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AEROSPACE RECOMMENDED PRACTICE

ARP 497A

PRECISION CONTROL MOTORS - 400 CYCLES

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INTRODUCTION

Specifications written around precision control motors have specified certain necessary characteristics, such as stall torque and power input, under production test conditions and techniques that are mainly and properly concerned with accuracy and the shortest possible test time. The controlling factors in these characteristics are copper and aluminum, which are inherently temperature sensitive, and therefore these characteristics are degraded when the motor is operating for a period of time. In large power motors this degradation is relatively inconsequential, but in precision control motors the reduced size of the motor and the high resistance to reactance ratio of the rotor combine to make this degradation a factor of importance. The amount of change for a given temperature variation, though, will vary with frame size and internal design, so that it is not practicable to assign a definite limiting percentage value of degradation to either control motors as a class or to frame sizes.

In order to ease the equipment design engineer's problem and at the same time provide a basis for more accurate comparable measurements between manufacturer and user, this recommended practice sets up "standard conditions" for design assurance testing and tabulated values which differ from previous publications by requiring the motor to be in a warmed-up condition which approximates its average use temperature. These conditions and the basic tests to which the tabulated characteristics refer are grouped in section 2.2 (Design Assurance) and compose a complete list of defining characteristics of the motor.

Since this standard (warmed-up) condition is impractical for 100% production testing or incoming inspection testing, an additional section 2.3 (Performance Testing) has been provided. Most section headings in 2.3 are identical to section headings in 2.2, but it will be noted that no warm-up period is required. However, all paragraphs dealing with a parameter that could change with warm-up have a statement that, "the values obtained should (exceed, or be less than) those shown in Table I <u>when corrected for non-standard</u> (cold, or no-mounting plate) <u>conditions.</u>" This means that the manufacturers must determine and use the proper degradation factor for their motors so that they can properly guarantee rated (warmed-up) performance even though they use a simpler test for production acceptance.

The repetitious use of the phrase "Motor should be as specified in 2.2.1.3" in section 2.2 paragraphs, and the equally repetitious use of the phrase "when corrected for non-standard conditions" in section 2.3 paragraphs is intentional. This recommended practice is not in itself a purchasing document, but will serve as the basis for such documents. It is conceivable that certain purchasing documents may not require control of all parameters listed. If these phrases did not appear in every paragraph to which they apply, the specification writer who does not need control of all parameters might very easily miss the important first paragraphs defining conditions and in so doing would be left with a specification that would not give him satisfactory reduction of this degradation that comes with normal operating temperature.

1. SCOPE

1.1 General: This recommendation establishes objectives for high performance control motors to be used with aeronautical and associated equipment in protective enclosures or completely within the shell of the aircraft so that they are subjected only to the internal climatic conditions of heat, cold, shock, vibration, altitude, and humidity. Control motors larger than size #23 are not covered in this document.

1.2 Type Designation of Control Motors: Control motors are classified according to frame size, control winding voltage, power supply, variable, and environmental capability. This information is contained in the type designation which should consist of five blocks of alternate numerals and letters as follows:

Number 1.2.1	Letter 1.2.2	Number 1.2.3	Letter 1.2.4	Number 1.2.5
Frame Size	Control Winding Voltage	Fixed Winding Power Supply	Variable	Environmental Capability

1.2.1 Frame Size: The two numerals in the first block of the type designation number, multiplied by 0.1 indicate approximately the maximum diameter of the unit in inches. If the diameter is not exactly a whole number of tenths, the next higher tenth is used. Frame sizes and exact dimension should be limited to those shown in Figure 8.

1.2.2 Control Winding Voltage: The second block of the type designation number should be the letter V, L, or T, indicating a winding for vacuum tube amplifiers, line voltage, or transistor amplifiers. The table below indicates the voltage value associated with V, L, and T for each frame size. Note that only sizes 11, 15, and 18 have all three recommendations.

Frame Size	Control Winding Voltage		
	V	L	T
23	None	115	36
20	None	115	None
18	282	115	36
15	230	115	36
11	180	115	36
10	None	26	36
8	None	26	36
5	None	26	36

1.2.3 Fixed Winding Power Supply: The third block of the type designation number should indicate the nominal power supply in accordance with the following table:

CODE	VOLTS	FREQUENCY (cps)
1	115	400
2	26	400

1.2.4 Variable: The fourth block of the type designation number should indicate a variable applicable to the particular unit such as terminals, leads, and shaft in accordance with the following table:

CODE	VARIABLE
A	Terminal connection, smooth shaft
B	Flexible leads, smooth shaft
C	Terminal connection, pinion
D	Flexible leads, pinion

1.2.5 Ambient Temperature Capabilities: The fifth block of the type designation number should indicate the service conditions which the unit is designed to withstand according to the following table:

CODE	SERVICE CONDITION	AMBIENT TEMPERATURE RANGE
1	Normal Temp.	-55 to +85 C
2	Extended Temp.	-55 to +125 C
3	High Temp.	-55 to +175 C

1.2.6 Marking: Each motor should have the following minimum information:

1. Name (Motor, Control)
2. Rated frequency
3. Rated voltage of each phase
   Symbols Ø 1 and Ø 2 can be used instead of "fixed winding" and "control winding", respectively.
4. a) Manufacturer's name, symbol, or trademark
   b) Address (city and state)
   c) Manufacturer's part number
   d) Manufacturer's serial number
   e) Date of Manufacture (eg., 11/59)

1.3 Definitions:

1.3.1 Precision Control Motor: A precision control motor is a reversible, two-phase induction type of motor specifically designed to be operated from two independent voltage sources of the same frequency with one voltage source maintained at a fixed voltage and phase direction and with the second source varied in voltage and phase direction to control speed, torque, and direction of rotation of the motor. A high torque to inertia ratio and an approximately straight line torque-speed curve are inherent characteristics of good control motors.

1.3.2 Mechanical:

1.3.2.1 Perpendicularity of Mounting Faces is the total maximum difference between high and low readings of a dial indicator suitably arranged to denote the out of squareness relation of the mounting surface at a specified distance from the OD of the motor with respect to the rotational axis of the shaft when the housing is rotated about its fixed shaft.

