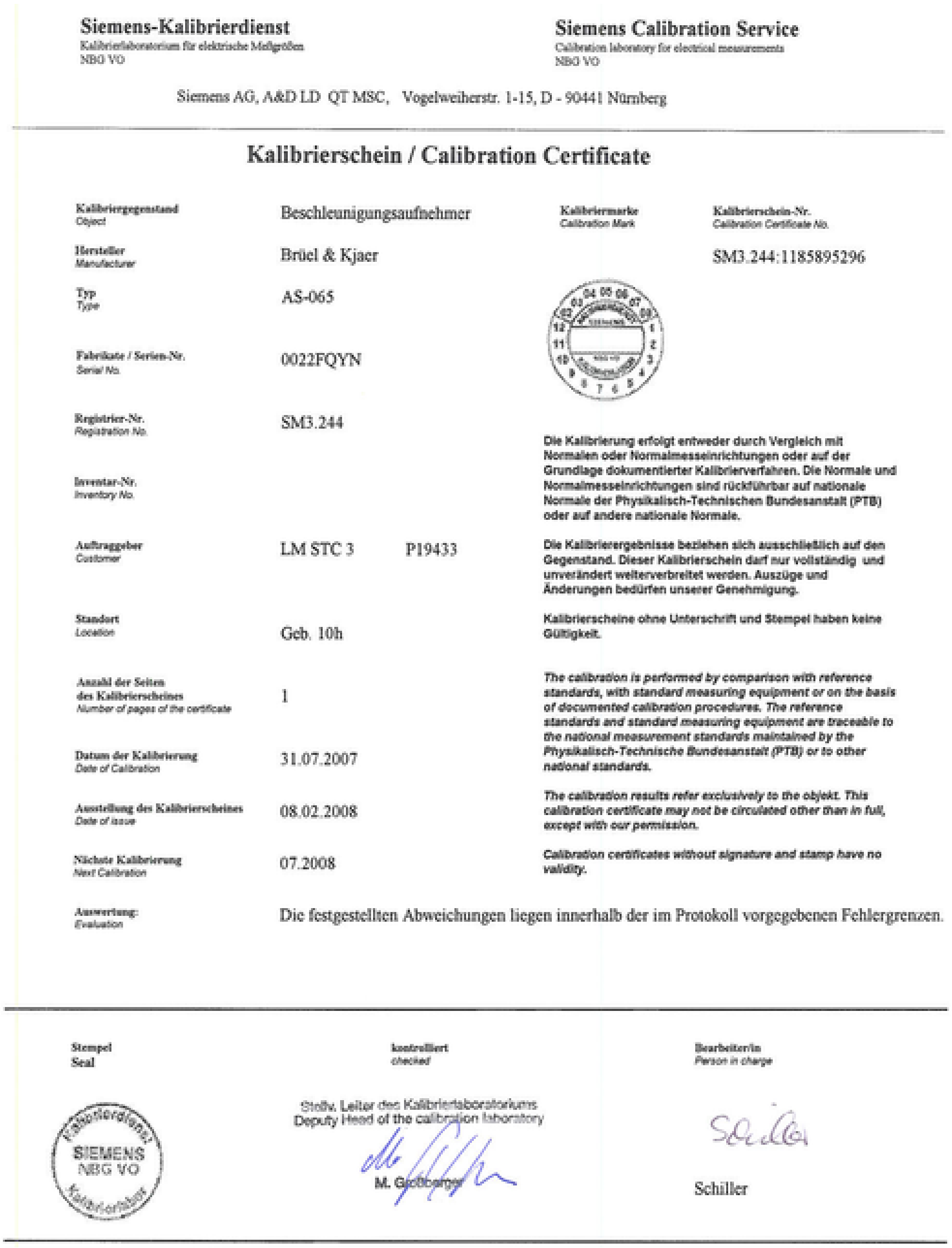
#### Calibration certificate

Each calibration certificate describes the calibration item, calibration procedure, measurement uncertainties and ambient conditions.

