AEROSPACE RECOMMENDED PRACTICE

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BALANCING EQUIPMENT FOR JET ENGINE COMPONENTS COMPRESSORS AND TURBINE - ROTATING TYPE FOR MEASURING UNBALANCE IN ONE OR MORE THAN ONE TRANSVERSE PLANES

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1. PURPOSE

1.1 The purpose of this document is to delineate the technical specifications for rotating type of balancing equipment for measuring the amount and angle of unbalance corrections required in one or more than one transverse planes to balance jet engine components. (For Glossary of Terms and Nomenclature, see Appendix 2)

1.2 This document also delineates performance tests to be used to ensure compliance with this document.

1.3 This document was prepared to give a general description of balancing equipment which will be capable of balancing all jet engine 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, or ounce-inches^2.

2. SCOPE

This document specifies those requirements of balancing equipment which make it suitable for the subject class of work.

It will specify:

(a) Sensitivity,
(b) Accuracy of indications of amount and angle of unbalance,
(c) Ability to separate the Dynamic Unbalance into two planes and to separate Static and 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) Standard shroud mounting pads,
(h) Power requirements.

3. REQUIREMENTS

3.1 Plane Separation:

3.1.1 The balancing machine shall read out the amount and angle of the unbalance in each of one or more selected correction planes in the proving rotor.

3.1.2 The balancing equipment shall indicate less than 2 A Units of unbalance in one selected correction plane of a proving rotor when 40 A Units of unbalance are added in the other selected correction plane of the proving rotor. See A.2.8 and 3.9.13 for definition and numerical values of A. (Test 4.4.2)

3.2 Static and Couple Unbalance Separation:

3.2.1 The balancing equipment shall read out the amount and angular location of both the Static Unbalance and Couple Unbalance, separately, for the selected correction planes in the proving rotor.

3.2.2 The balancing equipment shall indicate less than 2 A Units unbalance in the static correction plane of the proving rotor when 40 A Units of unbalance are added in the couple correction planes of the proving rotor. It shall also indicate less than 2 A Units unbalance in the couple correction planes of the proving rotor when 40 A Units of unbalance are added in the static correction plane of the proving rotor. (Test 4.8.4 and 4.8.5)

3.3 Amount Indication:

3.3.1 All analogue types of amount of unbalance readout devices shall have at least 1/8 in. (3.17 mm) displacement for measurement of one A Unit of unbalance over a range up to 20 A Units (4.3.7).

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

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

3.3.4 The unbalance measuring range shall extend to at least 50 A Units. (Test 4.5.1)

3.3.5 If the indicated unbalance is less than one A Unit successive application of the indicated corrections shall not result in a new indicated unbalance greater than one A Unit. (Test 4.3.3 and 4.8.3)

3.3.6 Static and Couple Indicated Unbalance Linearity shall be within 5% of the Static and Couple applied unbalance for the applied unbalances of 45A, 25A and 10A. For an applied Static and Couple unbalance of 2.5A, the indicated Static and Couple unbalance shall be between 2.25A and 2.75A. (Test 4.8.6)

3.3.7 A proving rotor corrected for unbalance until the amount of unbalance indicator shows a minimum reading shall not have a residual unbalance greater than 0.5 A Units. (Test 2 of 4.3.5)

3.4 Correction Indication:

3.4.1 The equipment shall read out the locations where addition or removal of material is necessary to balance the rotor. Neither the locations in all correction planes, nor both the location for addition and removal of material in any plane need be read out simultaneously. (Test 4.6.2)

3.4.2 The equipment shall indicate the location in each selected plane of the proving rotor to such accuracy that for actual unbalance conditions up to 5 A Units only a single correction in each plane is required. When the indicated unbalance amounts of correction are applied simultaneously at the indicated location in each respective correction plane, the equipment shall indicate that such single corrections have been effective by indicating the residual unbalance amounts of less than one A Unit in each correction plane. (Test 4.3.5)

3.4.3 For equal unbalances of any value from 5A to 40A applied in both planes, the equipment shall indicate the correct amount and angle of the unbalance in each plane. These equipment indications shall be of such accuracy that when the indicated required corrections are made in each plane the resulting unbalance in each plane shall not exceed 10% of the original applied unbalance. (Tests 4.5.1 and 4.6.2)

3.5 Practical Correction Units: The balancing equipment shall provide unbalance amount readout in terms of the correction units actually used, number of weights, number of washers, etc., within the requirements of 3.3 and 3.4 subject to the interpretation by the test procedure 4.2.2. (Tests 4.3.2, 4.5.1 and tests for 3.3 and 3.4) Because of the many different types of readout devices, it is considered impractical to write a specific test procedure to satisfy 3.5 for all equipment. However, it is necessary that the balance equipment manufacturer demonstrate to the purchaser that his equipment 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 3.3.1 and the sensitivity required in other portions of this document.

3.6 Drive for Workpiece Rotor:

3.6.1 The maximum unbalance disturbance of the drive system shall not exceed 0.5 A 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 proving rotor. (Test 4.7)

3.6.2 All end drive flanges shall conform to drawings specified in 3.9.10.

3.6.3 The primary direction of rotation shall be counterclockwise when viewed from the end drive flange attachment toward the workpiece. Clockwise rotation of some engine components is not permissible. The driven end and position of the rotor should be selected to provide the desired rotor rotation. Belt drive equipment should provide for the application of the belt drive along the full length of the equipment either between or outside the work supports over the length specified in 3.9.8.

3.7 Speed of Rotation During Balancing: The equipment shall be capable of operating at variable speeds as shown in 3.9.14.

3.8 Driving Motor and Control: Reference to details of contractual negotiations Appendix 3.

3.8.1 The machine shall be capable of making six consecutive starts and stops to full speed of the maximum weight test rotor at any time during normal operation.

3.9 General Dimensional and Capacity Requirements: The following table lists the general requirements for each class of equipment:

Characteristic	300 lb Machine	1000 lb Machine	3000 lb Machine
3.9.1 Capacity Designation			
3.9.2 Minimum Load - lb	45	150	450
3.9.3 Maximum Load - lb (See also NOTE A)	450	1500	4500
3.9.4 Maximum Load on one work support - lb (See also NOTE A)	300	1000	3000
3.9.5 Maximum Negative Load on one work support - lb (See NOTE D)	45	150	450
3.9.6 Maximum Moment on work Supports - lb-in.	300	1000	3000
3.9.7 Maximum Diameter of Rotors			
3.9.7.1 Maximum diameter of rotors including shroud (over tie bars) - in.	31	55	66
3.9.7.2 Maximum Diameter of Outboard Rotor - in.	-	90	110
3.9.8 Distance between supports - Centerline to Centerline - in. (See also NOTE B)	50	75	100

	Characteristic	300 lb Machine	1000 lb Machine	3000 lb Machine
3.9.9	Work Supports as per Fig. No. (See also NOTE D)	1	1	1
3.9.10	End Drive Adaptor Flange as per Fig. No.	2A	2B	2C
3.9.11	Shroud Mounting Pads as per Fig. No.	3	3	3
3.9.12	Test Rotors as per Fig. No.	4	4	4
3.9.12.1	Inboard Rotor - Weight - lb	51.75	170	452.65
3.9.12.2	Outboard Rotor - Weight - lb	180	600	1800
3.9.13	A Units (See A.2.10) in micro in.	25	14.5	14.5
3.9.14	Balancing Speed Range	600-5000	600-3000	600-1500
3.9.15	Horsepower versus speed requirements	See NOTE C	See NOTE C	See NOTE C
3.9.16	Range of Workpiece Pulley Diameters - in.	1-9	2-12	3-18
3.9.17	Maximum Belt Width - in.	2.5	3.5	4.5

NOTE A: Overloading of balancing equipment beyond 3.9.3 and 3.9.4 is not recommended unless such action is approved by the particular balancing equipment manufacturer.

NOTE B: (3.9.8 above) Provision shall be made to extend the distance between supports by 30%. This may be done either by providing an option at the time of purchase or by a modification kit which may be purchased later.

NOTE C: (3.9.15 above) The user should specify to the manufacturer the horsepower requirements at specific balancing speeds. For belt drives, full horsepower is intended to be transmitted only by the largest pulley diameter and belt width.

Ø NOTE D: To accommodate certain large fan type engines, maximum negative load of 700 lb and work support bore diameter of 20 in. is required for the 300 lb machine.

4. TEST REQUIREMENTS

4.1 Proving Rotors:

4.1.1 Each piece of balancing equipment shall be tested with one weight of Inboard SAE proving rotor and one weight of Outboard SAE proving rotor as specified in 3.9.12.

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

A. Proving rotor with bearings
B. Test weights as defined in 4.1.6
C. Adaptors for bearings, as required for SAE standard work supports only
D. Proving Rotor Storage Box
E. Test instructions

4.1.3 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 bearing, bearing adaptors and test weights maintained at any installation or to be shipped to an installation for tests.

4.1.4 All SAE test weights shall conform to the Unbalance Test Unit system of A.2.8, A.2.9, A.2.9.1, A.2.9.2, and A.2.9.3.

4.1.5 Test weight classes, other than those specified in this document, 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.

4.1.6 Two Inboard Dynamic test weights of 2.5 A Units, One Inboard Dynamic test weight of 40 A Units, One Outboard Static test weight of 40 A Units and Two Outboard Couple test weights of 40 A Units, should be provided for the proving rotors for each class of equipment.

4.2 Performance Tests:

4.2.1 The tests described in the following paragraphs represent a minimum test procedure. The Requirements, Section 3, have been written to define the characteristics of the equipment. 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 of any particular balancing equipment, such as lack of ruggedness or equipment not being properly leveled or anchored to the floor.

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

4.2.3 The manufacturer and user shall be satisfied with the weighing and location of correction weights, and that the proving rotor and test weights conform to the SAE specifications (Figure 4, a, b, c, and d). The user shall be permitted to witness or check any of this work.

4.2.4 An accurate and precise weighing scale shall be available for the test. This scale shall be accurate and precise to at least two decimal places beyond the smallest A Units test weight. For example if the A Units test weight weighs 0.00842 ounces the scale should be accurate to 0.00008 ounces.

4.2.5 With the Inboard Proving Rotor, follow procedures 4.3, 4.4, 4.5, 4.6 and 4.7. With the Outboard Rotor, follow procedures 4.10.2.2, 4.8 and 4.9 in that order.

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

4.2.7 All tests shall be performed at the minimum operating speed for the class of equipment.

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

4.2.8.1 Each test specifies the conditions for conformance (acceptability) or non-conformance (non-acceptability) to the specific test.

4.2.8.2 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 non-conformance.

4.2.9 Transparent Overlay, Figure 7, is designed for use with Keuffel & Esser Company #359-31 co-ordinate graph paper, Figure 6.

4.3 Testing Procedure for Readout Sensitivity (3.3.1), Accurate Amount Indication (3.3.2 and 3.3.3), Stable End Point (3.3.5), Residual Unbalance (3.3.7) and Correction Indication of Angle and Amount (3.4.2):

4.3.1 Set up the equipment for Dynamic balancing with the Inboard Proving Rotor (see 3.9.12.1) according to the written procedures specified by the manufacturer. The equipment shall be set up to indicate the location at which weight should be removed to balance the proving rotor.

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

4.3.3 Using the normal balancing procedure, read the unbalance in planes 1 and 2. If the unbalance is less than 5 A Units, shut down and apply arbitrary unknown weights to the proving rotor to give a resultant unbalance in each plane greater than 5 A Units, but less than 20A. Apply correction weights of the indicated amounts of unbalance at the indicated locations. Record the angular location and the amount reading in each plane on the test log sheet 4.3.3. Record 4 more successive sets of readings for each plane, always applying the indicated corrections. Do not apply further corrections in a plane after these 5 recorded corrections.

Test: After the initial correction, if any of the last 4 recorded amount readings are greater than one A Unit, the equipment does not conform since it cannot consistently balance to a value of one A Unit. (See 3.3.5)

Note: The unbalance now remaining in the proving 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 manufacturer is permitted to check, modify and adjust the equipment prior to a recheck. The proving rotor should be unbalanced beyond 5A in both planes. Repeat 4.4.3 twice in succession. (See 4.2.7 and 4.2.7.2)

4.3.4 Fit a 2.5 A Units Test Weight at any one of the following locations in plane 1; 15, 165, 195 or 345 degrees. (Call this location angle E). This weight remains on the rotor at this location for the following series of tests except for ** (See Test Log Sheet for 4.3.5 and 4.3.6).

4.3.5 Fit another 2.5 A Units Test Weight at the locations in plane 1 as indicated in column G of the Test Log Sheet for 4.3.5. Read and record the amount and location of the resultant unbalance as indicated by the balancing equipment in plane 1 for each of these locations. Repeat these tests twice more. Plot the results with the symbols shown on the polar graph, Fig. 6. Rule in heavily the line from the origin in the direction of E.

Test 1: Place the transparent Overlay, Fig. 7, over the graph and adjust it keeping the 0° to 180° axis 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 ensure that they have been correctly plotted. If no more than one point falls outside its region, the equipment conforms. If two points fall outside, the equipment does not conform because of lack of repeatibility, amount indication errors, angular indication errors, or cut off at low unbalance.