1.3.2.2 Run-Out of Smooth Shaft is the maximum difference between the high and low readings of a dial indicator suitably arranged to measure the eccentricity of the smooth shaft at a point 1/8 inch from its end when rotated in its own bearings with the body of the motor held stationary.

1.3.2.3 Run-Out of Mounting Diameters is the maximum difference between the high and low readings of a dial indicator suitably arranged to measure the eccentricity of the mounting diameters with respect to the rotational axis of the shaft.

1.3.2.4 Radial Play is the maximum difference between the high and low readings of a dial indicator suitably arranged to measure the total radial travel (sum of both directions) of the shaft in its own bearings. It is measured 1/8 inch from the extreme forward surface of the housing, upon reversal of a specified radial load applied at that same distance from the housing.

1.3.2.5 End Play is the maximum difference between the high and low readings of a dial indicator suitably arranged to measure the total axial travel of the shaft in its own bearings upon the reversal of a specified axial load. This measurement to be made with motor shaft horizontal.

1.3.3 Electrical

1.3.3.1 Control Voltage Winding is the motor winding which is excited by a varying voltage at a time phase difference from the voltage applied to the fixed voltage winding.

1.3.3.2 Fixed Voltage Winding is the motor winding which is excited by a fixed voltage.

1.3.3.3 Center Tapped Winding is a winding having an internal tap at the center (3 external leads).

1.3.3.4 Split Winding is a winding divided into two equal parts which will allow series or parallel external connections of the divided winding (4 external leads).

1.3.3.5 No Load Speed is the speed of the shaft rotation with no load applied to the shaft and rated voltage and frequency with proper phase relationships applied to both windings.

1.3.3 6 Stall-Torque is the torque developed at speeds in excess of 1 rpm but less than 1/2% of synchronous speed, with rated voltage and frequency of proper phase relationship applied to both windings. Locked Rotor Torque is not used for the motors covered in this document.

1.3.3.7 Starting Voltage is the voltage of rated frequency applied to the control voltage winding necessary to start the rotor turning at no-load conditions with rated voltage and frequency on the fixed voltage winding.

1.3.3.8 Slot Effect is the variation of magnetic interlocking between the rotor and stator.

1.3.3.9 Single Phasing is the tendency of the rotor to continue to rotate when one winding is opened and the other winding remains excited.

1.3.3.10 Time Constant is the time required for the motor to accelerate from 0 to 63.2% of its final no-load speed when rated voltage, with proper phase relationship, is applied to both windings.

1.3.3.10.1 Reversing Time is the time required for the motor to reach 63.2% of the no-load speed upon the phase reversal of the control winding voltage after initially running at the no-load speed in the opposite direction. It is approximately equal to the time constant multiplied by 1.69 seconds.

1.3.3.11 Theoretical Acceleration at Stall is a figure of merit derived from the stall torque to rotor inertia ratio which indicates how rapidly a motor will accelerate from stall.

1.3.3.12 Effective Resistance is the equivalent pure d-c resistance which when substituted for the winding being checked will draw the same power. It is also equivalent to the impedance of a circuit with a capacitor connected in parallel with the winding and the capacitor adjusted to unity power factor for the circuit.

1.3.3.13 Mutual Coupling: The voltage transfer between the halves of a control voltage winding when either half is energized.

1.3.3.14 Damping Control of a servo motor is the slope of the speed torque curve

2. CONTROL MOTOR CHARACTERISTICS

2.1 Physical

2.1.1 General - Each motor should be inspected to verify conformance with the applicable envelope dimensions, leadwire and/or terminal identification, and markings.

2.1.2 Envelope Dimensions (See Figure 8.)

2.1.3 Leadwire Identification (See Figure 4.)

2.1.4 Terminal Identification (See Figure 4.)

2.1.5 Marking (See paragraph 1.2.6.)

2.2 Electrical (Design Assurance) (See Introduction.)

2.2.1 Standard Test Conditions: Motor Performance should be based upon operation at the conditions specified below. Motors tested under other conditions should provide specified performance when tested at the conditions specified below.

2.2.1.1 Ambient Atmosphere

(a) Temperature - 25 ± 5 C
(b) Pressure - 30 in. Hg ± 2 in.
(c) Humidity - 75% max.

2.2.1.2 Power Supply - Excitation voltage should be provided by a two-phase source having the following characteristics, unless otherwise specified:

(a) Voltage amplitude should be maintained within 1% of rated value.
(b) Phase angle between phase voltages of fundamental frequency should be 90 ± 5°.
(c) Wave form should be essentially sinusoidal having a Crest Factor of 1.41 ± 10% and a form factor of 1.11 ± 5%. Harmonic content should not exceed 5% of the voltage of fundamental frequency.
(d) Frequency should be 400 ± 5 cycles.

2.2.1.3 Motor Condition for Tests 2.2.2 through 2.2.8

(a) Motor temperature should be maintained within ± 5 C of the value of which it stabilizes after the fixed voltage winding has been energized at rated voltage for one hour
(b) when motor is mounted on standard mounting plate, as shown in Figures 1, 2 and 3, and when
(c) motor is shielded from stray air currents and
(d) ambient atmosphere is as defined in paragraph 2.2.1.1.

2.2.1.4 Motor Condition for Tests 2.2.9 and 2.2.10 - Windings should be at standard ambient temperature and humidity.

2.2.2 Direction of Rotation Test - Viewed from the shaft end the direction of rotation should be counterclockwise when motor is connected as shown in Figure 4.

2.2.3 Starting Voltage Test - Motor should be as specified in 2.2.1.3 and connected as in Figure 4. Slowly increase control winding voltage from zero until motor shaft starts to rotate continuously. Control winding starting voltage for both clockwise and counter-clockwise directions of rotation should not exceed value given in Table I. This test should be performed twice in each direction.

2.2.4 No-Load Speed Test - Motor should be as specified in 2.2.1.3 and connected as in Figure 4. Raise control winding voltage to rated value and measure no-load speed. Speed should exceed the value shown in Table I.

