VRCI-P-100A

Industry Standard

Wirewound and Nonwirewound PRECISION POTENTIOMETERS

TERMS and DEFINITIONS
INSPECTION and TEST PROCEDURES

Revision A Reaffirmed January, 1988

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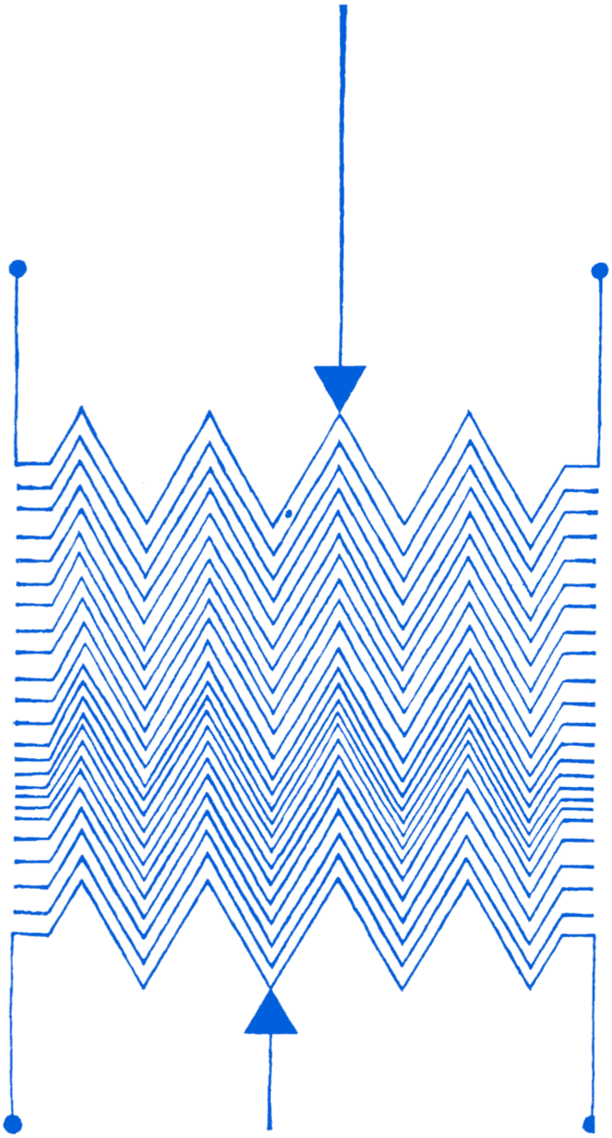
VARIABLE RESISTIVE COMPONENTS INSTITUTE

INDUSTRY STANDARD

Nonwirewound Precision Potentiometers



The Variable Resistive Components Institute is a National Trade Association representing manufacturers and users of precision potentiometers and trimmers. Since 1960 VRCI has been a formidable body of members dedicated to the pursuit of standardization and improvement of potentiometer design for military, industrial and commercial applications.

Since its founding in 1960, this organization has maintained in addition to contemporary programs the following objectives:

- To encourage excellence in product performance and reliability.
- To encourage the voluntary standardization of ratings as applied to manufactured products.
- To encourage the standardization of test procedures and test equipment.
- To promote and extend throughout all industry technical information, and to encourage the proper application of precision potentiometers.
- To collect and disseminate statistical information relating to the industry.
- To represent and to act for the industry before all divisions of Government, and for those public and private organizations whose work affects the industry.
- To provide meetings for the voluntary exchange of information on technical and management problems within the industry.
- To conduct any additional activities or programs which will advance the interest of the industry and which are in accord with the public interest.

The standard published here contains the Institute's updated wirewound and nonwirewound terms, definitions and test procedures, representing the achievement of a portion of the above objectives. Like any standard it is always open to modifications and additions, as the VRCI constantly strives to meet the challenge imposed upon it by new designs and new system objectives.

Your comments and suggestions are wanted; address them to:

Variable Electronic Components Institute
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VRCI-P-100A Standard for Wirewound and Nonwirewound Precision Potentiometers

This document presented in two parts provides industry-approved terms, definitions and test procedures for precision potentiometers.

The inherent construction difference between wirewound and nonwirewound resistance elements, with respect to both geometry and methods of termination, results in somewhat different output characteristics. Those same construction characteristics that provide for substantially infinite resolution in nonwirewound pots also eliminate distinct step-off voltages at the ends of electrical travel, a reference point for some wirewound potentiometer definitions and tests. For this reason, the VRCI has, where necessary, provided alternate definitions and test procedures for both types of pots. This approach provides the user with a better understanding of each type of unit and provides a uniform source of communication throughout the industry.

PART I

TERMS and DEFINITIONS

PART II

INSPECTION and TEST PROCEDURES

(Begins on page 11)

Supersedes combination of

VRCI-P-100A and VRCI-P-200A

VARIABLE RESISTIVE COMPONENTS INSTITUTE

PART I TABLE OF CONTENTS

1 *symbols and general terms*

1.1 ■ LIST OF SYMBOLS

C = CONFORMITY
CT = CENTER TAP
CW = CLOCKWISE
CCW = COUNTERCLOCKWISE
E = TOTAL APPLIED VOLTAGE
e = OUTPUT VOLTAGE
e_i = INPHASE OUTPUT VOLTAGE
e_q = QUADRATURE VOLTAGE
e/E = OUTPUT RATIO (Output Voltage Ratio)
V_e = END VOLTAGE
R_T = TOTAL RESISTANCE
R_L = LOAD RESISTANCE
R_e = END RESISTANCE
TC = TEMPERATURE COEFFICIENT OF RESISTANCE
RTC = RESISTANCE-TEMPERATURE CHARACTERISTIC
A = OUTPUT SLOPE
G = GRADIENT
θ = SHAFT POSITION
ϕ = PHASE SHIFT
θ_T = THEORETICAL ELECTRICAL TRAVEL
θ_A = ACTUAL ELECTRICAL TRAVEL

LEGEND:

☐ **WIREWOUND**
■ **WIREWOUND AND NONWIREWOUND**
🟦 **NONWIREWOUND**

1.2 ■ GENERAL TERMS

1.2.1 ■ PRECISION POTENTIOMETER A mechanical-electrical transducer dependent upon the relative position of a moving contact (wiper) and a resistance element for its operation. It delivers to a high degree of accuracy a voltage output that is some specified function of applied voltage and shaft position.

1.2.1.1 ☐ WIREWOUND PRECISION POTENTIOMETER A precision potentiometer characterized by a resistance element made up of turns of wire on which the wiper contacts only a small portion of each turn.

1.2.1.2 🟦 NONWIREWOUND PRECISION POTENTIOMETER A precision potentiometer characterized by the continuous nature of the resistance element in the direction of wiper travel.

1.2.3 ■ CUP A single mechanical section of a potentiometer which may contain one or more electrical resistance elements.

1.2.4 ■ GANG An assembly of two or more cups on a common operating shaft.

1.2.5 ■ SHAFT The mechanical input element of the potentiometer.

1.2.6 ■ SHAFT POSITION An indication of the position of the wiper relative to a reference point.

1.2.7 ■ TERMINAL An external member that provides electrical access to the potentiometer resistance element and wiper.

1.2.8 ■ INTEGRAL RESISTOR An internal or external resistor preconnected to the electrical element and forming an integral part of the cup assembly to provide a desired electrical characteristic. The resistor may be a separate entity, a part of the wirewound or nonwirewound resistance element, or a layer type resistor formed on the same insulating substrate as the resistance element.

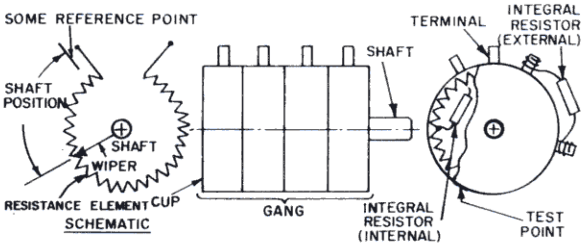


FIGURE 1.2.8 Precision potentiometer

1.2.9 ■ **TEST POINT** An additional terminal used only to facilitate measurements.

1.2.10 ■ **TAP**

1.2.10.1 ■ **CURRENT TAP:** An electrical connection fixed to the resistance element which is capable of carrying *rated* element current and may distort the output characteristic. **Note: Current taps on non-wirewound units commonly have significant width, but low resistance. See paragraph 3.13.**

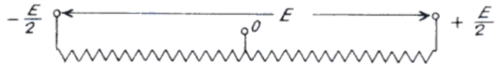
1.2.10.2 ■ **VOLTAGE TAP:** An electrical connection fixed to the resistance element which introduces no significant distortion in the output characteristic. A voltage tap usually has significant tap resistance and *may* not be capable of carrying rated element current. **Note: The distinction between current and voltage taps basically applies to taps on non-wirewound units. Most taps on wirewound potentiometers are attached to one turn of wire and can carry rated element current. They do not usually have an effect on resolution or output characteristics.**

2 *input and output terms*

2.1 ■ INPUT TERMS

2.1.1 ■ TOTAL APPLIED VOLTAGE (E) The total voltage applied between the designated input terminals.

Note: When plus (+) and minus (—) voltages are applied to the potentiometer, the Total Applied Voltage (commonly called peak-to-peak applied voltage) is equal to the sum of the two voltages. Each individual voltage is referred to as zero-to-peak applied voltage.



E = TOTAL APPLIED VOLTAGE (PEAK-TO-PEAK APPLIED VOLTAGE)
$\frac{E}{2}$ = ZERO-TO-PEAK APPLIED VOLTAGE.

FIGURE 2.1.1 Total applied voltage

LEGEND:

☐ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
🟦 NONWIREWOUND

2.2 ■ OUTPUT TERMS

2.2.1 ■ OUTPUT VOLTAGE The voltage between the wiper and the designated reference point. Unless otherwise specified, the designated reference point is the CCW terminal.

2.2.2 ■ OUTPUT RATIO The ratio of the Output Voltage to the designated input reference voltage. Unless otherwise specified the reference voltage is the Total Applied Voltage (see 2.1.1).

2.2.3 ■ TOTAL VARIABLE OUTPUT The difference between the maximum and minimum Output Ratios. These ratios correspond to the Minimum Voltages at each input terminal.

2.2.4 ☐ 🟦 END VOLTAGE

2.2.4.1 ☐ END VOLTAGE — WIREWOUND The voltage between the wiper terminal and an end terminal when the shaft is positioned at the corresponding End Point. End Voltage is expressed as a percent of the Total Applied Voltage.

2.2.4.2 🟦 END VOLTAGE — NONWIREWOUND The voltage between the wiper terminal and an end terminal when the shaft is positioned at the corresponding Theoretical End Point. End Voltage is expressed as a percent of the Total Applied Voltage.

2.2.5 ■ MINIMUM VOLTAGE The smallest or lowest voltage between the wiper terminal and an end terminal when the shaft is positioned near the corresponding end of Electrical Continuity Travel. Minimum Voltage is expressed as a percent of the Total Applied Voltage.

2.2.6 ☐ JUMP-OFF VOLTAGE (WIREWOUND POTENTIOMETERS ONLY) The magnitude of the first measurable voltage change as the wiper moves from the overtravel region onto the Actual Electrical Travel. It is expressed as a percent of the Total Applied Voltage.

2.2.7 ■ SHORTED SEGMENT A portion of the resistance element over which the Output Ratio remains constant within specified limits as the wiper traverses the segment with a specified Load Resistance.

2.2.8 ■ OUTPUT SLOPE The ratio between the rate of change of Output Ratio and the rate of change of shaft travel.

MATHEMATICALLY: $$A = \frac{\Delta \frac{e}{E}}{\Delta \frac{\theta}{\theta_T}}$$

θ_A may be substituted for θ_T where applicable

Note: The theoretical output slope is the first derivative of the normalized Theoretical Function Characteristic.

MATHEMATICALLY: $$A = \frac{d\,f(\theta/\theta_T)}{d(\theta/\theta_T)} = \frac{d(e/E)}{d(\theta/\theta_T)}$$

2.2.9 ■ SLOPE RATIO The ratio of the largest to the smallest Output Slopes of a monotonic Theoretical Function Characteristic.

2.2.10 ■ GRADIENT The rate of change of Output Ratio relative to shaft travel

MATHEMATICALLY: $$G = \frac{d(e/E)}{d\theta}$$

2.3 ■ LOAD TERMS

2.3.1 ■ LOAD RESISTANCE (R_L) The external resistance as seen by the Output Voltage; (connected between the wiper and the designated reference point).

Note: No load means an infinite Load Resistance.

2.3.2 ☐ LOADING ERROR The difference between the Output Ratio with an infinite Load Resistance and the Output Ratio with a specified finite Load Resistance, at the same shaft position.

Note: Elimination of Loading Error, by compensating the resistance element to give the desired output with a specified Load Resistance, is referred to as "Load Compensation."

3 *rotation and translation*

3.1 ■ DIRECTION OF TRAVEL For rotary potentiometers, clockwise (CW) or counterclockwise (CCW) when viewing the specified mounting end of the potentiometer. The designation of terminals in the figure corresponds to the direction of shaft travel.

For translatory potentiometers, "extending" or "retracting" when viewing the specified end of the potentiometer.

The Output Ratio and shaft position increase with clockwise (or extending) direction of travel unless otherwise specified.

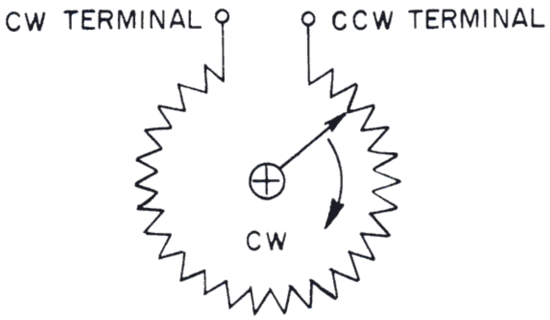


FIGURE 3.1 View of shaft and element from specified mounting end

3.2 ■ TOTAL MECHANICAL TRAVEL The total travel of the shaft between integral stops, under specified stop load. In potentiometers without stops, the mechanical travel is continuous.

3.3 ☐ 🟦 MECHANICAL OVERTRAVEL

3.3.1 ☐ MECHANICAL OVERTRAVEL — WIREWOUND The shaft travel between each End Point (or Theoretical End Point for Absolute Conformity or Linearity units) and its adjacent corresponding limit of Total Mechanical Travel.

3.3.2 🟦 MECHANICAL OVERTRAVEL — NONWIREWOUND The shaft travel between each Theoretical End Point and its adjacent corresponding limit of Total Mechanical Travel.

LEGEND:

☐ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
🟦 NONWIREWOUND

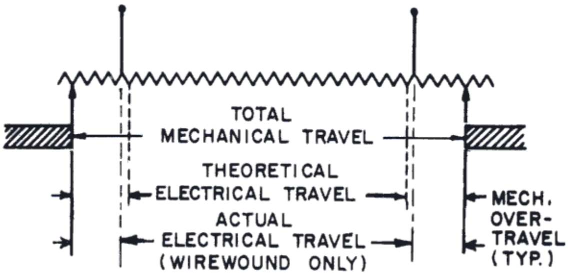


FIGURE 3.3.2 Mechanical overtravel

Note: The relationship of the electrical travels to each other and to the input terminals shown above is given for illustration only and may vary from one potentiometer to another.

3.4 ■ BACKLASH The maximum difference in shaft position that occurs when the shaft is moved to the same actual Output Ratio point from opposite directions.

3.5 ☐ END POINT (WIREWOUND POTENTIOMETERS ONLY) The shaft positions immediately before the first and after the last measurable change(s) in Output Ratio, after wiper continuity has been established, as the shaft moves in a specified direction.

3.6 ■ THEORETICAL END POINT The shaft positions corresponding to the ends of the Theoretical Electrical Travel as determined from the Index Point.

3.7 ■ INDEX POINT A point of reference fixing the relationship between a specified shaft position and the Output Ratio. It is used to establish a shaft position reference.

