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Balancing Machines - Description and Evaluation Vertical, Single-Plane, Soft-Bearing Type for Gas Turbine Rotors

RATIONALE

This document has been determined to contain basic and stable technology which is not dynamic in nature.

STABILIZED NOTICE

This document has been declared "Stabilized" by the SAE EG-1A Balancing Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

FOREWORD

Revision "B" of ARP588 contains numerous corrections and improvements intended to make the document easier to read and understand.

The document has been restructured and the title changed. A drawing of the test masses for use with the proving rotors has also been added. The format of all tests has been standardized, and the requirements for each test together with the test procedure consolidated into a single section of the document.

ARP1342, Periodic Surveillance Procedure for Horizontal Balancing Machines has been incorporated into Section 10 herein.

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1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) specifies the requirements of balancing machines that make them suitable for the subject class of work. It was developed for soft-bearing balancing machines but may also be used for hard-bearing machines until ARP4050 is issued for that type of machine.

1.1 Purpose:

1.1.1 This Aerospace Recommended Practice (ARP) delineates the technical specifications for the rotating type of soft-bearing, single plane (i.e., static) balancing machine used for measuring the amount and angle of unbalance in gas turbine rotors.

1.1.2 This document also delineates performance tests to be used to ensure conformance with the requirements in this ARP.

1.1.3 This document was prepared to describe dimensional and performance requirements for machines capable of balancing most rotors either now in service or to be put into service in the foreseeable future. This will enable both rotor and balancing machine manufacturers to standardize, avoiding the need for separate tooling to adapt a particular rotor to a variety of machines in one capacity range. It can also be used as a general specification by purchasers (users) in procuring suitable balancing machines from manufacturers (suppliers).

1.1.4 To make this ARP sufficiently flexible so that it can be adapted to a variety of applications (such as rotors to be balanced by the accessory and missile industries where a wide range of balance tolerances are specified), the test procedures have been written in terms of A units rather than fixed physical values such as ounces, ounce-inches, or microinches.

1.2 Particular note should be taken that this ARP only examines the capability of a balancing machine to indicate the correct amount of static unbalance in specified proving rotors. Such rotors are commonly used for testing balancing machines to provide precisely controlled and comparable test results. Further tests of a particular machine may be necessary to assess its capability to balance rotors of different weights and configurations and those with disturbance causing features, such as rotors subject to blade scatter, windage, etc.

1.3 This ARP specifies dimensional and performance requirements in the following areas:

a. Machine capacity relating to weight and physical dimensions of rotors that can be balanced

b. Accuracy of amount and angle indication

c. Sensitivity and linearity of amount indication

d. Ability to measure static unbalance unaffected by couple unbalance

1.3 (Continued):

e. Balancing speed and direction of rotation

f. Drive requirements

g. Standard drive adapter flange requirements

h. Proving rotors, test masses, and rotor safety enclosures

2. REFERENCES:

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

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP587B Balancing Machines - Description and Evaluation Horizontal, Two Plane, Soft-Bearing Type for Gas Turbine Rotors

2.2 U.S. Government Publications:

Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-167 Mechanical Vibrations of Shipboard Equipment, Department of the Navy, Bureau of Ships

MIL-B-25510 (USAF) Military Specification, Balancing Machines - Static-Single Plane

MIL-B-25511 (USAF) Military Specification, Balancing Machine, Dynamic-Static, Two Plane

Report No. 371=V-24; Department of the Navy, Bureau of Ships, Code 371

2.3 ANSI Publications:

Available from American National Standards Institute, 1430 Broadway, New York, NY 10018

"Balancing Machines - Enclosures and Other Safety Measures" ISO 7475-1984

American National Standards Institute 52.7-1982 Balancing Terminology

2.4 Other Documents:

Balancing Technology - Hatto Schneider

2.5 Definitions:

Definitions are given for those technical terms which have a particular meaning for this document. Some of these terms have been written with capitals throughout the document particularly where they have definite meaning in this context. The more general use of the same word will not be capitalized. An attempt has been made to use the same words to express the same idea. They are given in the approximate order in which they first occur. For additional information see ARP587, Appendix 2.

2.5.1 BALANCING MACHINE: A machine that provides a measure of the unbalance in a rotor which can be used for adjusting the mass distribution of that rotor mounted on it so that once per revolution vibratory motion of the journals or force at the bearings can be reduced, if necessary.

2.5.2 BALANCING EQUIPMENT: A combination of the balancing machine, proving rotor, tooling, and accessories necessary to accomplish a balancing operation.

2.5.3 MICROINCH: $1\ \mu in = 1 \times 10^{-6}$ in

2.5.4 STATIC UNBALANCE: That condition of unbalance for which the central principal axis is displaced only parallel to the shaft axis.

