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AEROSPACE RECOMMENDED PRACTICE

ARP 588

FORCE BALANCING MACHINES FOR JET ENGINE COMPRESSOR AND TURBINE COMPONENTS - ROTATING TYPE

Issued 10-25-65
Revised

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I. PURPOSE

1.1 The purpose of this recommended practice is to delineate the technical specifications for rotating type of force-balancing equipment for measuring the amount, and determining the location, of correction required in any transverse plane to balance jet-engine components. (For Glossary of Terms and Nomenclature, see Appendix 1.)

1.2 Another purpose of this document is to delineate performance tests to be used to insure compliance with its recommendations.

1.3 This document was prepared to give a general description of balancing equipment which will be capable of balancing all jet-engine compressor and turbine-rotor components either now in service or to be put into service in the foreseeable future. This will enable both engine and balancing-machine manufacturers to standardize in order to avoid the need for separate tooling to adapt a particular component to a variety of machines in one capacity range. It can also be used as a general specification for purchasers in procuring suitable balancing equipment for this type of work.

1.4 To make this document sufficiently flexible so that it can be adapted to other applications requiring smaller or larger components to be balanced by the accessory and missile industries where smaller or larger balancing tolerances are required, it has been written in terms of A units rather than fixed physical values such as ounces, ounce-inches, microinches.

2. SCOPE - This recommended practice specifies those requirements of balancing equipment which make it suitable for the subject class of work.

It will specify:

a. Sensitivity
b. Accuracy of indication of amount and location of unbalance
c. Ability to measure force unbalance unaffected by couple unbalance
d. Machine capacity relating to weight and physical dimensions of the rotors which can be balanced
e. Balancing speed of rotation
f. Standard balancing-machine drive-adapter flange dimensions
g. Power requirements

3. REQUIREMENTS

3.1 Force and Couple Unbalance Separation

3.1.1 The balancing machine shall read out the amount and angular location of the force unbalance unaffected by couple unbalance, for any selected correction plane in the test rotor.

3.1.2 The balancing machine shall indicate less than 2A units unbalance in the force correction plane of the test rotor when 40A units of unbalance (force test weights) are added in the couple test planes of the test rotor. (Test of 4.4.)

3.2 Amount Indication

3.2.1 All analogue types of amount of unbalance readout devices shall have at least 1/8 in. displacement for measurement of A units unbalance over a range up to 20A units. (Test of 4.3.6.)

3.2.2 For any amount of unbalance less than 5A units, the unbalance measuring device shall deviate by less than 0.25A units from the actual amount of unbalance in the test rotor. (Test 1 of 4.3.5.)

3.2.3 For all unbalances above 5A units, readout amount shall not deviate more than 5% from the applied unbalance. (Test of 4.5.1.)

3.2.4 The unbalance measuring range shall extend to at least 50A units. (Test of 4.5.1.)

3.2.5 If the indicated unbalance is less than A units, successive application of the indicated corrections shall not result in a new indicated unbalance greater than A units. (Test of 4.3.3.)

3.2.6 Indicated force unbalance linearity shall be within 5% of the applied force unbalance for the applied unbalances of 40A, 20A and 10A. For an applied force unbalance of 2.5A, the indicated force unbalance shall be between 2.25A and 2.75A units. (Test of 4.8.)

3.2.7 A test rotor corrected for unbalance until the amount of unbalance indicator shows a minimum reading shall not have an unbalance greater than 0.5A units. (Test 2 of 4.3.5.)

3.3 Correction Indication

3.3.1 The machine shall read out the location where addition or removel of material is necessary to balance the rotor. (Test of 4.6.2.)

3.3.2 The machine shall indicate the location in any plane of the test rotor to such accuracy that for actual unbalance conditions up to 5A units only a single correction is required. When the indicated amount of correction is applied at the indicated location in any correction plane, the machine shall indicate that such single correction has been effective by indicating a residual unbalance amount of less than A units. (Test 1 of 4.3.5.)