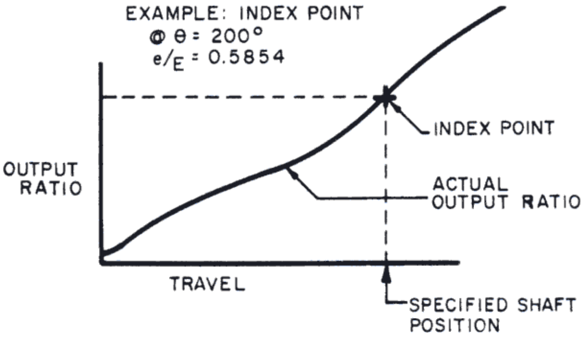


FIGURE 3.7 Index point

3.8 ☐ ACTUAL ELECTRICAL TRAVEL (WIREWOUND POTENTIOMETERS ONLY) The total travel of the shaft between End Points.

3.9 ■ THEORETICAL ELECTRICAL TRAVEL The specified shaft travel over which the theoretical function characteristic extends between defined Output Ratio limits, as determined from the Index Point.

3.10 ☐ 🟦 ELECTRICAL OVERTRAVEL

3.10.1 ☐ ELECTRICAL OVERTRAVEL — WIREWOUND The shaft travel over which there is continuity between the wiper terminal and the resistance element beyond each end of the Actual Electrical Travel. (Theoretical Electrical Travel is substituted for Actual Electrical Travel in Absolute Conformity or Linearity units.)

3.10.2 🟦 ELECTRICAL OVERTRAVEL — NONWIREWOUND The shaft travel over which there is continuity between the wiper terminal and the resistance element beyond each end of the Theoretical Electrical Travel.

3.11 ■ ELECTRICAL CONTINUITY TRAVEL The total travel of the shaft over which electrical continuity is maintained between the wiper and the resistance element.

3.12 ■ TAP LOCATION The position of a tap relative to some reference. This is commonly expressed in terms of an Output Ratio and/or a shaft position. When a shaft position is specified, the Tap Location is the center of the Effective Tap Width.

3.13 ■ EFFECTIVE TAP WIDTH The travel of the shaft during which the voltage at the wiper terminal and the tap terminal are the same, as the wiper is moved past the tap in one direction.

Note: In some instances, particularly nonwirewound pots, the tap width may be essentially zero (i.e., no flat zone) but the tap may have a significant effect on conformity. In these cases the term "Effective Tap Width" should not be applied. Instead, the effect of the tap on the output characteristics should be considered in terms of conformity.

3.14 ☐ 🟦 PHASING POINT — WHEN INDEX POINT (3.7) IS NOT EMPLOYED

3.14.1 ☐ PHASING POINT — WIREWOUND A reference point on a cup of a gang, usually an Output Ratio, an End Point, or an intermediate tap.

3.14.2 🟦 PHASING POINT — NONWIREWOUND A reference point on a cup of a gang, usually an Output Ratio or an intermediate tap (not an end tap).

3.15 ■ PHASING (SEE ALSO SIMULTANEOUS CONFORMITY PHASING PARA. 5.10) The relative alignment of the Phasing Points of each cup of a gang potentiometer.

Note: Unless otherwise specified, phasing requirements apply to a single specified Phasing Point in each cup and all cups are aligned to the Phasing Point of the first cup.

4 *resistance*

4.1 ■ TOTAL RESISTANCE (DC INPUT IMPEDANCE) The DC resistance between the input terminals with the shaft positioned so as to give a maximum resistance value.

4.2 ■ DC OUTPUT IMPEDANCE The maximum DC resistance between the wiper and either end terminal with the input shorted.

4.3 ☐ 🟦 MINIMUM RESISTANCE

4.3.1 ☐ MINIMUM RESISTANCE — WIREWOUND The resistance measured between the wiper terminal and any terminal with the shaft positioned to give a minimum value.

4.3.2 🟦 MINIMUM RESISTANCE — NONWIREWOUND Refer to Tap Resistance (4.5) or Minimum Voltage (2.2.5) for applicable definition.

4.4 ☐ 🟦 END RESISTANCE

4.4.1 ☐ END RESISTANCE — WIREWOUND The resistance measured between the wiper terminal and an end terminal with the shaft positioned at the corresponding End Point.

4.4.2 🟦 END RESISTANCE — NONWIREWOUND Refer to End Voltage (2.2.4.2) for applicable definition.

4.5 🟦 TAP RESISTANCE (NONWIREWOUND POTENTIOMETERS ONLY) The minimum resistance obtainable between a tap terminal and a wiper position on the resistance element, measured without drawing wiper current.

Note: This definition applies only to intermediate taps. For End Terminations refer to End Voltage (2.2.4.2)

LEGEND:

- □ WIREWOUND
- ■ WIREWOUND AND NONWIREWOUND
- ■ NONWIREWOUND

4.6 ■ APPARENT CONTACT RESISTANCE (NONWIREWOUND POTENTIOMETERS ONLY) Refer to Output Smoothness (6.2)

4.7 □ ■ EQUIVALENT NOISE RESISTANCE (ENR)

4.7.1 □ EQUIVALENT NOISE RESISTANCE — WIREWOUND Refer to Noise (6.1).

4.7.2 ■ EQUIVALENT NOISE RESISTANCE — NONWIREWOUND Refer to Output Smoothness (6.2).

4.8 □ TEMPERATURE COEFFICIENT OF RESISTANCE (WIREWOUND POTENTIOMETERS ONLY) The unit change in resistance per degree celsius change from a reference temperature, expressed in parts per million per degree Celsius as follows:

$$\text{T. C.} = \frac{R_2 - R_1}{R_1(T_2 - T_1)} \times 10^6$$

Where:

R_1 = Resistance at reference temperature in ohms.
R_2 = Resistance at test temperature in ohms.
T_1 = Reference temperature in degrees celsius.
T_2 = Test temperature in degrees celsius.

4.9 ■ RESISTANCE — TEMPERATURE CHARACTERISTIC (NONWIREWOUND POTENTIOMETERS ONLY) The change in Total Resistance over a specified temperature range expressed as a percent of the Total Resistance at a specified reference temperature.

$$\text{RTC} = \frac{R_2 - R_1}{R_1} \times 100$$

Where:

R_1 = Resistance at reference temperature in ohms.
R_2 = Maximum or minimum resistance at any of the test temperatures, in ohms.

Note: Although Temperature Coefficient of Resistance can be applied to Nonwirewounds, the Tempco of many Nonwirewounds is not linear over the normal use temperature range and this can be misleading.

5 *conformity and linearity*

5.1 ■ FUNCTION CHARACTERISTIC The relationship between the Output Ratio and the shaft position.

MATHEMATICALLY: $\frac{e}{E} = f(\theta)$

5.2 ■ CONFORMITY The fidelity of the relationship between the actual function characteristic and the theoretical function characteristic.

MATHEMATICALLY: $\frac{e}{E} = f(\theta) \pm C$

5.3 ■ ABSOLUTE CONFORMITY The maximum deviation of the actual function characteristic from a fully defined theoretical function characteristic. It is expressed as a percentage of the Total Applied Voltage and measured over the Theoretical Electrical Travel. An Index Point on the actual output is required.

MATHEMATICALLY: $\frac{e}{E} = f(\theta/\theta_T) \pm C;\ 0 \leq \theta \leq \theta_T$

Note: The theoretical function characteristic is assumed to be a smooth curve when it can be described by a mathematical expression. When empirical data are provided, the points are assumed to be joined by straight line segments.

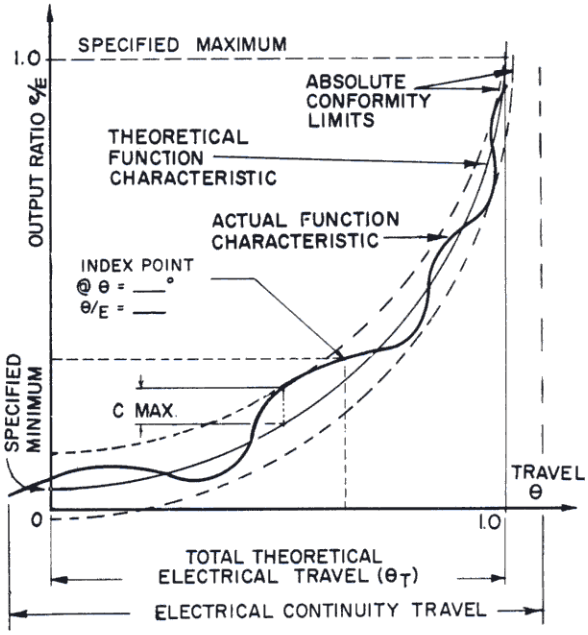


FIGURE 5.3 Absolute conformity

5.4 ■ LINEARITY A specific type of conformity where the theoretical function characteristic is a straight line.

MATHEMATICALLY: $\frac{e}{E} = f(\theta) \pm C = A(\theta) + B \pm C$

Where:
A is given slope; B is given intercept at $\theta = 0$.

5.5 ■ ABSOLUTE LINEARITY The maximum deviation of the actual function characteristic from a fully defined straight reference line. It is expressed as a percentage of the Total Applied Voltage and measured over the Theoretical Electrical Travel. An Index Point on the actual output is required.

The straight reference line may be fully defined by specifying the low and high theoretical end Output Ratios separated by the Theoretical Electrical Travel. Unless otherwise specified, these end Output Ratios are 0.0 and 1.0, respectively.

MATHEMATICALLY: $\frac{e}{E} = A(\theta/\theta_T) + B \pm C$

Where:
A is given slope; B is given intercept at $\theta = 0$.
Unless otherwise specified:
$A = 1;\ B = 0.$

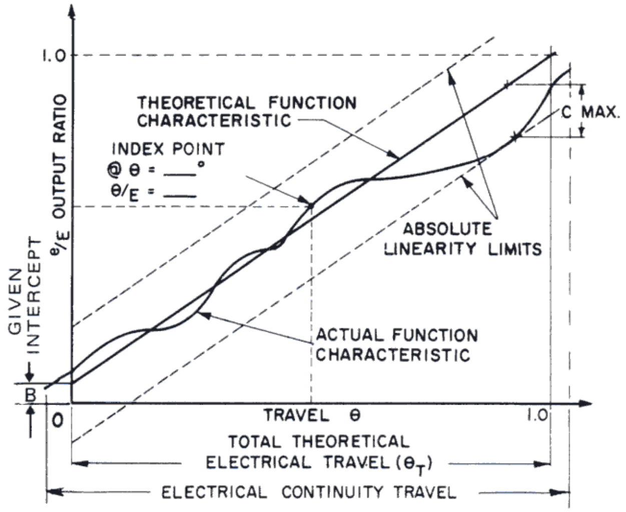


FIGURE 5.5 Absolute linearity

5.6 ☐ TERMINAL BASED LINEARITY (WIREWOUND POTENTIOMETERS ONLY) The maximum deviation, expressed as a percent of the Total Applied Voltage, of the actual function characteristic from a straight reference line drawn through the specified minimum and maximum Output Ratios which are separated by the Actual Electrical Travel. Unless otherwise specified, minimum and maximum Output Ratios are, respectively, zero and 100% of Total Applied Voltage.

MATHEMATICALLY: $\frac{e}{E} = A(\theta/\theta_A) + B \pm C$

Where:
A is given slope; B is given intercept at $\theta = 0$.
Unless otherwise specified:
$A = 1$; $B = 0$.

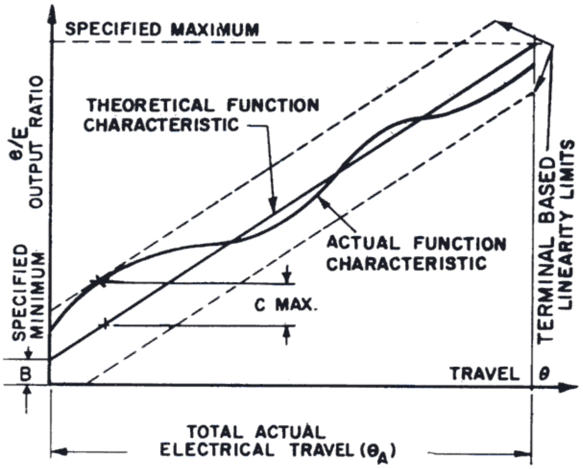


FIGURE 5.6 Terminal based linearity — wirewound

5.7 ☐ ZERO BASED LINEARITY (WIREWOUND POTENTIOMETERS ONLY) The maximum deviation, expressed as a percent of Total Applied Voltage, of the actual function characteristic from a straight reference line drawn through the specified minimum Output Ratio, extended over the Actual Electrical Travel, with its slope chosen to minimize the maximum deviations. Any specified End Voltage requirement may limit the slope of the reference line. Unless otherwise specified, the specified minimum Output Ratio will be zero.

MATHEMATICALLY: $\frac{e}{E} = P(\theta/\theta_A) + B \pm C$

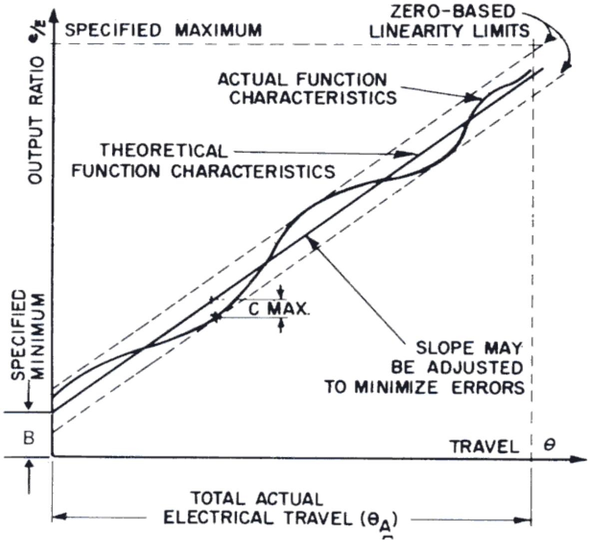


FIGURE 5.7 Zero based linearity — wirewound

Where:
P is unspecified slope limited by the End Voltage requirements, at the maximum output ratio end.
Unless otherwise specified:
$B = 0$.

5.8 ☐ ■ INDEPENDENT LINEARITY (BEST STRAIGHT LINE)

5.8.1 ☐ INDEPENDENT LINEARITY — WIREWOUND The maximum deviation, expressed as a percent of the Total Applied Voltage, of the actual function characteristic from a straight reference line with its slope and position chosen to minimize deviations over the Actual Electrical Travel, or any specified portion thereof.

Note: End Voltage requirements, when specified, will limit the slope and position of the reference line.

MATHEMATICALLY: $\frac{e}{E} = P(\theta/\theta_A) + Q \pm C$

Where:
P is unspecified slope; Q is unspecified intercept at $\theta = 0$.
And both are chosen to minimize C but are limited by the End Voltage requirements.

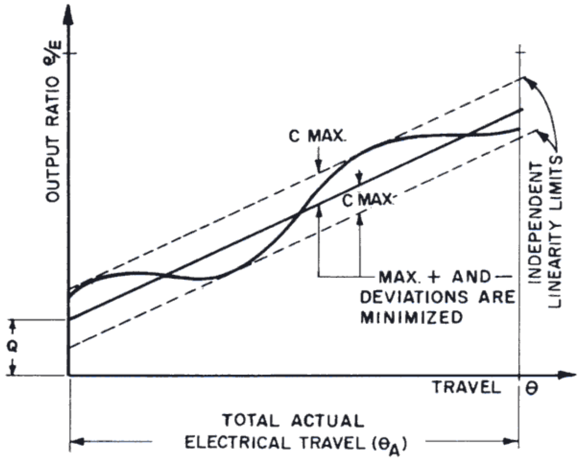


FIGURE 5.8.1 Independent linearity — wirewound

5.8.2 ■ INDEPENDENT LINEARITY — NONWIREWOUND The maximum deviation of the actual function characteristics from a straight reference line with its slope and position chosen to minimize the maximum deviations. It is expressed as a percentage of the Total Applied Voltage and is measured over the specified Theoretical Electrical Travel. The slope of the reference line, if limited, must be separately specified. An

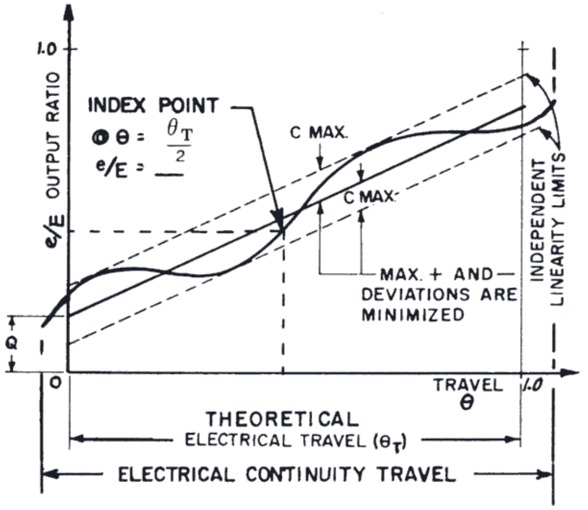


FIGURE 5.8.2 Independent linearity — nonwirewound

LEGEND:

☐ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
🟦 NONWIREWOUND

Index Point on the actual output is required. Unless otherwise specified, the Index Point will be at $\theta = \frac{\theta_T}{2}$.