#### Calibration process

The calibration process is documented by the following specifications:

- Measuring range
- Condition
- Setpoint
- Actual value
- Permissible deviations
- Measurement uncertainty
- Evaluation of the measurement



**Siemens-Kalibrierdienst**
Kalibrierlaboratorium für elektrische Meßgrößen
NBG VO

**Siemens Calibration Service**
Calibration laboratory for electrical measurements
NBG VO

Siemens AG, A&D LD QT MSC, Vogelweiherstr. 1-15, D - 90441 Nürnberg

**Kalibrierschein / Calibration Certificate**

| | |
|---|---|
| Kalibriergegenstand / Object | Beschleunigungsaufnehmer |
| Hersteller / Manufacturer | Brüel & Kjaer |
| Typ / Type | AS-065 |
| Fabrikate / Serien-Nr. / Serial No. | 0022FQYN |
| Registrier-Nr. / Registration No. | SM3.244 |
| Inventar-Nr. / Inventory No. | |
| Auftraggeber / Customer | LM STC 3 P19433 |
| Standort / Location | Geb. 10h |
| Anzahl der Seiten des Kalibrierscheines / Number of pages of the certificate | 1 |
| Datum der Kalibrierung / Date of Calibration | 31.07.2007 |
| Ausstellung des Kalibrierscheines / Date of issue | 08.02.2008 |
| Nächste Kalibrierung / Next Calibration | 07.2008 |
| Auswertung: / Evaluation | Die festgestellten Abweichungen liegen innerhalb der im Protokoll vorgegebenen Fehlergrenzen. |

Kalibriermarke / Calibration Mark

Kalibrierschein-Nr. / Calibration Certificate No.
SM3.244:1185895296

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Deputy Head of the calibration laboratory
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Figure 3-38 Example of a calibration certificate

### 3.2.4.6 Stator Inspection Prior to VPI

#### Fundamentals

- API 4th edition: 4.3.4.5
- API 5th edition: 6.3.4.5

Prior to impregnation, a visual acceptance of the winding that is fully inserted and connected in the laminated stator core is carried out.

## Result

The certificate can also include the data and results from the preliminary test, i.e. visual inspection, dimensional check, electrical testing. The test result is documented in a 3.1 certificate – or in the case that the customer has ordered the acceptance test, in a 3.2 certificate.

### 3.2.4.7 Sound pressure level test

**Fundamentals**

Unless other customer requirements apply, the noise measurement is performed on the basis of ANSI/NEMA MG-1 Part 9 in accordance with ISO 3744 and ISO 1680. The measurement is performed in accordance with accuracy class 2.

The measurement verifies that possibly applicable limit values are complied with.

---

**Note**

**Limit values**

The limit values from the respective catalog serve as reference values for evaluating the noise measurement. In the event of unexpected individual noises, such as magnetic sounds, sirens, etc., an additional noise analysis can be performed.

---

Further, it may be necessary to make modifications at the motor for example, to check the effect of the changes regarding the noise emission. The noise measurement is performed in the following situations:

- When required by the customer or purchaser
- For new motors as part of the type test

In order to clarify the causes of noise, especially of individual tones, additional frequency analyses can be carried out.

**Test equipment**

- Measuring systems in accordance with ISO 3744 based on IEC 61672-1:2002 Class 1 with valid calibration are used
- A "wind shield" manufactured out of foam is used in front of the microphone. This stops noises from the draft falsifying the measurement result.

## Measuring procedure

The noise measurement is performed in no-load operation at the rated voltage and rated frequency. The thermal state the machine is not relevant. The sound pressure level is calculated on an A-weighted basis.

1. The sound pressure level of the machine noise is recorded at each measuring point.
2. Every measured sound pressure level is corrected by applying correction factors $K_1$ (external noise) and $K_2$ (to take into account the acoustic profile of the room).
   The noise levels can also be measured in an acoustic measuring chamber. In this case, the correction factor for external noise is not applied.