3.3.3 For applied unbalance conditions in the test rotor of any value from 5A to 40A units, the machine indications shall be of such accuracy that when the indicated correction is made the resulting unbalance shall not exceed 10% of the original applied unbalance. (Tests of 4.5.1 and 4.6.2.)

3.4 Practical Correction Units - The balancing machine shall provide unbalance amount readout in terms of the correction units actually used, number of weights, number of washers, etc., within the requirements of 3.2 and 3.3, subject to the interpretation by the test procedure of 4.2.2. (Tests of 4.3.2, 4.5.1 and tests for 3.2 and 3.3.) Because of the many different types of readout devices, it is considered impractical to write a specific test procedure to satisfy paragraph 3.4 for all machines. However, it is necessary that the balance-machine manufacturer demonstrate to the purchaser that this machine will read out in the terms of correction units actually used, such as number of weights, number of washers, etc. At the same time, the readout shall retain the requirements of paragraph 3.2.1 and the sensitivity required in other portions of this document.

3.5 Drive for Workpiece Rotor

3.5.1 The maximum unbalance disturbance of the drive system shall not exceed 0.5A units. Correction means shall be provided in order to make subsequent unbalance adjustments which may be necessitated by wear or abuse. The drive system includes all components necessary to drive the test rotor. (Test of 4.7.3.)

3.5.2 All drive flanges shall conform to drawings specified in 3.8.6.

3.5.3 The direction of rotation shall be counterclockwise when viewed from the drive adapter flange toward the workpiece.

3.6 Speed of Rotation During Balancing - The machine shall be capable of operating at a single speed of at least 900 rpm.

3.7 Driving Motor and Control - Refer to details of contractual negotiations, Appendix A.2.

3.7.1 The minimum motor horsepower shall be as shown in 3.8.10 and Note C.

3.7.2 The machine shall be capable of making repeated starts and stops to full speed with the maximum weight test rotor for one hour in accordance with the test of 4.7.1, during which time a minimum of 30 recorded cycles must be completed.

3.8 General Dimensional and Capacity Requirements - The following table lists the general requirements of each class of machine.

Characteristic		25 lb. Machine	250 lb. Machine
3.8.1	Capacity designation		
3.8.2	Minimum load - lb. (See also Note A below.)	1	10
3.8.3	Maximum load - lb. (See also Notes A and B below.)	25	250
3.8.4	Maximum height of load above machine spindle - in.	5	10
3.8.5	Maximum diameter of rotor - in.	24	60
3.8.6	Drive adapter flange, as per Figure	1, Table A	1, Table B
3.8.7	Test Rotors, as per Figure	2	3
3.8.8	A units (See A.1.7.)	50	50
3.8.9	Minimum balancing speed (rpm)	900	900
3.8.10	Minimum horsepower at minimum balancing speed (See also Note C below.)	3/4	7.5

Note A - (3.8.2 and 3.8.3 above). Load consists of combined weights of workpiece and any adapters necessary to attach workpiece to machine-drive adapter flange, as specified in 3.8.6.

Note B - (3.8.3 above). Overloading of balancing machines beyond limits specified for the particular class of machine is not recommended unless such action is approved by the particular balancing machine manufacturer.

Note C - Horsepower at higher speeds, N, if used shall be $\left[\frac{N}{900}\right]^2$ X (tabulated values of 3.8.10.)

4. TEST REQUIREMENTS

4.1 Test Rotors

4.1.1 Each machine shall be tested with its appropriate SAE test rotor.

4.1.2 All SAE test rotors shall be composed of the following units complete to SAE drawings and specifications:

a. Test rotor
b. Test weights as defined in 4.1.5 and Figure 4
c. Reuseable shipping container
d. Test instructions

4.1.3 All SAE test weights shall conform to the unbalance test unit system of A.1.7 and A.1.8.

4.1.4 Test weight classes, other than those specified in this recommended practice, shall be provided when special test points are required which are not specified herein. These test weights shall conform in design, specifications, dimensional tolerances, and weight tolerances to the specified SAE test weights.

4.1.5 The following quantities and classes of test weights should be provided for the test rotors for each class of machine.