MATHEMATICALLY: $\frac{e}{E} = P(\theta/\theta_T) + Q \pm C$

Where:
P is unspecified slope; Q is unspecified intercept at $\theta = 0$. And both are chosen to minimize C but are limited by the End Voltage requirements.

5.9 ■ TOLERANCE LIMITS

5.9.1 ■ CONSTANT LIMITS Permissible Conformity deviations specified as a percentage of the Total Applied Voltage.

Note: Unless otherwise specified, all definitions in this document employ Constant Limits.

5.9.1.1 ■ ZERO-TO-PEAK CONSTANT LIMITS Permissible Conformity deviations specified as a percentage of Zero-To-Peak Applied Voltage.

Note: The numerical value of zero-to-peak errors is double that of equal peak-to-peak errors, because the reference zero-to-peak applied voltage is one-half of the Total (peak-to-peak) Applied Voltage (see 2.1.1).

5.9.2 ■ PROPORTIONAL LIMITS Permissible Conformity deviations specified as a percentage of the theoretical Output Ratio at the point of measurement.

Note: Proportional limits may become impossibly restrictive in the vicinity of zero theoretical output and should be modified to provide a practical tolerance in that region, if the theoretical Output Ratio approaches zero.

5.9.3 ■ MODIFIED PROPORTIONAL LIMITS Any combination of Constant and Proportional Limits.

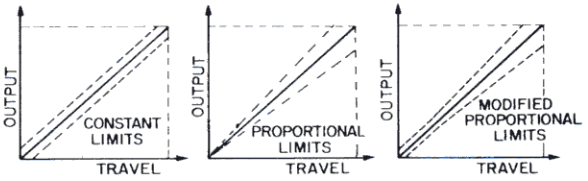


FIGURE 5.9.3 Tolerance limits

5.10 ■ SIMULTANEOUS CONFORMITY PHASING The relative alignment of the cups of a gang potentiometer, from a common index point, such that the Output Ratios of all cups fall within their respective Conformity limits over the Theoretical Electrical Travel.

5.11 ■ VOLTAGE TRACKING ERROR The difference, at any shaft position, between the Output Ratios of any two commonly actuated similar electrical elements, expressed as a percentage of the single total voltage applied to them.

6 *general electrical characteristics*

6.1 ☐ NOISE (WIREWOUND POTENTIOMETERS ONLY) Any spurious variation in the electrical output not present in the input, defined quantitatively in terms of an equivalent parasitic, transient resistance in ohms, appearing between the contact and the resistance element when the shaft is rotated or translated. The Equivalent Noise Resistance is defined independently of the resolution, the functional characteristics, and the total travel. The magnitude of the Equivalent Noise Resistance is the maximum departure from a specified reference line. The wiper of the potentiometer is required to be excited by a specified current and moved at a specified speed.

6.2 🟦 OUTPUT SMOOTHNESS (NONWIREWOUND POTENTIOMETERS ONLY) Output Smoothness is a measurement of any spurious variation in the electrical output not present in the input. It is expressed as a percentage of the Total Applied Voltage and measured for specified travel increments over the Theoretical Electrical Travel. Output Smoothness includes effects of contact resistance variations, resolution, and other micro-nonlinearities in the output.

6.3 ■ RESOLUTION A measure of the sensitivity to which the Output Ratio of the potentiometer may be set.

6.4 ☐ THEORETICAL RESOLUTION (LINEAR WIREWOUND POTENTIOMETERS ONLY) The reciprocal of the number of turns of wire in resistance winding in the Actual Electrical Travel, expressed as a percentage.

N = Total number of resistance wire turns.

$\frac{1}{N} \times 100$ = Theoretical Resolution percent.

6.5 ☐ TRAVEL RESOLUTION (WIREWOUND POTENTIOMETERS ONLY) The maximum value of shaft travel in one direction per incremental voltage step in any specified portion of the resistance element.

6.6 ■ VOLTAGE RESOLUTION The maximum incremental change in Output Ratio with shaft travel in one direction in any specified portion of the resistance element.

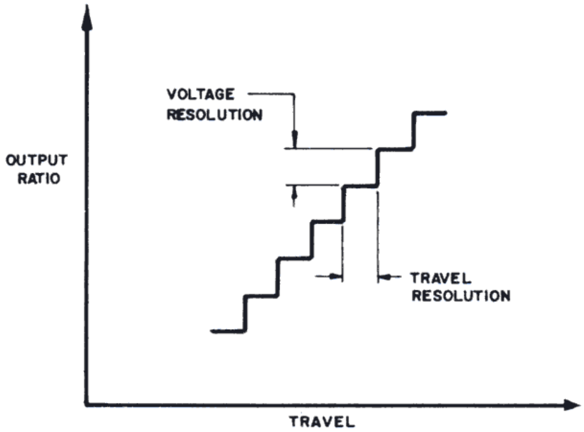


FIGURE 6.6 Wirewound resolution

Note: The illustration above is valid only for wirewound potentiometers because of the "stepped" nature of the output function. For determination of the effects of resolution in a nonwirewound potentiometer, refer to Output Smoothness (6.2).

6.7 ■ DIELECTRIC WITHSTANDING VOLTAGE Ability to withstand under prescribed conditions, a specified potential of a given characteristic between the terminals of each cup and the exposed conducting surfaces of the potentiometer, or between the terminals of each cup and the terminals of every other cup in the gang without exceeding a specified leakage current value.

6.8 ■ INSULATION RESISTANCE The resistance to a specified impressed DC voltage between the terminals of each cup and the exposed conducting surfaces of the potentiometer, or between the terminals of each cup and the terminals of every other cup in the gang, under prescribed conditions.

6.9 ■ POWER RATING The maximum power that a potentiometer can dissipate under specified conditions while meeting specified performance requirements.

6.9.1 ■ POWER DERATING The modification of the nominal power rating for various considerations such as Load Resistance, Output Slopes, Ganging, nonstandard environmental conditions and other factors.

6.10 ■ LIFE The number of shaft revolutions or translations obtainable under specific operating conditions and within specified allowable degradations of specific characteristics.

7 *ac characteristics*

7.1 ■ TOTAL INPUT IMPEDANCE The impedance between the two input terminals with open circuit between output terminals, and measured at a specified voltage and frequency with the shaft positioned to give a maximum value.

FIGURE 7.1 Total input impedance

7.2. ■ OUTPUT IMPEDANCE Maximum impedance between slider and either end terminal with the input shorted, and measured at a specified voltage and frequency.

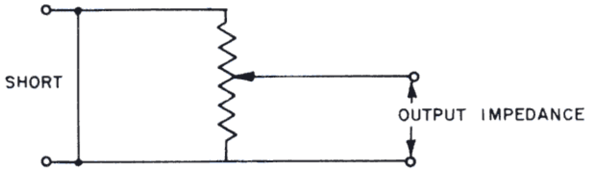


FIGURE 7.2 Output impedance

7.3 ■ QUADRATURE VOLTAGE The maximum value of that portion of the output voltage which is ±90° out of time phase with the input voltage, expressed as volts per volt applied, measured at a specified input voltage and frequency.

7.4 ■ PHASE SHIFT The phase difference, expressed in degrees, between the sinusoidal input and output voltages measured at a specified input voltage and frequency with the shaft at a specified position.

MATHEMATICALLY: $\phi = \sin^{-1}(e_q/e) = \tan^{-1}(e_q/e_i)$

Where:

ϕ = phase shift in degrees
e_q = quadrature voltage
e_i = inphase output voltage
e = output voltage

8 *mechanical characteristics*

8.1 ■ SHAFT RUNOUT The eccentricity of the shaft diameter with respect to the rotational axis of the shaft, measured at a specified distance from the end of the shaft. The body of the potentiometer is held fixed and the shaft is rotated with a specified load applied radially to the shaft. The eccentricity is expressed in inches, TIR.

8.2 ■ LATERAL RUNOUT The perpendicularity of the mounting surface with respect to the rotational axis of the shaft, measured on the mounting surface at a specified distance from the outside edge of the mounting surface. The shaft is held fixed and the body of the potentiometer is rotated with specified loads applied radially and axially to the body of the pot. The Lateral Runout is expressed in inches, TIR.

8.3 ■ PILOT DIAMETER RUNOUT The eccentricity of the pilot diameter with respect to the rotational axis of the shaft, measured on the pilot diameter. The shaft is held fixed and the body of the potentiometer is rotated with a specified load applied radially to the body of the pot. The eccentricity is expressed in inches, TIR.

8.4 ■ SHAFT RADIAL PLAY The total radial excursion of the shaft, measured at a specified distance from the front surface of the unit. A specified radial load is applied alternately in opposite directions at a specified point. Shaft Radial Play is expressed in inches.

8.5 ■ SHAFT END PLAY The total axial excursion of the shaft, measured at the end of the shaft with a specified axial load supplied alternately in opposite directions. Shaft End Play is expressed in inches.

8.6 ■ STARTING TORQUE The maximum moment in the clockwise and counterclockwise directions required to initiate shaft rotation anywhere in the Total Mechanical Travel.

8.7 ■ RUNNING TORQUE The maximum moment in the clockwise and counterclockwise directions required to sustain uniform shaft rotation at a specified speed throughout the Total Mechanical Travel.

8.8 ■ MOMENT OF INERTIA The mass moment of inertia of the rotating elements of the potentiometer about their rotational axis.

8.9 ■ STOP STRENGTH

8.9.1 ■ STATIC STOP STRENGTH The maximum static load that can be applied to the shaft at each mechanical stop for a specified period of time without permanent change of the stop positions greater than specified.

8.9.2 ■ DYNAMIC STOP STRENGTH The inertia load, at a specified shaft velocity and a specified number of impacts, that can be applied to the shaft at each stop without a permanent change of the stop position greater than specified.

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VRCI-P-100A Standard for Wirewound and Nonwirewound Precision Potentiometers

PART II

INSPECTION and TEST PROCEDURES

Test procedures reported in this revised standard cover all characteristics that can be measured without seriously affecting the remaining life in a potentiometer. These procedures specifically exclude environmental exposure tests, life tests and power ratings. The purpose of these test procedures is to assist you in obtaining better correlation of inspection results between the users facility and the manufacturer's plant. Although the VRCI realizes that there are alternate methods to those proposed here, it believes that standardization can better achieve a common basis for evaluation. If you prefer to use an alternate procedure, you should realize the responsibility associated with such substitution.

The test procedures are to be performed at, or corrected to standard conditions as follows, unless otherwise specified: 25° Celsius (formerly Centigrade), 760 mm of HG and 50% relative humidity. Where measurements are not corrected to these standard conditions, the burden of proof of equivalency lies with the individual tester.

Many of these procedures call for specifying important test parameters with numerical values; for example, shaft loads, operating speeds, applied voltages and currents, etc. Various factors governed their selection—standardization, availability of equipment, ease of test and, above all, the prevention of damage to the potentiometer. It should be noted, however, that these are only recommended typical values and are subject to modification in individual cases depending upon specific requirements of end use.

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8.6	Starting Torque
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LEGEND:

☐ **WIREWOUND**
■ **WIREWOUND AND NONWIREWOUND**
🟦 **NONWIREWOUND**

1 *equipment description*

1.1 ■ MECHANICAL EQUIPMENT

1.1.1 ■ POTENTIOMETER MOUNTING FIXTURE A fixture to rigidly hold the test specimen by the normal mounting means leaving the shaft free to move. When utilized for Dynamic Stop Strength measurements, the mounting should be of massive construction to prevent absorption of energy during impact.

1.1.2 ■ SHAFT POSITIONING DEVICE A device to provide a means for moving the shaft to any position relative to the potentiometer body and maintaining a stable setting during electrical measurements.

The shaft positioning device must not apply any axial or radial loads on the shaft of a rotary potentiometer.

1.1.3 ■ TRAVEL MEASURING DEVICE A device composed of a shaft position indicator and a potentiometer mounting fixture, which will precisely indicate shaft position relative to the potentiometer body. The device has an over-all accuracy of at least 0.1°, or such other value required to make total measuring errors for any test less than 1/10th the specified tolerance. THE TRAVEL MEASURING DEVICE MOUNTING PROVISION SHOULD IN NO WAY DISTORT OR MAR THE FINISH OF THE PART NOR EXERT ANY RADIAL OR AXIAL LOADS.

1.1.4 ■ LOAD DEVICE A device that provides a means for applying a force or torque of known magnitude to a pot shaft. The device, such as a spring scale, weight at a known radius, torque wrench, etc., should have an accuracy of 1/10th the specified value.

1.1.5 ■ DIAL INDICATOR The minimum dial division must be equal to or less than 1/10th the specified tolerance and must have a readability to 0.00005 inches for measurements below 0.001 inches. The indicator should not be used over a range of more than 1/3 of the total travel of the probe without error correction. If a dial indicator is used with a pivot-type pointer, the longitudinal C/L of the stylus must remain normal to the workpiece during measurement or the applicable correction factor must be used.

1.1.6 ■ DIAL INDICATOR HOLDING FIXTURE The dial indicator holding fixture must hold the dial indicator rigidly, maintaining its proper attitude to the workpiece during measurement. It should provide for fine adustment of the indicator position such that the dial indicator is not damaged as the probe approaches the workpiece.

1.1.7 ■ POTENTIOMETER SHAFT HOLDING FIXTURE This fixture must hold the test specimen by the shaft in either a horizontal or vertical position leaving the potentiometer body free to move.

1.1.8 ■ CYLINDRICAL SHAFT ADAPTOR An adaptor with a smooth cylindrical surface and which, when mounted on the pot shaft, adds eccentricity no greater than 1/10th the specified runout tolerance.

1.1.9 ■ DEAD WEIGHT LOAD The load may be applied using a spring scale, weights or equivalent, accurate to 1/10th the specified value.

1.1.10 ■ SHAFT LOAD ADAPTOR When it is necessary to transmit loads larger than can be accommodated with frictional clamping devices and without relative movement of more than 1/10th the specified allowable change in stop position, a suitable permanent attachment to the shaft, such as a pinned bushing, is used.

1.1.11 ■ INERTIA LOAD An inertia load of known magnitude and capable of being driven in opposite directions at a specified constant velocity should be used. Input energy should be removed rapidly so that the inertia load is the only source of energy during impact. The inertia load is the sum total of Moments of Inertia of all moving components attached to it. The potentiometer shaft and ALL COUPLINGS AND INERTIA LOAD MOUNTINGS MUST BE OF HEAVY DUTY CONSTRUCTION TO MINIMIZE LOSS OF ENERGY DURING IMPACT, THEREBY TRANSMITTING THE FULL INERTIA LOAD TO THE SHAFT.

1.1.12 ■ CONSTANT SPEED DRIVE The drive must be able to operate at a constant velocity of 4 ± 1 RPM or 18 ± 3″/minute. For Output Smoothness measurements, the short term speed variation must not exceed 1/10th the specified Output Smoothness. The device should have a slip clutch provision to prevent damage to the mechanical stops in the unit, where applicable.

1.1.13 ■ MOMENT OF INERTIA ADAPTOR An adaptor of known inertia to couple the suspended steel wire to the rotating elements of the potentiometer. It must attach to each at the centerline of its mass.