2.2.5 Single Phasing Test - Motor should be as specified in 2.2.1.3, connected as in Figure 4, and running at no-load speed. Disconnect control voltage winding. Motor should stop within 15 seconds.

2.2.6 Stall Torque Gradient - Motor should be as specified in 2.2.1.3 and connected as in Figure 4. Using equipment and procedure of Figure 10, or equivalent, measure and record stall torques with fixed winding voltage held constant at rated value and the control winding voltage adjusted successively to 20, 40, 60, 80, 100 and 110% of rated value. Motor winding temperature variation should be less than 5 C during this test. Stall torque at 100% control phase voltage should be as shown in Table I. Plot stall torque gradient limiting curves as shown in Figure 9. Stall torques at 20, 40, 60, 80, and 110% must fall between limiting curves.

2.2.7 Speed at Half-Measured Stall Torque - Motor should be as specified in 2.2.1.3 and connected as in Figure 4. Using equipment of Figure 10 or equivalent adjust W1-W2 to equal 1/2 of measured W1-W2 at 100% control winding voltage torque. Apply rated voltage and measure motor speed. Speed at this torque should not exceed value shown in Table I.

2.2.8 Impedance - Motor should be as specified in 2.2.1.3 during this test. The following methods may be used.

(a) Series Resonant Bridge using an oscilloscope as the null detector. (See Figure 7.)

Where $Z = R + j \dfrac{1}{2 \pi fc}$

$R_a = R_b \approx R$

(b) Parallel Tuning (See Figure 6.)

$$Z = R + jX$$
$$R = \frac{V}{I} \cos \Theta$$
$$X = \frac{V}{I} \sin \Theta$$
$$\Theta = \arccos \frac{I_t}{I}$$

I_t = Tuned Current

I = Untuned Current

(c) Wattmeter-Ammeter (See Figure 5.)

$$Z = R + JX$$
$$R = \frac{V}{I} \cos \Theta$$
$$X = \frac{V}{I} \sin \Theta$$
$$\Theta = \arccos \frac{W}{VI}$$

2.2.9 High Potential Test - Motor winding should be at ambient temperature (25 ± 5 C). Each motor should be tested for electrical breakdown of insulation and at rated test voltage of 60 cycle frequency. Test voltage should have the amplitude and should be applied at the location and for the duration specified below. The minimum source impedance of the Hipot voltage supply should be 100,000 ohms. A voltmeter should be connected across the location to indicate the voltage applied.

(a) Amplitude
1. 500 volts rms if both windings are rated 60 volts rms or less.
2. 1000 volts rms if either winding is rated above 60 volts rms.
3. 500 volts between insulated halves of dual control voltage windings.

(b) Location
1. From fixed voltage winding to frame.
2. From control voltage winding(s) to frame.
3. From fixed voltage to control voltage winding(s).

(c) Duration
1. Increase test voltage gradually to max. rms value at rate not exceeding 75 volts per second.
2. Hold test voltage at max. rms value for sixty (60) seconds plus or minus five (5) seconds.
3. Decrease test voltage gradually to zero amplitude at rate not exceeding 75 volts per second.

(d) Failure - A leakage current in excess of 3 milliamperes should be considered a failure.

Initial High Potential Tests by qualifying agency should be performed at voltage indicated. Subsequent High Potential Tests should be performed at voltages not in excess of 80% of these values.

2.2.10 Insulation Resistance Test - Motor windings should be at ambient temperature (25 ± 5 C). The resistance measured at 500 volts, d-c between separate windings and from windings to frame should not be less than 100 megohms. The test should be performed after the high potential test.

2.2.11 Temperature Rise Test - Position motor on a standard plate, Figure 1, and shield assembly from stray air currents. Lock rotor shaft in a fixed position using a suitable heat insulating clamp. Apply rated voltage to both fixed and control voltage windings. Temperature rise should be measured by the change of resistance method, using the following formula:

$$\text{Temperature Rise C} = \frac{R_h - R_c}{R_c} \quad (234.5 + t)$$

R_h = resistance of winding at equilibrium temperature

R_c = resistance of winding at starting temperature t

t = ambient temperature (C) at start of test

The winding will have reached thermal equilibrium when the change of (hot) resistance over a five minute period is less than 0.4% of the nominal cold resistance value.

Temperature rise should not exceed the value specified in Table I.

2.2.12 Power Output - Maximum power output in watts should be computed from torque-speed measurements obtained from 2.2.7 as follows:

$$P \text{ max.} + 7.4 \times 10^{-4} \times T \times S$$

T = 1/2 measured stall torque (in.-oz)

S = Speed in rpm obtained for a load of "T" in.-oz above

Power output thus determined should exceed the value specified in Table I.

2.2.13 Mutual Coupling - Excite one-half of the control voltage winding with one-half rated control voltage. The voltage developed in the other half of the winding, expressed as a ratio to one-half the rated control winding voltage, should be as specified in Table II.

2.2.14 Rotor Inertia

2.2.14.1 General - Rotor Inertia of control motors covered by this document should be tested by the following method, and should be in accordance with the value listed in Table I.

2.2.14.2 Theory - When a weight is attached to a vertical wire and is twisted so that oscillation occurs about its axis, it will act as a torsional pendulum. The ratio of the restoring torque in the wire to the displacement angle of the weight will be proportional to the square of the frequency of oscillation and the moment of inertia. Therefore, the moment of inertia will be proportional to the square of the period for a given setup.

2.2.14.3 Test Equipment Required

1. Steel (piano) wire
2. Adapter* (for fastening rotor to wire)
   Lowest possible inertia
3. Body of known inertia*. Should be similar in dimensions and weight to body of unknown inertia.
4. Timing clock.

* The inertia of these bodies may be calculated.

2.2.14.4 Test Procedure - Fasten adapter to steel wire so when suspended and rotor is fastened to adapter, centerline of shaft will coincide with centerline of wire.