NOTE: The quantitative measure of static unbalance can be given by the resultant of the two dynamic unbalance vectors.

2.5.5 COUPLE UNBALANCE: The condition of unbalance for which the central principal axis intersects the shaft axis at the center of gravity.

NOTE 1: The quantitative measure of couple unbalance can be given by the vector sum of the moments on the two dynamic unbalance vectors about a certain reference point in the plane containing the center of gravity and the shaft axis.

NOTE 2: If static unbalance in a rotor is corrected in any plane other than the plane containing the reference point, the couple unbalance will be changed.

2.5.6 DYNAMIC UNBALANCE: That condition in which the central principal axis is neither parallel to nor intersects the shaft axis.

NOTE 1: The quantitative measure of dynamic unbalance can be given by two complementary unbalance vectors in two specified planes (perpendicular to the shaft axis) which completely represent the total unbalance of the rotor.

2.5.6 (Continued):

NOTE 2: Dynamic unbalance is a combination of static unbalance and couple unbalance resolved into two (and in some cases more than two) transverse planes. Analytical conversion by vector analysis can be made from dynamic unbalance to static plus couple unbalance and vice versa. The correction of dynamic unbalance will achieve complete unbalance correction.

2.5.7 QUASI-STATIC UNBALANCE: That condition of unbalance for which the central principal axis intersects the shaft axis at a point other than the center of gravity.

NOTE: Quasi-static unbalance is a special case of dynamic unbalance where the angle of the static unbalance coincides with the angle of one of the couple unbalances.

2.5.8 ANGLE OF UNBALANCE: Given a polar coordinate system fixed in a plane perpendicular to the shaft axis and rotating with the rotor, the angle of unbalance is that angle at which an unbalance mass is located with reference to the given coordinate system.

2.5.9 READOUT: As a verb, readout means to provide an answer or result by whatever means the particular machine might use, such as a meter indication, position of a control, scale reading, punched card, or counter number. As a noun, readout refers to the result itself.

2.5.10 ONE A UNIT: Specified required sensitivity of the balancing machine under test, stated in microinch displacement of the principle axis of inertia from the shaft axis (if the rotor rotated in free space without restraint).

a. In the place of the c.g. for static unbalance
b. In each bearing plane for couple unbalance

NOTE 1: For static unbalance an A unit is identical to a stated amount of specific unbalance; i.e. the displacement of rotor c.g. from the shaft axis (e) in microinch; e.g., if one A unit is specified to be 50 μin it produces a displacement of rotor c.g. from the shaft axis of 50 μin.

NOTE 2: The specified required sensitivity of one A unit must be tested as described herein. To meet the various tests the machine must actually be capable of indicating 0.25 A or better.

2.5.11 UNBALANCE TEST UNIT Vs: The unbalance test unit Vs differs from the unbalance test unit Vc as defined in ARP587B in that Vs constitutes static unbalance whereas Vc constitutes couple unbalance. When a static unbalance test unit Vs is applied in any plane other than the plane of the c.g. it causes a quasi-static unbalance condition. Nevertheless, the displacement of c.g. is the same as if the mass were placed in the plane of the c.g.

2.5.11 (Continued):

An unbalance test unit Vs may be determined by the following:

$$Vs = \frac{16W x 10-6}{r} \quad \text{(Eq.1)}$$

where:

Vs = Unbalance test unit in ounces for 1 μin c.g. displacement of rotor
W = Weight of rotor in pounds
r = Radius of test mass in inches

Examples:

If, for a particular rotor, Vs = 0.0003368 oz and A = 50, then 1A = 0.0003368 oz x 50 = 0.01684 oz to be applied at the same radius for which Vs was calculated. A 40 A test mass for the same rotor (for checking range of unbalance indication, for example) would weigh 40 x 0.01684 oz = 0.6736 oz (or 40 A x Vs = 2000 Vs).

2.5.12 ANALOG: Means a readout which is measured on a continuous scale and whose readability depends on the length of the scale.

2.5.13 NUMERICAL READOUT: See 4.3.2 The arithmetic number indicated by the readout unit without any physical size or unit. Actual physical unbalance is obtained by multiplying the numerical readout by the appropriate value depending on the setup of the machine to which a physical unit is assigned.

2.5.14 ONE POUND = 453.6 g (454 g round numbers)
= 16 oz

2.5.15 ONE OUNCE = 28.35 g

2.5.16 PLANE 1, PLANE 2, and PLANE 3, are test or correction plane designations for proving rotors only.

2.5.17 HARD BEARING (BELOW RESONANCE) BALANCING MACHINE: A machine having a balancing speed range below the natural frequency of the suspension-and-rotor system.