1.1.14 ■ MASS OF KNOWN INERTIA A mass calculated to have a known moment of inertia, similar in dimension and weight to the unknown inertia to be evaluated.

1.1.15 ■ TIMING CLOCK A timing clock with readability and repeatability to 0.1 second.

1.1.16 ■ TEMPERATURE TEST CHAMBER The temperature of the chamber should be adjustable within ±3°C of the test temperature. The chamber should be stable within ±0.5°C at any given point in the proximity of the test specimens. The temperature gradient in this area should not exceed ±1°C. If larger gradients exist, the temperature must be monitored with a thermocouple immediately adjacent to the test specimen. Air flow around the area of the test specimens should be at least 60 feet per minute.

1.1.17 ■ VARIABLE SPEED DRIVE The drive must be capable of variability from 1/4 to 20 RPM, or mean speeds of 1.0 to 80 inches/minute. Provisions should be made, where applicable, for a slip clutch to prevent damage to the potentiometer mechanical stops.

1.2 ■ ELECTRICAL EQUIPMENT

1.2.1 ■ VOLTAGE RATIO EQUIPMENT The Kelvin-Varley Voltage Divider or a modification of it is recommended for measurement of the output voltage ratio of precision potentiometers. The voltage dividers for precision potentiometers are usually of two types.

(1) Decade Voltage Dividers (4 or 5 decades)

(2) Digital Ratiometers (4 or 5 places)

The Decade Voltage Divider is used in conjunction with a null detector described in Paragraph 1.2.19. The Digital Ratiometers are generally self-nulling with direct numerical readouts. The equipment accuracy, resolution and repeatability must

LEGEND:

- □ WIREWOUND
- ■ WIREWOUND AND NONWIREWOUND
- 🟦 NONWIREWOUND

equal or be less than 1/10th of the specified tolerance. The voltage applied should never exceed the voltage/power rating of the test unit.

1.2.2 ■ RESISTANCE MEASURING DEVICE CARE MUST BE TAKEN WHEN USING ANY RESISTANCE MEASURING DEVICE THAT THE CURRENT DRAWN DOES NOT EXCEED THE CURRENT CARRYING CAPACITY OR RATING OF THE UNIT.

1.2.2.1 ■ OHMMETER (HAND SET VOLT-OHMMETER) This type ohmmeter generally is not sufficiently accurate for quantitative measurements and, when used on its lowest scale, applies a voltage without internal impedance limits. Its use should be avoided.

1.2.2.2 ■ WHEATSTONE BRIDGE When resistance tolerances are less than 10% and the resistance values are above 10 ohms, use a Wheatstone bridge with an accuracy of 1/10 the tolerance to be measured. For resistance values above 1 megohm it is necessary to use a guarded Wheatstone bridge. (Commercially available Wheatstone bridges have an accuracy of 0.01% to 10 megohms and 0.5% to 1000 megohms.) A null detector recommended for use in the bridge circuit is described in Paragraph 1.2.19.

1.2.2.3 ■ KELVIN BRIDGE For resistance values less than 10 ohms a Kelvin (Thomson) bridge is used. The accuracy of the bridge required is 1/10 the specified tolerance to be measured. (Commercially available Kelvin bridges have an accuracy of 0.25% from 0.0005 ohms and 0.5% from 0.0001 to 0.0005 ohms.)

A null detector recommended for use in the bridge circuit is described in Paragraph 1.2.19.

1.2.2.4 ■ DIGITAL OHMMETER Digital ohmmeters are self balancing Wheatstone bridges and can be used in place of Wheatstone or Kelvin bridges.

1.2.3 ■ POWER SUPPLIES

Note: A DC voltmeter should be used with all power supplies to determine actual voltage to permit proper evaluation of traces in percent total applied voltage.

1.2.3.1 ■ FOR OUTPUT RATIO MEASUREMENT 10 ±3 volts DC with no limitations on voltage stability, current regulation or line regulation. If its capacity is sufficient for the current drawn by potentiometer, a battery may be used.

1.2.3.2 ■ BALANCED POWER SUPPLY FOR OUTPUT RATIO MEASUREMENT 10 ±3 volts each side of center tap. Halves balance ±0.01%; halves balance stability ±0.01% per hour. No requirements for voltage or current regulation, line regulation or total voltage, as long as balance is maintained.

1.2.3.3 ■ POWER SUPPLY FOR ERROR TRACE OR OUTPUT SMOOTHNESS RECORDING Same as 1.2.3.1 or 1.2.3.2 with additional requirement for voltage ripple not to exceed 1/10 value of Conformity or Output Smoothness limit.

1.2.4 ■ RECORDER A continuous paper chart recorder with a flat frequency response within 3 db from DC to a minimum of 100 Hz, and a maximum drift less than 1%. The recorder is combined with a high gain DC amplifier with sufficient power output to drive the chart recorder and, if desired, a null detector. The amplifier zero line stability should be better than 1% per hour.

1.2.5 ■ CONSTANT CURRENT SOURCE The source should produce a 1.0 ±5% milliamperes DC current under load. A suggested circuit for a constant current generator is shown in Figure 1.2.5A.

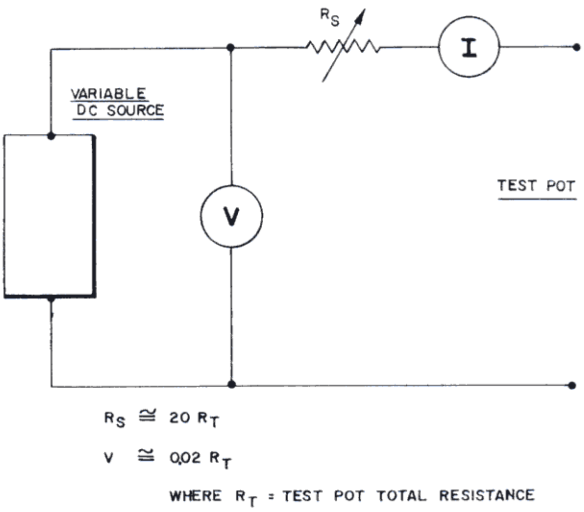


FIGURE 1.2.5A Constant current source

1.2.6 ■ OSCILLOSCOPE A high gain DC oscilloscope should have a high persistence screen to retain the image for a minimum of 1/2 second. It should have a minimum input impedance of one megohm and a flat frequency response from DC to a minimum of 50 KHz.

1.2.7 ■ LOW PASS FILTER The filter has the following characteristics:

Band Pass Frequency:	0-1000 Hz
Insertion Loss:	2 db
Attenuation Outside Band Pass:	6 db/octave
Input Impedance:	2 Megohms
Output Impedance:	2 Megohms
Maximum Current:	5 Milliamperes

A suggested filter circuit is presented in Figure 1.2.7A.

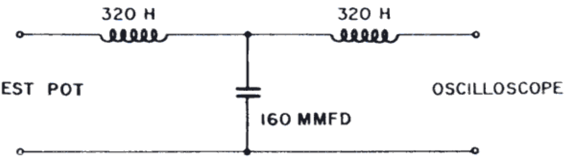


FIGURE 1.2.7A Low pass filter

1.2.8 ■ OUTPUT SMOOTHNESS FILTER The standard filter below is basically designed to measure output discontinuities (sudden output changes) occurring over 0.5° travel or less at 4 r.p.m. The low pass time constant of this filter is 20 milliseconds. At 4 r.p.m., this value corresponds to a shaft travel of 0.5°.

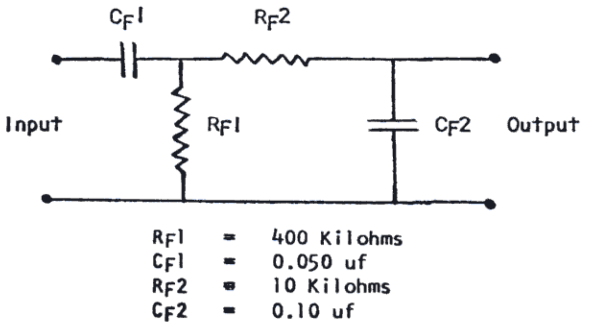


FIGURE 1.2.8A Output smoothness filter

LEGEND:

☐ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
🟦 NONWIREWOUND

1.2.9 ■ **VARIABLE RESISTOR** A variable resistor with a range of 0.5 megohms in steps of 1 ohm or less and a minimum current rating of 10 ma.

1.2.10 ■ **HIGH VOLTAGE SOURCE** A source variable from zero to the maximum specified VRMS @ 60 Hz of sine waveform with 5% maximum distortion. A current limiter to limit the leakage current to 150% of the maximum specified value should be provided.

1.2.11 ■ **AC VOLTMETER** The AC Voltmeter should have the following characteristics:

Voltage Range:	133% of the specified or test value minimum.
Approximate Impedance in Ohms at 60 Hz	1000 ohms/volt
Frequency Range:	50-125 Hz minimum.
Accuracy:	±5% at the specified voltage and frequency.
Temperature Stability:	0.1%/°C maximum at the specified or test voltage and frequency.

1.2.12 ■ **LEAKAGE CURRENT INDICATING DEVICE** An AC ammeter with an accuracy of 5% of the allowable leakage rate and covering the applicable range.

1.2.13 ■ **AC VOLTAGE SOURCE** An AC source, variable in voltage magnitude and frequency to accommodate the specified values and having an isolation transformer of very low capacitance at its output.

1.2.14 ■ **RATIO TRANSFORMER** A variable device with an accuracy and resolution of 1/10 the value to be measured.

1.2.15 ■ **AC VACUUM TUBE VOLTMETER** The AC Vacuum Tube Voltmeter should have the following characteristics:

Voltage Range:	133% of specified or test value minimum.
Frequency Response:	Flat to within 1 db over the frequency range.
Frequency Range:	10-250K Hz
Accuracy:	2% over the voltage range within the frequency range.
Input Impedance:	1 megohm minimum

1.2.16 ■ **AC AMMETER** The AC Ammeter should have the following characteristics:

Current Range:	133% of specified or test value.
Accuracy:	1% of full scale value
Frequency Range:	25-125 Hz minimum.
Temperature Stability:	0.1%/°C maximum at the specified or test current and frequency.

1.2.17 ■ **AC MICROAMMETER** The AC Microammeter should have the following characteristics:

Current Range:	133% of the specified or test value minimum.
Accuracy:	2.5% of full scale value
Frequency Range:	25-125 Hz minimum
Temperature Stability:	0.5%/°C maximum at the specified or test current and frequency.

1.2.18 ■ **CONFORMITY TESTER** The conformity tester shown in Figure 1.2.18A is comprised of a precision master potentiometer housed in a travel measuring device that mechanically locks the master potentiometer shaft with a test potentiometer shaft for simultaneous movement. The coupling must not introduce misalignment errors between the two shafts.

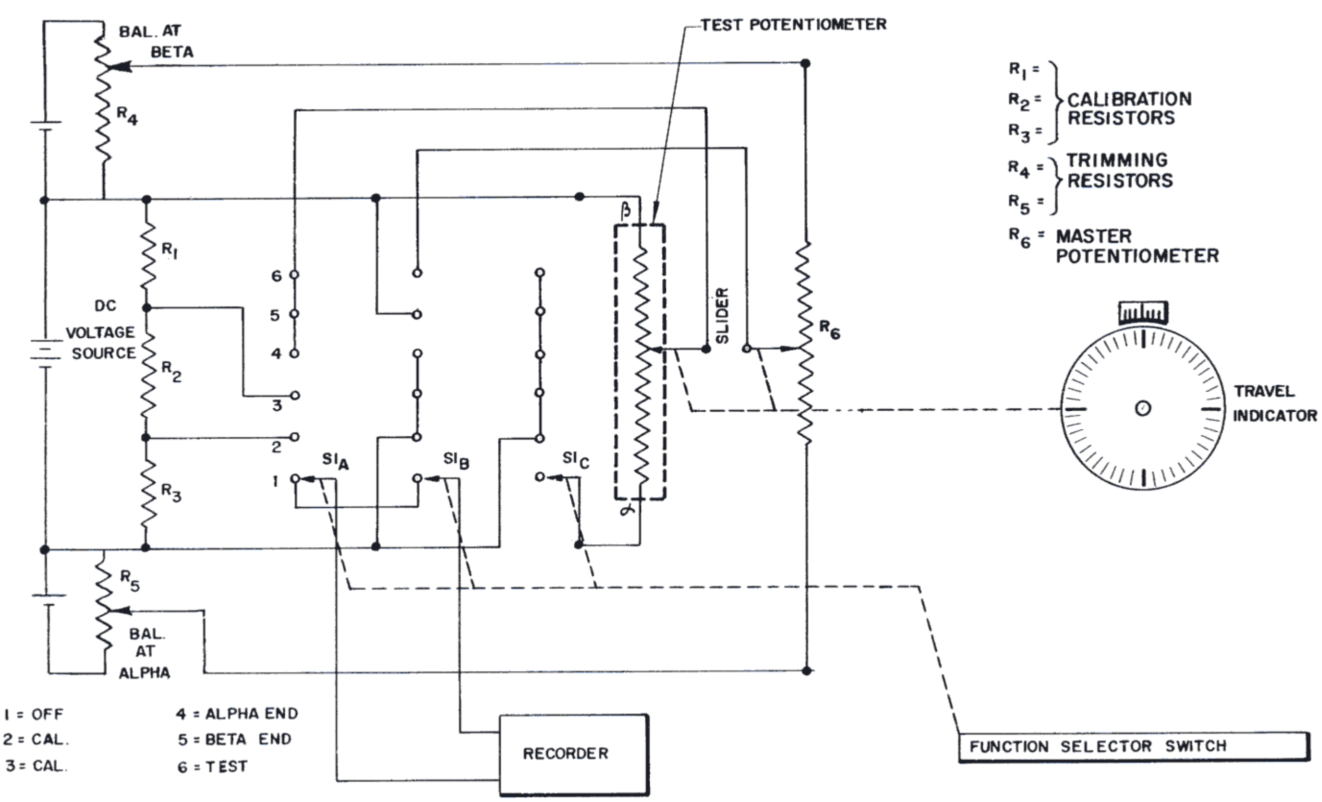


FIGURE 1.2.18A Conformity tester

LEGEND:

☐ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
■ NONWIREWOUND

The master potentiometer must be aligned with respect to the travel measuring device such that the End Points of the master potentiometer correspond as nearly as possible to the mechanical end point indications of the travel measuring device.

A constant speed drive motor should be incorporated into its design so as to cause a constant shaft velocity during a conformity test. For rotary potentiometers a nominal speed of 1 RPM in a CW direction is recommended. For translatory potentiometers a speed of 10″/min. in an extending direction is recommended.

The total equipment error from the combined effects of master potentiometer conformity error and shaft coupling errors must not exceed 1/10 of the minimum conformity tolerance to be tested.

1.2.19 ■ NULL DETECTOR The null detector should have the following characteristics:

Sensitivity:	
Current	1 x 10^{-9} amp/mm
Voltage	1 x 10^{-6} volts/mm
Stability:	1 mm drift per hour
Damping:	Critical
Response:	To final value within 1 second.

1.2.20 ■ THERMOCOUPLE BRIDGE The most common form of thermocouple bridge consists of a highly accurate potentiometer used in conjunction with an appropriate thermocouple. The accuracy of the measurement equipment should be 0.5% and temperature changes of 0.5°C should be detectable.

1.2.21 ■ INSULATION RESISTANCE TEST SET A suitable commercial megohm bridge, megohmmeter or equivalent with an accuracy of 1/10 the value to be measured and a built-in source voltage of the specified magnitude.

2 *input-output measurements*

2.1 ☐ ■ END VOLTAGE

2.1.1 ☐ END VOLTAGE — WIREWOUND

2.1.1.1 ☐ OBJECT To measure the voltage between the wiper terminal and an end terminal when the shaft is positioned at the corresponding End Point. End Voltage is expressed as a percentage of the Total Applied Voltage.

2.1.1.2 ☐ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1

2.1.1.3 ☐ TEST PROCEDURE Mount the potentiometer to the travel measuring device. Connect the zero potential reference lead of the voltage ratio equipment with the appropriate end terminal of the potentiometer. Locate and position the shaft at the End Point (3.4). The Output Ratio measured at this position, expressed as a percentage, is the End Voltage corresponding to that end terminal.