Suspend wire from a rigid point making sure that air circulation or vibration does not cause pendulum to sway. Twist the rotor so oscillation will be about its axial centerline. Measure the period of oscillation of the body with known inertia and then measure the period of the rotor.

By the use of the following equation the moment of inertia of the rotor may be found.

$$I_a = (I_b + I_{ad}) \frac{T_a^2}{T_b^2} - I_{ad}$$

Where I_a = moment of inertia of rotor in gm-cm^2.

I_b = known inertia of body in gm-cm^2.

I_{ad} = calculated inertia of adapter in gm-cm^2.

T_a = period of rotor and adapter in sec.

T_b = period of body and adapter in sec.

2.3 Electrical (Performance) (See Introduction.)

2.3.1 High Potential Test - Each motor should be tested for electrical breakdown of insulation at rated test voltage of 60 cycle frequency. Test voltage should be of proper amplitude and should be applied at the location and for the duration specified below. The minimum source impedance of the Hipot voltage should be 100,000 ohms. A voltmeter should be connected across the location to indicate the voltage applied.

(a) Amplitude

1. 500 volts rms if both windings are rated 60 volts rms or less.
2. 1000 volts rms if either winding is rated above 60 volts rms.
3. 500 volts between insulated halves of dual control voltage windings.

(b) Location

1. From fixed voltage winding to frame.
2. From control voltage winding(s) to frame.
3. From fixed voltage to control voltage winding(s).

(c) Duration

1. Increase test voltage gradually to max. rms value at rate not exceeding 75 volts per second.
2. Hold test voltage at max. rms value for fifteen (15) seconds plus or minus five (5) seconds.
3. Decrease test voltage gradually to zero amplitude at rate not exceeding 75 volts per second.

(d) Failure - A leakage current in excess of 3 milliamperes should be considered a failure.

Subsequent High Potential Test should be performed at voltage not to exceed 80% of rated amplitude (rms).

2.3.2 Insulation Resistance Test - The resistance measured at 500 volts, d-c between separate windings and from windings to frame should not be less than 100 megohms. This test should be performed after the High Potential Test.

2.3.3 Direction of Rotation Test - Viewed from the shaft end the direction of rotation should be counterclockwise when motor is connected as shown in Figure 4.

2.3.4 No Load Speed Test - When connected to an appropriate two phase voltage source (see Figure 4) the no-load speed for both clockwise and counterclockwise direction of rotation should be as specified in Table I when corrected for non-standard conditions.

2.3.5 Single Phasing Test - Connect motor as shown in Figure 4. Apply rated voltage to fixed and control windings. After motor has reached no-load speed disconnect the control voltage winding. Motor should stop within 15 seconds.

2.3.6 Starting Voltage Test - Connect motor as shown in Figure 4. Apply rated voltage to fixed voltage winding. Slowly increase control winding voltage from zero until motor shaft starts to rotate continuously. Control winding starting voltage for both clockwise and counterclockwise directions of rotation should not exceed value given in Table I when corrected for non-standard conditions. This test should be performed twice in each direction.

2.3.7 Stall Torque Test - Stall torque should be measured by any convenient, conventional method. Minimum stall torque should be as specified in Table I when corrected for non-standard conditions.

2.3.8 Power Test - Measure power taken by each winding at rated voltage and frequency with other winding open. Value should not exceed the value shown in Table I when corrected for non-standard conditions. Figures 5 and 6 show typical circuitry.

2.4 Environmental Conditions

2.4.1 Temperature Conditions

2.4.1.1 Low Temperature - All control motors covered by this document should sustain no damage or deterioration which could shorten life when subjected to the following test:

Place motor, properly mounted on a standard mounting plate, in a temperature-controlled chamber at atmospheric pressure, and reduce the chamber temperature to -85 F (-65 C). Neither phase of the motor should be energized. Hold this chamber temperature within ± 3 C for three hours or until the motor d-c resistance changes less than 1% in 15 minutes, whichever is least. Raise the chamber temperature to -65 F (-54 C), still without energizing the motor, and maintain this chamber temperature within ± 3 C for three hours or until the motor d-c resistance changes less than 1% in 15 minutes, whichever is less. While motor is still at this temperature, apply rated voltage and frequency to fixed voltage winding of motor for two minutes, then slowly increase control winding voltage from zero until motor starts and continues to run. Control winding voltage required for starting should not exceed 10% of rated value. Immediately after the motor starts, increase control winding voltage to rated value, and motor should attain a speed equal to or greater than 85% of the minimum specified no-load speed within 30 seconds.

2.4.1.2 High Temperature - Motors covered by this document should sustain no damage or deterioration which could shorten life when subjected to the following test:

Place motor, properly mounted on a standard mounting plate, in a temperature-controlled chamber at atmospheric pressure, and raise the chamber temperature to a value of 40 C higher than the maximum temperature rating of the motor as specified in paragraph 1.2.5. The motor should not be energized. Hold the chamber balance temperature within ± 3 C of this temperature for three hours or until the motor resistance changes less than 1% in 15 minutes, whichever is least. Reduce the chamber temperature to the maximum temperature rating of the motor, and maintain this temperature within ± 3 C for three hours or until the motor resistance changes less than 1% in 15 minutes, whichever is least. While motor is still at this temperature, apply rated voltage at rated frequency to the fixed voltage winding, and slowly raise the control winding voltage until motor starts and continues to run. The voltage at which the motor starts should be less than 3.5% of rated value.

Raise control winding voltage to rated value and measure no-load speed. Speed should be at least 95% of minimum specified no load speed. Allow motor to operate no load, while temperature is maintained, for four hours. Motor speed should not decrease by more than 10% during this period.

2.4.1.3 Thermal Shock - Control motors covered by this document should meet performance requirements of section 2.3 after having been subjected to the following test:

The control motor should be placed unenergized within a test chamber whose internal temperature is maintained within ±3 C of a value which exceeds the maximum temperature rating of the motor as specified in paragraph 1.2.5 by 40 C. After four hours in this chamber and within one minute after removal from this chamber, the motor should be transferred to a chamber whose internal temperature is maintained within ±3 C of -85 F (-65 C). After four hours in this chamber and within one minute of removal from this chamber, the motor should be transferred to the original high temperature chamber. This constitutes one cycle and should be repeated three more times for a total of four cycles. After the completion of this test, the unit should meet the no-load speed and starting voltage requirements of Table I under standard conditions.