2.5.18 SOFT BEARING (ABOVE RESONANCE) BALANCING MACHINE: A machine having a balancing speed range above the natural frequency of the suspension-and-rotor system.

2.6 Symbols:

U - Unbalance (oz-in)
A - Units - Required sensitivity of the machine (microinches). See 2.5.10
V - Mass of one Unbalance Static Test Unit (oz). See 2.5.11
W - Weight of the proving rotor (lb)
r - Radius to the center of gravity (c.g.) of V or w from journal axis (in)
d - Separation of the Couple Unbalance planes
w - Unbalance mass at the correction radius of a rotor or part (oz)

3. CONFORMANCE REQUIREMENTS:

The user or user's designated inspector shall assure that the machine meets the requirements of this document. Such assurance shall be ascertained by individual verification of full machine conformance in all of the following three areas:

3.1 Conformance with each line item of the capacity and dimensional requirements in Table 1.

3.2 Conformance with each of the performance tests in Section 9.

3.3 Conformance with User designated contractual requirements, see Appendix A.

NOTE: To keep the test procedures short enough to be practical, some requirements in Table 1 and elsewhere are not fully proven either through the line item verification or the tests in Section 9. Such requirements are intended as a guide to the balancing machine manufacturer, and will have to be covered by the warranty and reputation of the manufacturer.

4. CAPACITY AND DIMENSIONAL REQUIREMENTS:

Table 1 lists the capacity and dimensional requirements for each class of machine.

TABLE 1 - Dimension and Capacity Requirements

Characteristic		Dimensions and Capacities			
4.1	Machine Class (lb)	25	100	250	500
4.2	Rotor Weight (lb)				
4.2.1	Maximum *1	25	100	250	500
4.2.2	Minimum	1	2	10	20
4.3	Rotor Size (inch)				
4.3.1	Maximum diameter of rotor (in rotor safety enclosure)	24	43	59	59
4.3.2	Maximum height of rotor c.g. above machine spindle	5	5	10	10
4.3.3	Spindle adapter flange *2	Figure A1	Figure A1	Figure A1	Figure A1
4.3.4	Typical rotor enclosure *3	Figure A6	Figure A6	Figure A6	Figure A6
4.4	Unbalance Measurement (microinch)				
4.4.1	Sensitivity (see A.1.10) *4 one A unit	50	50	50	50
4.5	Drive and Balancing Speeds *5				
4.5.1	Minimum Test Speed (rpm) *7	900	900	900	900
4.5.2	Minimum Horsepower (hp) *6	0.75	5.0	7.5	10
4.6	Proving Rotors				
4.6.1	Design	Figure A2	Figure A3	Figure A4	Figure A4
4.6.2	Weight (lb) *8	25	100	250	250

NOTES:

*1. The rotor weight consists of the combined weights of the workpiece and any adapters necessary to attach the workpiece to the machine's spindle flange. Overloading of the balancing machine beyond 4.2.1 and 4.3.2 is not recommended unless approved by the balancing machine manufacturer.
*2. All drive spindle adapter flanges shall conform to Figure A1.
*3. The enclosure size is to be agreed upon between user and supplier. All enclosures shall have a safety interlock. Enclosures used for bladed rotors shall have a zero speed interlock.
*4. One A unit in Figures A2, A3, and A4 is equal to 50 μin.
*5. The machine shall be capable of driving and balancing rotors in both directions of rotation.
*6. The horsepower is determined by a balancing speed of 900 rpm, the user shall specify to the supplier any other balancing speeds and horsepower requirements.
*7. With the user's rotor which requires the most drive power, the machine shall be capable of accelerating to balancing speed and then stopping six times within an agreed upon time period.
*8. Machine capacity is limited by the combination of the rotor/tooling weight, Center of gravity height^2, and rpm^2. This is generally expressed by the manufacturers as a wh^2n^2 value.

5. PROVING ROTORS:

5.1 Tests with Proving Rotors:

Each balancing machine shall be tested with the appropriate size proving rotor specified in Table 1.

5.2 Rotors and Accessories:

All proving rotors shall consist of (be equipped with) the following items complete and in accordance with drawings and specifications herein:

a. Proving rotors
b. Test masses as listed in Section 9, Table 2
c. Proving rotor storage container

5.3 Commonality of Accessories:

In those cases where proving rotor accessories are common to more than one proving rotor, it shall not be necessary to provide duplicate sets of accessories for each proving rotor. This shall apply to storage containers and test masses maintained at a given user or supplier facility, or to be shipped to such a facility for tests.

6. TEST MASSES:

6.1 Required Test Masses:

The test masses required for the performance tests are listed in Section 9. The unbalance values are based on the unbalance test unit system. The dimensions and weights of the test masses shall be certified to the values shown in Appendix A, Figure A5.

