



AEROSPACE RECOMMENDED PRACTICE

ARP4050™**REV. A**

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Superseding ARP4050

(R) Balancing Machines - Description and Evaluation Vertical, Two-Plane,
Hard-Bearing Type for Gas Turbine Rotors

RATIONALE

SAE Document ARP4050 is being revised from current to update references to other documents, incorporate verbiage that permits the use of new and proven computer-based technology, and potentially amend references to machine classification, particularly to eliminate Class 25 vertical balancing machines from inclusion in this document. The proposed changes serve to refresh and update ARP4050 to reflect how this document is currently used within the Aerospace Industry.

ARP4050A has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE

- 1.1 Characteristics of vertical hard-bearing balancing machines are described which make such machines suitable for gas turbine rotor balancing.
- 1.2 This document specifies the following:
 - a. General dimensions and capacities
 - b. Performance requirements
 - c. Balancing speed ranges
 - d. Drive power requirements
 - e. Balancing machine spindle flange dimensions
 - f. Test procedures
- 1.3 Proving rotors and associated test masses required for the performance tests are described in ARP4162.
- 1.4 Test procedures are described in detail and test log samples along with a polar diagram for evaluating the test results are furnished.
- 1.5 The predecessor documents ARP588, ISO 2953, and the available technology of hard-bearing balancing machines have been considered in the preparation of this document.
- 1.6 This document was developed for hard-bearing balancing machines but may also be used for existing soft-bearing balancing machines.
- 1.7 Purpose

The purpose of this document is to delineate the technical specifications for vertical, rotating type, hard-bearing balancing machines for measuring the amount and angle of unbalance corrections required in one or more transverse planes to balance gas turbine rotors. (For Glossary of Terms and Nomenclature, see ISO 1925.)

Hard-bearing machines have been used for gas turbine rotor balancing for several years. They have largely replaced soft-bearing machines. Hard-bearing machines provide permanent calibration (see ISO 1925) with first-run readout, simpler operation, easy adaptation to computerization, and eliminate support locking requirements and windage fluctuations.

This document also delineates performance tests to ensure compliance with the document.

This document was prepared to give a general description of balancing equipment capable of balancing gas turbine rotors either now in service or to be put into service in the foreseeable future. Standardization of balancing machine to rotor interfaces is intended to enable a set of tooling for a particular component to be used on a variety of machines in one capacity range.

This document may also be used as a general specification for purchasers in procuring suitable vertical two-plane balancing machines.

The performance and test requirements may be used for periodic tests and/or after repairs that may have affected the balancing machine's performance. The test procedure shall be the same as described in this document.

The performance and test requirements have been written in terms of "e_{mar}" (minimum achievable residual specific unbalance), and A-units rather than fixed physical values, such as grams, millimeters, ounces, or inches (see ISO 1925).

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

The references give some earlier balancing equipment specifications and background information on topics allied to this document.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP588	Balancing Machines - Description and Evaluation Vertical, Single-Plane, Soft-Bearing Type for Gas Turbine Rotors
ARP1382	Design Criteria for Balancing Machine Tooling
ARP4048	Balancing Machines - Description and Evaluation Horizontal, Two-Plane, Hard-Bearing Type for Gas Turbine Rotors
ARP4162	Balancing Machine Proving Rotors
ARP4163	Balancing Machines: Tooling Design Criteria
ARP5323	Balancing Machines - Description and Evaluation Vertical, Single-Plane, Hard-Bearing Type for Gas Turbine Rotors

2.2 ANSI Publications

Copies of these documents are available online at <http://webstore.ansi.org>.

ISO 1925:2001	Mechanical Vibration – Balancing - Vocabulary
ISO 21940-21:2012	Mechanical Vibration - Rotor Balancing - Part 21: Description and evaluation of balancing machines
ISO 21940-23:2012	Mechanical Vibration - Rotor Balancing - Part 23: Enclosure and other protective measures for the measuring station of balancing machines

3. GENERAL PERFORMANCE REQUIREMENTS

3.1 Plane Separation

The balancing machine shall indicate the amount and angle of the unbalance in each of one or more selected planes in the rotor.