2.4.2 Altitude - Place the control motor, unenergized, in a test chamber at room temperature and evacuate the chamber to a simulated altitude of 80,000 ft. While this simulated altitude is maintained, energize the motor with rated voltage and frequency and allow the motor to run without load for 15 minutes or until the motor case temperature reaches 70% of maximum storage temperature, whichever is the shorter time. There should be no visible external arcing, and no evidence of internal arcing as indicated by sudden current or speed variations.

2.4.3 Vibration

2.4.3.1 The control motors covered by this document should meet the performance requirements of section 2.3, and there should be no loosening or breakage of parts after having been subjected to the following tests. The control motors will be both energized and not energized for various parts of these tests. The control motor should be solidly mounted to the vibration test equipment using the smaller pilot diameter for location and held in place by applying pressure to the clamping ring by three equally spaced clamps.

2.4.3.2 Resonant frequency surveys should be conducted along each of 3 mutally perpendicular axis (one axis being that of the motor shaft) for vibration having a double amplitude of .06 inches, or an acceleration of 10G, whichever is the limiting value, over a range of 10 to 2000 cps in 20-minute cycles. The amplitude or acceleration for the resonant survey should be within ±10% of the specified values. Two searches shall be made in each direction, one with the control motor not energized, and one with the control motor running at no-load with rated voltage and frequency applied to both phases.

2.4.3.3 The control motor should be vibrated at the most severe resonance condition of each axis for a period of 60 minutes along that axis. The control motor should be energized or not energized depending upon its condition when the resonance was determined. When more than one resonant frequency is encountered along any one axis the time of vibration may be shared equally between the resonant conditions except that in no instance should the vibration period at a resonant frequency be less than 30 minutes.

2.4.3.4 When resonant frequencies are not apparent within the specified frequency range, the control motor should be vibrated (not energized) at a frequency between 400 and 500 cps along each of the search axes for a period of 60 minutes for each axis. Upon completion of the vibration testing, the motor should meet the no-load speed and starting voltage requirements of Table I under standard conditions, and the end play and radial play requirements of Figure 8.

2.4.4 Shock

2.4.4.1 The control motors covered by this document should meet the performance requirements of section 2.3 after having been subjected to the following test, and there should be no loosening or breakage of parts. Motors should not be energized during this test.

2.4.4.2 The control motor should be solidly mounted to the shock test equipment using the smaller pilot diameter for location and held in place by applying pressure to the clamping ring by three equally spaced clamps. The motor should be subjected to 12 impact shocks of 30 g each, consisting of 2 shocks in each of the two opposite directions along each of three mutually perpendicular axes. One of these axes should be the motor shaft. Each shock impulse should have a time duration of 11 $\pm$ 1 milliseconds. The g values should be within $\pm$ 10% when measured with a 5 to 100 cps band width filter, and the maximum g value should occur at approximately 5.5 milliseconds. Upon completion of this test the motor should meet the no-load speed and starting voltage requirements of Table I under standard conditions, and the end play and radial play of Figure 8.

2.4.5 Endurance

2.4.5.1 Control motors covered by this document should meet performance requirements listed below after having been subjected to the following test.

2.4.5.2 The motor should be mounted on a standard mounting plate, Figure 1, and the frame of the unit grounded to the low side of both phases of the power supply. Starting voltage should be as per Table I. Apply rated voltage to both windings. Ambient temperature should be the maximum value specified in paragraph 1.2.5 for the class of motor under test. Operate motor for 1000 hours, reversing direction three times per week. At weekly intervals, de-energize the motor and allow it to cool to room temperature. Check starting voltage after each cool-down. At the completion of the test the motor should meet stall torque requirements of Table I and the no-load speed should be greater than 90% of the no-load speed value in Table I. If at any time during the test the starting voltage exceeds 5% of the rated control phase voltage, the unit should be considered a failure.

2.4.6 Humidity - Control motors covered by this document should meet performance requirements of section 2.3 after having been subjected to the following test:

The unenergized control motor should be placed in a test chamber and the temperature of the chamber raised at a uniform rate from between 20 and 38 C (68 and 100.4 F) to 71 C (160 F) during a two-hour period. The temperature of 71 C (160 F) should be maintained during the next six-hour period. During the following 16-hour period, the temperature in the chamber should be dropped at a uniform rate to between 20 C and 38 C (68 to 100.4 F) which completes one 24-hour cycle. The relative humidity throughout the cycle should be maintained at 90 to 95%. The cycle should be repeated a sufficient number of times to extend the total time of the test to 240 hours (10 cycles). Distilled or demineralized water having a pH value of between 6.5 and 7.5 at 25 C (77 F) should be used to obtain the desired humidity, and condensate from the walls of the chamber should not be permitted to drip directly on the motor. The air velocity in the test chamber should not exceed 150 ft per minute. While still in the chamber during the last part of the last cycle, rated voltage at rated frequency should be applied to the fixed voltage winding, and the voltage on the control winding raised slowly from zero. The motor should start and continue to run before the control winding voltage reaches 50% of rated value. Immediately after the motor starts the control winding voltage should be increased to rated value and the no-load speed of the motor should be in accordance with Table I when corrected for non-standard conditions. After the no-load speed is measured, stop and restart the motor. Starting voltage on this second start should meet the requirement of Table I when corrected for non-standard conditions. After a drying period of one hour at 110 ± 5 C followed by cooling to room temperature, the motor should meet the high potential requirements of section 2.3 (for subsequent tests) and the insulation resistance requirement of section 2.3.

2.4.7 Fungus Resistance - Modern manufacturing methods generally eliminate all organic filled plastics and use inorganic winding impregnants such as silicones and epoxies. This leaves all exposed surfaces of funginert material. The Fungus Resistance Test is time consuming, expensive, and relatively unnecessary if surface materials are as described above.