6.2 Special Test Masses:

Test masses other than those specified in this document shall be provided when special tests are required which are not specified herein. Special test masses shall conform in design, specifications, and dimensional and weight tolerances to those specified in Appendix A, Figure A5.

7. GENERAL TEST CONDITIONS:

7.1 Scope of Tests:

The specific performance requirements preceding each test in Section 9 have been written to define certain characteristics of the machine. Conformance with the tests constitutes what is considered minimum proof that the machine will meet these requirements.

7.1 (Continued):

The test procedures will not prove conformance with all requirements over the full range of all variables, and neither will they measure nor define the exact reasons for nonconformance in a given test.

Failure of a balancing machine to conform may be due to shortcomings in specific components or to more general reasons such as lack of ruggedness and improper leveling or anchoring to the floor, etc.

7.2 Operator Furnished by User or Supplier:

When performing these tests, the user shall provide an examiner trained in the use of balancing machines. The supplier shall instruct the user's representative in the use of the machine. The user shall either operate the machine or be satisfied that the same result as the supplier's operator could be obtained. The supplier shall ensure that the written operating instructions are followed by the user.

7.3 Verification of Rotor and Test Masses:

The user and supplier shall verify the certification and location of the test masses, and that the test masses and proving rotor conform to the applicable specifications in Appendix A.

7.4 Test Sequence and Evaluation:

The tests described in Section 9 shall be run in the sequence as listed. Each test generally requires that:

a. The appropriate proving rotor be run on the machine
b. Unbalance be measured and the readings be recorded in one of the test logs provided in Section 9
c. The recorded readings be plotted in the polar graph of Figure 4
d. The overlay of Figure 5 be placed over the polar graph to ascertain whether the plotted points fall within the windows of the overlay

NOTE: For the polar graph, only the following two types of polar graph paper, or the equivalent, are suitable:

a. #359-31 of Keuffel and Esser Company or
b. #AC-0815-OT or GI of Graphic Controls Corporation

CAUTION: Do not attempt to make copies of the polar graph or the overlay by photocopying or other duplicating processes that enlarge, reduce or distort the originals, as this will cause falsification of the test results. The test logs, however, may be reproduced to obtain working copies.

8. RECHECKS AND COMPLETE TEST REPETITION:

8.1 At the end of each test procedure the conditions for conformance (acceptability) are stated. If these are not met, the machine does not conform to the requirements.

8.2 A machine that would normally conform, could, by chance, fail in a single test run. If so, two rechecks of the specific test conditions and procedures shall be made. The machine shall then conform in both recheck tests to qualify as acceptable under the specified test.

NOTE: Between the failed test and the two recheck tests, only those types of adjustments to the machine shall be permitted that would not affect the results of any of the prior tests were they to be run again.

8.3 If conformance in any test or recheck tests necessitates adjustment(s) of the machine that might affect the results of prior tests, all tests shall be repeated starting with 9.1.

9. PERFORMANCE TESTS AND TEST LOGS:

Table 2 lists the 11 individual performance tests and the number and size of test masses required for each test.

TABLE 2

Test	Required Test Section	Masses	Periodic (see Section 10)
Minimum achievable residual unbalance	9.1	1 x 20 A	Applicable
Sensitivity of amount indication	9.2	1 x 20 A	Applicable
Range and linearity of amount indication	9.3	1 x 40 A	Applicable
Indication of heavy and light spot	9.4	1 x 40 A	Optional
Compensator	9.5	2 x 40 A	Applicable
Accuracy of amount and angle indication	9.6	2 x 12.5 A 2 x 10 A	Applicable
Static and couple unbalance separation	9.7	2 x 40 A	Optional
Practical correction units/other dimensional inspection	9.8 - 9.10		Optional

9.1 Minimum Achievable Residual Unbalance (see Figure 1):

9.1.1 Specific Performance Requirements: The machine shall be capable of consistently balancing the proving rotor down to .5 A units or less residual unbalance.

9.1.2 Test Conditions:

9.1.2.1 Set up the machine to indicate unbalance in the appropriate proving rotor (see 4.6) according to the supplier's operating manual.

9.1.2.2 Adjust the amount of calibration of a soft bearing machine or the radius setting of a hard bearing machine, so that the readout is directly in units of A (or 0.01, 0.1, 10, 100, etc. x A) as convenient. Use a 20 A test mass for the soft bearing machine calibration mass.

On a hard bearing machine, determine the proper radius setting by measuring the radius (i.e., radial distance from the spindle axis to the test mass center of gravity.

9.1.2.3 Using the normal operating procedure, indicate the rotor residual unbalance in plane 2. If it is less than 5 A units, apply unbalance mass to the rotor until the unbalance is between 5 and 20 A units.