Test 2: If the origin of the Overlay falls within radius 0.5 A Units when adjusted as for Test 1, the equipment conforms for residual unbalance. (See 3.3.7)

Recheck 1 and 2: In case of nonconformance, the manufacturer is permitted to check, modify and adjust the equipment 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 equipment conforms to this requirement. (See 4.2.7.2)

4.3.6 Remove the Test Weights from plane 1 and repeat 4.3.4 and 4.3.5 but for plane 2.

4.3.7 Measure the displacement of analogue readout device in inches. Divide measured displacement in inches by indicated unbalance in A Units.

Test: If the sensitivity is less than 0.125 in. per A Units, the equipment does not conform because of inadequate readout sensitivity. (See 3.3.1)

Recheck: In the case of nonconformance, the vendor is permitted to check, modify and adjust the equipment prior to a recheck. Repeat tests 4.4.4 and 4.3.7 for the first two readings for test log sheet 4.3.5. (See 4.2.7.2)

4.4 Testing Procedure for Plane Separation (3.1.2):

4.4.1 With the proving rotor set up and balanced as for the previous tests, continue by removing all 2.5 A Units Test Weights.

4.4.2 Apply a 40 A Units Test Weight to plane 2 at the locations shown in the Test Log Sheet and read the indicated unbalance and location in plane 1 and plane 2. Repeat these tests twice more. Plot the results with the symbol shown on the same graph used in 4.3.5.

Test: With the Overlay located in the same position as for the tests of 4.3.5 check the position of the points just plotted. If the points are all within the Separation Circle the machine conforms. (It is permissible to adjust the position of the Overlay if necessary to obtain conformance, provided that previous tests with the Overlay result in conformance simultaneously.)

Recheck: In case of nonconformance, the manufacturer is permitted to check, modify and adjust the equipment prior to a recheck. Repeat 4.3.3, 4.3.4, 4.3.5, 4.3.6, 4.4.1 and 4.4.2 twice in succession. (See 4.2.7.2)

4.4.3 Repeat 4.4.2 but applying Test Weights to plane 1 reading the unbalance in plane 2.

4.5 Test Procedure for Range of Unbalance (3.3.3 and 3.3.4):

4.5.1 With the 40 A Units Test Weight fitted to plane 1 at 270° as per last reading required of 4.4.3 read the unbalance in plane 1. 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 ensure that 4.3.7 be passed, it is now permissible to employ a range-multiplying device so that 1 unit on the readout scale now represents 5 A Units or some other convenient value without affecting the calibration, as set out in 4.3.2.

Test: If the indicated unbalance is between 38 A and 42 A Units, the equipment conforms. If the indicated unbalance is beyond this range, repeat the work of 4.5.1 so far, once more. If this does not give an indication within 38 A to 42A Units, the equipment does not conform. No further recheck is permitted.

4.6 Testing Procedure for Indication of Location for Removal or Addition of Material (3.4.1):

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

4.6.2 With the 40 A Units Test Weight fitted to plane 1 at 270° as per the last reading required of 4.4.3 read the location at which weight should be added to balance the proving rotor.

Test: If the indicated location is between 82° and 98° the equipment conforms. If the indicated location is beyond this range, repeat the work of 4.6 so far, once more. If this does not give an indication within 82° to 98°, the equipment does not conform. No further recheck is permitted.

4.7 Testing Procedure for Unbalance Disturbance by the Drive System (3.6.1):

4.7.1 Remove all Test Weights from the proving rotor.

4.7.2 Read and record the amount and angular location of the unbalance in both planes 1 and 2. These values should be entered opposite run 1 on the Test Log Sheet. This configuration is listed as Drive Angle 0°.

4.7.3 Turn the rotor 180° with respect to the drive and or measuring system of the balancing equipment. This can be done in the case of end drive systems by uncoupling the end drive. If belt drive is used the phase reference pick-up should be arranged to change the phase by 180°. (If there is no fixed angular relationship between the rotor and the equipment as in some forms of equipment with belt drive and stroboscopic location indicator this cannot be done and the equipment is considered to be acceptable under Test 4.7 without testing.) Read and record amount and angular location of the unbalance in both planes 1 and 2. These values should be entered opposite run 2 on the Test Log Sheet. This configuration is listed as Drive Angle 180°. Reverse the location by adding or substracting 180° as indicated in the Test Log Sheet.

4.7.4 Reverse the operations of 4.7.3 to put the system as it was for 4.7.2. Repeat the readings of 4.7.2 but enter opposite run 3.

4.7.5 Repeat 4.7.3 but enter opposite run 4.

4.7.6 Both belt and end drive should be tested except as noted in 4.7.3.

Test: Plot the data from Test Log Sheet under plane 1 on a polar graph, Fig. 6 with the symbols indicated. (Plot the amount and the angle in the box with the symbol.) Find the point P, the bisector of the line segment joining the +'s and the point Q, the bisector of the line segment joining the O's. (See Test Log Sheet for a typical construction.) If the length of the line PQ is less than one A Unit, the machine conforms. Repeat this test for plane 2.

Recheck: In case of nonconformance, the manufacturer is permitted to check, modify and adjust the equipment prior to a recheck. Repeat 4.7 in its entirety twice in succession. (See 4.2.7.2)

4.7.7 The manufacturer should demonstrate satisfactorily to the user the system provided for subsequent correction of static and couple unbalance in the workpiece drive system.

4.8 Testing Procedure for Static and Couple Unbalance Separation (3.2.2), and Static and Couple Indicated Unbalance Linearity (3.3.6):

4.8.1 Set up the equipment for Static and Couple balancing with the Outboard Proving Rotor (See 3.9.12.2) according to the written procedures specified by the manufacturer. The equipment should be set up to indicate the location at which weight should be added to balance the Proving Rotor. Use plane 3 for the Static plane and plane 4 and 5 for the Couple planes.

4.8.2 Adjust the amount calibration as in 4.3.2.

4.8.3 Using the normal balancing procedure, read the unbalance in the Static plane and in the Couple planes and apply correction weights of the indicated amounts at the indicated locations. Record the angular location and the amount of the indicated unbalance for the first Static amount of the indicated unbalance for the first Static amount reading and the first Couple amount reading on the Test Log Sheet 4.8.3. Record 4 more successive sets of readings for Static and Couple unbalance always applying the indicated corrections. Do not apply further corrections after these 5 recorded Static and Couple corrections.

4.8.4 Fit a 40 A Units Test Weight (Couple) to both planes 4 and 5 at the locations shown in the Test Log Sheet and read the indicated Static and Couple unbalance and location. Plot the last two Static unbalance readings from 4.8.3 with a ⊙ on a polar graph, Fig. 6. Plot the readings from 4.8.4 with a + on the same graph.

Test: Set the Overlay with its center midway between the two ⊙'s. If all the +'s are within the Separation Circle, the machine conforms. Static unbalance indication is independent of Couple unbalance.

Recheck: In case of nonconformance, the manufacturer is permitted to check, modify and adjust the equipment prior to a recheck. Repeat 4.8.4 twice in succession. (See 4.2.7.2)

4.8.5 Remove the weights from 4.8.4 and fit a 40 A Units Test Weight (Static) to plane 3 at the locations shown in the Test Log Sheet and read the indicated Couple unbalance and angular location. Plot the last two Couple unbalance readings from 4.8.3 with a ⊙ on a separate polar graph, Fig. 6. Plot the readings from 4.8.5 with a + on the same graph.

Test: Set the Overlay with its center midway between the two ⊙'s. If all of the +'s are within the separation circle, the equipment conforms. Couple unbalance indication is independent of Static unbalance.

Recheck: In case of nonconformance, the manufacturer is permitted to check, modify and adjust the equipment prior to a recheck. Repeat 4.8.5 twice in succession. (See 4.2.7.2)

4.8.6 To obtain a random order of application of unbalances and their positions on the Proving Rotor, proceed as follows: Mark five slips of paper with S2.5, S5, S10, S25 and S45 and five more slips with C2.5, C5, C10, C25 and C45. Place these in a hat or suitable box. For the first run applied unbalance, mix the slips and draw a slip. 'S' and a number indicates that the indicated Static unbalance should be applied in plane 3. 'C' and a number indicates that the Couple unbalance should be applied in planes 4 and 5, 180° apart. When all ten slips have been drawn, replace them and mix them for run 2; repeat for run 3.

To obtain the angular position to apply the unbalance in planes 1 and 2, mark four slips of paper with the angles 0, 90, 180, 270 and mix them in a hat or box. Draw one of these, note the angle, replace it and use the angle for the location of the applied unbalance.

Remove all applied unbalances from the Proving Rotor before starting this test. It is permissible to employ a range multiplying device so that one 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.

Complete the Test Log Sheet 4.8.6 and plot the 30 values on the Test Sheet for 4.8.6, using a ⊙ for all indicated Static unbalances and a ⊖ for all indicated Couple unbalances.

Test: If not more than one plotted point is outside the limit lines of the graph, the equipment conforms to these specifications for Static and Couple Indicated Unbalance Linearity. If more than one plotted point is outside the limits, recalibrate the equipment and Proving Rotor and repeat the entire test. If more than one point is outside the graph limits on the rerun, the equipment does not conform and no further recheck is permitted.

4.9 Drive System General:

4.9.1 The direction of rotation should be counterclockwise when viewed from the end drive flange attachment toward the workpiece.

4.9.2 Measure the operating speed of the Outboard Proving Rotor to ensure that it is 600 RPM or more.

4.10 Other Dimensional Inspection:

4.10.1 Ordinary dimensional inspection should be done to ensure that the equipment complies with 3.9.7, 3.9.8, 3.9.9, 3.9.10, 3.9.11 and that the scope of the belt drive complies with the requirements of 3.6.3. Other requirements of 3.9 are a guide to the equipment 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 work support drawing, Fig. 1 gives an angular dimension P for the minimum angular adjustment of outer race.

4.10.2.1 Anti-friction bearings and some sleeve bearings require either a relatively rigid work support structure to maintain accurate axial alignment between each bearing support or a low-friction mechanical system to permit each bearing support to seek its optimum position. Each work support should be provided with (a) an adjustable mechanical system to adjust and maintain bearing alignment or (b) an anti-friction system that will seek and maintain alignment. The outer race of the proving rotor anti-friction bearing or the sleeve of proving rotor plain bearing should be aligned with the axis of rotation within 0.0005 inch.

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

4.10.2.2.1 Test with the Outboard Rotor mounted on the balancing equipment.

4.10.2.2.2 Dial Test Indicators used for this test are classified in section 1.2 of Military Specification, MIL-I-18422B(Navy) 31 December 1956 where the Type and Styles referred to are described.

4.10.2.2.3 Fasten a low friction Type 1 (0.0001 in.) dial indicator to the proving rotor with the indicator tip contacting, in an axial direction, the outer race of the proving rotor anti-friction bearing, the face of the sleeve of the proving rotor plain bearing or a true face of the work support which holds the proving rotor bearing. The indicator may be held to the proving rotor by any rigid method such as a magnetic base holder or strap held by a bolt in any one of the lifting eyebolt holes or test weight holes. The indicator tip and arm, if it is the swivel tip, Style C or D, "universal" test type must contact the indicated face at an angle of less than 15°. If the indicator is a Style A or B type, the stem must be adjusted to an angle of 75 to 90 degrees to the indicated face.

4.10.2.2.4 Rotate the proving rotor slowly by hand and read the indicator for five full turns. If the indicator varies more than 0.0002 in. for a selected angular position of the proving rotor axial float of the rotor in its bearings prevents adequate readings for this procedure and this float must be reduced as described below.

4.10.2.2.5 Set up a rigid, metal, ground bar or toolmakers knee at one end of the proving rotor, perpendicular to the rotor axis. Place a precision steel ball in the center hole of the proving rotor and back it up with the perpendicular metal surface. Apply axial pressure manually or by means of a spring and show that this device has resulted in readings of the consistency required in 4.10.2.2.4.

4.10.2.2.6 Adjust the angular position of the bearing support until the indicator shows less than 0.0005 in. variation. (Total or partial depending whether a full 360° face is indicated.) By the means provided, lock the bearing support in this position and recheck to ensure that locking has not increased the variation beyond 0.0005 inch. (Note that the bearing support lock referred to here is not the floating work support lock. The work support should be floating for this test.)

4.10.2.2.7 Repeat 4.10.2.2.6 for the other bearing.

4.10.2.2.8 Without unlocking the bearing support after completing tests as per 4.8 and 4.9 set up the dial indicator etc., and show that the variation at both bearings has not increased beyond the original tolerance of 0.0005 inch.

4.10.2.2.9 On balancing equipment equipped with self-seeking alignment of bearings the procedures of 4.10.2.2.6, 4.10.2.2.7 and 4.10.2.2.8 shall be replaced with those paragraphs following. When setting up the indicator on such equipment as in 4.10.2.2.3 it shall contact the face of the outer race (anti-friction bearings are required for this test procedure) to ensure that the floating part is measured. To avoid axial thrust due to hand rotation it may be necessary to wind about 20 turns of twine around the body of the rotor and rotate it by pulling the twine up or down vertically at about two feet from the rotor.

4.10.2.2.10 Make 10 runs as follows:

4.10.2.2.10.1 Seat the rotor in the equipment and adjust the indicator against the outer race.

4.10.2.2.10.2 Rotate the proving rotor five turns or more freely by hand to ensure seating.

4.10.2.2.10.3 Rotate the rotor slowly and record the full indicator runout and note the high position within ± 15 degrees.

4.10.2.2.10.4 Lift the end of the rotor being measured just free and reseat it in the support. A small misalignment can purposely be applied to check realignment.