Quantity	Class
2	10 A units
2	12.5 A units
1	20 A units
1	30 A units
2	40 A units
1	50 A units

4.2 Performance Tests

4.2.1 The tests described in the following paragraphs represent a minimum test procedure. The requirements of paragraph 3 have been written to define the characteristics of the machine. This test procedure will not prove all requirements over the full range of all variables. The procedure proposed will not measure nor define the exact reasons for failure (such as lack of ruggedness, machine not being properly anchored to the floor, etc.) of any particular machine.

4.2.2 In applying these tests, the purchaser shall provide an examiner trained in the use of balancing machines. The vendor shall instruct the examiner in the use of the machine. The examiner shall either operate the machine or satisfy himself that he could obtain the same result as the vendor's operator. The vendor shall ensure that his written operating instructions are followed by the examiner.

4.2.3 The vendor and purchaser shall be satisfied with the weighing and location of correction weights and that the test rotor and the test weights conform to the SAE specifications (Figures 2, 3, and 4). The examiner shall be permitted to witness or check any of this work.

4.2.4 An accurate and precise weight scale shall be available for the test. This scale shall be accurate and precise to at least two decimal places beyond the smallest A unit test weight. For example, if the A unit test weight weighs 0.00842 ounce, the scale should be accurate to 0.00008 ounce. (See test of 4.3.3.)

4.2.5 For all calibrations, the following calibration weights shall be used: for tests from 0 to 5A, 10A; for tests from 5A to 20A, 30A; for tests from 20A to 40A, 50A.

4.2.6 Tests and Rechecks - In the following tests, a machine which would normally conform to a test could, by chance, fail to conform in a single test run. Therefore, in most tests, when a machine fails to conform in a single test run, two rechecks shall be made, in which case the machine shall conform in both recheck tests in order to qualify as acceptable under the specified test.

4.2.6.1 Each test specifies the conditions for conformance (acceptability) or nonconformance (nonacceptability) to the specific test.

4.2.6.2 It shall be understood that in all cases of rechecks, the same conditions for both rechecks as for the original test shall determine conformance or nonconformance.

4.2.7 Transparent overlay, Figure 6, is designed for use with Keuffel and Esser Company's #359-31 co-ordinate graph paper, Figure 5.

4.3 Test Procedure for Readout Sensitivity (3.2.1), Accurate Amount Indication (3.2.2), Stable End Point (3.2.5), Residual Unbalance (3.2.7), and Accurate Angle Indication (3.3)

4.3.1 Set up the machine with the appropriate test rotor (see 3.8.7) according to the written procedure specified by the manufacturer, the vendor, or the factory set-up engineer. The machine shall be set up to indicate the location at which weight should be removed to balance the test rotor.

4.3.2 Adjust the amount calibration of the machine to give readout directly in units of A (or 0.01, 0.1, 10, 100 etc. times A), as convenient. Use a 30A test weight for calibration in plane 2.

4.3.3 Using the normal balancing procedure, read the unbalance, as indicated. If the unbalance is less than 5A units, shut down and apply arbitrary unknown weight to the test rotor to give a resultant unbalance greater than 5A units, but less than 20A. Apply a correction weight of the indicated amount at the indicated location. Record the angular location and the amount reading on test log sheet. Record four more successive settings of readings, always applying the indicated correction. Do not apply further corrections after these five recorded corrections.

Test - After initial correction, if any of the last four recorded amount-readings are greater than 1A unit, the machine does not conform, since it cannot consistently balance to a value of A units. (See 3.2.5.) Note: The unbalance now remaining in the test rotor is considered to be the residual unbalance. Further tests will indicate its amount (but not measure it) and if it is too large will cause rejection.

Recheck - In case of nonconformance, the vendor is permitted to check, modify, and adjust the machine, prior to a recheck. The test rotor should again be unbalanced beyond 5A. Repeat the above test twice in succession.

4.3.4 Attach a 2.5A unit test weight at any one of the following locations: 15, 165, 195, or 345 deg. The actual value of the location is to be drawn with reference to it from those listed for each test. (Call this location angle E.) This weight remains on the rotor at this location for the following series of tests.