9.1.3 Test Procedure:

9.1.3.1 Measure and then correct the indicated unbalance in plane 2. Then measure and record the residual unbalance in the test log for 9.1.

9.1.3.2 Repeat 9.1.3.1 three more times, each time measuring the remaining unbalance, applying the indicated corrections, and then recording the new residual unbalance.

9.1.4 Conformance Requirement: All amount readings in lines 3 and 4 of the test log shall be no greater than .5 A units.

NOTE: Conformance provides no definite proof that the residual unbalance in the rotor is indeed no larger than .5 A units. However, such proof will be established by conformance with the test in 9.5.

9.2 Sensitivity of Amount Indication:

9.2.1 Specific Performance Requirements: All analog types of amount of unbalance readout devices shall have at least 1/8 in (3 mm) displacement of the pointer (or equivalent device) for an indication of 1 A unit over a range of 20 A units. All digital types of amount readout shall have at least 5 digits for an indication of 1 A unit over a range of 20 A units.

9.2.2 Test Procedure: Starting with the balanced proving rotor (i.e., same as after 9.1.3.2), add a 20 A unit test mass to the rotor in plane 2, and indicate the unbalance.

9.2.3 Conformance Requirement: On machines with analog indication, the amount indication shall be displaced by at least 2.5 in (60 mm) indicator displacement. On machines with digital indication, the indication shall be no less than 100 digits.

9.3 Range and Linearity of Amount Indication:

9.3.1 Specific Performance Requirements: For unbalances of less than 5 A units in the proving rotor, the indicated amount shall not deviate more than .25 A units from the applied unbalance.

For unbalances of 5 A units or more, the indicated amount shall not deviate more than 5% from the applied unbalance.

The range of unbalance indication shall extend to at least 50 A units.

9.3.2 Test Procedure: Starting with the balanced proving rotor (i.e., same as after 9.1.3.2), add a 40 A unit test mass at 270° to plane 2 and indicate the unbalance. It is permissible to change the indicating sensitivity from that previously used by means of a sensitivity (range-multiplying) switch.

For example, if for 9.1.4 one unit of the indicator scale represented 1 A unit it may now be changed to represent 2 or 5 A units without affecting the calibration of the machine as set up for 9.1.

9.3.3 Conformance Requirement: The indicated amount of unbalance shall be between 38 and 42 A units.

NOTE: The other requirements of 9.3.1 are proven by conformance with 9.5.

9.4 Indication of Heavy or Light Spot:

9.4.1 Specific Performance Requirements: With a 40 A unit test mass added to the proving rotor, the machine shall indicate selectively either the heavy or light spot within 3° of the true position.

9.4.2 Test Procedure: Starting with the balanced proving rotor (i.e., same as after 9.1.3.2), add a 40 A unit test mass at 270° to plane 2 and indicate the unbalance. It is permissible to change the indicating sensitivity from that previously used by means of a sensitivity (range-multipling) switch.

For example, if for 9.1.4 one unit of the indicator scale represented 1 A unit, it may now be changed to represent 2 or 5 A units without affecting the calibration of the machine as set up for 9.1.

9.4.3 Conformance Requirement: The indicated angle of unbalance shall be:

a. Between 267 and 273° when indication of the heavy spot is selected, or
b. Between 87 and 93° when indication of the light spot is selected

9.5 Compensator:

9.5.1 Specific Performance Requirements: The compensation shall be consistent in the zero readout to .2 A units or less at the end of the compensation procedure.

9.5.2 Test Procedure:

9.5.2.1 Use the balanced proving rotor (after 9.1.3.2), or ensure that the unbalance is smaller than 5 A units.

9.5.2.2 Add a 40 A unit test mass at 30° and a 40 A unit test mass at 150°, both in plane 3.

9.5.2.3 Set the compensator for the first step according to the manufacturer's manual.

9.5.2.4 Move the 40 A unit test mass from the 150° position to 330°, (180° shift), to simulate the indexing procedure, (do not index the rotor).

9.5.2.5 Set the compensator for the second step according to the manufacturer's manual.

9.5.2.6 Remove the 40 A unit test mass located at 330°.

9.5.2.7 Set the compensator to read rotor unbalance.

9.5.3 Conformance Requirements: The compensator conforms if the reading with a single test mass (40 A at 30°) is within .2 A units.

NOTE: The remaining requirements are proven by conformance with 9.6.

9.6 Accuracy of Amount and Angle Indication:

See Figure 2.

9.6.1 Specific Performance Requirements: With a stationary test mass with a given proving rotor in plane 2, and a second test mass being moved from position to position ("traversed") in the same plane, all but one of the readings recorded in the test log and then plotted on the polar graph must be within the windows of the overlay.