4.10.2.2.10.5 Repeat 4.10.2.2.10.2, 4.10.2.2.10.3 and 4.10.2.2.10.4 for a total of 10 times.

Test: If the maximum difference between the most divergent of the 10 readings 4.10.2.2.10.3 does not exceed 0.0005 in., the equipment conforms.

4.10.2.2.10.6 Repeat 4.10.2.2.9 through 4.10.2.2.10.5 for the other work support.

Recheck: In case any one or more of these tests fails to be within the specification limits the manufacturer is permitted to check modify and adjust the equipment prior to a recheck. Repeat the tests in any nonconforming section in their entirety. (See 4.2.7.2)

PREPARED BY
SAE COMMITTEE EG-1, AEROSPACE PROPULSION SYSTEMS SUPPORT EQUIPMENT

APPENDIX 1

PROVING ROTOR DIMENSIONS

CHARACTERISTICS / MACHINE SIZE	INBOARD PROVING ROTOR 300 lb	INBOARD PROVING ROTOR 1000 lb	INBOARD PROVING ROTOR 3000 lb	OUTBOARD PROVING ROTOR 300 lb	OUTBOARD PROVING ROTOR 1000 lb	OUTBOARD PROVING ROTOR 3000 lb
Weight of Proving Rotor - W - lb	51.75	170	452.65	180	600	1800
Plane Separation - d - in	8.	15	40	1.000	1.000	2.870
Bearing Separation - D - in	23.625	38.25	83.18	23.625	38.250	83.180
Correction Radius - r - in	1.25	2.0	3.550	---	---	---
Correction Radius - r - in (plane 3)	---	---	---	1.25	2.00	3.55
Correction Radius - r - in (plane 4&5)	---	---	---	8.950	16.062	20.025
Transverse Inertia - Ix-lb-in^2	6243.	44012.	594195.	17149	131782	1437595
Polar Inertia - Iz - lb-in^2	90.	738.	4651.	5704	59925	279801
One Unbalance						
Test Unit - V_{DI} - oz	0.000474	0.0008715	.001246	---	---	---
Specified Sensitivity	$(25x10^{-6})$	$(14.5x10^{-6})$	$(14.5x10^{-6})$	$(25x10^{-6})$	$(14.5x10^{-6})$	$(14.5x10^{-6})$
A Units - oz	0.01185	0.01264	0.01807	---	---	---
2.5 A Units - oz	0.02963	0.03160	0.04518	---	---	---
40 A Units - oz	0.4740	0.50560	0.72280	---	---	---
One Unbalance - (Plane 3)						
Test Unit - V_S - oz	---	---	---	0.00230	0.00480	0.00811
40 A Units - oz	---	---	---	2.304	2.784	4.704
One Unbalance - Planes 4 & 5)						
Test Unit - V_{CO} - oz	---	---	---	0.000756	0.001691	0.003655
40 A Units - oz	---	---	---	0.756	0.981	2.120

APPENDIX 2 - 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. In general, the terminology of ISO/TC 108 DR 1925 and ANSI S2/65 has been used.

A.2.1 Symbols:

U - Unbalance (oz-in.)
A - Units - Required sensitivity of the equipment in microinches. See A.2.8.
W - weight of the proving rotor (lb)
r - radius of the center of gravity (c.g.) of V or w from journal axis (in.)
I_x - moment of inertia of the proving rotor about a transverse axis through its c.g. (lb-in.^{2})
ø I_z - moment of inertia of the proving rotor about its axis of rotation (lb-in.^{2})
d - separation of the Couple Unbalance or the Dynamic Unbalance planes (in.)
B - separation of the left hand bearing mid-point and the c.g. of the proving rotor (in.)
D - separation of the bearing mid-points (in.)
C - separation of the left hand bearing mid-point and the left hand Dynamic Unbalance plane (in.)
w - weight of unbalance in ounces at the correction radius of a rotor or part

A.2.1.1 Subscripts:

S - for Static Unbalance
C - for Couple Unbalance
I - for Inboard Rotor
ø O - for Outboard Rotor
1 - for the plane 1
2 - for the plane 2
3 - Mid-plane on proving rotor
4 - for plane 4
5 - for plane 5

A.2.1.2 Microinch:

One microinch = 10^{-6} in.

A.2.2 Unbalance: That condition which exists in a rotor when vibratory force or motion is imparted to its bearing as a result of centrifugal forces. (See General)

Note 1: The term "unbalance" is sometimes used as a synonym for "amount of unbalance", or "unbalance vector".

Note 2: Unbalance will in general be distributed throughout the rotor but can be reduced to:

a. static unbalance and couple unbalance described by three unbalance vectors in three specified planes, or

b. dynamic unbalance described by two unbalance vectors in two specified planes.

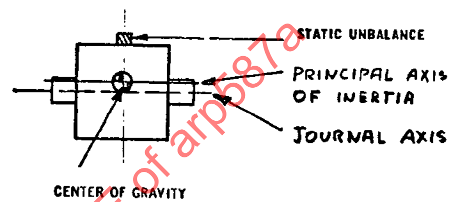
A.2.3 Amount of Unbalance: The amount of unbalance is the quantitative measure of unbalance in a rotor (referred to a plane), without referring to its angular position. It is obtained by taking the product of the unbalance mass and the distance of its center of gravity from the shaft axis.

Note 1: Units of unbalance are, for example, oz - in, g - mm, etc.

Note 2: Weight may be substituted for mass in certain countries.

A.2.4 Angle of Unbalance: Given a polar coordinate system fixed in a plane perpendicular to the shaft axis, the angle of unbalance is that angle at which an unbalance mass is located with reference to the given coordinate system.

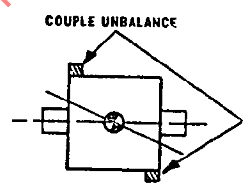
A.2.5 Static Unbalance: Static unbalance is that condition of unbalance for which the central principal axis is displaced only parallel to the shaft axis.



Ø

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

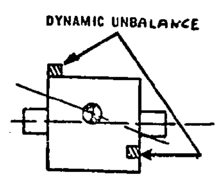
A.2.6 Couple Unbalance: Couple unbalance is that condition of unbalance for which the central principal axis intersects the shaft axis at the center of gravity.



Note 1: The quantitative measure of couple unbalance can be given by the vector sum of the moments of 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 that containing the reference point, the couple unbalance will be changed.

A.2.7 Dynamic Unbalance: Dynamic unbalance is that condition in which the central principal axis is not coincident with the shaft axis.



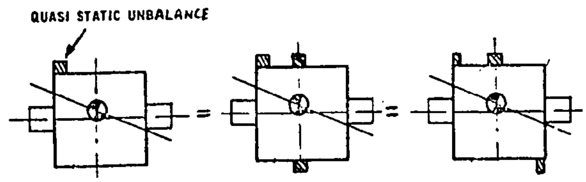
(UNBALANCE WEIGHTS NOT DIAMETRICALLY OPPOSED)

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)
Ø which completely represent the total unbalance of the rotor.

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. Only the two-plane case is covered in this document. 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.

A.2.8 Quasi-static Unbalance: Quasi-static unbalance is 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. ∅



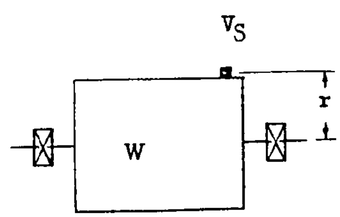
All three figures represent the same Quasi-static unbalance.

A.2.9 Readout: As a verb means to provide an answer or result by whatever means the particular equipment 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.2.10 One A Unit: The specified required sensitivity of the balancing equipment in Unbalance Test Units as defined in A.2.11. The numerical value of A is given 3.9.13. When a number is used with A as in 40 A Units an unbalance of 40 times the required sensitivity is implied. If the value of A is as specified in 3.9.13 is 25 microinches, then 40 A Units is the unbalance which causes a displacement of the c.g. of 1000 microinches from the journal axis.

A.2.11 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 ounces and A = 25, the minimum weight which must be detected is 25V = 0.00842 ounces. A much larger unbalance of 40 A Units which might be used for equipment calibration or a plane separation check is produced by a weight of 1000V = 0.3368 ounces. Or, the weight for 40 A Units is given by 40 (A) (V).

A.2.11.1 Static Unbalance: One Unbalance Test Unit for Static Unbalance should be that amount of weight which will produce a calculated one microinch radial displacement of the centre of gravity of an SAE proving rotor when applied in any axial plane and at the specified radius on the SAE proving rotor.

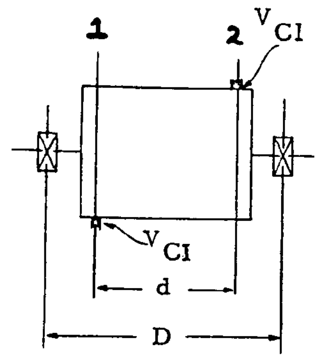


Note: When this weight is applied in any plane other than the plane of the c.g., it causes a Quasi-static Unbalance condition. Nevertheless, the displacement of the c.g. is the same as if the weight where placed in the plane of the c.g.

center of gravity displacement =

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

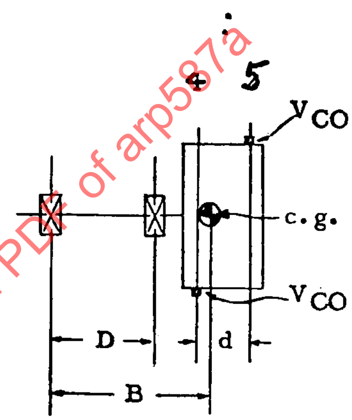
A.2.11.2 Couple Unbalance: One Unbalance Test Unit for Couple Unbalance should be that amount of weight which, when applied to the two specified couple unbalance planes at locations 180° apart at the specified radius, will produce a calculated one microinch radial displacement of the SAE Inboard proving rotor at the mid-point of each bearing and a calculated one microinch radial displacement of the mid-point of the bearing of the Outboard rotor opposite the Outboard end.



$$V_{CI} = \frac{32(I_x - I_z) \cdot 10^{-6}}{r \quad d \quad D}$$

(for symmetrical rotor)

$$V_{CO} = \frac{16(I_x - I_z) \cdot 10^{-6}}{r \quad d \quad B}$$

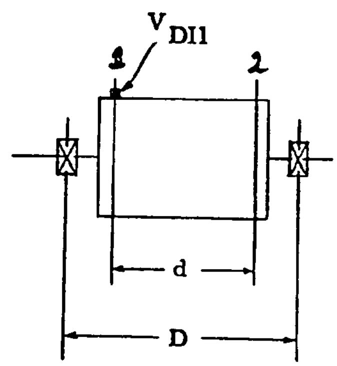


$(I_x - I_z)$ above must always have a value different from zero.

i.e., $\frac{I_x}{I_z} > 1.1$

or $\frac{I_x}{I_z} < 0.9$

A.2.11.3 Dynamic Unbalance: One Unbalance Test Unit for Dynamic Unbalance should be that amount of unbalance which, when applied in either plane 1 or plane 2 of the SAE Inboard Proving Rotor, will produce a calculated one microinch radial displacement of the axial midpoint of the adjacent bearing; or when applied in either plane 4 or 5 of the SAE Outboard Proving Rotor, will produce a calculated one microinch radial displacement of the axial midpoint of the corresponding bearing.



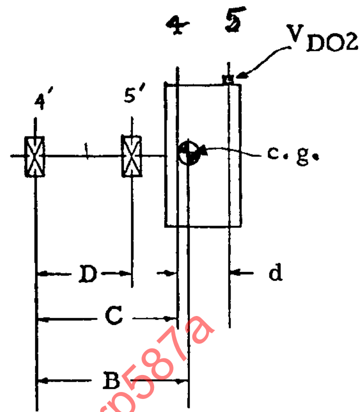
$$V_{DI} = \frac{16 \cdot 10^{-6}}{\frac{r}{W} + \frac{r\ d\ D}{4(I_x - I_z)}}$$

(for symmetrical rotor)

$$V_{DO1} = \frac{16 \cdot 10^{-6}}{\frac{r}{W} - \frac{r\ (C-B)\ B}{(I_x - I_z)}}$$

$$V_{DO2} = \frac{16 \cdot 10^{-6}}{\frac{r}{W} - \frac{r\ (C+d-B)\ (B-D)}{(I_x - I_z)}}$$

$(I_x - I_z)$ has same restriction as in A.2.11.2.



A.2.12 Outboard: An adjective to describe a rotor with the aero-dynamic functional part on the outside of one or more bearings.

A.2.13 Inboard: An adjective to describe a rotor with the aero-dynamic functional part between the two bearings.

A.2.14 Analogue: Means a readout which is measured on a continuous scale and whose readability depends on the length of the scale.

A.2.15 Numerical Readout: See 3.5. 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 equipment to which a physical unit is assigned.

A.2.16 One pound = 453.6 grams (454 grams round numbers) = 16 ounces.

A.2.17 One ounce = 28.35 grams.

A.2.18 Plane 1, Plane 2, Plane 3, Plane 4 and Plane 5 are balancing plane designations for proving rotors only.

APPENDIX 3 - 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 ensure compliance with these requirements are beyond the scope of this document.

A.3.1 The balancing equipment should operate in a satisfactory manner over an ambient temperature range of XX-XXX°F, and at 100% relative humidity.

A.3.2 All units of the electrical equipment should comply with applicable electrical specifications such as NEMA and other local codes.