4.3.5 Attach another 2.5A unit test weight at the locations indicated in column G of the test log sheet. Read and record the amount and location of the resultant unbalance as indicated by the balancing machine for each of these locations. Repeat these tests twice more. Plot the results with the symbols shown on the polar graph, Figure 5. Rule in heavily the line from the origin in the direction of E.

Test 1 - Place the transparent overlay, Figure 6, over the graph and adjust it keeping the reference lines parallel to the direction of E until all the plotted points are enclosed in their respective regions as indicated by the symbols. If any points fall outside their regions, check to insure that they have been correctly plotted. If no more than one point falls outside its region, the machine conforms. If two points fall outside, the machine does not conform because of lack of repeatability, amount indication errors, angular indication errors, or cut off at low unbalance.

Test 2 - If the origin of the overlay falls within radius 0.5A units when adjusted as for test 1, the machine conforms for residual unbalance. (See 3.2.7.)

Recheck 1 and 2 - In case of nonconformance, the vendor is permitted to check, modify and adjust the machine prior to a recheck. Repeat 4. 3. 3, 4. 3. 4 and 4. 3. 5 twice in succession. If both tests 1 and 2 result in conformance both times, the machine conforms to this requirement. (See 4. 2. 6. 2.)

4. 3. 6 Measure the displacement of analogue readout device in inches. Divide the measured displacement in inches by the indicated unbalance in A units.

Test - If the sensitivity is less than 0. 125 in. per A units, the machine does not conform because of inadequate sensitivity.

Recheck - In case of nonconformance, the vendor is permitted to check, modify and adjust the machine prior to a recheck. Repeat tests of 4. 3. 3 and 4. 3. 6 for the first two readings for test log sheet, as specified in 4. 3. 5. (See 4. 2. 6. 2.)

4. 4 Test Procedure for Force and Couple Separation (3. 1)

4. 4. 1 With the test rotor set up and balanced as for the previous tests, continue by removing all 2. 5A unit test weights.

4. 4. 2 Fit a 40A unit force test weight to both planes 1 and 3 of test rotor at locations shown in test log sheet and read the indicated force unbalance and location. Plot the last two force readings of 4. 3. 3 with a ⊙ on a polar graph, Figure 5. Plot the readings of 4. 4. 2 with a + on the same graph.

Test - Set overlay with its center midway between the two ⊙ points. If all the + points fall within the force-couple separation circle, the machine conforms. Force unbalance indication is independent of couple unbalance.

Recheck - In case of nonconformance, the vendor is permitted to check, modify and adjust the machine prior to recheck but preceding tests must be redone also.

4. 5 Test Procedure for Range of Unbalance

4. 5. 1 With a 40A unit test weight attached at a known angle in plane 2 of the test rotor, read the unbalance. It is permissible to change the readout units from those used so far for this test. For example, if 1 unit on the readout scale represented A units to insure that 4. 3. 6 be passed, it is now permissible to employ a range-multiplying device so that 1 unit on the readout scale now represents 5A units or some other convenient value without affecting the calibration, as set out in 4. 3. 2.

Test - If the indicated unbalance is between 38A and 42A units, the machine conforms. If the indicated unbalance is beyond this range, repeat the work of 4. 5. 1 to this point once more. If this does not give an indication within 38A to 42A units, the machine does not conform. No further recheck is permitted.

4.6 Test Procedure for Indication of Location for Removal or Addition of Material (3.3.1)

4.6.1 Set the machine, as necessary, to readout the location at which weight should be added to balance the test rotor.

4.6.2 With the 40A unit test weight attached, as specified in 4.5.1, read the location at which weight should be added to balance the test rotor.

Test - If the indicated location is diametrically opposite the test weight within ± 8 deg, the machine conforms. If the indicated location is beyond this range, repeat the procedure of 4.6 to this point once more. If this does not give an indication within the ± 8 deg, the machine does not conform. No further recheck is permitted.