3.2 Static and Couple Unbalance Separation

The balancing machine shall indicate, for the selected planes in the rotor, the amount and angular location of the static unbalance and couple unbalance.

3.3 Unbalance Indication

- 3.3.1 Digital devices indicating amount of unbalance shall have a resolution of at least 10% of one A-unit.
- 3.3.2 The angle resolution shall be at least 1°.
- 3.3.3 The amount and angle indication shall be simultaneous in two planes.
- 3.3.4 The amount and angle readout shall be provided on the first spin up of the rotor.
- 3.3.5 The radius setting shall be selectable, with a minimum of 1 inch or, alternatively, of 10 mm.
- 3.3.6 Amount indication shall be available in metric and/or English units (grams, ounces, and fractions thereof).
- 3.3.7 Unbalance indication shall be available for clockwise and counterclockwise direction of rotation.

3.4 Balancing Machine Construction

- 3.4.1 The machine must be constructed for floor mounting. The supporting floor / foundation must be rigid, in accordance with machine manufacturer recommendations.
- 3.4.2 An appropriate size of shroud must be interlocked for operator safety.
- 3.4.3 The machine must be equipped with the appropriate spindle mounting flange as specified in Appendix A.

3.5 Drive for Workpiece

- 3.5.1 The drive system shall include all components necessary to drive the proving rotor.
- 3.5.2 The drive system shall be functional in both directions of rotation.

3.6 Speed of Rotation during Balancing

The machine shall be capable of operating at variable speeds within the range shown in Table 1, section 4.5.2.

3.7 Drive Motor and Controls

The machine shall be capable, within the agreed upon time period, of making six consecutive starts and stops to the balancing speed of the rotor requiring the most drive power.

4. DIMENSIONS AND CAPACITIES

Table 1 lists the required dimensions and capacities for each machine size and associated proving rotor.

Table 1

Characteristics		Dimensions and Capacities				
4.1	Machine Class	50	100	250	500	1000
4.2	Load Capacity (lb)					
4.2.1	Maximum ¹⁾	50	100	250	500	1000
4.2.2	Minimum ²⁾	2	4	10	20	50
4.2.3	Maximum $W \cdot h^2 \cdot n^{23}$ (lb-ft ² x rpm ² x 10 ⁶)	32	45	140	325	400
	(kgm ² x rpm ² x 10 ⁶)	1.4	2.0	6.0	14	17
4.3	Rotor Dimensions (inch)					
4.3.1	Maximum diameter	24	39	57	70	82
4.3.2	Maximum height at maximum diameter	10	10	20	20	24
4.3.3	Rotor envelope	See Appendix A	See Appendix A	See Appendix A	See Appendix A	See Appendix A
4.3.4	Spindle flange (Figure)	A3	A3	A3	A3	A4
4.4	Unbalance Measurement (Microinch)					
4.4.1	Required e_{mar} (equal to 1 A-unit)	30	30	50	50	50
4.4.2	Required URR	95%	95%	95%	95%	95%
4.5	Drive and Balancing Speeds					
4.5.1	Drive power (hp) ⁴⁾	2	5.0	7.5	10	15
4.5.2	Balancing speed range (rpm)	750 1500	600 1200	600 1100	600 1100	400 900
4.5.3	Test speed range (rpm)	900 1300	800 1100	800 1000	800 1000	600 900
4.6	Proving rotors (see ARP4162 for details)					
4.6.1	Mass (lb)	25	25	80	250	250
4.6.2	Interface dia. (inch)	4.5	4.5	4.5	4.5	4.5

Table 1 (continued)

-
- 1) Total mass (rotor and tooling), mounted to machine spindle.
 - 2) Approximate guideline. Minimum rotor limits are generally governed by the spindle flange dimensions and the required e_{mar} .
 - 3) The maximum Wh^2n^2 value, specified by the machine manufacturer, should have the stated capacity as a minimum requirement.
 W = Rotor + tooling mass, expressed in pounds (kilograms).
 $h = h_1 + h_2$, where h_1 is the height from the spindle flange to the rotor + tooling mass center, expressed in feet (meters) and h_2 is an assumed machine constant of 0.33 feet (0.1 m).
 n = Balancing speed (test speed) in rpm.
 If the balancing speed is given in units of 1/min, the units of the equation are lb-ft²/min² (kgm²/min²).
 - 4) Approximate guideline. The user should specify to the supplier the horsepower requirements at specific balancing speeds.
-