A.3.3 The electrical systems should operate satisfactorily with line voltage variations up to ± XX%, line frequency variations up to ± XX% and waveform harmonic distortion of up to XX%.

A.3.4 All electrical systems should be arranged for operation from a supply of XXX volts, X phase, XX cycles/second.

A.3.5 Any need for radio interference suppression should be specified.

A.3.6 Balancing equipment performance is 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 particular equipment to a particular environment should be defined.

A.3.7 The balancing equipment prospective user should specify the required distance between the work supports. See 3.9.8 and 3.9 NOTE B.

A.3.8 Ø The balancing equipment prospective user should specify the required horsepower at specific balancing speeds. See 3.9.15 and 3.9 NOTE C.

A.3.9 All tests should be run at the manufacturer's plant before shipment or at the user's plant after installation. Facilities for making all tests to be provided by the manufacturer or the user. Proving rotors to be provided by the manufacturer or the user.

A.3.10 Installation and service.

A.3.11 Operating and maintenance personnel training.

A.3.12 Operating Manual, Maintenance Manual, Circuit Diagrams, Spare Parts Ordering Information.

APPENDIX 4 - BIBLIOGRAPHY

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

A.4.1 Report No. 371-V-24; Department of the Navy, Bureau of Ships, Code 371.

A.4.2 MIL-STD-167; Mechanical Vibrations of Shipboard Equipment, Department of the Navy, Bureau of Ships.

A.4.3 MIL-B-25511 (USAF): Military Specification, Balancing Machine, Dynamic-Static, Two Plane.

A.4.4 A.S.T.E. Handbook.

A.4.5 "Performance Tests for Balancing Machines", Werner I. Senger, Machinery's Reference Section, March - April, 1958.

A.4.6 ø S2.7 - 1964 American Standard Terminology for Balancing Rotating Machinery, as amended by ISO/TC 108 DR 1925 and ANSI S2/65.

ø A.4.7 ARP 588, Force Balancing Machines for Jet Engine Compressor and Turbine Components - Rotating Type.

TEST LOG SHEET FOR 4.3.3 - STABLE END POINT

PLANE 1		PLANE 2	
Angular Location Degrees	Amount A Units	Angular Location Degrees	Amount A Units

TEST LOG SHEET FOR 4.3.5 AND 4.3.6

RESIDUAL UNBALANCE AND ACCURATE ANGLE AND AMOUNT INDICATION

E =   Plane 1 or 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 4.3.7 for readout 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 AND 4.4.3

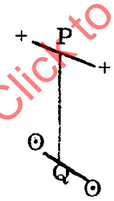
PLANE SEPARATION

	SYMBOL +					
Location of 40 A Weight Degrees	Indicated Balance					
	1st Run		2nd Run		3rd Run	
	Location Degrees	Amount A Units	Location Degrees	Amount A Units	Location Degrees	Amount A Units
Plane 2	Plane 1					
0						
90						
180						
270						
Plane 1	Plane 2					
0						
90						
180						
270						

TEST LOG SHEET FOR 4.7

UNBALANCE DISTURBANCE BY THE DRIVE SYSTEM

Run #	Drive Angle Degrees	Indicated Unbalance					
		Plane 1			Plane 2		
		Amount A Units	Location Degrees J	Reversed Location Degrees K = J ± 180	Amount A Units	Location Degrees M	Reversed Location Degrees N = M ± 180°
1	0		+			⊡	
3	0		+			⊡	
2	180			⊙			△
4	180			⊙			△



P bisects + +

Q bisects ⊙ ⊙

TEST LOG SHEET FOR 4.8.3 - STATIC AND COUPLE UNBALANCE SEPARATION

	STATIC UNBALANCE		COUPLE UNBALANCE	
GRAPH SYMBOL	Angular Location Degrees	Amount A Units	Angular Location Degrees	Amount A Units
None				
None				
None				
⊙				
⊙				

TEST LOG SHEET FOR 4.8.4 AND 4.8.5

STATIC AND COUPLE UNBALANCE SEPARATION

SYMBOL +			
Location of 40 A Weight Degrees		Indicated Unbalance	
		Location Degrees	Amount A Units
Plane 4	Plane 5	Static	
60	240		
150	330		
240	60		
330	150		
Plane 3		Couple	
60			
150			
240			
330			

TEST LOG SHEET FOR 4.8.6

STATIC UNBALANCE LINEARITY

Applied Static Unbalance, A Units		Indicated Static Unbalance in A Units		
		1st Run	2nd Run	3rd Run
2.5				
5				
10				
25				
45				

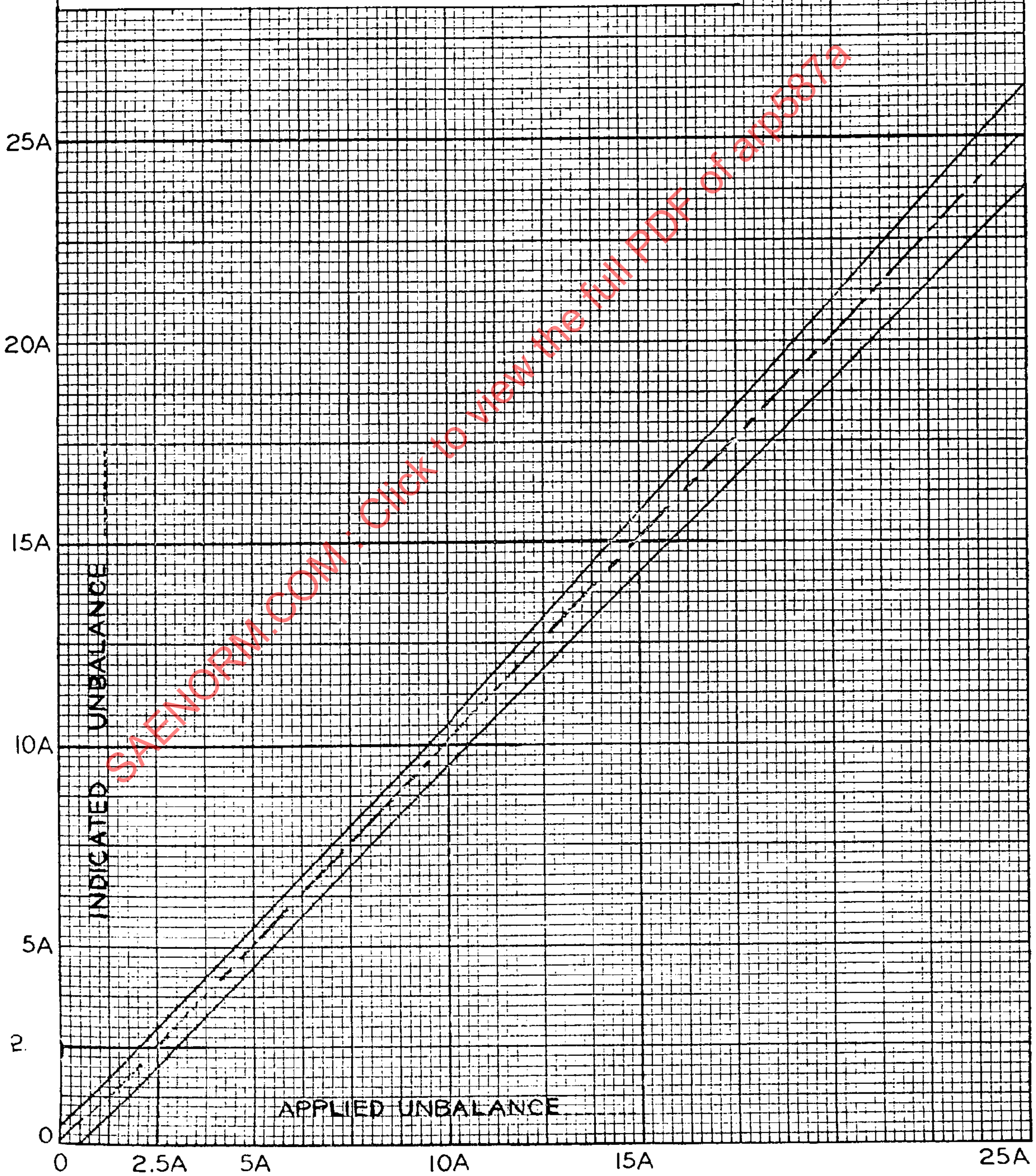
COUPLE UNBALANCE LINEARITY

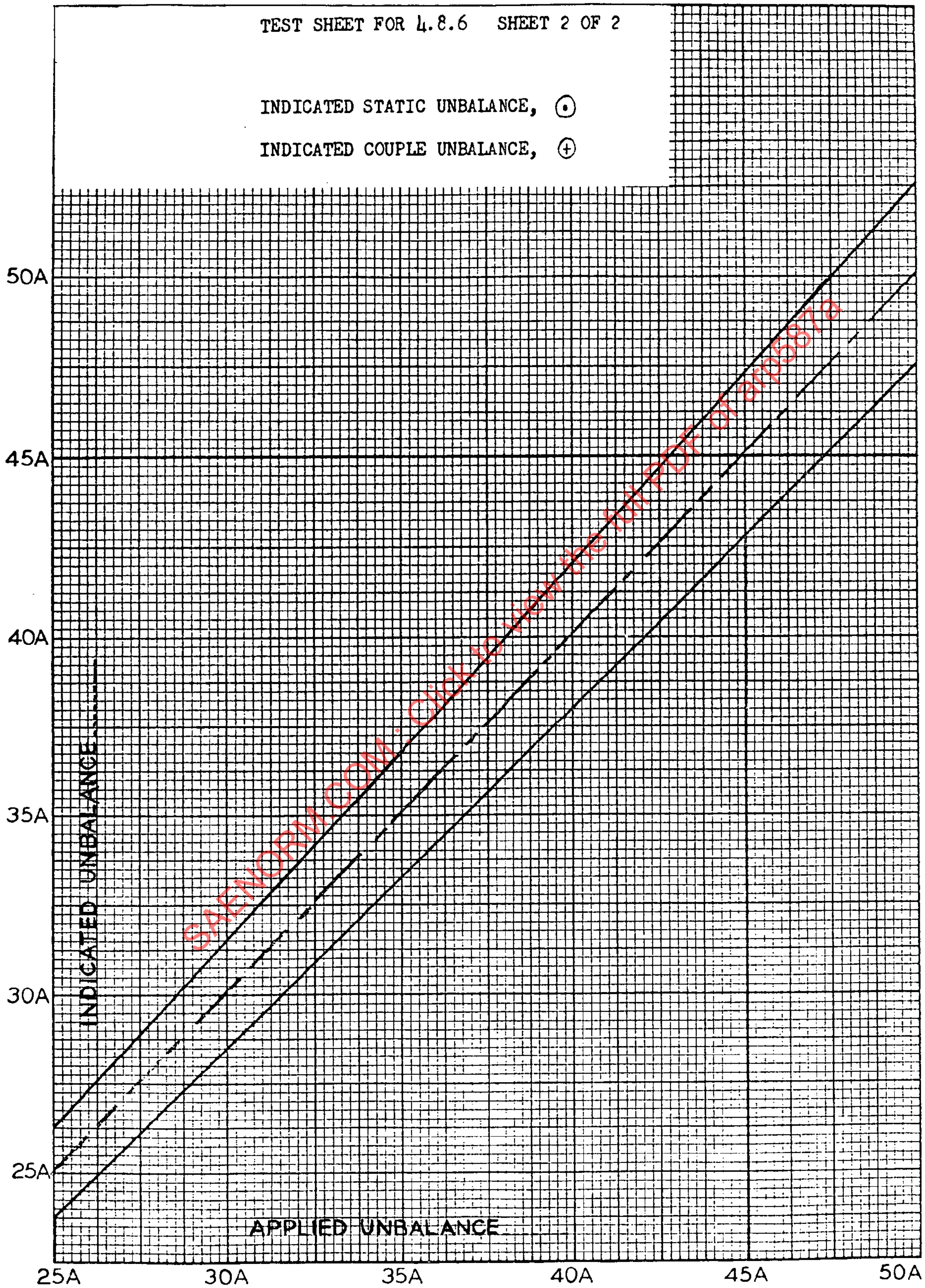
Applied Couple Unbalance, A Units		Indicated Couple Unbalance in A Units		
		1st Run	2nd Run	3rd Run
2.5				
5				
10				
25				
45				