4.7 Test Procedure for the Drive System Reliability and Unbalance Disturbance

4.7.1 With the 40A unit test weight still attached, cycle the machine repeatedly from start to full speed and then to a stop condition. Time at full speed should be only sufficient to readout the amount and location of unbalance. Time at the stop condition should be only sufficient to record the amount and location of unbalance in test log sheet. These cycles should continue for a period of one hour during which time at least 30 cycles must be completed. This test must be performed without the use of auxiliary cooling devices which are not a part of the basic machine.

Test 1 - Reliability - If the machine fails to function mechanically during any part of the test, it does not conform and no further checks are permitted.

4.7.2 Within 5 minutes of completion of 4.7.1, the test rotor must be removed from the machine and test 4.7.3 completed.

4.7.3 With the machine running at full speed and without changing the previously established machine calibration, record the amount of unbalance indication.

Test 2 - Drive System Unbalance Disturbance - If the value of this unbalance reading exceeds 0.5A units, the machine does not conform. No further rechecks are permitted.

4.7.4 The vendor should demonstrate satisfactorily to the customer that the system provided for subsequent correction of force unbalance in the workpiece drive system is adequate.

4.8 Test Procedure for Linearity (3.2.6)

Reinstall the test rotor and remove all test weights to return rotor to balanced condition as obtained in 4.3.3. It is permissible to change the readout units from those used so far as described in 4.5.1.

To obtain a random order of application of unbalances and their positions on the test rotor, proceed as follows. Mark four slips of paper with 2.5A, 10A, 20A, and 40A. Place this in a hat or suitable box. For the first run applied unbalance, mix the slips and draw a slip. Place a test weight of the amount shown on this slip in plane 2 of the test rotor. Continue drawing remaining slips until all four runs have been made. Repeat this procedure three times.

To obtain the angular position for the applied unbalance runs in the previous paragraph, mark four slips of paper with 0, 90, 180, and 270 deg and mix them in a hat or container. Draw one of these, note the angle, replace it and use the angle for the location of the unbalance to be applied.

Record the 12 runs on the test log sheet and plot each point on graph for this test.

Test - If not more than one plotted point is outside the limit lines of the graph, the machine conforms to these specifications for force indicated unbalance linearity. If more than one plotted point is outside the limits, recalibrate the machine and test rotor and repeat the entire test. If more than one point is outside the graph limits on the return, the machine does not conform to this specification.

4.9 Drive System, General

4.9.1 Check direction of rotation to insure that it is counterclockwise when viewed from the drive adapter flange toward the workpiece.

4.9.2 Measure the operating speed of the test rotor to insure that it is 900 rpm or more.

4.10 Other Dimensional Inspection

4.10.1 Ordinary dimensional inspection should be done to insure that the machine complies with 3.8.5 and 3.8.6. Other requirements of 3.8 are a guide to the machine designer, are met if the detailed performance tests are passed, or are demonstrated by the performance tests. To keep the test procedures short enough to be practical, some requirements are accepted on faith or as corollaries of the successful completion of the test procedures specified.

4.10.2 The test rotor and the drive spindle of the balancing machine should be made so as to allow no radial play in the attachment of the latter to the spindle. The drive spindle by itself shall not have a radial runout in excess of .0005 in. (T.I.R.).

4.10.2.1 The procedure to be followed in checking this alignment is:

The spindle concentricity test shall be made without the use of the test rotor.

Fasten a low-friction , type 1 (0.0001 in.) dial indicator to the balancing-machine frame. Lock the flexing head. Adjust the dial indicator so that the indicator tip contacts the outside diameter of the piloting portion of the spindle.

Test - Rotate the spindle slowly by hand and read the indicator for five (5) full turns. The full indicator runout should not exceed 0.0005 in.

PREPARED BY THE BALANCING MACHINE STANDARDS SUBCOMMITTEE OF
SAE COMMITTEE EG-1, AEROSPACE PROPULSION SYSTEMS SUPPORT EQUIPMENT

APPENDIX 1 - GLOSSARY OF TERMS AND NOMENCLATURE

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 meanings in this context. The more general use of the same word will not be capitalized. An attempt has been made throughout 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 ARP 587. (See Appendix 3.)