9.6.2 Test Procedure: Use the rotor as it leaves 9.5.3 with the compensator in set position.

9.6.2.1 Apply a 2.5 A differential test mass at any one of the following positions in plane 2 of the proving rotor: 15, 165, 195, or 345°. Call this position angle E. This is the stationary test mass. It remains in the same position for the tests in 9.6.2.2 and 9.6.2.3 except for the position marked with an asterisk (*) on the test log for 9.6. Add the E angle to each angle shown in column H of the test log and insert the result in column G.

9.6.2.2 Apply a second 2.5 A differential test mass (the "traveling" test mass) in successive runs at the positions in plane 2 as listed in column G on the test log. Record the amount and angle readings for plane 2 after each run for each position of the traveling test mass.

9.6.2.3 Repeat 9.6.2.2 twice more, always recording the readings in the test log.

9.6.3 Preparation of Polar Graph:

9.6.3.1 Plot the results on a polar graph of the type illustrated in Figure 4, using the symbols shown in the left column of the test log.

9.6.3.2 Draw a line from the polar graph origin in the direction of E.

9.6.3.3 Place the overlay of Figure 5 over the graph and move the position of the overlay so that:

a. Its 0 to 180° axis is parallel to the direction of E in the graph
b. The greatest possible number of plotted points are in their respective windows as indicated by the symbols
c. The origin of the overlay is within a radius of .5 A units from the origin of the graph

9.6.4 Conformance Requirement: All but one of the plotted points shall be in their respective windows.

NOTE 1: If the machine conforms, the requirement of 9.1.1 is also proven due to the restriction in 9.6.3.3 (c) to the graph adjustment.

NOTE: If two points or more fall outside their windows, the machine failed this test because of any number of reasons, e.g., lack of repeatability, amount, and/or angle indication errors, lack of sensitivity to small unbalances, etc.

9.7 Static and Couple Unbalance Separation (see Figure 3):

9.7.1 Specific Performance Requirements: The machine shall indicate 2 A units or less of unbalance when 40 A unit test masses are added to plane 1 and plane 3 simultaneously and at opposite angular locations.

9.7.2 Test Procedure:

9.7.2.1 Starting with the balanced proving rotor (i.e., same as after 9.1.3.2), set up the machine according to the supplier's operating manual to indicate the heavy spot on the rotor.

9.7.2.2 Apply one 40 A unit test mass at 60° in plane 1 of the proving rotor, and another 40 A unit test mass in plane 3 at 240°.

9.7.2.3 Run the machine and record the indicated static unbalance in the test log for 9.7.

9.7.2.4 Move both test masses successively to the angles shown in the test log for three more runs and each time record the indicated static unbalance.

9.7.3 Preparation of Polar Graph: Plot the readings on the polar graph used before, using a (+). Place the overlay of Figure 5 over the polar graph in the same position as 9.6.3.

9.7.4 Conformance Requirement: All plotted points shall be within the separation circle.

9.8 Practical Correction Units:

9.8.1 Specific Performance Requirements: The machine shall be capable of indicating unbalance directly in terms of practical correction units such as ounces, grams, ounce-inches, number of standardized washers or weights, etc.

9.8.2 Test Conditions and Procedure: Because of the many different types of unbalance indicating devices it is considered impractical to establish specific conditions and procedures for testing this capability.

9.8.3 Conformance Requirement: In the absence of specific conditions and procedures it is nevertheless important that the supplier demonstrate to the user that the machine will, when the instructions in the operating manual are followed, indicate unbalance in practical correction units as cited in 9.8.1 without significant loss in sensitivity and indicating range.

9.9 Other Dimensional Inspection:

9.9.1 The female location pilot of the drive spindle flange shall not have a radial runout in excess of .0005 inch F.I.R. and axial runout not in excess .0005 inch F.I.R.

9.9.2 Test Procedure: Remove proving rotor. Fasten a low friction, type 1 (0.0001 inch/division) dial indicator to the balancing machine housing. Lock the vibratory system. Adjust the dial indicator so that the indicator tip contacts the inside diameter of the spindle flange pilot. Rotate the spindle slowly by hand and read the indicator for five full revolutions for radial runout.

Move the dial indicator to the face of the spindle flange. Rotate the spindle flange slowly by hand and read the indicator for five full revolutions for axial runout.

9.9.3 Conformance Requirement: The F.I.R. shall not exceed .0005 inch for radial or axial runout.

10. PERIODIC TEST PROCEDURE:

Each balancing machine shall be tested periodically and/or after repairs that may have affected its performance. The test procedure for such periodic tests shall be the same as described in Section 9 except that it may be shortened by deleting those parts of the test designated optional in the last column of Table 2.

The periodic test procedure replaces ARP1340 in its entirety.