TEST SHEET FOR 4.8.6 SHEET 1 OF 2

INDICATED STATIC UNBALANCE, ⊙

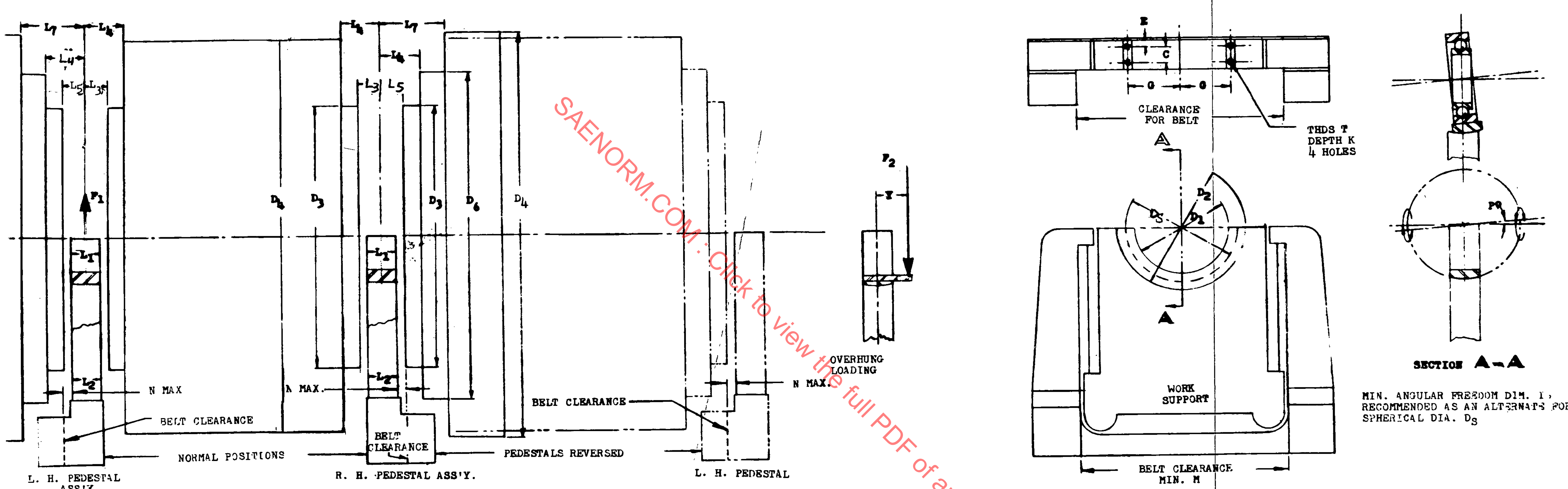
INDICATED COUPLE UNBALANCE, ⊕




TEST SHEET FOR 4.8.6 SHEET 2 OF 2
INDICATED STATIC UNBALANCE, ⊙
INDICATED COUPLE UNBALANCE, ⊕
INDICATED UNBALANCE
APPLIED UNBALANCE
25A
30A
35A
40A
45A
50A

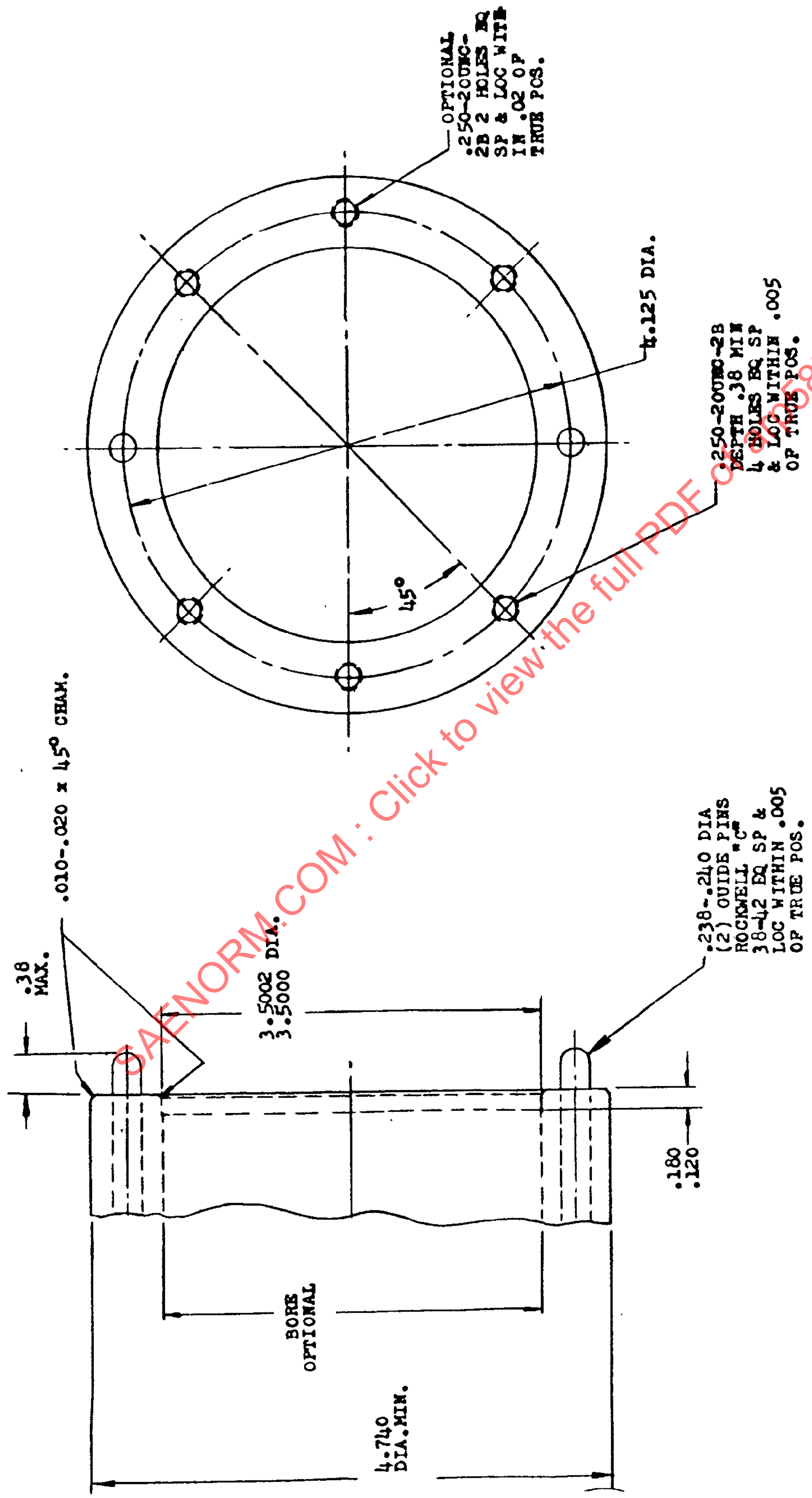
WORK SUPPORT ENVELOPE

FIG 1



MIN. ANGULAR FREEDOM DIM. P, RECOMMENDED AS AN ALTERNATE FOR SPHERICAL DIA. D_S

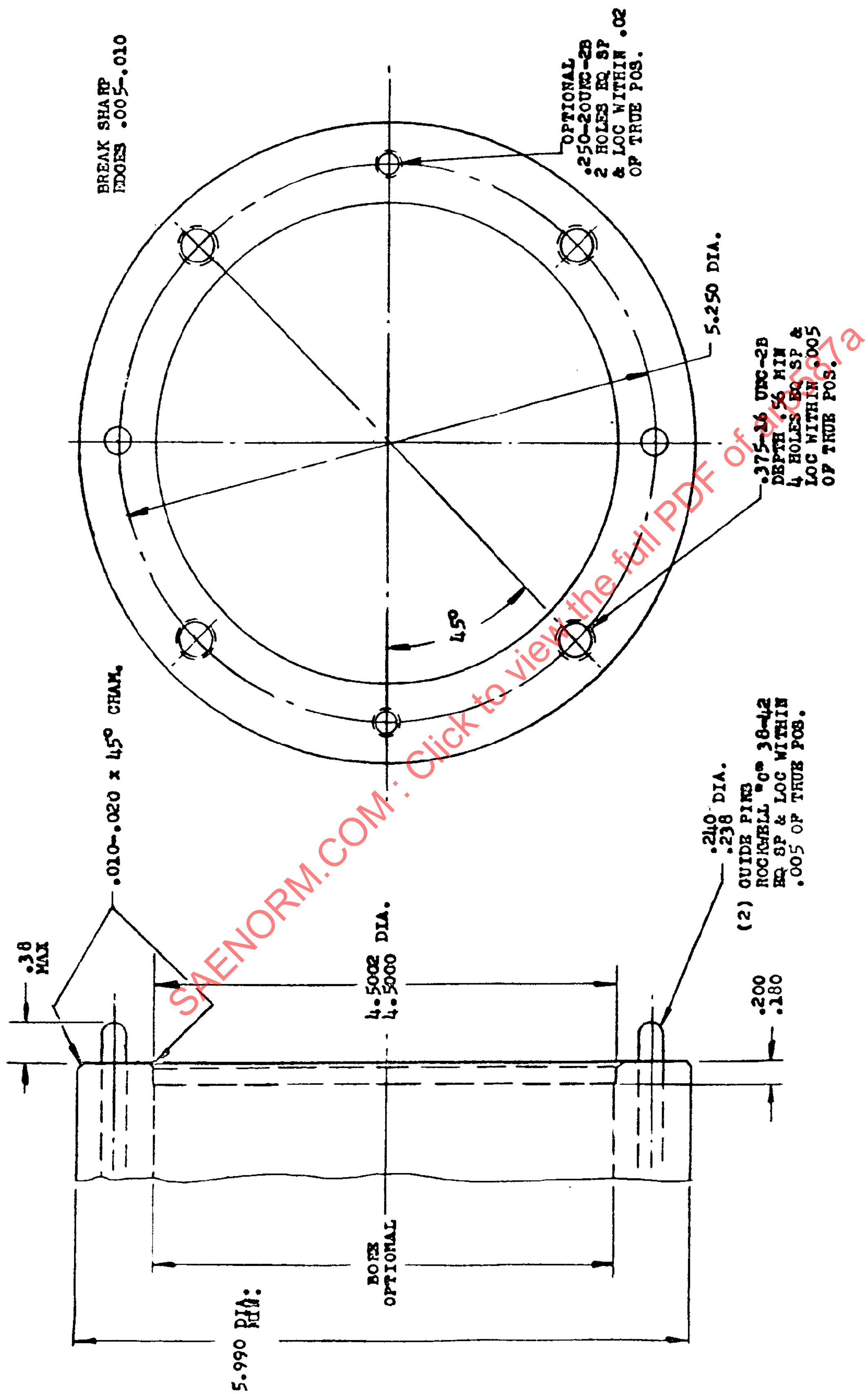
CLASS: WEIGHT CAPACITY-LBS	WORK SUPPORT BORE D_1	WORK SUPPORT WIDTH L_1	FINISH DIA. FOR WIDTH L_1 D_2	PEDESTAL C'STG. WIDTH L_2	ALL "D" REFERENCES = SWING DIA'S. ALL "L" REFERENCES = DISTANCES FROM WORK SUPPORT TRANSVERSE ℄ TO CORRESPONDING SWING DIA. (UNLESS OTHERWISE SHOWN) D_3	L_3	D_4	L_4	M	L_5	D_6	N	L_7	MIN. ANG. ADJ. OF OUTER RACE P°	NEGATIVE LOAD -POUNDS- P_1	MOMENT IN IN. LBS. P_2Y	TIE BARS	HOLD DOWN SCREW DIMENSIONS T	K	C	E	G
300	8.0005 / 8.0000	1.502 / 1.498	8.50	1.50	12.00	1.24	31.00	2.50	10.00	1.24	24.00	1.00	4.00	1°	60	750	NO	.250-20-UNC-2B	.50	.880 / .870	.32	4.255 / 4.245
1000	13.001 / 13.000	2.015 / 1.985	13.50	2.00	24.00	1.00	55.00	3.50	13.00	1.50	36.00	1.50	5.00	2°	200	2500	YES	.3125-18-UNC-2B	.76	.755 / .745	.62	7.505 / 7.495
3000	15.001 / 15.000	2.015 / 1.985	15.50	2.00	36.00	1.00	66.00	3.50	20.00	1.50	50.00	1.50	5.00	- 2°	600	7500	YES	.3125-18-UNC-2B	.76	.755 / .745	.62	8.505 / 8.495



FLANGE ATTACHMENT FOR 300 LB MACHINE SIZE

ROCKWELL C-58 MIN.