A. 1. 1 Symbols

V - weight of one Unbalance Test Unit. (oz.) See A. 1. 8.
W - weight of the test 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. (in.)
w - weight of unbalance in ounces at the correction radius of a rotor or part.
U - Unbalance. (oz. -ins.)
A Units - Required sensitivity of the machine in microinches. See A. 1. 7.

A. 1. 1. 1 Subscripts

F - for Force Unbalance
C - for Couple Unbalance

A. 1. 1. 2 Microinch

One microinch = 10^{-6} in.

A. 1. 2 Force Unbalance - A term used to refer to a lack of coincidence of the rotor's center of gravity and the rotor's journal axis. It is the product of the mass of the rotor times the distance between the c. g. of the rotor and the rotor's journal axis. This is sometimes called static unbalance. See also A. 1. 4.

A. 1. 3 Couple Unbalance - is the resultant moment of all unbalance forces about the center of gravity. The Couple Unbalance tends to cause an angular displacement of the principal axis of inertia with respect to the journal axis. See also A. 1. 4.

A. 1. 4 Force Plus Couple Unbalance - The correction of Force plus Couple Unbalance (Dynamic Unbalance) will achieve complete unbalance correction. Analytical conversion by vector analysis can be made from Dynamic Unbalance to Force plus Couple Unbalance and vice versa.

Couple Unbalance is the product of unbalance correction weight times (X) correction radius times (X) plane separation.

Couple Unbalance remains unchanged by the addition of any unbalance in the transverse plane through the center of gravity. Force Unbalance remains unchanged by the addition of any pure couple as defined in A. 1. 3.

Force Unbalance is the product of unbalance correction weight times (X) correction radius.

A. 1. 5 Location - is used to mean the angular location of the correction or Unbalance Test Unit weights in any transverse plane.

A. 1. 6 Readout - as a verb 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 means the result itself.

A. 1. 7 One A Unit - the specified required sensitivity of the balancing machine in Unbalance Test Units as defined in A. 1. 8. The numerical value of A is given in 3. 8. 8. When a number is used with A as in 40A units, an unbalance of 40 times (X) the required sensitivity is implied. If the value of A, as specified in 3. 8. 8, is 50, then 40A units is the unbalance which causes a radial displacement of the c. g. of 2000 microinches from the journal axis.

A. 1. 8 Unbalance Test Units, V - The Unbalance Test Units for the various types of rotors and balancing methods are defined by the amount of displacement they would produce if the rotor rotated in gravitationless free space without any restraint. Note that the Unbalance Test Unit, V, is an amount of weight, as defined by the following equations, which always produces a displacement of one microinch when applied at radius r. If for some particular rotor V = 0. 0003368 ounce and A = 50, the minimum weight which must be detected is 50V = 0. 01684 ounce. A much larger unbalance of 40A units which might be used for machine calibration or a plane separation check is produced by a weight of 2000V = 0. 6736 ounce. Or, the weight for 40A units is given by 40 (A) (V).

A. 1. 8. 1 Force Unbalance - One Unbalance Test Unit (V_F) for Force Unbalance should be that amount of weight which will produce a calculated one microinch radial displacement of the center of gravity of an SAE test rotor when applied in any axial plane and at the specified radius on the SAE test rotor. Center of gravity displacement =

$$\frac{(V_F)\,(r)}{16\,W} = 10^{-6} \text{ inches for one Unbalance Test Unit in ounces.}$$

$$V_F = \frac{16W \cdot 10^{-6}}{r}$$

A. 1. 9 Analogue - means a readout which is measured on a continuous scale and whose readability depends on the length of the scale.

A. 1. 10 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 set-up of the machine to which a physical unit is assigned.