2.1.2 ■ END VOLTAGE — NONWIREWOUND

2.1.2.1 ■ OBJECT To measure the voltage between the wiper terminal and an end terminal when the shaft is positioned at the corresponding Theoretical End Point. End Voltage is expressed as a percentage of the Total Applied Voltage.

2.1.2.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1

2.1.2.3 ■ TEST PROCEDURE Mount the potentiometer to the travel measuring device and phase the shaft to the Index Point (3.6). Connect the voltage ratio equipment to the appropriate potentiometer terminals such that the zero potential reference lead is connected to the end terminal concerned. Locate and position the shaft at the Theoretical End Point (3.5). The Output Ratio measured at this position, expressed as a percentage, is the End Voltage corresponding to that end terminal.

2.2 ■ MINIMUM VOLTAGE

2.2.1 ■ OBJECT To measure the voltage between the wiper terminal and an end terminal when the shaft is positioned near the corresponding end of the Electrical Continuity Travel such that a minimum voltage reading is obtained. Minimum Voltage is usually expressed as a percentage of the Total Applied Voltage.

2.2.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1

2.2.3 ■ TEST PROCEDURE Mount the potentiometer to the travel measuring device and connect the voltage ratio equipment to the appropriate potentiometer terminals such that the zero potential reference lead is connected to the end terminal concerned. The travel measuring device provides fine control of the shaft position. Move the shaft until a minimum reading is indicated on the voltage ratio equipment. This reading is expressed as a percentage and is the Minimum Voltage.

2.3 ☐ JUMP-OFF VOLTAGE (APPLICABLE TO WIREWOUND ONLY)

2.3.1 ☐ OBJECT To measure the magnitude of the first measurable voltage change as the wiper is displaced from the overtravel region onto the Actual Electrical Travel region. Jump-Off Voltage is expressed as a percentage of the Total Applied Voltage.

2.3.2 ☐ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1

2.3.3 ☐ TEST PROCEDURE Mount the potentiometer to the travel measuring device. Connect the voltage ratio equipment to the appropriate terminals such that the zero potential reference lead is connected to the end terminal concerned. Locate and position the shaft at the End Point (3.4). Record the Output Ratio. Move the shaft toward the Actual Electrical Travel (3.7) to the position of the first incremental change in output ratio $\geq$ 20% of Voltage Resolution in that region and record that Output Ratio. The difference between the two readings, expressed as a percentage of Total Applied Voltage, is the Jump-Off Voltage corresponding to that End Point.

2.4 ■ SHORTED SEGMENT

2.4.1 ■ OBJECT To determine that the Output Ratio remains constant within specified limits as the wiper traverses the shorted segment with a specified load resistance. Since the Output Ratio may remain within the specified limits of the shorted segment for a segment longer than specified, it is the purpose of this procedure to assure that the Output Ratio is within limits for at least the minimum shorted segment length specified.

2.4.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1

See applicable sections for locating a reference point.

2.4.3 ■ TEST PROCEDURE Mount the potentiometer to the travel measuring device by normal means. Locate the reference point for the Shorted Segment in accordance with the applicable sections of this document. Connect the specified load resistance and the voltage ratio equipment to the potentiometer. If the reference point is not coincident with the beginning of the short, move the shaft in the direction of the short (be certain Backlash has been removed) the minimum specified distance from the reference point. If the Output Ratio is not within the specified limits, continue shaft movement to the first point at which the Output Ratio is within limits and note the shaft position. Continuing in the same direction, displace the shaft the minimum specified length of the Shorted Segment or until the Output Ratio exceeds the specified limits, whichever occurs first. Compare the results with the specification as to both location of the short with respect to the reference point and the length of the Shorted Segment.

3 *rotation and translation*

3.1 ■ TOTAL MECHANICAL TRAVEL

3.1.1 ■ OBJECT To measure the total travel of the shaft between integral stops, under a specified stop load. In potentiometers without stops, the mechanical travel is continuous.

3.1.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Load device	1.1.4

3.1.3 ■ TEST PROCEDURE Mount the potentiometer to the travel measuring device and move the shaft to each stop, applying a stop load of 150% of the maximum specified actuating force or starting torque against each stop. Note reading of the travel measuring device at each stop with load applied. The difference between the two readings is the Total Mechanical Travel.

Note: In no case should the applied load exceed 75% of the Static Stop Strength.

3.2 □ ■ MECHANICAL OVERTRAVEL

3.2.1 □ MECHANICAL OVERTRAVEL — WIREWOUND

3.2.1.1 □ OBJECT To measure the shaft travel between the limits of the Actual Electrical Travel and the corresponding limits of Total Mechanical Travel. Theoretical Electrical Travel is substituted for Actual Electrical Travel when Absolute Linearity or Absolute Conformity is specified.

3.2.1.2 □ EQUIPMENT

Travel measuring device	1.1.3
Load device	1.1.4
Voltage ratio equipment	1.2.1

3.2.1.3 □ TEST PROCEDURE Mount the potentiometer to the travel measuring device. Locate the limits of Actual Electrical Travel, which are the End Points, (3.4) and the limits of Total Mechanical Travel (3.1) and note the readings on the travel measuring device at these points. The Mechanical Overtravel at each end is the difference between the readings at the End Point and the corresponding limit of Total Mechanical Travel. When Absolute Linearity or Absolute Conformity is specified, the Theoretical End Points, as determined from the Index Point (3.6), are used in place of End Points.

3.2.2 ■ MECHANICAL OVERTRAVEL — NONWIREWOUND

3.2.2.1 ■ OBJECT To measure the shaft travel between the limits of the Theoretical Electrical Travel and the corresponding limits of Total Mechanical Travel.

3.2.2.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Load device	1.1.4
Voltage ratio equipment	1.2.1

3.2.2.3 ■ TEST PROCEDURE Mount the potentiometer to the travel measuring device. Locate the Theoretical End Points (3.5), and the limits of Total Mechanical Travel (3.1) and note the readings on the travel measuring device at these points. The Mechanical Overtravel at each end is the difference between the readings at the Theoretical End Points and the corresponding limits of Total Mechanical Travel.

3.3 ■ BACKLASH

3.3.1 ■ OBJECT To measure the maximum difference in shaft position that occurs when the shaft is moved to the same actual output ratio point from opposite directions.

3.3.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1

3.3.3 ■ TEST PROCEDURE The potentiometer is mounted in the travel measuring device, connected to the voltage ratio equipment and the operating shaft is displaced to approximately the 40 percent voltage point (not in a tap or shorted area). The voltage ratio equipment is then adjusted to obtain zero indication on the null indicator. The shaft is moved approximately 1/4 revolution (or 10%) in the direction of decreasing output voltage and then in a reverse direction until the null detector first approaches a zero reading. At this point a travel reading is taken. The shaft is then moved to approximately the 80 percent voltage point and returned in the opposite direction until the null detector passes through zero and shows its first perceptible change from zero. At this point the position of the shaft is again noted. The difference between the two shaft position readings is the Backlash.

3.4 □ END POINT (APPLICABLE TO WIREWOUND ONLY)

3.4.1 □ OBJECT To determine the location of the End Points which are the shaft positions immediately before the first and after the last measurable change(s) in Output Ratio, after wiper continuity has been established, as the shaft moves in the specified direction.

3.4.2 □ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1
Load device (when applicable)	1.1.4

3.4.3 □ TEST PROCEDURE Mount the potentiometer to the travel measuring device and connect the output ratio equipment to the appropriate terminals. Move the potentiometer shaft in the direction opposite "specified direction" until the voltage ratio equipment indicates the wiper is in the overtravel region by an amount $>>$ Backlash. The specified direction is CW for rotary potentiometers and extending for translatories. Move the shaft in the specified direction until the voltage ratio equipment indicates the first single discrete change in actual output ratio $\geqq$ 20% of Voltage Resolution in that region, after wiper continuity has been established. The shaft position immediately preceding this change is the first End Point. Continue the shaft motion in the same direction to the point where the last discrete change in output ratio $\geqq$ 20% of Voltage Resolution occurs. The shaft position immediately after this change is the other End Point. In the case where normal resolution steps are observed to the limits of Total Mechanical Travel (3.1) the End Points are the limits of Total Mechanical Travel.

3.5 ■ THEORETICAL END POINT

3.5.1 ■ OBJECT To determine the location of the Theoretical End Points which are the shaft positions corresponding to the ends of the Theoretical Electrical Travel as determined from the Index Point.

LEGEND:

- □ WIREWOUND
- ■ WIREWOUND AND NONWIREWOUND
- 🟦 NONWIREWOUND

3.5.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1
Load device (when applicable)	1.1.4

3.5.3 ■ TEST PROCEDURE Mount the potentiometer to the travel measuring device and connect the voltage ratio equipment to the appropriate terminals. Phase the potentiometer and travel measuring device at the Index Point (3.6). Move the potentiometer shaft in the direction opposite to the "specified direction" until the voltage ratio equipment indicates the wiper is in the overtravel region by an amount $>>$ Backlash. The specified direction is CW for rotary potentiometers and extending for translatories, unless otherwise indicated. Move the shaft in the specified direction until the travel measuring device indicates the beginning of the Theoretical Electrical Travel (3.8). This is one Theoretical End Point. Continuing in the same direction move the shaft until the travel measuring device indicates the opposite limit of Theoretical Electrical Travel which is the other Theoretical End Point.

3.6 ■ INDEX POINT

3.6.1 ■ OBJECT To provide a procedure for establishing a shaft position reference for the related specified Output Ratio when the shaft is moved in the specified direction.

3.6.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1

3.6.3 ■ TEST PROCEDURE The potentiometer is mounted in the travel measuring device and is electrically connected to the voltage ratio equipment. Move the travel measuring device in the specified direction (unless otherwise stated, this is CW for rotary and extending for translatories) to the position at which the Output Ratio of the Index Point is first reached. Holding the potentiometer shaft fixed, adjust the indicator of the travel measuring device to read precisely the specified shaft position. The travel measuring device and voltage ratio equipment now read the corresponding values of the Index Point.

3.7 □ ACTUAL ELECTRICAL TRAVEL (APPLICABLE TO WIREWOUND ONLY)

3.7.1 □ OBJECT To measure the total travel of the shaft between the End Points.

3.7.2 □ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1
Load device (when applicable)	1.1.4

3.7.3 □ TEST PROCEDURE Mount the potentiometer to the travel measuring device and locate the End Points (3.4). Note the reading on the travel measuring device at both End Points. The difference between these two readings is the Actual Electrical Travel.

3.8 ■ THEORETICAL ELECTRICAL TRAVEL

3.8.1 ■ OBJECT To determine the limits of the Theoretical Electrical Travel (the Theoretical End Points) utilizing the Index Point.

3.8.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1
Load device (when applicable)	1.1.4

3.8.3 ■ TEST PROCEDURE The Theoretical Electrical Travel is a value given as part of the potentiometer specifications whose limits have been defined as the Theoretical End Points. To physically locate these limits see Paragraph 3.5.

3.9 □ 🟦 ELECTRICAL OVERTRAVEL

3.9.1 □ ELECTRICAL OVERTRAVEL — WIREWOUND

3.9.1.1 □ OBJECT To measure the shaft travel between the limits of the Actual Electrical Travel and the corresponding limits of Electrical Continuity Travel. Theoretical Electrical Travel is substituted for Actual Electrical Travel when Absolute Conformity or Linearity is specified.

3.9.1.2 □ EQUIPMENT

Travel measuring device	1.1.3
Resistance measuring device	1.2.2
Load device (when applicable)	1.1.4
Voltage ratio equipment	1.2.1

3.9.1.3 □ TEST PROCEDURE Mount the potentiometer to the travel measuring device. Locate the limits or End Points of the Actual Electrical Travel (3.4) and the limits of Electrical Continuity Travel (3.10) and note the readings on the travel measuring device at these points. The Electrical Overtravel at each end is the difference between the reading at the End Point and the corresponding limit of Electrical Continuity Travel. When Absolute Linearity or Absolute Conformity is specified, the limits of the Theoretical Electrical Travel, as determined from the Index Point (3.6), are used in place of the End Points.

3.9.2 🟦 ELECTRICAL OVERTRAVEL — NONWIREWOUND

3.9.2.1 🟦 OBJECT To measure the shaft travel between the Theoretical End Points and the corresponding limits of Electrical Continuity Travel.

3.9.2.2 🟦 EQUIPMENT

Travel measuring device	1.1.3
Resistance measuring device	1.2.2
Load device (when applicable)	1.1.4
Voltage ratio equipment	1.2.1

3.9.2.3 🟦 TEST PROCEDURE Mount the potentiometer to the travel measuring device. Locate the Theoretical End Points (3.5) and the limits of Electrical Continuity Travel (3.10) and note the readings on the travel measuring device at these points. The Electrical Overtravel at each end is the difference between the reading at the Theoretical Point and the corresponding limit of Electrical Continuity Travel.

3.10 ■ ELECTRICAL CONTINUITY TRAVEL

3.10.1 ■ OBJECT To measure that portion of shaft travel over which electrical continuity is maintained between the wiper and the resistance element.

3.10.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Resistance measuring device (1.0 ma max through specimen)	1.2.2
Load device (when applicable)	1.1.4

3.10.3 ■ TEST PROCEDURE Mount the potentiometer to the travel measuring device. Ascertain that the current in the potentiometer from the resistance measuring device will not exceed 1.0 ma, then connect the resistance measuring device between the wiper and the interconnected terminals. Move the shaft in the specified direction (CW for rotary potentiometers and extending for translatories) until the resistance measuring device first indicates loss of continuity; note this position. Move the shaft in the reverse direction until loss of continuity is again observed on the resistance measuring device and continue beyond this point by an amount $>>$ Backlash. Move the shaft in the initial direction until con-

LEGEND:

□ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
🟦 NONWIREWOUND

tinuity is first observed; note this position. The difference between the two noted positions is the Electrical Continuity Travel.

Note: In some potentiometers there may not be a position at which a discontinuity is indicated. In these cases, the limits of Electrical Continuity Travel are the end(s) of continuity or the end(s) of Total Mechanical Travel, whichever occurs first.

3.11 ■ TAP LOCATION

3.11.1 ■ OBJECT To measure the location of a tap from some reference point. This is commonly expressed in terms of Output Ratio or shaft position. When a shaft position is specified, the tap position is the center of the Effective Tap Width, exclusive of Backlash.

3.11.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1
Null indicator	1.2.19
Power supply	1.2.3

3.11.3 ■ TEST PROCEDURE

3.11.3.1 ■ TRAVEL LOCATED TAP Mount the potentiometer to the travel measuring device. Locate the End Point (3.4 or 3.5), or other specified reference point and note the reading on the travel measuring device. Connect the power supply to the potentiometer input terminals and connect the null indicator between the wiper terminal and the tap terminal to be measured. Using the same direction of motion as when locating the End Point, or other reference point, move the shaft to the center of the Effective Tap Width (3.12). The displacement from the specified reference point to the center of the Effective Tap Width is the Tap Location.

3.11.3.2 ■ VOLTAGE RATIO LOCATED TAP Position the wiper on the Electrical Overtravel or beyond the Electrical Continuity Travel, or if neither of these is possible, in the region having the least effect on the measurement. Measure the voltage ratio between the tap and the specified reference terminal.

3.12 ■ EFFECTIVE TAP WIDTH

3.12.1 ■ OBJECT To measure the travel of the shaft during which the voltage at the wiper terminal and the tap terminal are the same as the wiper is moved past the tap in one direction.

3.12.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Null indicator	1.2.19
Power supply	1.2.3

3.12.3 ■ TEST PROCEDURE Mount the potentiometer to the travel measuring device. Connect the power supply to the potentiometer input terminals and connect the null detector between the wiper terminal and the tap terminal to be measured. Move the shaft to obtain a null voltage between the wiper and the tap. Continue to move the shaft in that same direction to the point immediately preceding the first measurable change in voltage; note the reading of the travel measuring device. Move the shaft in the opposite direction past the region of null by an amount much greater than the Backlash. Move the shaft in the original direction to the point at which the last measurable change in voltage occurs as the null is reached; note the reading on the travel measuring device. The difference in shaft displacement between the two positions is the Effective Tap Width.