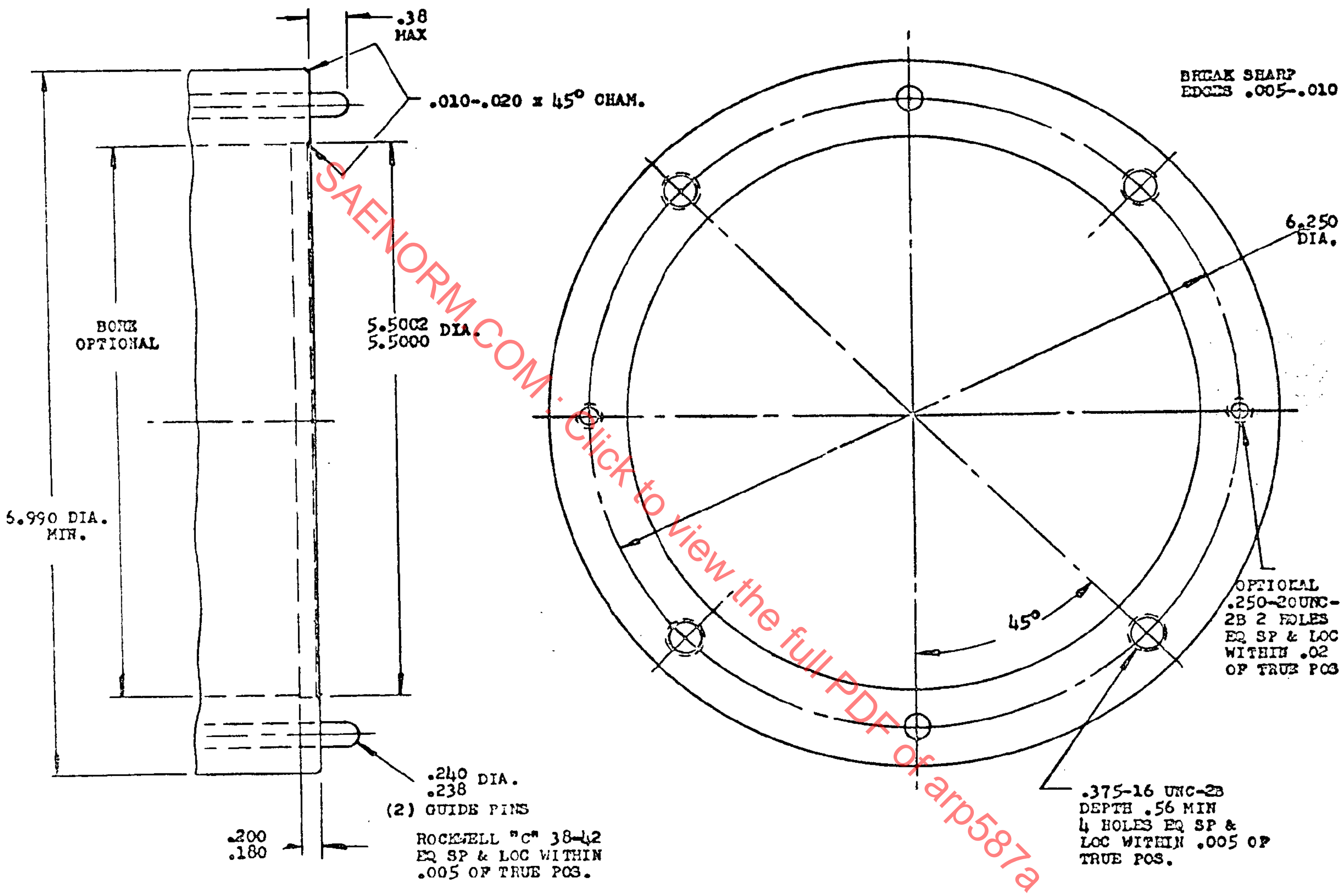
FIG 2A



FLANGE ATTACHMENT FOR 1000 LB MACHINE SIZE

ROCKWELL C-58 MIN.

FIG 2B

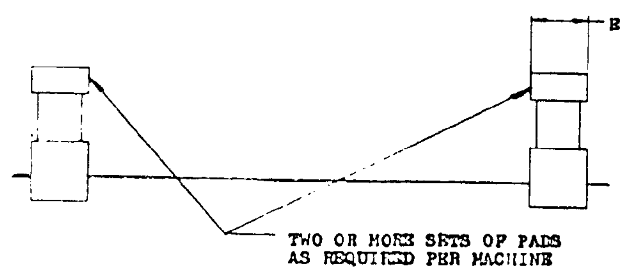


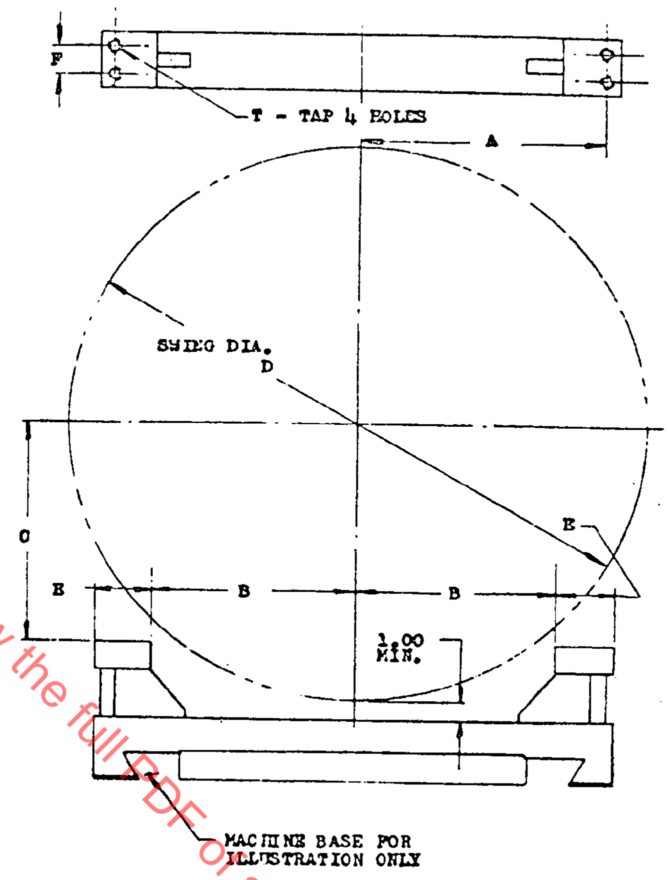
FLANGE ATTACHMENT FOR 3000 LB MACHINE SIZE

ROCKWELL C-58 MIN.

FIG 2C

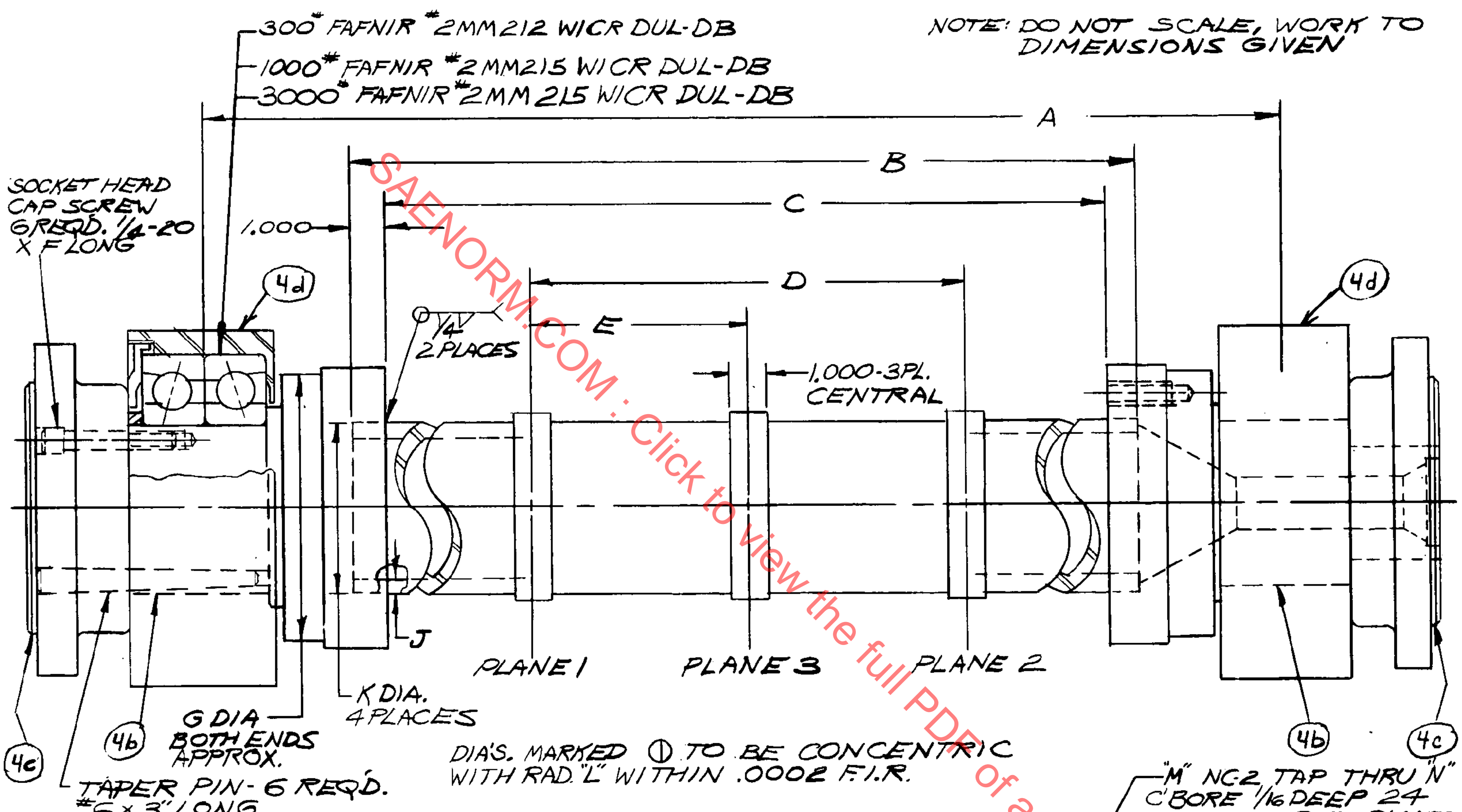
NOTES:
1) FOR SWING DIA. D REFER TO SAE SURVEY B-21-BB3-9 (WORK SUPPORT) DIMENSION D_4



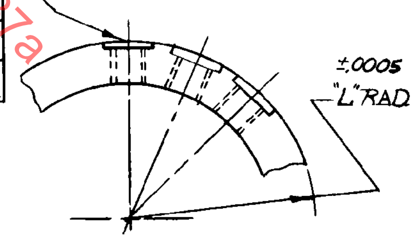


CLASS: WEIGHT CAPACITY IN POUNDS							
	A	B	C	D	E	F	T
300	13.50	11.25	12.00	31.00	3.00	2.00	.375-16UNC-2B
1000	22.38	10.12	22.00	55.00	5.00	3.50	.500-13UNC-2B
3000	27.25	22.00	26.00	66.00	6.00	4.00	.500-13UNC-2B

FIG 3 SHROUD MOUNTING PADS



ROTOR	A	B	C	D	E	F	G	H	J	K	L	M	N
300#	23.625	17.175	15.175	8.000	4.000	1 1/2	2.877	51.75	.234	2.469	1.2500	8-32	3/16
1000#	38.250	29.000	27.000	15.000	7.500	2	5.889	170.0	.468	3.937	2.000	1/4-20	9/32
3000#	83.180	73.000	71.000	40.000	20.000	2	10.875	452.65	.500	6.937	3.550	5/16-18	11/32