A. 1. 11 One pound = 453. 6 grams (454 grams round numbers) = 16 ounces.

A. 1. 12 One ounce = 28. 35 grams.

A. 1. 13 Plane 1, Plane 2, and Plane 3 are balancing plane designations for test rotors only.

APPENDIX 2 - DETAILS FOR CONTRACTUAL NEGOTIATION

The following details are considered to be important. The values given may be adjusted for any particular requirement. Test procedures to insure compliance with these requirements are beyond the scope of this document.

A.2.1 The balancing machine should operate in a satisfactory manner over an ambient temperature range of XX-XXX F, and under 100% relative humidity.

A.2.2 All units of the electrical equipment should comply with applicable electrical specifications such as N. E. M. A. and other local codes.

A.2.3 The electrical systems should operate satisfactorily under line voltage variations of ± XX%, line frequency variations of ± XX% and waveform harmonic distortion of up to XX%.

A.2.4 All electrical systems should be arranged for operation from a supply of XXX volts, X phase, XX cycles/second.

A.2.5 Any need for radio interference suppression should be specified.

A.2.6 Balancing machine performance may be sensitive to environmental vibratory conditions. No general requirement can be specified due to the wide range of environmental frequencies and amplitudes and due to the varied response of different balancing systems to these excitations.

The responsibility for special mounts which may be necessary to adapt any particular machine to a particular environment should be defined.

A.2.7 All tests should be run at the vendor's before shipment to or at the purchaser's after installation. Facilities for making all tests to be provided by the vendor or the purchaser. Test rotors to be provided by the vendor or the purchaser as per agreement.

A.2.8 Installation and service.

A.2.9 Operating and maintenance personnel training.

A.2.10 Operating Manual, Maintenance Manual, Circuit Diagrams, Spare Parts Ordering Information.

APPENDIX 3 - BIBLIOGRAPHY

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

A. 3. 1 Report No. 371-V-24; Department of the Navy, Bureau of Ships, Code 371.

A. 3. 2 MIL-STD-167; Mechanical Vibrations of Shipboard Equipment, Department of the Navy, Bureau of Ships.

A. 3. 3 MIL-B-25511 (USAF); Military Specification, Balancing Machine, Dynamic-Static, Two Plane.

A. 3. 4 A. S. T. E. Handbook.

A. 3. 5 "Performance Tests for Balancing Machines", Werner I. Senger, Machinery's Reference Section, March - April, 1958.

A. 3. 6 ARP No. 587, Balancing Machines for Jet Engine Components—Compressors and Turbines—Rotating Type For Measuring Unbalance in One or More Than One Transverse Planes.

A. 3. 7 S2. 7 - 1964 American Standard Terminology for Balancing Rotating Machinery.

A. 3. 8 MIL-B-25510 (USAF); Military Specification, Balancing Machines - Static-Single Plane.

TEST LOG SHEET FOR 4.3.3

PLANE 2	
Angular Location Degrees	Amount A Units

TEST LOG SHEET FOR 4.3.5 AND 4.3.6

E = Plane 2

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

* See 4.3.6 for sensitivity test when this reading is indicated.

** For this set of readings remove both 2.5 A Units Test Weights of 4.3.4 and 4.3.5. Be sure to install the same weight at the same angle as 4.3.4 for the next set of readings.

TEST LOG SHEET FOR 4.4.2

		SYMBOL +	
Location of 40 A Weight Degrees		Indicated Unbalance	
		Location Degrees	Amount A Units
Couple Plane 1	Couple Plane 3	Force Plane 2	
60	240		
150	330		
240	60		
330	150		

TEST LOG SHEET FOR 4.7.1 and *4.7.3

Run #	Amount A Units	Location Degrees		Run #	Amount A Units	Location Degrees	
1				26			
2				27			
3				28			
4				29			
5				30			
6				31			
7				32			
8				33			
9				34			
10				35			
11				36			
12				37			
13				38			
14				39			
15				40			
16				41			
17				42			
18				43			
19				44			
20				45			
21				46			
22				47			
23				48			
24				49			
25				50			
				*			

* Record Drive System Unbalance Disturbance after removing test rotor per 4.7.2.

TEST LOG SHEET FOR 4.8

Run #	Amount A Units	Angle Degrees
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12