3.13 ■ PHASING POINT

3.13.1 ■ OBJECT To provide a method of locating a point of reference on each electrical element used to describe the relative alignment of the electrical elements of a gang.

3.13.2 ■ EQUIPMENT Refer to equipment used for measurement of the specific characteristic by which the phasing point is described.

3.13.3 ■ TEST PROCEDURE Since phasing points are commonly specified in terms of Index Points (3.6), Tap Locations (3.11), Output Voltage Ratios, etc., refer to the applicable section of this document for the appropriate procedure.

3.14 ■ PHASING

3.14.1 ■ OBJECT To measure the relative alignment of the Phasing Points of each cup of a gang potentiometer.

3.14.2 ■ EQUIPMENT Refer to the equipment used for measurement of the specific characteristic by which the Phasing Point is described.

3.14.3 ■ TEST PROCEDURE When shaft displacement is required, set the potentiometer to the Phasing Point (3.13) of the first cup utilizing the applicable section of this document. Moving in the same direction (to eliminate Backlash) displace the shaft to the respective Phasing Point or Points of the subsequent cups of the gang. The measurements of the electrical or mechanical relationship of the Phasing Points is compared with the specified Phasing allowance.

4 *resistance*

4.1 ■ TOTAL RESISTANCE (DC INPUT IMPEDANCE)

4.1.1 ■ OBJECT To measure the DC resistance between the input terminals with the shaft positioned so as to give a maximum value.

4.1.2 ■ EQUIPMENT

Resistance measuring device	1.2.2

4.1.3 ■ TEST PROCEDURE With the aid of a resistance measuring device (10 ma maximum current) connected between the wiper and one input terminal, position the wiper on the Electrical Overtravel. If this is not possible due to the limitations of Total Mechanical Travel or the existence of continuous Electrical Travel and the Total Resistance measurement is critically close to the tolerance limits, the shaft should be moved to a region which maximizes the resistance reading during the Total Resistance measurement. Connect the resistance measuring device to the input terminals of the potentiometer. The maximum reading observed is the Total Resistance. The voltage applied during measurement should be minimized to avoid errors in the measurement due to heating.

4.2 ■ DC OUTPUT IMPEDANCE

4.2.1 ■ OBJECT To determine the maximum DC resistance between the wiper and either end terminal with the input shorted.

4.2.2 ■ EQUIPMENT

Wheatstone bridge	1.2.2.2

4.2.3 ■ TEST PROCEDURE The resistance measuring bridge is connected to the potentiometer between the wiper and either end terminal with the input terminals shorted. The resistance is monitored as the pot shaft is rotated or translated over the Total Variable Output. The maximum resistance reading is the DC Output Impedance.

4.3 □ ■ MINIMUM RESISTANCE

4.3.1 □ MINIMUM RESISTANCE — WIREWOUND

LEGEND:

□ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
🟦 NONWIREWOUND

4.3.1.1 □ OBJECT To determine the resistance value between the wiper terminal and any other specified terminal with the shaft positioned to give a minimum value.

4.3.1.2 □ EQUIPMENT

Shaft positioning device	1.1.2
Resistance measuring device (10 ma maximum output into potentiometer or the wiper/tap current rating whichever is less)	1.2.2

4.3.1.3 □ TEST PROCEDURE Mount the potentiometer to the shaft positioning device and connect the resistance measuring device between the wiper terminal and the specified terminal. The shaft positioning device provides fine control of the shaft position. Move the shaft until a minimum reading is indicated on the resistance measuring device. This reading is the Minimum Resistance.

4.3.2 🟦 MINIMUM RESISTANCE — NONWIREWOUND Refer to Tap Resistance (4.5) for applicable test procedure.

4.4 □ 🟦 END RESISTANCE

4.4.1 □ END RESISTANCE — WIREWOUND

4.4.1.1 □ OBJECT To determine the resistance value between the wiper terminal and an end terminal with the shaft positioned at the corresponding End Point.

4.4.1.2 □ EQUIPMENT

Shaft positioning device	1.1.2
Voltage ratio equipment	1.2.1
Resistance measuring device (10 ma maximum output into potentiometer of the wiper/tap current rating whichever is less)	1.2.2

4.4.1.3 □ TEST PROCEDURE Mount the potentiometer to the shaft positioning device which provides fine control of the shaft position. With the voltage ratio equipment, position the shaft at the applicable End Point (3.4).

The End Resistance is determined with the resistance measuring device connected between the wiper and the end terminal.

4.4.2 🟦 END RESISTANCE — NONWIREWOUND Refer to End Voltage (2.1) for applicable test procedure.

4.5 🟦 TAP RESISTANCE (APPLICABLE TO NONWIREWOUND ONLY)

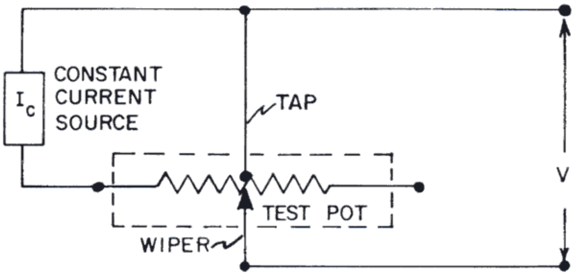


FIGURE 4.5A Tap resistance

4.5.1 🟦 OBJECT To measure the resistance between a tap terminal (other than end terminations) and the wiper terminal, with the wiper positioned to give a minimum value, without drawing wiper current.

4.5.2 🟦 EQUIPMENT

Shaft positioning device	1.1.2
Constant current source	1.2.5
Oscilliscope or DC Voltmeter	

4.5.3 🟦 TEST PROCEDURE Connect the constant current source to the test pot as indicated in Figure 4.5A and adjust the source to 1.0 ma or the maximum current rating of the tap and/or resistance element whichever is less. Using the shaft positioning device move the shaft to the position on the resistance element that minimizes the Voltage V. The Tap Resistance is determined from V and I_e.

4.6 🟦 APPARENT CONTACT RESISTANCE (APPLICABLE TO NONWIREWOUND ONLY) Refer to Output Smoothness (6.2) for applicable test procedure.

4.7 □ 🟦 EQUIVALENT NOISE RESISTANCE (ENR)

4.7.1 □ EQUIVALENT NOISE RESISTANCE — WIREWOUND Refer to Noise (6.1) for applicable test procedure.

4.7.2 🟦 EQUIVALENT NOISE RESISTANCE — NONWIREWOUND Refer to Output Smoothness (6.2) for applicable test procedure

4.8 □ TEMPERATURE COEFFICIENT OF RESISTANCE (APPLICABLE TO WIREWOUND ONLY)

4.8.1 □ OBJECT To determine the unit change in resistance per degree celsius change for a reference temperature, expressed in parts per million per degree celsius.

4.8.2 □ EQUIPMENT

Resistance measuring device	1.2.2
Temperature test chamber	1.1.16
Thermocouple bridge	1.2.20

4.8.3 □ TEST PROCEDURE Position the shaft of the potentiometer with the wiper off the Actual Electrical Travel or at a point that maximizes the Total Resistance (4.1) if no overtravel exists. Subject the pot to two standard series of test temperatures in the sequence described. The first series is room temperature (defined at 25°C) down to —55°C or the lowest rated operating temperature with two intermediate temperature steps at 0°C and —25°C; the second series is room temperature to +125°C or the highest rated operating temperature (whichever is less) with two intermediate temperature steps at +50°C and +85°C. The Total Resistance is measured after the temperature chamber has been stabilized for each temperature (a minimum of 30 minutes, but avoid overaging) with 25°C as the reference temperature for both series. The Temperature Coefficient of Resistance at each test temperature is computed with the following formula:

$$\text{Tempco} = \frac{R_2 - R_1}{R_1(T_2 - T_1)} \times 10^6$$

Where:

R_1 = Resistance at reference temperature in ohms.
R_2 = Resistance at test temperature in ohms.
T_1 = Reference temperature in degrees celsius.
T_2 = Test temperature in degrees celsius.

The Temperature Coefficient of Resistance of the potentiometer is the maximum value calculated.

4.9 🟦 RESISTANCE - TEMPERATURE CHARACTERISTIC (APPLICABLE TO NONWIREWOUND ONLY)

4.9.1 🟦 OBJECT To determine the maximum change in total resistance over a specified temperature range expressed as a percent of the total resistance at a specified reference temperature.

4.9.2 🟦 EQUIPMENT

Resistance measuring device	1.2.2
Temperature test chamber	1.1.16
Thermocouple bridge	1.2.20

4.9.3 🟦 TEST PROCEDURE Position the shaft of the potentiometer with the wiper off the Theoretical Electrical Travel

LEGEND:

- □ WIREWOUND
- ■ WIREWOUND AND NONWIREWOUND
- 🟦 NONWIREWOUND

or at a point that maximizes the Total Resistance (4.1) if no overtravel exists. Subject the pot to two standard series of test temperatures in the sequence described. The first series is room temperature (defined at 25°C) down to —55°C or the lowest rated operating temperature with two intermediate temperature steps at 0°C and —25°C; the second series is room temperature to +125°C or the highest rated operating temperature (whichever is less) with two intermediate temperature steps at +50°C and +85°C. The Total Resistance is measured after the temperature chamber has been stabilized for each temperature (a minimum of 30 minutes, but avoid overaging) with 25°C as the reference temperature for both series. Compute the Resistance-Temperature Characteristic for each temperature interval with the following formula:

$$RTC = \frac{R_2 - R_1}{R_1} \times 100$$

Where:

R_1 = Resistance at reference temperature in ohms.

R_2 = Maximum or minimum resistance at any of the test temperatures, in ohms.

The Resistance-Temperature Characteristic of the potentiometer is the maximum value calculated.

5 *conformity and linearity*

5.1 ■ ABSOLUTE CONFORMITY

5.1.1 ■ OBJECT To measure the maximum deviation expressed as a percent of Total Applied Voltage of the actual function characteristic from theoretical function characteristic extending between the specified Output Ratios which are separated by the Theoretical Electrical Travel. An Index Point on the actual output is required.

5.1.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Voltage ratio equipment	1.2.1

5.1.3 ■ TEST PROCEDURE Mount the potentiometer in the travel measuring device and connect electrically to the voltage ratio equipment. Set the pot shaft to the Index Point (3.6). Then move the shaft to the beginning of the Theoretical Electrical Travel. The Index Point and beginning of Theoretical Electrical Travel must be approached from the same direction to eliminate effects of Backlash. Continuing in the same direction compare the actual output ratio of the test potentiometer to the theoretical function output ratio and note deviations for each shaft position. When an empirical function is specified the deviations are noted at the given data points only. When the function is described by a mathematical equation, deviations are noted at every 3-1/2% of Theoretical Electrical Travel or 45°, whichever is less. The maximum deviation from the theoretical, expressed as a percentage of the Total Applied Voltage, is the Absolute Conformity.

Note: In no case should the applied voltage exceed the voltage or power rating of the unit being tested.

5.1.4 ■ ALTERNATE PROCEDURE If a master of sufficient accuracy is available, test by the same procedure used for Absolute Linearity (5.2), substituting the proper non-linear master for the linear master.

5.2 ■ ABSOLUTE LINEARITY

5.2.1 ■ OBJECT To measure the maximum deviation (expressed as a percent of the Total Applied Voltage) of the actual function characteristic from a fully defined straight reference line over the Theoretical Electrical Travel as determined from the Index Point.

5.2.2 ■ EQUIPMENT

Conformity tester	1.2.18
Recorder	1.2.4
Power Supply	1.2.3
Voltage ratic equipment	1.2.1

5.2.3 ■ TEST PROCEDURE — CONTINUOUS METHOD Locate the Index Point (3.6) using the conformity tester as a travel measuring device. Disconnect the voltage ratio equipment and electrically connect the test potentiometer to the conformity tester as shown in Figure 1.2.18A and proceed as follows:

A. With switch in position 1, adjust recorder to null at center of chart.

B. With switch in position 6

1. Move the travel indicator to the Beta limit of Theoretical Electrical Travel.
2. By external means, short the slider terminal to the Beta terminal of the potentiometer under test.
3. Adjust "BAL AT BETA" control to produce a null on the recorder.
4. Remove the jumper (step 2) and move the travel indicator to the Alpha limit of Theoretical Electrical Travel.
5. By external means, short the slider terminal to the Alpha terminal of the potentiometer under test.
6. Adjust "BAL AT ALPHA" control to produce a null on the recorder.
7. Remove the jumper (step 5).

Note: Since "BAL" controls interact to some extent, it may be necessary to repeat step B until no further adjustment is needed.

C. With switch in position 2 or 3 as desired, adjust recorder gain to produce desired deflection.

D. After completing balancing and calibrating operations, set switch to position 6 and move the travel indicator over the full extent of the Theoretical Electrical Travel in the specified direction at a uniform speed noting linearity deviations on the recorder. The maximum deviation from the reference line, expressed in percent, is the Absolute Linearity.

5.2.4 ■ TEST PROCEDURE — POINT-BY-POINT METHOD The point-by-point method for testing Absolute Linearity is the same as the procedure for Absolute Conformity with the function described by a linear equation.

5.3 □ TERMINAL BASED LINEARITY (APPLICABLE TO WIREWOUND ONLY)

5.3.1 □ OBJECT To measure the maximum deviation (expressed as a percent of the Total Applied Voltage) of the actual function characteristic from a straight reference line drawn through the specified minimum and maximum output voltage ratios, which are separated by the Actual Electrical Travel. Unless otherwise specified minimum and maximum output ratios are respectively zero and 100% of Total Applied Voltage.

5.3.2 □ EQUIPMENT

Conformity tester	1.2.18
Recorder	1.2.4
Power supply	1.2.3

5.3.3 □ TEST PROCEDURE

A. Connect the potentiometer Electrically to the conformity tester as shown in Figure 1.2.18A.

LEGEND:

□ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
🟦 NONWIREWOUND

B. Set function selector switch at position 1 and adjust recorder to null at center line of chart paper.

C. Set function selector switch to position 2 or 3 as desired and adjust recorder gain control to produce desired deflection.

D. Set function selector switch to position 4 and locate the Alpha End Point (3.4) approximately, moving the shaft by hand.

E. Set the travel indicator of the conformity tester at or near zero and mount the potentiometer in the conformity tester by normal means.

F. Locate the exact position of the Alpha End Point (3.4) and note the shaft position.

G. Set the function selector switch to position 6, short the slider terminal to the Alpha terminal by external means and adjust the "BAL AT ALPHA" control to obtain a null on the recorder.

H. Remove the short, set function selector switch to position 5, locate the Beta End Point exactly and note the shaft position.

J. Set the function selector switch to position 6, short the slider terminal to the Beta terminal by external means and adjust the "BAL AT BETA" control to obtain a null on the recorder.

Note: It may be necessary to repeat steps F through J several times because of interaction of the balance controls.

K. After completing balancing and calibrating operations, set selector switch to position 6 and move the travel indicator over the full extent of the Actual Electrical Travel (3.7), in the specified direction at uniform speed, noting the linearity deviations on the recorder. The maximum deviation from the reference line, expressed as a percent of Total Applied Voltage, is the Terminal Based Linearity.

5.4 □ ZERO BASED LINEARITY (APPLICABLE TO WIREWOUND ONLY)

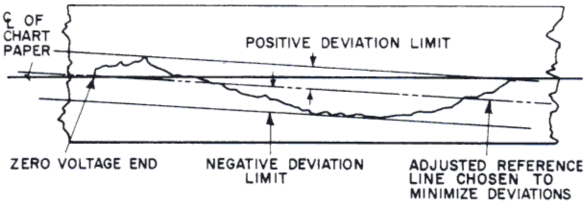


FIGURE 5.4A Determination of zero based linearity

5.4.1 □ OBJECT To determine the maximum deviation, expressed as a percent of Total Applied Voltage, of the Actual function characteristic from a straight reference line drawn through the specified minimum Output Ratio, extended over the Actual Electrical Travel, and rotated to minimize the maximum deviations. Unless otherwise specified, the specified minimum Output Ratio will be zero.