STRESS RELIEVE BEFORE FINISH MACHINING

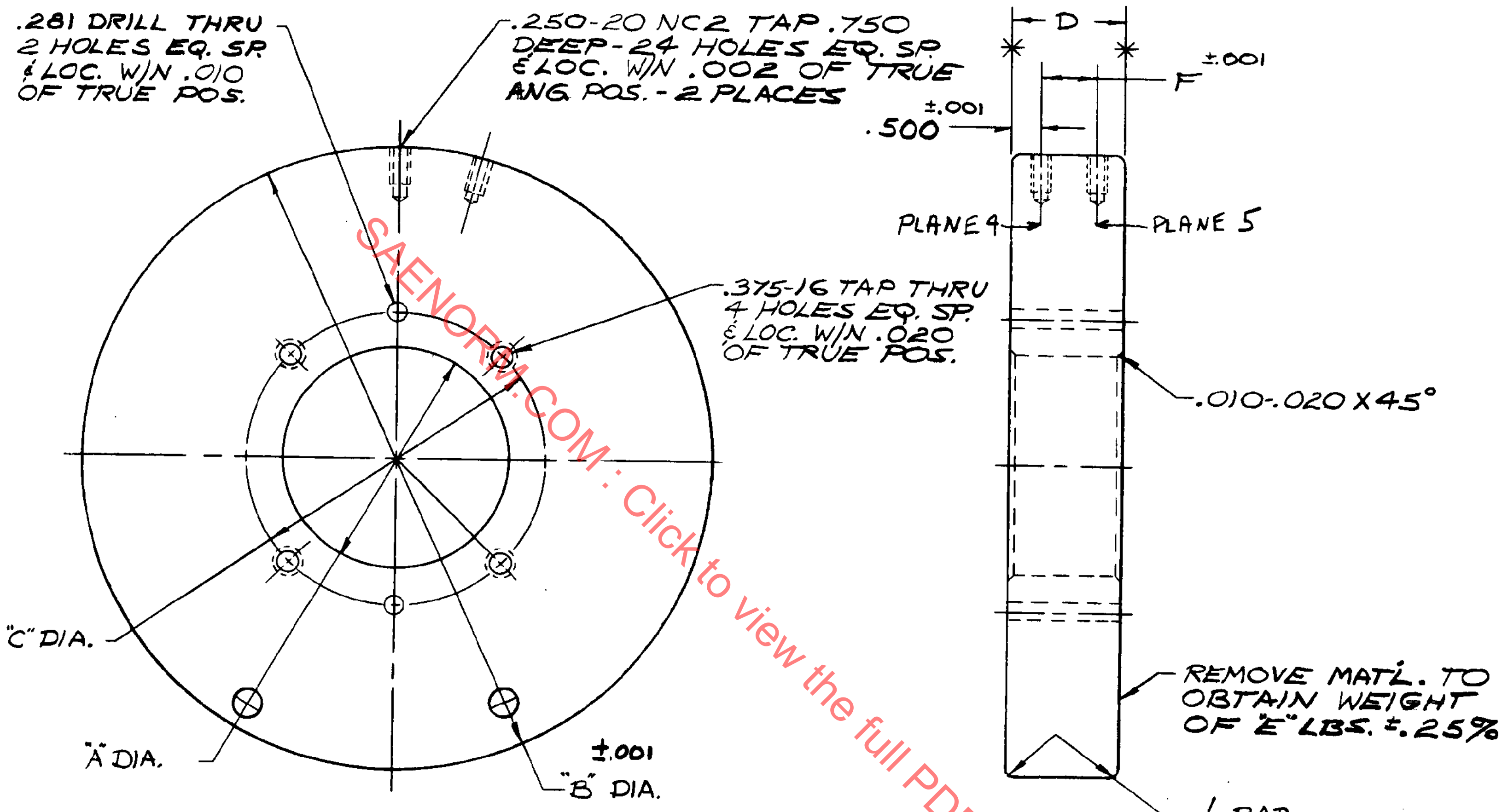
MACHINE DIA. G TO MAINTAIN TOTAL WEIGHT OF H POUNDS ±.25%

MATERIAL- STEEL AISI 4140-4150

BLACK OXIDE PER AMS 2485C ALL STEEL DETAILS IN DETAIL

PROVING ROTOR ASSEMBLY

FIG 4 ϕ



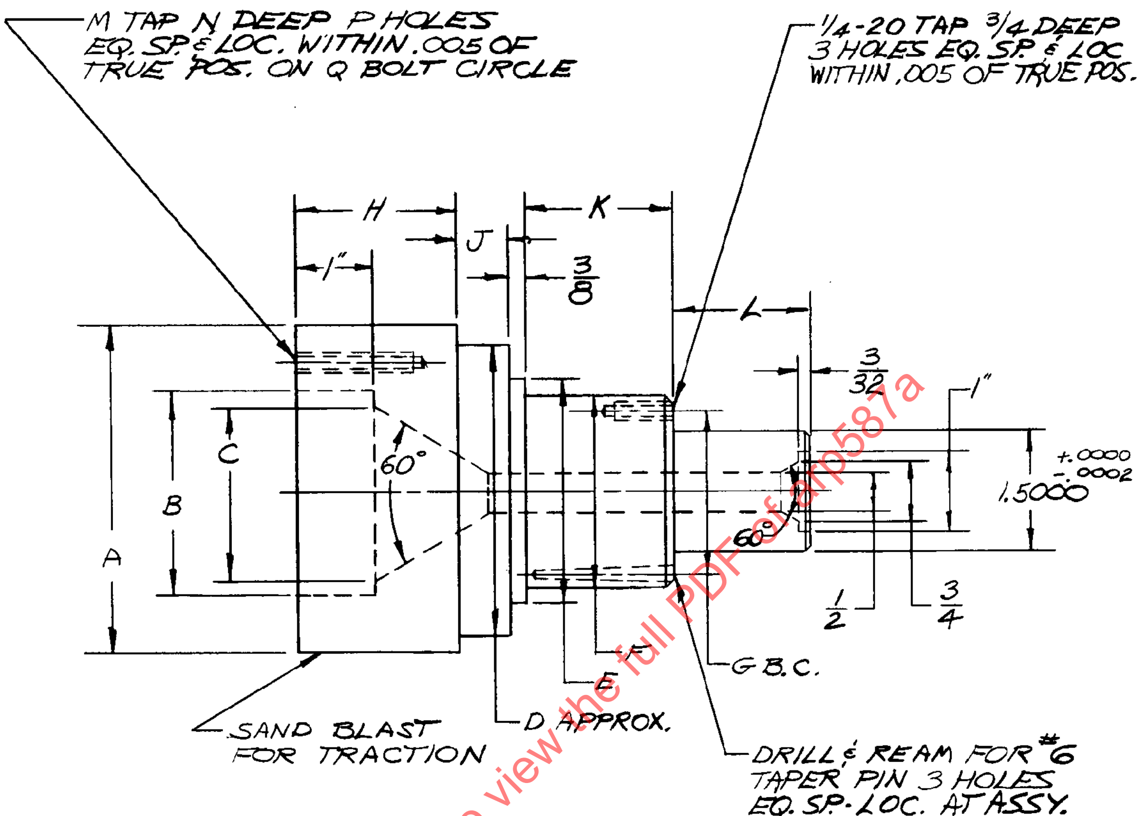
⊕ CONCENTRIC W/N .005 F.I.R
✳ PARALLEL W/N .002 F.I.R.

1 REQ. - AISI 4140-4150
BLACK OXIDE PER AMS 2485

OUTBOARD
PROVING
ROTOR

ROTOR	A	B	C	D	E	F
300	3.5000 3.5002	17.900	4.125	2.000	128.25	1.000
1000	4.5002 4.5000	32.125	5.250	2.000	183.00	1.000
3000	5.5002 5.5000	40.050	6.250	3.869	1,347.35	2.870

FIG. 4a ϕ



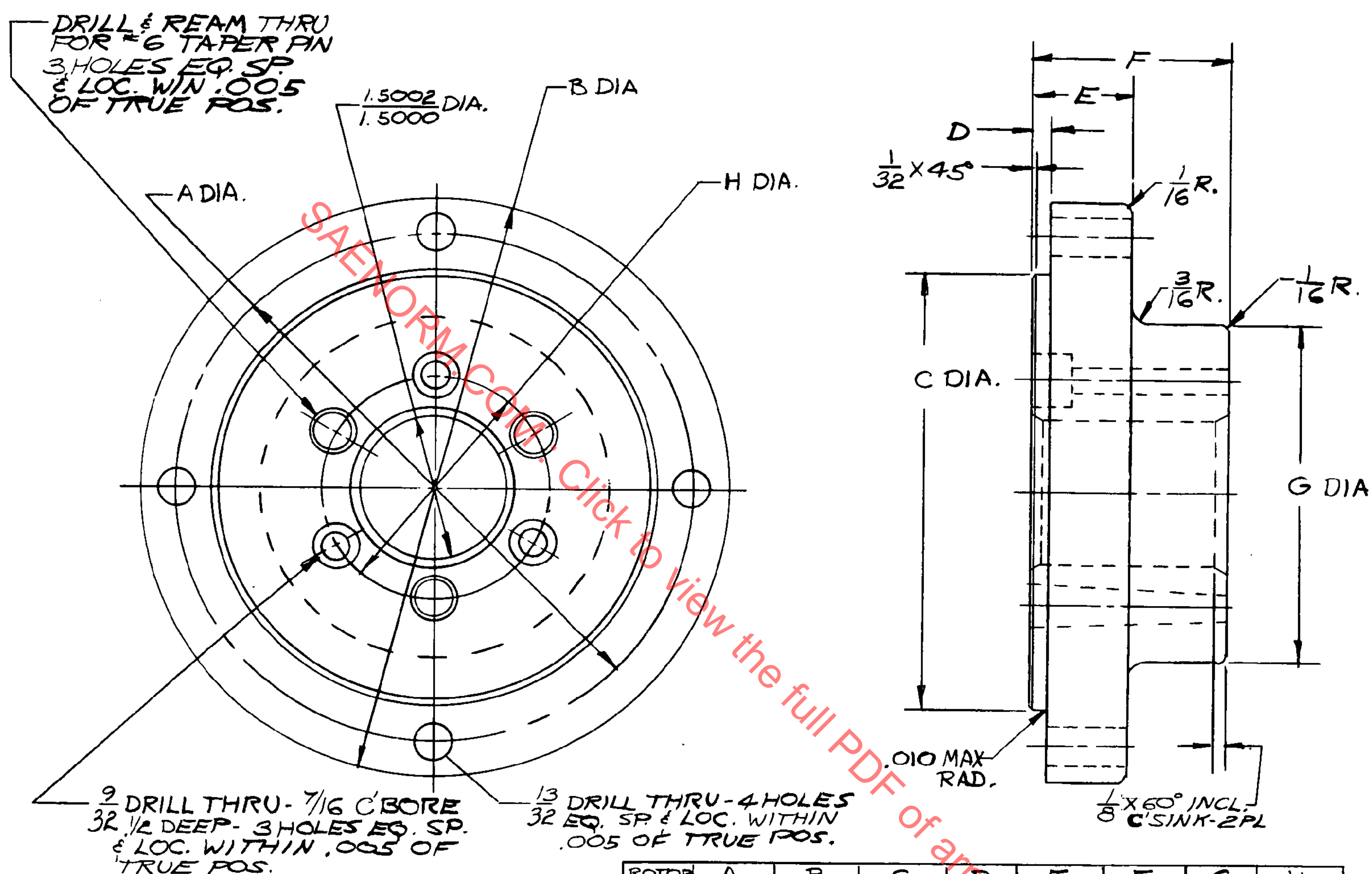
ROTOR	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q
300#	3.500	2.469	2 1/8	2.877	2 3/4	2.3624	2.0000	1 3/4	1 15/64	1.898	1 7/16	1/4-20	1 1/2	12	3.000
1000#	6.625	3.9375	3 1/8	5.889	3 3/8	2.9530	2.3125	3 1/2	49/64	2.218	1 15/16	3/8-16	2	16	6.000
3000#	11.000	6.9375	6	7.541	3 3/8	2.9530	2.3125	3 13/16	59/64	2.218	1 15/16	3/8-16	2	16	10.000

2 REQ'D.- STEEL - AISI 4140 - 4150

STUB SHAFT

FIG. 4 b Φ

NOTE: DO NOT SCALE, WORK TO DIMENSIONS GIVEN

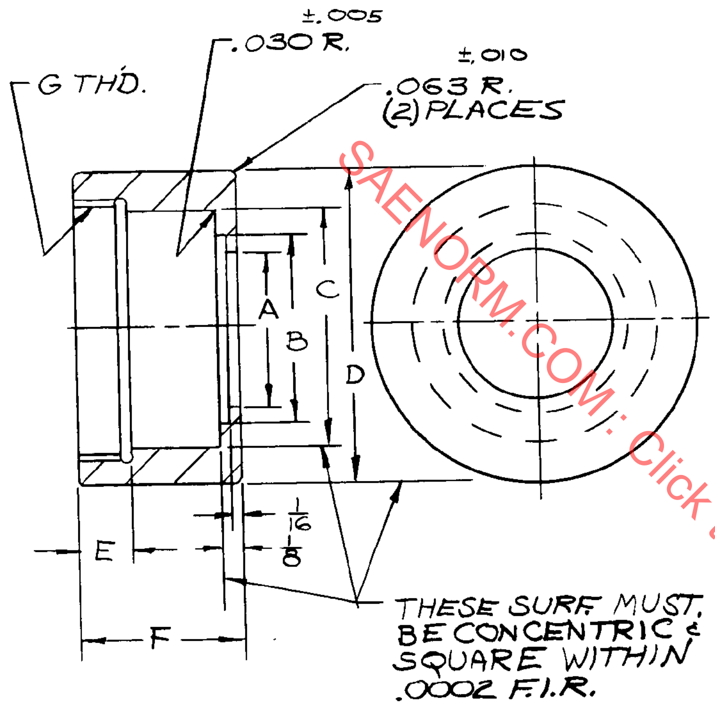


ROTOR	A	B	C	D	E	F	G	H
300#	4.125	4.750	3.5000 3.4998	.115 .110	.750	1.500	3.500	2.000
1000#	5.250	6.000	4.5000 4.4998	.175 .170	1.000	2.000	3.500	2.3125
3000#	6.250	7.000	5.5000 5.4998	.175 .170	1.000	2.000	4.500	2.3125

COUPLING

2 REQ'D. - STEEL - AISI 4140-4150

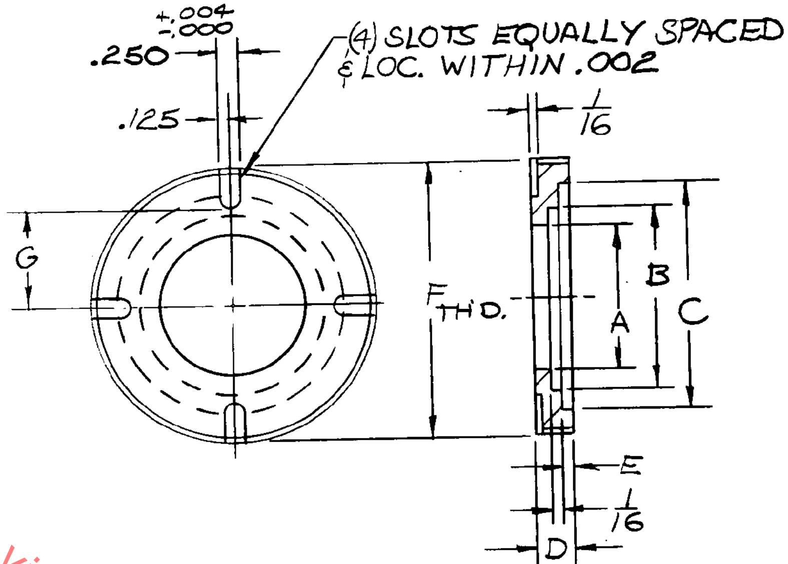
FIG. 4c φ



ROTOR	A ±.005	B +.000 -.010	C +.001 -.000	D +.000 -.001	E ±.010	F ±.010	G THD
300#	2.770	3.500	4.3307	5.000	.375	2.000	4¾-12
1000#	3.395	4.760	5.1181	6.000	.281	2.312	5¼-12
3000#	3.395	4.760	5.1181	6.000	.281	2.312	5¼-12

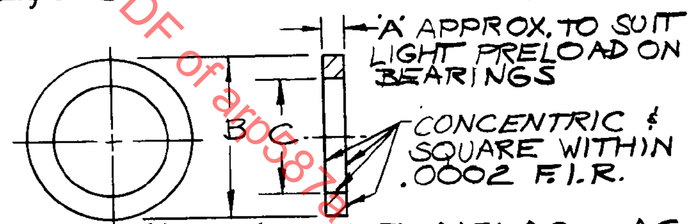
(2) REQ'D - STEEL - AISI A2 or A6 HDN. R_c 50-55