3. The corrected sound pressure levels are averaged, resulting in the measuring-surface sound pressure level.
4. The **sound power level** $L_{WA}$ is calculated from the following relationship:
   $L_{WA} = \overline{L}_{pfA} + 10 \log (S/1m^2)$
   $L_{WA}$ = A-weighted sound power level
   $\overline{L}_{pfA}$ = A-weighted measuring-surface sound-pressure level
   S = measuring surface in $m^2$

## Result

The measurement report contains the following data:

- Motor dimensions
- Position and the number of measuring points according to the motor dimensions
- Measuring conditions, such as used measuring equipment and where relevant, external noise
- Background noise correction value
- Measuring-surface sound-pressure level
- Measuring-surface sound-power level

### 3.2.4.8 Noise analysis

**Fundamentals**

A noise analysis can be performed at the request of the customer or if unexpected individual noises occur, such as magnetic sounds, sirens, etc.

The noise analysis is performed even if a third octave or octave spectrum of the machine noise is required. Based on a third octave or octave spectrum, for example, active or passive noise reduction measures can be applied.

## Test procedure

1. Octave and third-octave frequency spectrums recorded on the measuring path 1. The number of measuring points depends on the machine size and the radiation characteristics. If the frequency spectrum is only measured at one measuring point, then a point is selected where the average sound pressure level exists.
2. Additional external noise profiles can be measured depending on the equipment available in the test field.
   – If the external noise over the complete third-octave medium-frequency range has **> 15 dB distance** to the A-weighted measured values, the external noise is measured only at a representative measuring point; $K_1$ = 0 dB.
   – If the external noise over the complete third-octave medium-frequency range has **< 15 dB distance** to the A-weighted measured values, the external noise is measured at every measuring point.

### Result

The results are provided in different forms depending on the particular factory:

- In Ruhstorf, the report includes the measured measuring-surface sound pressure level in the octave spectrum $f_{Octave}$ in a graphic form.
- In Nuremberg, the report contains the measured measuring-surface sound-pressure levels and measuring-surface sound-power levels in the third-octave spectrum $f_{third\text{-}octave}$ in tabular and graphic form.

As documentation of the test result, a 3.1 certificate is issued, or for acceptance tests witnessed by the customer, a 3.2 certificate is issued.

### See also

Sound pressure level test (Page 119)

## 3.2.4.9 Function test at the test field converter

For this test, the motor is tested together with the test field converter.

- High-voltage motors connected to SINAMICS Perfect Harmony GH180
- Low-voltage motors connected to SINAMICS S120

### Basic scope of the function test

1. Measuring the resistance of the stator winding (Page 35) when cold
2. Temperature rise test at the rated operating point
3. Measuring the resistance of the stator winding when warm
4. Load test (Page 95) at four operating points (speed, torque)

### Load points

1. Temperature rise test under load
2. The following parameters are measured at different speeds at each load point:
   – Converter output frequency
   – Motor current, motor voltage
   – Motor speed
   – Torque and power at the motor shaft

### Motor high-voltage test

A motor high-voltage test is already part of the test; however, it can be repeated as part of the system test.

### Visual inspection

- Visual inspection of motor

### Noise measurement at the motor

The noise is only measured with option F28/F29 or F62/F63.

1. The motor is operated at the converter and at rated speed without any load.
2. The sound pressure level of the machine is recorded at defined measuring points. The sound pressure level is calculated on an A-weighted basis.

### Vibration test at the motor

1. The motor is operated at the converter and at rated speed without any load.
2. The vibration velocities are measured for the rated voltage and frequency at the bearing housing.
3. For journal bearings, the shaft vibration is also measured if the appropriate transducer is mounted.

### See also

Component test (Page 32)

Time required (Page 33)

## 3.2.4.10 Certified data prior to shipment

#### Basis

- API 5th edition 8.6.2a

After the motor has been produced and tested, the manufacturer provides all of the agreed certificates ("Certified data prior to shipment"). Depending on the archiving guidelines, every document is archived for a specific time.

A separate meeting can be arranged for requirements relating to packaging and shipping, where details can be discussed and agreed on.

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