5.4.2. □ EQUIPMENT

Conformity tester	1.2.18
Recorder	1.2.4
Power supply	1.2.3

5.4.3 □ TEST PROCEDURE To employ the specified conformity tester in this procedure, connect the specified minimum (or zero) output ratio end of the potentiometer to the "ALPHA" end of the tester.

A. Connect the potentiometer electrically to the conformity tester as shown in Figure 1.2.18A.

B. Set function selector switch at position 1 and adjust recorder to null at centerline of chart paper.

C. Set function selector switch to position 2 or 3 as desired and adjust recorder gain control to produce desired deflection.

D. Set function selector switch to position 4 and locate the Alpha End Point (3.4) approximately, moving the shaft by hand.

E. Set the travel indicator of the conformity tester at or near zero and mount the potentiometer in the conformity tester by its normal mounting means.

F. Locate the exact position of the Alpha End Point (3.4) and note the shaft position.

G. Set the function selector switch to position 6, short the slider terminal to the alpha terminal by external means and adjust the "BAL AT ALPHA" control to obtain a null on the recorder.

H. Remove the short, set function selector switch to position 5, locate the Beta End Point exactly and note the shaft position.

J. Set the function selector switch to position 6, and adjust the "BAL AT BETA" control to obtain a null on the recorder.

Note: It may be necessary to repeat steps F through J several times due to the interaction of the balance controls.

K. After completing balancing and calibrating operations, set selector switch to position 6 and move the travel indicator over the full extent of the Actual Electrical Travel (3.7), in the specified direction at a uniform speed, noting the linearity deviations on the recorder.

Referring to Figure 5.4A, determine Zero Based Linearity by drawing a reference line through the recording so that it intersects the centerline of the recording at the "zero voltage" end and is rotated about this point until the positive and negative deviations from it are minimized. Draw lines parallel to the reference line through the maximum deviations from it to establish the limits of the Zero Based Linearity. Express as a percent of the Total Applied Voltage.

5.5 □ 🟦 INDEPENDENT LINEARITY

5.5.1 □ INDEPENDENT LINEARITY — WIREWOUND

5.5.1.1 □ OBJECT To measure the maximum deviation, expressed as a percent of the Total Applied Voltage, of the actual function characteristic from a straight reference line whose slope and position minimize the maximum deviations over the Actual Electrical Travel, or any specified portion thereof.

5.5.1.2 □ EQUIPMENT

Conformity tester	1.2.18
Recorder	1.2.4
Power supply	1.2.3

5.5.1.3 □ TEST PROCEDURE

A. Connect the potentiometer electrically to the conformity tester as shown in Figure 1.2.18A.

B. Set function selector switch at position 1 and adjust recorder to null at centerline of chart paper.

C. Set function selector switch to position 2 or 3 as desired and adjust recorder gain control to produce desired deflection.

D. Set function selector switch to position 4 and locate the Alpha End Point (3.4) approximately, moving the shaft by hand.

E. Set the travel indicator of the conformity tester at or near zero and mount the potentiometer in the linearity tester by its normal mounting means.

F. Locate the exact position of the Alpha End Point (3.4) and note the shaft position.

LEGEND:

☐ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
🟦 NONWIREWOUND

G. Set the function selector switch to position 6, and adjust the "BAL AT ALPHA" control to obtain a null on the recorder.

H. Set the function selector switch to position 5, locate the Beta End Point exactly, and note the shaft position.

J. Set the function selector switch to position 6, and adjust the "BAL AT BETA" control to obtain a null on the recorder.

Note: It may be necessary to repeat steps F through J several times because of the interaction of the balance controls.

K. After completing balancing and calibrating operations, set selector switch to position 6, and move the travel indicator over the full extent of the Actual Electrical Travel (3.7), in the specified direction at a uniform speed, noting the linearity deviations on the recorder.

Referring to Figure 5.5A, determine Independent Linearity by drawing the best straight line through the recording so as to minimize the maximum positive and negative deviations from the line irrespective of position or slope. Draw lines parallel to this reference line, through the maximum deviations from it to establish the limits of the Independent Linearity. Express as a percent of the Total Applied Voltage.

Note: If point-by-point method is used, the best straight line must be determined graphically by plotting.

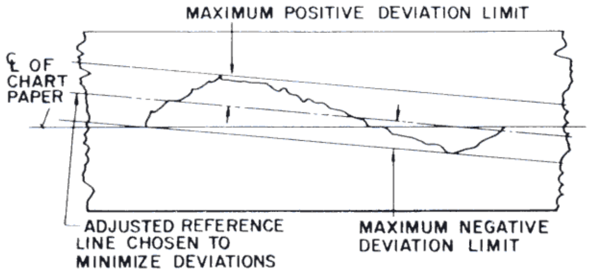


FIGURE 5.5A Determination of independent linearity

5.5.2 🟦 INDEPENDENT LINEARITY — NONWIREWOUND

5.5.2.1 🟦 OBJECT To measure the maximum deviation, expressed as a percent of the Total Applied Voltage, of the actual function characteristic from a straight reference line whose slope and position minimize the maximum deviations over the Theoretical Electrical Travel, or any specified portion thereof. An Index Point on the actual output is required.

5.5.2.2 🟦 EQUIPMENT

Conformity tester	1.2.18
Recorder	1.2.4
Power supply	1.2.3
Voltage ratio equipment	1.2.1

5.5.2.3 🟦 TEST PROCEDURE Locate the Index Point (3.6) using the conformity tester as the travel measuring device. Disconnect the voltage ratio equipment, electrically connect the test pot to the conformity tester as shown in Figure 1.2.18A and proceed, as follows:

A. With switch in position 1, adjust recorder to null at center of chart.

B. With switch in position 6

1. Move the travel indicator to the Beta limit of Theoretical Electrical Travel.
2. Adjust "BAL AT BETA" control to produce a null on the recorder.
3. Move the travel indicator to the Alpha limit of Theoretical Electrical Travel.
4. Adjust "BAL AT ALPHA" control to produce a null on the recorder.
5. Because of the possible interaction of the Bal controls, repeat steps 1 through 4 until no further adjustment is necessary.

C. With switch in position 2 or 3 as desired, adjust recorder gain to produce desired deflection.

D. After completing balancing and calibration, set selector switch to position 6, and move the travel indicator over the full Theoretical Electrical Travel, in the specified direction at a uniform speed, noting the linearity deviations on the recorder.

Referring to Figure 5.5A, determine Independent Linearity by drawing the best straight line through the recording so as to minimize the maximum positive and negative deviations from the line irrespective of position or slope. Draw lines parallel to this reference line through the maximum deviations from it to establish the limits of the Independent Linearity. Express as a percent of the Total Applied Voltage.

Note: If point-by-point method is used, the best straight line must be determined graphically by plotting.

5.6 ■ SIMULTANEOUS CONFORMITY PHASING

5.6.1 ■ OBJECT To determine that the electrical elements of a gang potentiometer are so aligned that each electrical element falls within its conformity or linearity limits when a common Index Point is used.

5.6.2 ■ EQUIPMENT See Absolute Conformity (5.1), Absolute Linearity (5.2) or Independent Linearity (Nonwirewound — 5.5.2).

5.6.3 ■ TEST PROCEDURE Determine Simultaneous Conformity Phasing in the same manner as Absolute Conformity (5.1), Absolute Linearity (5.2), or Independent Linearity — Nonwirewound (5.5.2), for each electrical element, using a common Index Point (3.6). The Index Point is on the first cup unless otherwise specified.

When running point-by-point tests described in the Absolute Conformity test procedure, take Output Voltage Ratio readings for each shaft setting simultaneously on all cups in the gang.

5.7 ■ VOLTAGE TRACKING ERROR

5.7.1 ■ OBJECT To measure the difference at any shaft position between the Output Ratios of any two commonly actuated similar electrical elements; expressed as a percentage of the single Total Voltage Applied to them.

5.7.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Recorder	1.2.4
Power supply	1.2.3

5.7.3 ■ TEST PROCEDURE Connect the power supply across the corresponding ends of all similar electrical elements in the gang which are to be tracked. Connect the recorder between the wiper terminal of the reference element and the wiper terminal of the element to be tracked. Move the shaft throughout the travel range over which tracking is specified and directly observe the Voltage Tracking Error on the recorder.

Compare all cups/electrical elements to the first element, unless otherwise specified.

6 *general electrical characteristics*

6.1 ☐ NOISE (EQUIVALENT NOISE RESISTANCE)

6.1.1 ☐ INTRODUCTION Perhaps the most persistent problem affecting potentiometer manufacturers and users is the so-

LEGEND:

- ☐ WIREWOUND
- ■ WIREWOUND AND NONWIREWOUND
- 🟦 NONWIREWOUND

called "Noise" problem. Countless man-hours have been expended over the last two decades, and longer, investigating the sources of potentiometer Noise and means for eliminating or controlling it. Considerable headway has already been made in this area and the future portends even greater achievements.

The need exists right now, however, for putting the problem in its proper perspective. For twenty years, or more, practically all potentiometer noise measurements have been made using the 1.0 ma constant current source and oscilloscope detection technique currently defined in NAS710 and MIL-R-12934.

This technique is arbitrary and suffers from the following disabilities:

A. Virtually no potentiometer is ever used in such a circuit. Most precision potentiometer applications involve negligible slider current.

B. The bandwidth of the measuring instrument (>50 KHz) is at least three orders of magnitude greater than the bandwidth of most servo systems, which constitute a large percentage of precision potentiometer applications.

The advantage of the technique is its simplicity.

The Variable Resistive Components Institute has chosen to establish a new test procedure (6.1.4) for measuring equivalent noise resistance in wirewound potentiometers. This new procedure is not unlike earlier versions. It retains their simplicity and yet provides a basis for Noise measurement technique more realistically related to actual system usage.

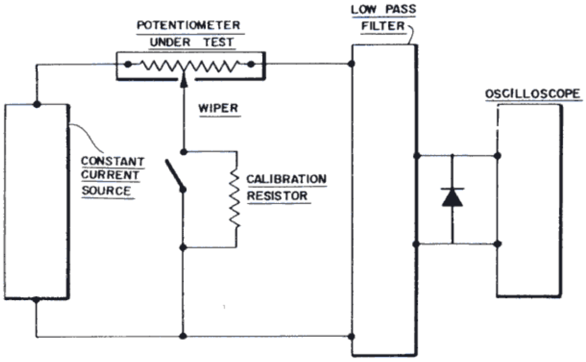


FIGURE 6.1A Noise test circuit — with low pass filter

Very simply, the new procedure recommends the insertion of a 1000 Hz low pass filter in the circuit (see Figure 6.1A).

In view of the wide disparity between bandwidths used previously, and this procedure, it would appear at first glance that the new procedure simply disguises potentiometer Noise. It is clear, in view of the "spikey" nature of pot Noise, that with the low pass filter, less Noise will be indicated. A bandwidth of 1000 Hz, however, is still well in excess of the bandwidth of most servo systems.

Unfortunately, the new procedure is no less arbitrary than its predecessors since it still measures Noise in a non-typical circuit. The ultimate in Noise tests would be to dynamically extract the desired signal from the potentiometer output and record the residual Noise under conditions of voltage and loading corresponding to its actual usage. Such a measurement requires special pot test equipment and detailed knowledge of potentiometer application. In the usual situation, the user doesn't have the proper equipment and the manufacturer is unable to obtain sufficient data on the potentiometer's application. For purposes of standardization the two must generally meet, therefore, on the common ground of the arbitrary but simple constant current rheostat approach.

It is not anticipated that this simple modification will eliminate the Noise problem, nor that it will be a suitable procedure for all applications. For this reason the larger bandwidth test (0-50KHz) has been included as an alternate procedure (6.1.5) to be specified where the application dictates its use.

It is expected that by standardizing on the limited bandwidth test procedure a large number of unnecessary rejections will be eliminated and focus users' attention on the need to more clearly define their requirements in situations where the standard procedure is inadequate.

6.1.2 ☐ OBJECT To measure the spurious variations in the electrical output not present in the input, defined quantitatively in terms of the equivalent parasitic transient resistance in ohms, appearing between the contact and the resistance element when the shaft is rotated or translated. The equivalent noise resistance is defined independently of resolution, the functional characteristics, and the total travel. The magnitude of the equivalent noise resistance is the maximum departure from a specified reference line. The wiper of the potentiometer is required to be excited by a specified current and moved at a specified speed.

6.1.3 ☐ EQUIPMENT

Constant speed drive	1.1.12
Constant current source	1.2.5
Oscilloscope	1.2.6
Low pass filter	1.2.7
Zener diode (6v)	

6.1.4 ☐ TEST PROCEDURE (SEE FIGURE 6.1A) The potentiometer shaft is cycled not less than ten times over a minimum of 95% of the Electrical Continuity Travel (3.10) within the rated travel speed of the potentiometer just prior to making Noise measurements. The potentiometer shaft is then connected mechanically to the constant speed drive and electrically connected in the Noise test circuit as shown in the Figure 6.1A. With the constant speed drive engaged, the potentiometer Noise characteristic may then be noted on the oscilloscope as the wiper traverses one complete cycle over the full Electrical Continuity Travel and the maximum values are compared to the specified limit.

If only random spikes of Noise are noted, the potentiometer should be cycled again. If the random spikes are repetitive, the maximum values should be noted. Otherwise, do not consider the initial measurements Noise.

Take care to discount apparent contact resistance change due to secondary current paths present in potentiometers with shunting or padding resistors, continuous windings or windings with resistance overtravels or shorts.

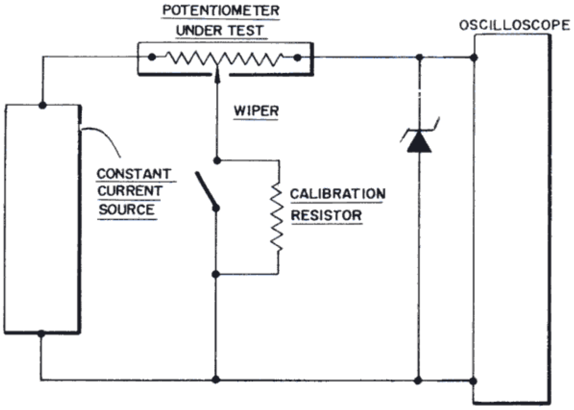


FIGURE 6.1B Noise test circuit — without low pass filter

LEGEND:

☐ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
🟦 NONWIREWOUND

It is recommended that a zener diode be placed across the scope input to protect the terminations of the potentiometer from excessive arcing occurring at discontinuities in the output, such as at the dead space in single turn pots.

6.1.5 ☐ ALTERNATE TEST PROCEDURE Use this procedure only when specified on the procurement documents or individual control drawings.

The procedure is identical to the standard Noise test procedure (6.1.4) except that the low pass filter is removed from the test circuit as indicated in Figure 6.1B.

Test conducted with this circuit will show an off set from the baseline corresponding to the apparent contact resistance in the wiper circuit and/or the value of a wiper protecting resistor. Apparent contact resistance will be found especially in non-wirewound potentiometers with relatively large ratios of track width or cross section to wiper contact area.

6.2 ☐ OUTPUT SMOOTHNESS

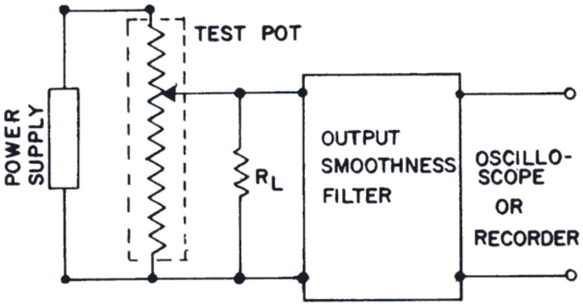


FIGURE 6.2A Output smoothness

6.2.1 ■ INTRODUCTION The "noise" test in paragraph 6.1 measures ENR (equivalent nosie resistance), which is a variation in real or apparent contact resistance in the wiper circuit. This measurement is significant for units used in rheostat applications, but not for voltage dividers, in which very little, if any, current flows in the wiper circuit. For these applications the output smoothness test is used, which reflects sudden variations in output of voltage dividers. If the units are used with finite loads, the effect of contact resistance variation is included in the output smoothness test along with all other causes of noise in the output signal.