5. VERIFICATION TESTS

5.1 Requirements for Tests

To verify the claimed performance of a balancing machine, separate tests are required. The first test is for minimum achievable residual specific unbalance (e_{mar} test), and the second is the test for unbalance reduction ratio (URR test). These tests represent a minimum test procedure designed to establish essential compliance with the requirements for minimum achievable residual unbalance and for combined accuracy of amount of unbalance indication, angle indication, and plane separation. The test procedure will not prove compliance with all requirements over the full range of variables nor will it define the exact reason in case the machine fails to comply.

If the machine is equipped with a compensator, its performance shall be tested.

Equipment parameters, including physical inspection of various dimensions, features, instrumentation, tooling, and accessories, shall be verified.

5.2 Duties of the Supplier and User¹

- 5.2.1 For these tests, the user shall provide an examiner trained in the use of balancing machines. The supplier shall instruct the examiner in the use of the machine. The examiner may either operate the machine or satisfy himself/herself that he/she could obtain the same results as the operator. The supplier shall ensure that his/her written instructions are followed by the examiner.
- 5.2.2 The examiner shall print or read the unbalance indication off the machine's instrumentation, log the values, and subsequently plot them or log the readings electronically with proven software. The supplier shall be entitled to check the accuracy of the examiner's work.
- 5.2.3 The supplier as well as the examiner shall be allowed to verify the condition of the proving rotor, the correctness of the test masses, and the location of the test masses.

5.3 Requirement for Machine Spindle Mounting Flange

The female location pilot of the drive spindle flange shall have a radial runout not to exceed 0.0005 inch F.I.R. The axial runout of the locating surface shall not exceed 0.0005 inch F.I.R. (0.001 inch for class 1000 flange). Each reading should be taken using five complete revolutions of the spindle and be taken with a low friction dial indicator with a resolution of 0.0001 inch/division.

¹ The supplier is understood to be the balancing machine manufacturer and/or supplier, the user is understood to be the prospective or actual user of the machine.

5.4 Requirement for Proving Rotor

The machine shall undergo the following tests with the appropriate proving rotor described in ARP4162. The correction planes on the rotor are designated:

- a. Plane 1: Lower Plane
- b. Plane 2: Upper Plane
- c. Plane 3: Center Plane

5.5 Requirement for Weighing Scale

A calibrated weighing scale shall be available having sufficient accuracy to verify the correctness of the test masses.

5.6 Test and Rechecks

When a machine fails either the e_{mar} URR test, or Compensator test, adjustments shall be permitted to the machine, after which a complete retest shall be made and the machine shall then pass. If it does not, it is considered not acceptable.

5.7 Balancing Speed for Test

The balancing speed for tests must fall within the range specified in 4.5.3.

5.8 Test for Minimum Achievable Residual Specific Unbalance (e_{mar} Test)

- 5.8.1 Perform the mechanical adjustment, calibration, and/or setting of the machine for planes 1 and 2 of the proving rotor, ensuring that the unbalance in the proving rotor is smaller than five A-units per plane.

NOTE: Figure D1 gives examples to convert A-units to units of unbalance.

5.8.2 Readings

Unbalance readings for successive runs are recorded or logged and subsequently plotted or recorded electronically with proven software.

- 5.8.3 Add two unbalance masses (such as balancing clay) to the rotor. They shall be equivalent to 10 to 20 A-units. The unbalance masses shall not be:

- a. In the same transverse plane
- b. In plane 1 and/or 2
- c. At the same angle
- d. Displaced by 180°

Record or log the unbalance readings in test sheet (per figure D3 under "Initial Unbalance").

- 5.8.4 Balance the rotor as well as possible (following the standard procedure for the machine) using four runs. Apply correction masses in planes 1 and 2. Record or log the readings of all four runs per Figure D3.

NOTE: If residual unbalance after four runs is more than 0.5 A-units in each lane, the machine will not pass the following tests.