2.4.8 Additional Requirements - The precision control motors covered by this document are designed to provide maximum performance with minimum size, weight, and power consumption. They will perform properly in the widely varying ambient conditions of temperature, humidity, pressure, etc. which they encounter in their normal use in flight instruments, computers, and navigation instruments where they are essentially protected from the elements such as salt spray, sand and dust, rain, etc. If subjected directly to these elements without additional protection, they will be affected adversely and will be rendered unfit for use due to build-up of salt or sand in bearings and air gaps. In addition, rain and salt deposits around terminals may cause impedance changes and short circuits.

3. QUALITY ASSURANCE

3.1 Classification of Tests

Classification of Tests	Symbol
(a) Performance	(P)
(b) Qualification	
1. Design Assurance	(C)
2. Environmental	
a. Non-Destructive	(E)
b. Destructive	(D)

3.1.1 Performance Tests - Tests performed on each unit, using production test equipment, to determine whether expected normal manufacturing variations are exceeded.

3.1.2 Qualification Tests - Measurements which provide type approval for the component in terms of its conformance to intended requirements (design assurance) and/or in terms of its capability to meet and survive various environmental conditions.

3.1.2.1 Design Assurance Tests - Qualification tests which measure, using laboratory methods and equipment, all control motor characteristics other than environmental capabilities.

3.1.2.2 Environmental Tests - Qualification tests which measure the motor's reaction to temperature, pressure, vibration, shock, etc.

3.1.2.2.1 Non-Destructive Tests - Those tests which cause no damage or deterioration which could shorten life or permanently impair performance.

3.1.2.2.2 Destructive Tests - Qualification tests which could cause damage or deterioration that would shorten life or permanently impair performance. After having been subjected to these tests, a motor could not reasonably be expected to have the same life as a motor not so subjected.

3.1.3 Index of Tests Required

3.1.3.1 Qualification Tests for Type Approval

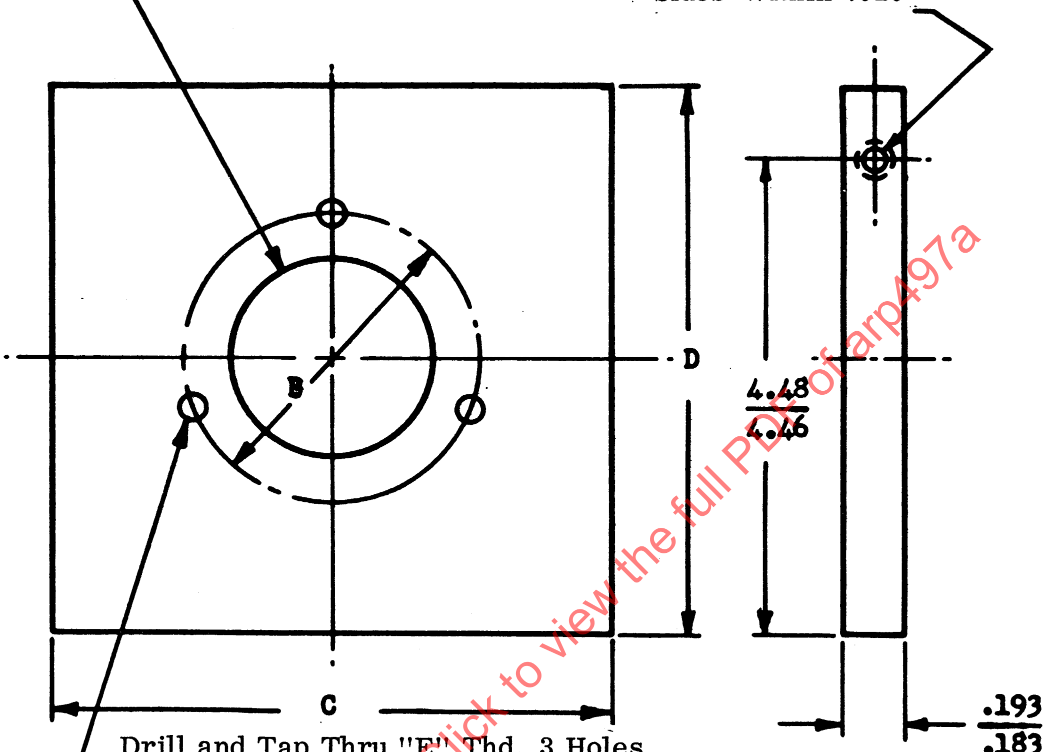
Test	Classification Para. 3.1.2	Paragraph
Mechanical	C	2.1.1
Dir. of Rotation	C	2.2.2
Starting Voltage	C	2.2.3
No-Load Speed	C	2.2.4
Single Phasing	C	2.2.5
Stall Torque Gradient	C	2.2.6
Speed 1/2 Stall Torque	C	2.2.7
Impedance	C	2.2.8
High Potential	C	2.2.9
Insulation Res.	C	2.2.10
Temperature Rise	C	2.2.11
Power Output	C	2.2.12
Mutual Coupling	C	2.2.13
Rotor Inertia	D	2.2.14
Low Temperature	E	2.4.1.1
High Temperature	E	2.4.1.2
Thermal Shock	D	2.4.1.4
Altitude	E	2.4.2
Vibration	D	2.4.3
Shock	D	2.4.4
Humidity	D	2.4.6.1
Endurance	D	2.4.5

3.1.3.2 Performance Tests for Production Acceptance

Test	Paragraph
Mechanical	2.1.1
High Potential	2.3.1
Insulation Res.	2.3.2
Direction of Rotation	2.3.3
No-Load Speed	2.3.4
Single Phasing	2.3.5
Starting Voltage	2.3.6
Stall Torque	2.3.7
Power	2.3.8

"A" DIA. Centrally Located to Sides Within .010

Drill for Tapping Depth .500 Max. Tap #6 (.138) - 32 NC Thd. .125 Min. Full Thd. Depth. Locate Central to Sides Within .010