NOTE: DO NOT SCALE, WORK TO DIMENSIONS GIVEN



ROTOR	A±.005	B±.010	C±.010	D±.010	E±.010	F THD	G±.010
300#	2.770	3.500	4.375	.250	.093	4¾-12	1.875
1000#	3.395	4.000	4.760	.219	.063	5¼-12	2.125
3000#	3.395	4.000	4.760	.219	.063	5¼-12	2.125

2 REQ'D. - STEEL - AISI A2 or A6 - HDN. R_c 38-42

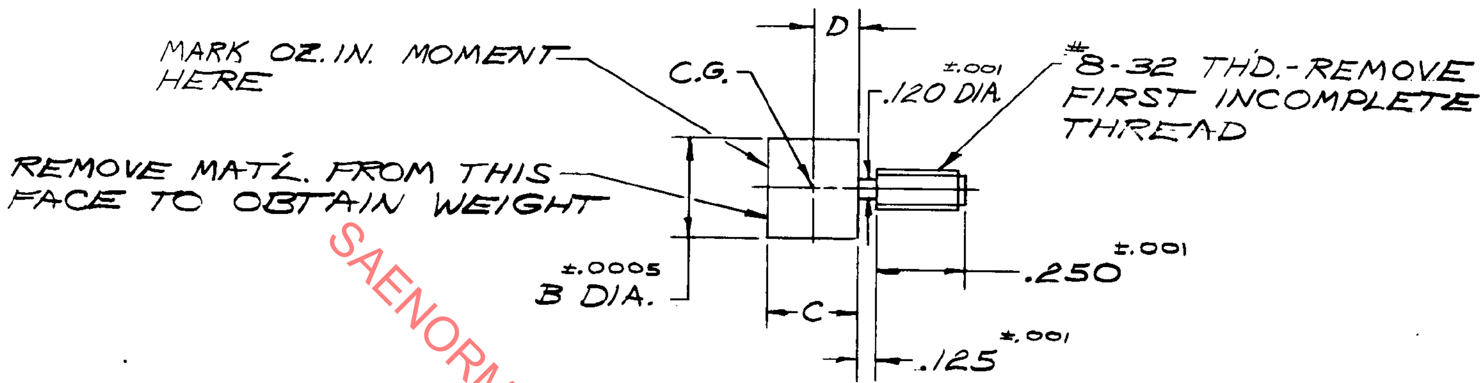


(2) REQ'D. - STEEL - AISI A2 or A6 HDN. R_c 50-55

ROTOR	A	B +.000 -.010	C +.0010 -.0000
300#	.166	2.750	2.3634
1000#	.266	3.375	2.9540
3000#	.266	3.375	2.9540

BEARING RETAINER ASSEMBLY

FIG. 4 d



TEST WEIGHT FOR USE WITH 300 LB. ROTOR

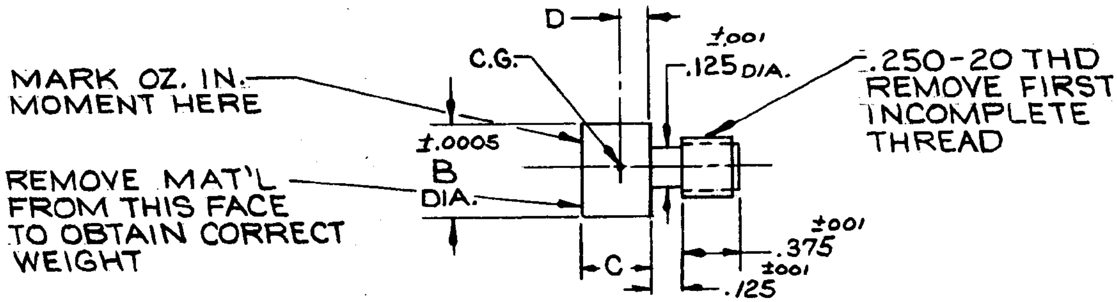
A = 25.0 MICRO INCHES DISPLACEMENT

Weight Class	No. Req'd.	Moment Oz. In.	±.0005 Oz. Weight	B	C Ref.	D	Effect. Radius	Use Std. Weight	Material
Std.	4	.055	.04136	.300	.302	.081	1.331	No	Alum.*
1A	2	.070	.0530	.4076	.234	.070	1.320	Yes	Alum.*
2.5A	2	.092	.0638	.300	.5065	.1947	1.4447	Yes	Alum.*
5A	2	.074	.0548	.3671	.300	.100	1.350	No	Alum.*
10A	2	.148	.1450	.3855	.534	.230	1.480	No	Alum.*
12.5A	2	.185	.12135	.3855	.62454	.2898	1.5398	No	Alum.*
20A	2	.296	.2176	.4248	.298	.110	1.360	No	SST.**
30A	2	.444	.3171	.4770	.358	.150	1.400	No	SST.**
40A	2	.592	.3947	.4297	.558	.250	1.500	No	SST.**
50A	2	.740	.5103	.5544	.440	.200	1.450	No	SST.**

* SAE 6061-T6 Alum Blue Anodize Finish

** SAE 304 Stainless Steel

Ø Fig. 4e



TEST WEIGHT FOR USE WITH 1000 LB. ROTOR

A = 14.5 MICRO-INCHES DISPLACEMENT

Wt. Class	Moment Oz. In.	±.0005 Oz. Weight	B	C	D	Effective Radius	Material
5A	.126	.0640	.3632	.250	-.029	1.971	Aluminum*
10A	.252	.1205	.4604	.375	+.093	2.093	Aluminum*
11A	.278	.1321	.4871	.375	+.101	2.101	Aluminum*
12.5A	.317	.1493	.5246	.375	+.126	2.126	Aluminum*
20A	.504	.2299	.5823	.500	+.194	2.194	Aluminum*
30A	.756	.3613	.4643	.375	+.094	2.094	Steel **
40A	1.008	.4654	.4686	.500	+.168	2.168	Steel **
50A	1.261	.5638	.4685	.625	+.237	2.237	Steel **

TEST WEIGHT FOR USE WITH 1000 LB. ROTOR

A = 25.0 MICRO-INCHES DISPLACEMENT

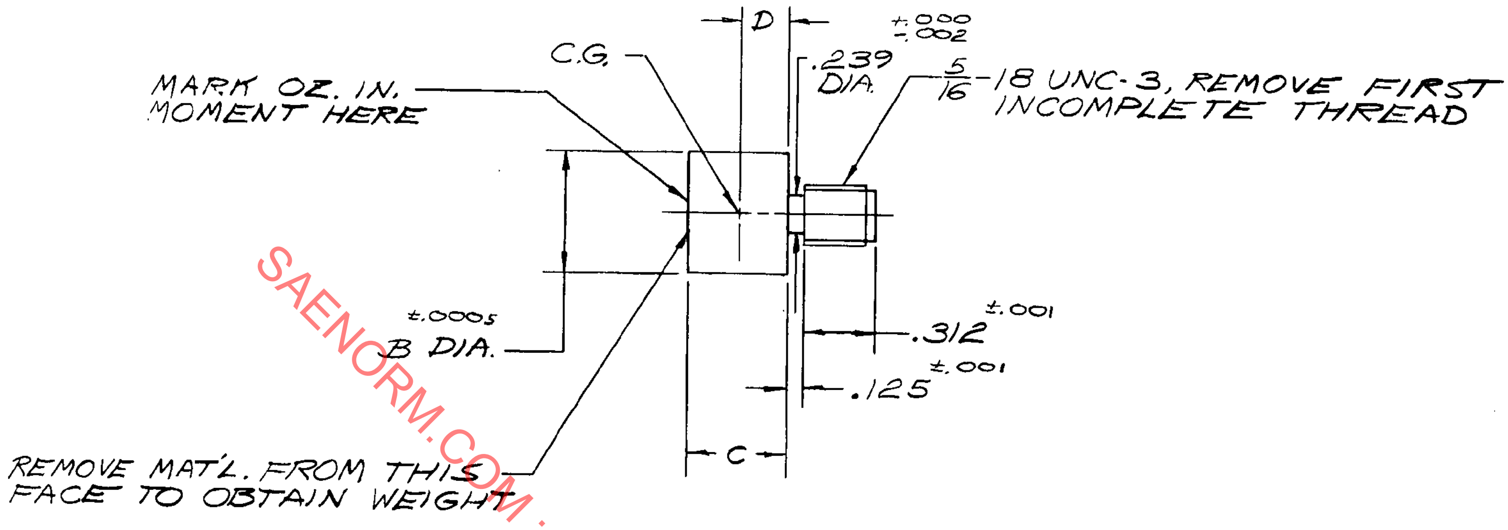
Wt. Class	Moment Oz. In.	±.0005 Oz. Weight	B	C	D	Effective Radius	Material
2.5A	.109	.0558	.3239	.250	-.051	1.949	Aluminum*
3.5A	.152	.0748	.3341	.375	+.035	2.035	Aluminum*
5A	.218	.1046	.4208	.375	+.079	2.079	Aluminum*
10A	.435	.1990	.5368	.500	+.186	2.186	Aluminum*
20A	.870	.4130	.5039	.375	+.106	2.106	Steel **
30A	1.305	.5968	.5411	.500	+.186	2.186	Steel **
40A	1.740	.7523	.5028	.750	+.313	2.313	Steel **
50A	2.174	.9107	.5124	.890	+.388	2.388	Steel **

* SAE 6061-T6 ALUMINUM BLUE ANODIZE FINISH

** SAE 4140 Rc 35-40 BLACK OXIDE FINISH

Ø Fig. 4 f

NOTE: DO NOT SCALE, WORK TO DIMENSIONS GIVEN



TEST WEIGHT FOR USE WITH 3000 LB. ROTOR

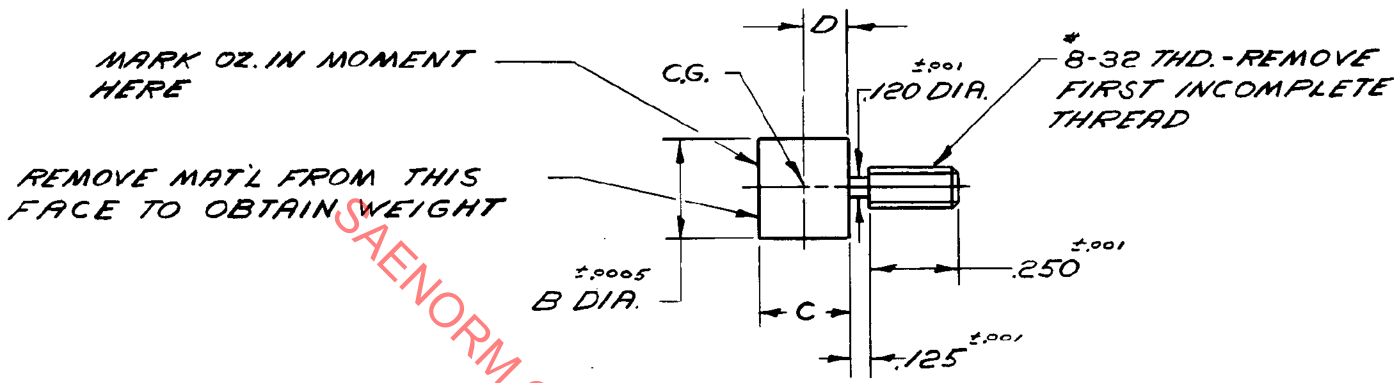
A UNIT = 14.5 MICROINCH DISPLACEMENT

WEIGHT CLASS	NO. REQ'D.	MOMENT OZ. IN.	± .0005 OZ. WEIGHT	B	REF.	D	EFFECTIVE RADIUS	MATERIAL
10A	2	.6315	.1750	.6250	.285	.058	3.608	ALUM. *
12.5A	2	.7881	.2154	.6250	.369	.108	3.658	ALUM. *
15A	2	.9443	.2543	.6250	.450	.163	3.713	ALUM. *
20A	2	1.2638	.3545	.5000	.271	.015	3.565	S. ST. **
30A	2	1.8921	.5237	.6250	.294	.062	3.613	S. ST. **
40A	2	2.5261	.5756	.6250	.410	.129	3.679	S. ST. **
50A	2	3.1559	.8590	.7500	.370	.129	3.679	S. ST. **

* SAE 6061-T6 ALUMINUM - BLUE ANODIZE FINISH

** SAE 304 STAINLESS STEEL

Ø FIG. 4g



TEST WEIGHT FOR USE WITH 300 LB. OUTBOARD ROTOR

A = 25 MICRO INCHES

PLANE #3

WT. CLASS	MOMENT OZ. IN.	± .0005 OZ. WEIGHT	B	C	D	EFFECTIVE RADIUS	MATERIAL
2.5A	.1800	.1353	.3313	.281	.080	1.330	STEEL
5A	.3590	.2689	.5472	.226	.085	1.335	STEEL
10A	.7190	.5229	.6991	.282	.125	1.375	STEEL
25A	1.7970	1.1980	.7911	.518	.250	1.500	STEEL
40A	2.8750	1.7424	.7624	.817	.400	1.650	STEEL
45A	3.2340	1.9600	.8103	.815	.400	1.650	STEEL

MATERIAL SAE 4140-4150

BLACK OXIDE

NOTE:
DO NOT SCALE WORK TO DIMENSIONS GIVEN

Ø FIG. 4h