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COMMITTEE EG-1, AEROSPACE PROPULSION SYSTEMS SUPPORT EQUIPMENT

LINE	PLANE 2	
	AMOUNT A UNITS	ANGLE DEGREES
1		
2		
3		
4		

FIGURE 1 - Test Log for 9.1
Minimum Achievable Residual Unbalance

Symbol	Angle H Degrees	Angle G Traveling Test Mass Degrees G=H+E (or H+E-360)	Indicated Unbalance					
			1st Run		2nd Run		3rd Run	
			Amount A Units	Angle Degrees	Amount A Units	Angle Degrees	Amount A Units	Angle Degrees
⊙	15							
⊡	60							
△	90							
⊙	120							
⊡	150							
△	165							
⊙	*	N.R.						
⬡	195							
⊡	210							
△	240							
⊡	270							
⊙	300							
△	330							

* For this set of readings remove both stationary and traveling masses. Be sure to re-install the stationary test mass again at E after this run.

FIGURE 2 - Test Log for 9.6
Accuracy of Amount and Angle Indication

Angle of 40 A Test Mass Degrees		Indicated Unbalance	
		Amount A Units	Angle Degrees
Plane 1	Plane 3	Static Unbalance Indication	
60	240		
150	330		
240	60		
330	150		

FIGURE 3 - Test Log for 9.7
Static and Couple Unbalance Separation

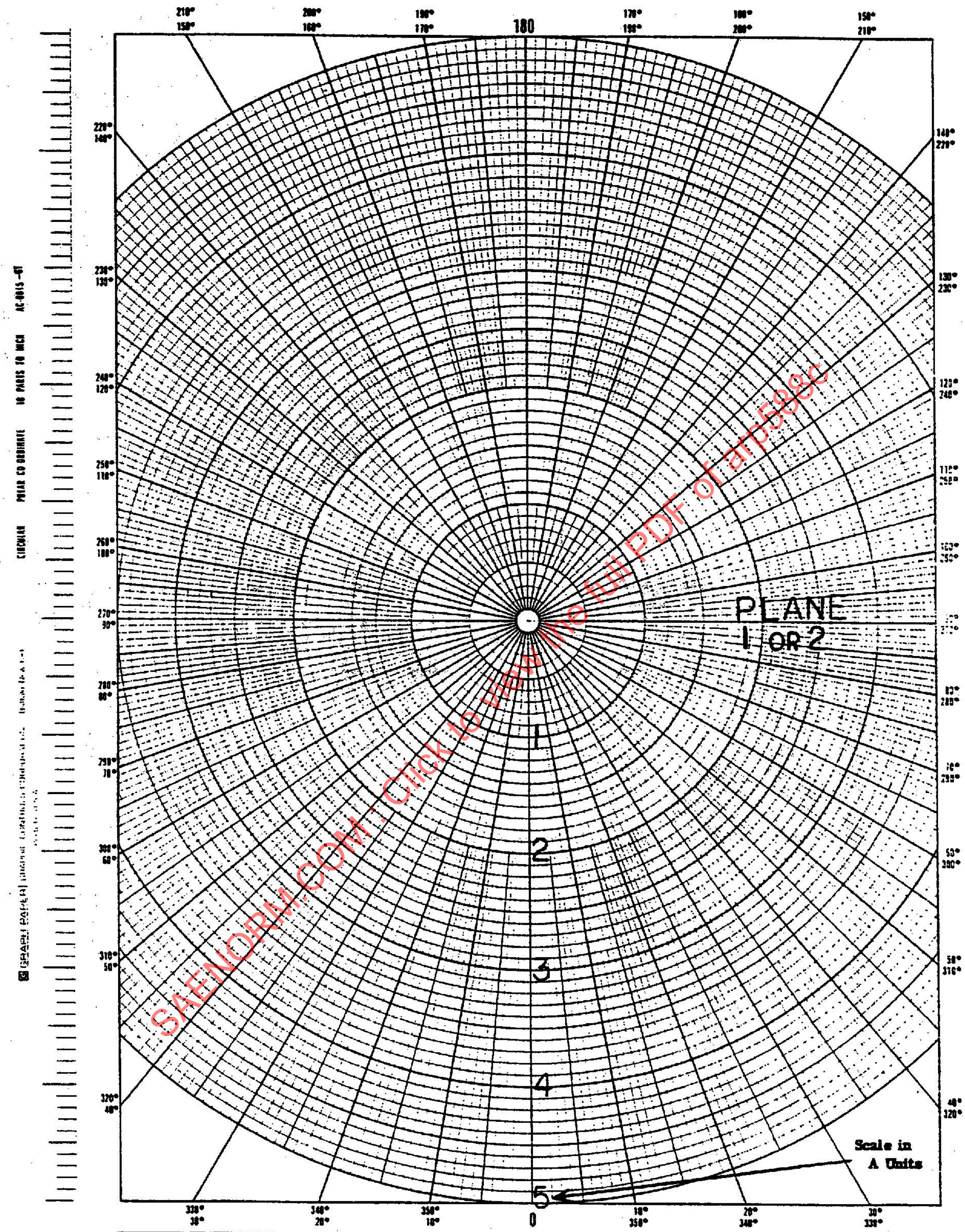

FIGURE 4 - Sample of Paper (photographically reduced) for Plotting Data Log Sheets