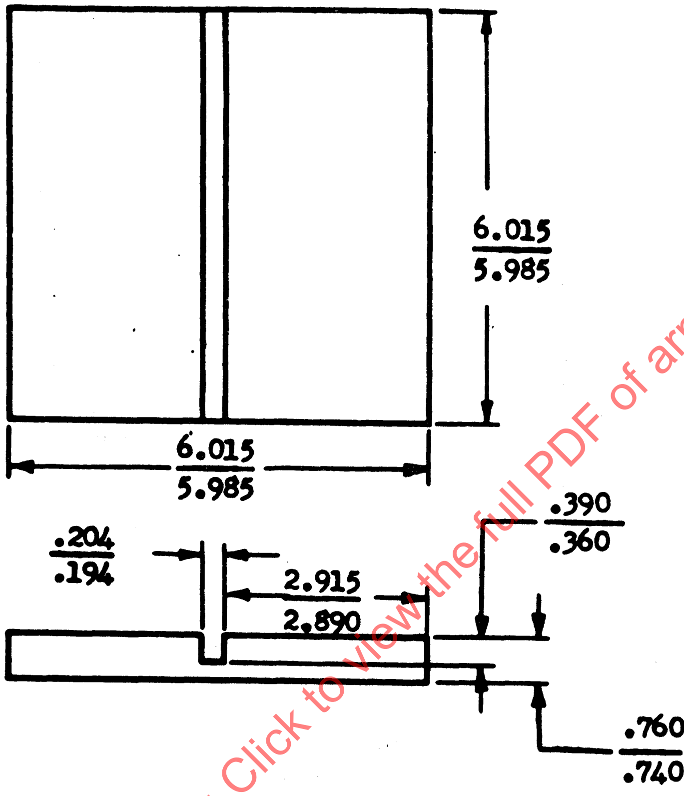
Drill and Tap Thru "E" Thd. 3 Holes Equally Spaced and Located Within .002 of True Position in Relation to DIA. "A"

<u>MATERIAL</u>: ALUMINUM 24ST
<u>FINISH</u>: BLACK ANODIZE

FIGURE 1

CONTROL MOTOR MOUNTING PLATES
(Dimensions - Inches)

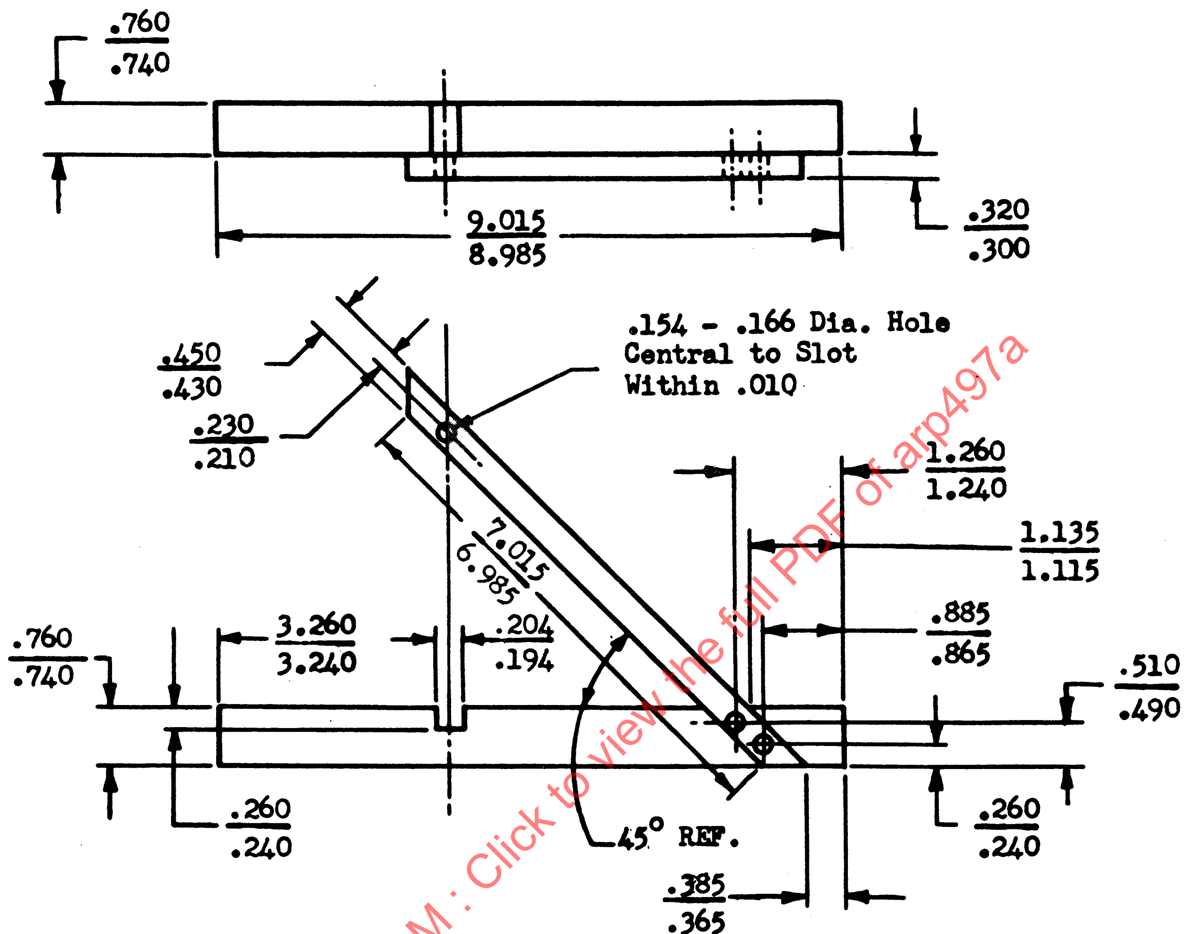
Size	A+0.001 -0.000	B Basic	C$\pm$0.015	D$\pm$0.015	E Thread
5	0.376	0.625	1.500	1.500	2-64
8	0.501	0.875	2.250	2.250	3-56
10	0.501	1.187	2.800	2.800	3-56
11	0.626	1.375	3.200	3.200	3-56
15	0.876	1.688	4.300	4.300	3-56
18	0.938	1.956	5.250	5.250	3-56
20	0.938	2.750	6.000	6.000	6-32
23	0.938	3.009	6.750	6.750	6-32



Material: Linen Laminated Phenolic or other suitable heat insulating material

Insulating Base for Sizes 5, 8, 10, 11, 15, and 18 Control Motor Mounting Plates

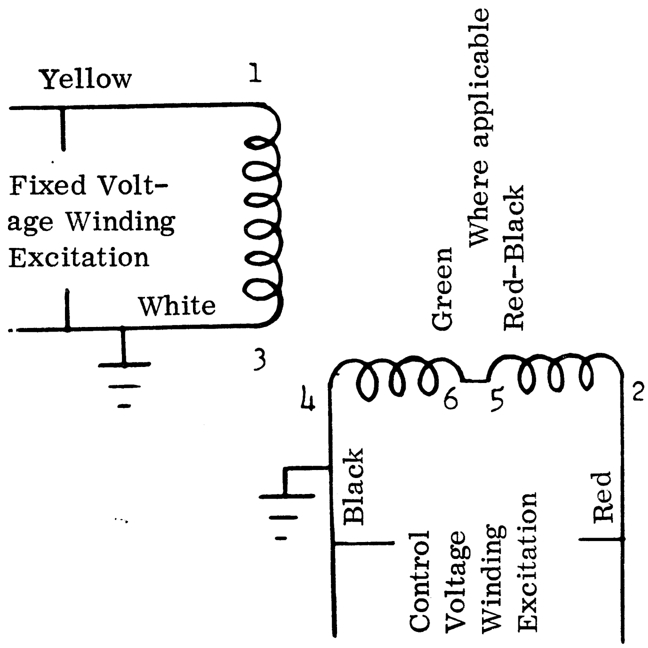
FIGURE 2



Material: Linen Laminated Phenolic or other suitable heat insulating material.

Insulating Stand for Sizes 20 and 23 Control Motor Mounting Plates

FIGURE 3

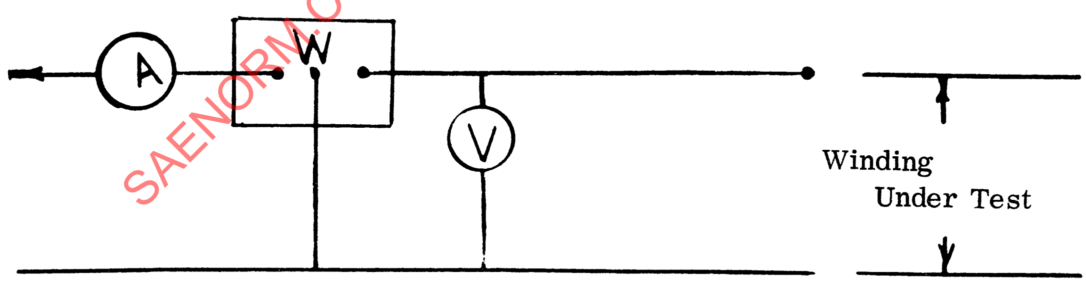


Voltage at terminal 2 must lead voltage at terminal 1 by $90^{\circ} \pm 5^{\circ}$

Where the center tapped winding is furnished a red-black lead or terminal #5 should be used.

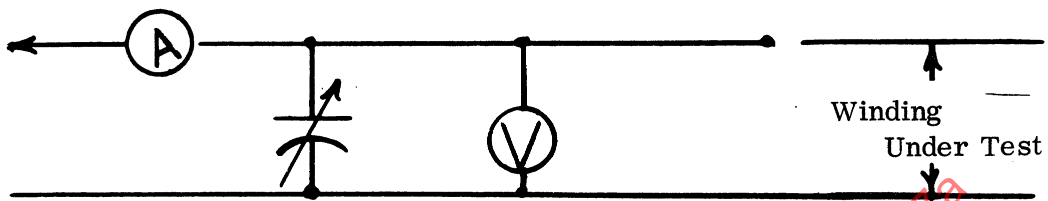
TWO PHASE POWER TEST CIRCUIT & TERMINAL LEAD DESIGNATION

FIGURE 4



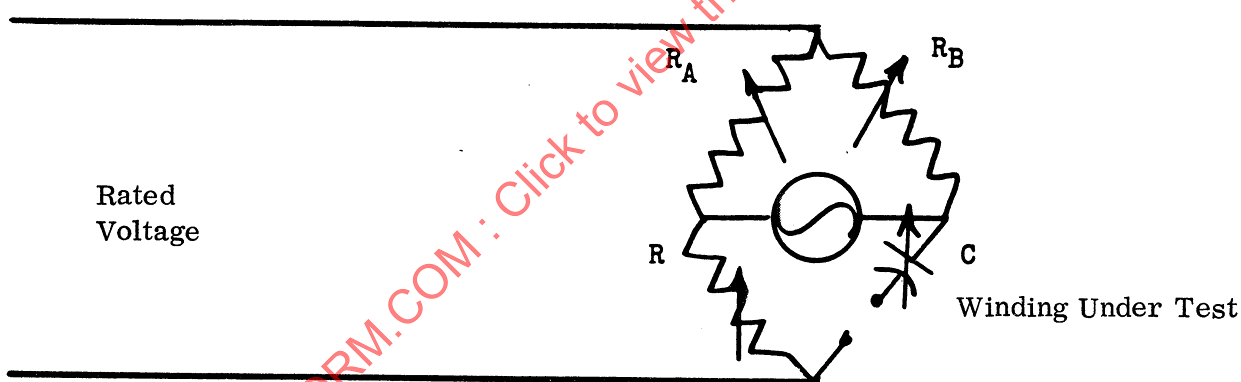
TYPICAL WATTMETER-AMMETER CIRCUIT

FIGURE 5



TYPICAL PARALLEL TUNING CIRCUIT

FIGURE 6



IMPEDANCE MEASUREMENT SERIES RESONANT BRIDGE

FIGURE 7