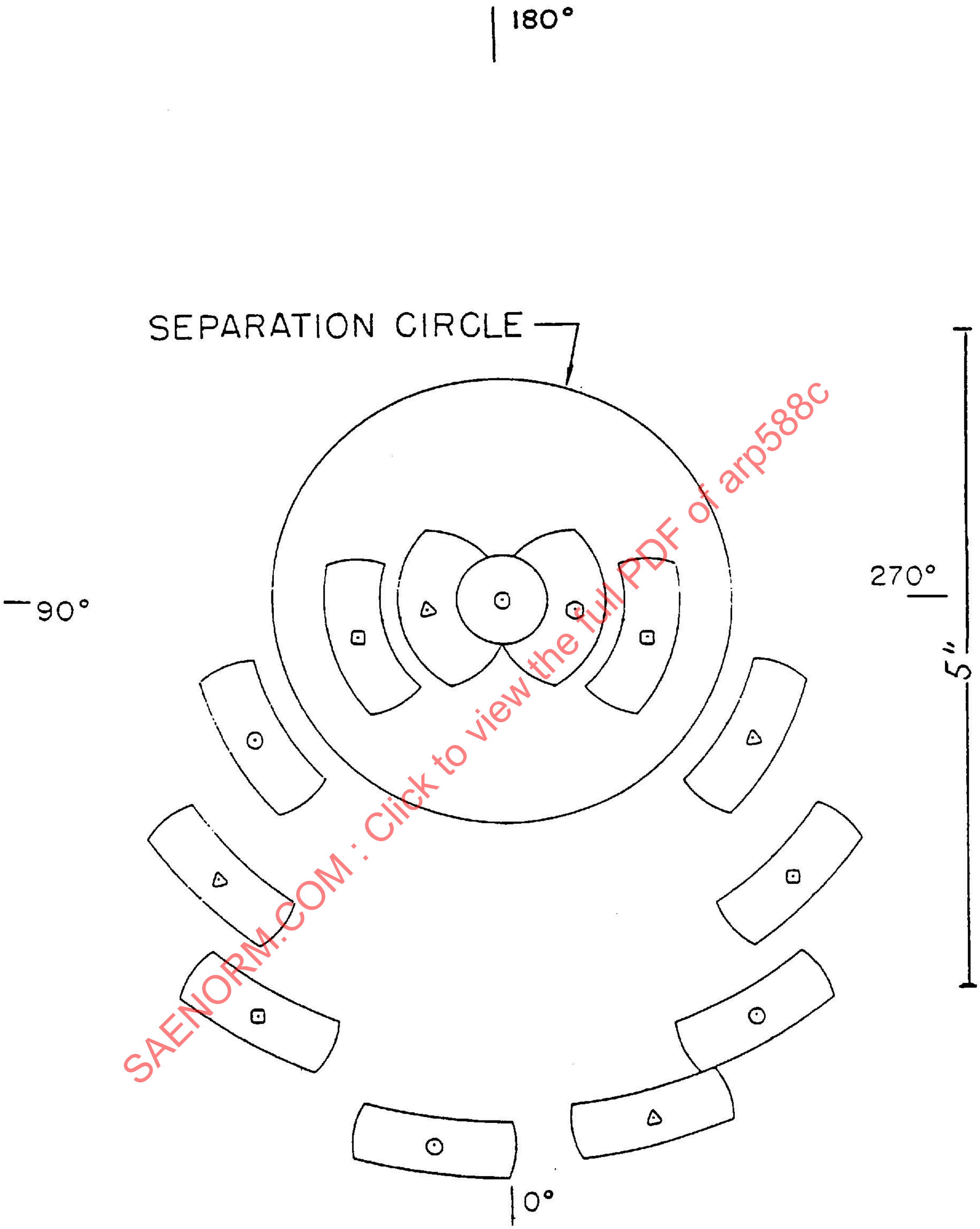

FIGURE 5 - SAE Balancing Machine Standards Test Overlay

CAUTION: This is a photographically reduced sample of the overlay. It is not suitable for evaluating test results. Use only the transparent overlay furnished with this document for evaluating test results.