While different use circuits may well be sensitive to different types or frequencies of output variations, the VRCI has chosen one output smoothness filter for a standardized test which has proven adequate for a wide range of uses. It should be used, unless all conditions are sufficiently known and understood to permit design of another filter tailored to that application.

6.2.2 ■ OBJECT To measure the spurious variations in the electrical output not present in the input. They are measured for specified travel increments over the Theoretical Electrical Travel and expressed as a percentage of the Total Applied Voltage.

6.2.3 ■ EQUIPMENT

Power supply	1.2.3
Output smoothness filter	1.2.8
Oscilloscope	1.2.6
Constant speed drive	1.1.12

6.2.4 ■ TEST PROCEDURE Mount the potentiometer in the 4 RPM constant speed drive and excite it with the power supply. Connect the wiper and power common lead to the input of the filter and the output of the filter to the oscilloscope as shown in Figure 6.2A. When a load is specified for a Conformity test, use that load for the Output Smoothness test. When no load is specified for the Conformity test, apply a load $R_L = 100 \times R_T$ between the wiper and the CCW end for the Output Smoothness test, unless otherwise specified. The Output Smoothness is the largest excursion voltage occurring over one specified travel increment, divided by the Total Applied Voltage. Unless otherwise specified, the travel increment is 1% of the Theoretical Electrical Travel. Excursions occurring at the point of abrupt changes in output slope (start, end, and reversal) are not considered Output Smoothness faults.

Proper trace evaluation requires examining the trace over one specified travel increment (θ_i) at a time. The travel increment is placed on the trace to include the maximum excursion within the increment, using the oscilloscope. Determine the increment by adjusting the sweep of the oscilloscope, (for example, Theoretical Electrical Travel 300°; $\theta_i = 3°$; at 4 RPM $3° = 0.12$ sec.; at 1 cm/sec. sweep $\theta_i = 1.2$ cm).

In most cases you can obtain equivalent results on a standard recorder on which the travel increment is easily calibrated by measuring the total trace length and evaluating the trace as shown in Figure 6.2B.

Exercise care in evaluating the magnitude of the excursion voltages because of the substantial attenuation of pot output voltage through the Output Smoothness filter.

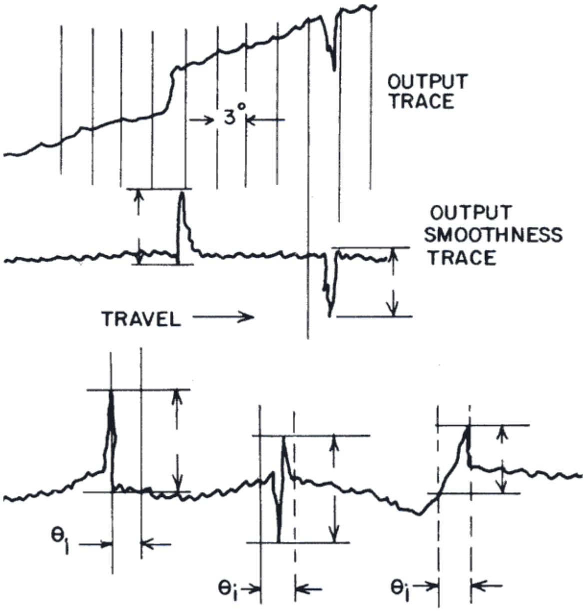


FIGURE 6.2B Evaluation of output smoothness trace

6.3 ☐ VOLTAGE RESOLUTION (APPLICABLE TO WIREWOUND ONLY)

6.3.1 ☐ OBJECT To measure the maximum incremental change in Output Ratio, in any specified portion of the resistance element, with shaft travel in one direction.

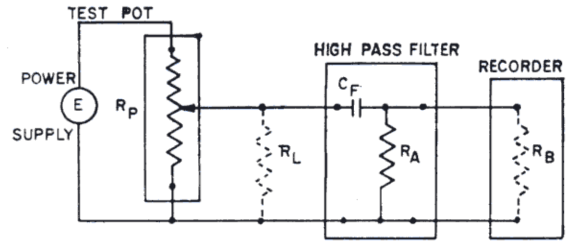
LEGEND:

☐ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
■ NONWIREWOUND

6.3.2 ☐ EQUIPMENT

Power supply	1.2.3
Recorder	1.2.4
Variable speed drive	1.1.17

6.3.3 ☐ TEST PROCEDURE (SEE FIGURE 6.3A) To properly measure Voltage Resolution the values of the high pass filter must first be determined. Referring to Figure 6.3A, C_F and R_A are dependent upon the desired time constant, test pot resistance and input impedance to the recorder. The desired time constant is further dependent upon the rate of "cutting turns" determined from the velocity of the drive and the Theoretical Resolution. The following guides are given for the determination of the numerical values of the components of the high pass filter and shaft travel velocity:



WHERE: E = INPUT VOLTAGE

R_P = TOTAL RESISTANCE OF TEST POT

R_L = LOAD RESISTANCE SIMULATING USER APPLICATION (USED ONLY WHEN SPECIFIED.)

C_F = FILTER CAPACITANCE

R_A = FILTER SHUNT RESISTANCE

R_B = INPUT IMPEDANCE TO RECORDER

FIGURE 6.3A Measurement of voltage resolution

A. R_F is a value chosen to minimize the loading effect on the test pot. It should be at least ten (10) times the Total Resistance of the test pot. Should the ratio become much less than 10:1, the apparent magnitude of the Voltage Resolution will be distorted.

B. R_A is determined from the total effective shunt resistance (R_F) and is calculated from $R_A = R_B R_F/(R_B - R_F)$.

C. The filter capacitance is calculated from R_F and the desired time constant ($R_F C_F$) for the filter network. The time constant should be approximately 1/10th the rate of "cutting turns" such that each resolution spike decays sufficiently before another is generated. Obviously, this depends upon the travel speed of the test pot and its inherent Theoretical Resolution. It should be further noted that the allowable rate of "cutting turns" must be commensurate with the frequency response of the recorder.

Example:

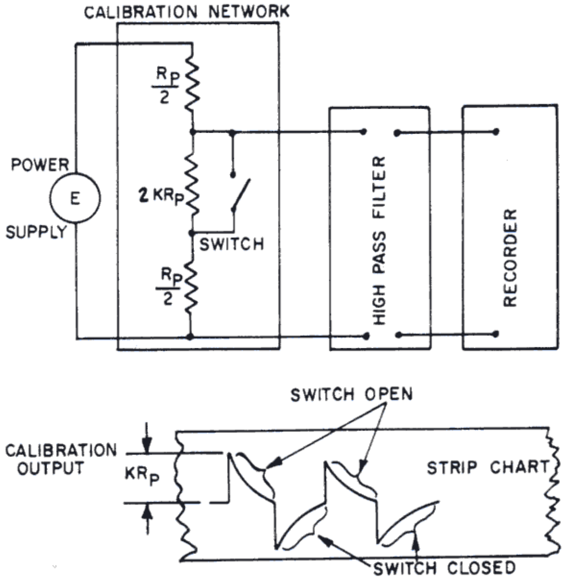
If: $R_p = 50$ KΩ
$R_B = 1$megΩ
Theoretical Resolution = 3000 turns or 0.033%
Frequency Response of Recorder = 100 Hz

Then:

1. R_F should be at least 500KΩ
2. $R_A = R_B R_F (R_B - R_F) = 1$ megΩ
3. Assuming a test pot drive speed of 1 RPM, the rate of cutting turns = 0.02 sec/turn
4. The desired time constant (T) should then be approximately 0.002 sec
   Therefore, $C_F = T/R_F = 0.004$ μf
5. In this case the rate of "cutting turns" (20 milliseconds/pulse) is significantly large when compared with the time constant of the filter network and the approximate response time (0.35/100) of a 100 Hz recorder, thus permitting proper display of the resolution of the test pot.

D. The resistor R_L shown in Figure 6.3A is employed only when specified by the user. It is intended to simulate the load in the actual application such that the recorder output of the Voltage Resolution test will depict as closely as possible the output of the pot in use.

Having determined the high pass filter constants, the calibration circuit of Figure 6.3B is established. The constant K is chosen as some convenient increment of the magnitude of the Voltage Resolution to be displayed on the recorder. For example, if it is desired to calibrate the recorder to the limit of a desired resolution of 0.1% then K = 0.001.



WHERE: E = INPUT VOLTAGE

R_P = TOTAL RESISTANCE OF TEST POT

K = CONSTANT EQUAL TO CALIBRATION SIGNAL LIMIT FOR EVALUATION OF VOLTAGE RESOLUTION RECORDING

FIGURE 6.3B Calibration circuit

Set the power supply to a voltage providing sufficient sensitivity, but small enough to prevent overheating of the pot under test. With the switch closed the recorder is nulled to the center of the recording. Then, while opening and closing the switch, adjust the recorder gain until the zero to peak output being recorded is some convenient distance on the chart recording.

Then replace calibration network with the test pot as shown in Figure 6.3A. With the recorder chart speed set to a convenient value for displaying the resolution, the pot is driven in one direction through the full Actual Electrical Travel (3.7) or specified portion thereof with the variable speed drive set

LEGEND:

☐ WIREWOUND
■ WIREWOUND AND NONWIREWOUND
🟦 NONWIREWOUND

to a predetermined value. Compare the magnitude of the maximum incremental pulse change shown on the recording with the zero to peak calibration signal to determine the Voltage Resolution.

Note 1: Toward the center of the test pot the Voltage Resolution appears as half the magnitude and double the number of steps unevenly spaced. This is due to the leading and trailing edge effects of the wiper contact. This effect should be considered when determining the proper time constant for the high pass filter and the drive speed for the test pot, if true representation of this region is deemed important.

Note 2: If a dropping resistor is used in series with the power supply to establish the desired input voltage, it will have the effect of shifting the aforementioned half steps to one end of the test pot and not give true indication of the Voltage Resolution. Should the dropping resistor be made sufficiently large, the half steps may be eliminated completely.

6.4 ■ DIELECTRIC WITHSTANDING VOLTAGE

6.4.1 ■ OBJECT To measure the ability of a potentiometer to withstand a specified potential of a given characteristic between the terminals of each cup and the exposed conducting surfaces of the potentiometer, or between the terminals of each cup and the terminals of every other cup in the gang under prescribed conditions without exceeding a specified leakage current value.

6.4.2 ■ EQUIPMENT

High voltage source	1.2.10
AC voltmeter	1.2.11
Leakage current indicating device	1.2.12

6.4.3 ■ TEST PROCEDURE The magnitude of the test voltage should be as specified. The voltage is taken from an alternating current supply of a commercial 60 cycle line frequency and waveform. Connect the equipment by applying the high voltage source between the potentiometer terminals (interconnected) and the shaft or case. Raise the test voltage gradually from zero to the proper maximum value at a rate of 500 volts per second maximum. Maintain the test voltage at this value while the shaft is moved through one full sweep of Total Mechanical Travel (3.1) in a time interval not less than 5 seconds nor more than 60 seconds. Monitor the leakage current indicating device throughout this test for evidence of damage, arcing, breakdown, or leakage currents in excess of 1 milliampere. Upon completion of the test, the voltage should be reduced gradually to zero prior to disconnecting the test leads, for operator safety.

For ganged potentiometers, repeat the foregoing applying the high voltage between the terminals of each cup and the terminals of every other cup.

6.5 ■ INSULATION RESISTANCE

6.5.1 ■ OBJECT To measure the resistance of a potentiometer to a specified impressed DC voltage between the terminals of each cup and the exposed conducting surfaces of the potentiometer, or between the terminals of each cup and the terminals of every other cup in the gang under prescribed conditions.

6.5.2 ■ EQUIPMENT

Insulation resistance test set	1.2.21
Shaft positioning device	1.1.2

6.5.3 ■ TEST PROCEDURE Interconnect all electrically insulated terminals of each cup of the potentiometer. Connect the insulation resistance test set to the terminal of the first cup and to some exposed conducting surface of the potentiometer (as shaft or case) and apply the specified test voltage. Unless otherwise specified the test voltage is 500V DC. Maintain the test voltage at this value for 5 to 10 seconds before initiating movement of the shaft through one full sweep of the Total Mechanical Travel (3.1) in a time interval of not less than 5 seconds nor more than 60 seconds. Monitor the indicated Insulation Resistance during this voltage application. The Insulation Resistance is the minimum value observed during the movement of the shaft.

Note: Any region where there is sharp decrease in the measured value during shaft travel should be examined at reduced speed to ascertain that damping of the indicating meter has not passed the region of lower values than that indicated.

For gang potentiometers, repeat the procedure for each cup applying the high voltage between the terminals of each cup and the exposed conducting surface of the potentiometer. The procedure is continued by applying the high voltage between the terminals of each adjacent cup in the gang.

7 *ac characteristics*

7.1 ■ TOTAL INPUT IMPEDANCE

7.1.1 ■ OBJECT To measure, at a specified voltage and frequency and with the shaft positioned to give a maximum value, the Total Input Impedance between the two input terminals with open circuit between output terminals.

7.1.2 ■ EQUIPMENT

AC voltage source	1.2.13
AC vacuum tube voltmeter	1.2.15
AC ammeter	1.2.16

7.1.3 ■ TEST PROCEDURE Connect the potentiometer to the source at the input terminals with the wiper open circuited. Move the pot shaft to a position on the Electrical Overtravel or against the stop at minimum voltage if no Electrical Overtravel or discontinuity exists. Measure the current through the resistance element and the voltage across the element at the specified voltage and frequency. The Total Input Impedance is calculated from the formula:

$$\text{Total Input impedance} = \frac{\text{Voltage applied}}{\text{Current}}$$

7.2 ☐ 🟦 OUTPUT IMPEDANCE

7.2.1 ☐ OUTPUT IMPEDANCE — WIREWOUND

7.2.1.1 ☐ OBJECT To measure the Output impedance defined as the maximum impedance between wiper and either end terminal with the input shorted and at a specified voltage and frequency.

7.2.1.2 ☐ EQUIPMENT

AC voltage source	1.2.13
AC vacuum tube voltmeter	1.2.15
AC microammeter	1.2.17

7.2.1.3 ☐ TEST PROCEDURE The source is connected to the potentiometer between the wiper and either end terminal with the input terminals shorted. The voltage applied and the current through the wiper are measured at the specified voltage and frequency as the pot shaft is rotated or translated over the Actual Electrical Travel (3.7). The Output Impedance is the applied voltage divided by the minimum current reading. The applied voltage should not exceed that which would cause a current to flow greater than 10 milliamperes.

7.2.2 🟦 OUTPUT IMPEDANCE — NONWIREWOUND

7.2.2.1 🟦 OBJECT To measure the Output Impedance defined as the maximum impedance between wiper and either end

LEGEND:

- □ WIREWOUND
- ■ WIREWOUND AND NONWIREWOUND
- 🟦 NONWIREWOUND

terminal with the input shorted and at a specified voltage and frequency.

7.2.2.2 🟦 EQUIPMENT

AC voltage source	1.2.13
AC vacuum tube voltmeter	1.2.15
AC microammeter	1.2.17

7.2.2.3 🟦 TEST PROCEDURE Connect the source to the potentiometer between the wiper and either end terminal with the input terminals shorted. The voltage applied and the current through the wiper are measured at the specified voltage and frequency as the pot shaft is rotated or translated over the Theoretical Electrical Travel (3.8). The Output Impedance is the applied voltage divided by the minimum current reading. The applied voltage should not exceed that which would cause a current flow greater than 1.0 milliamperes.

7.3 □ 🟦 QUADRATURE VOLTAGE

7.3.1 □ QUADRATURE VOLTAGE — WIREWOUND

7.3.1.1 □ OBJECT To measure the maximum value of that portion of the output voltage which is ±90° out of time phase with the input voltage, expressed as volts per volt applied, at a specified input voltage and frequency.

7.3.1.2 □ EQUIPMENT

AC voltage source	1.2.13
Ratio transformer	1.2.14
AC vacuum tube voltmeters	1.2.15
Potentiometer mounting fixture	1.1.1

7.3.1.3 □ TEST PROCEDURE Mount the potentiometer in the potentiometer mounting fixture and connect in the circuit shown in Figure 7.3A. Set the test pot to a position on the Actual Electrical Travel (3.7). Adjust the ratio transformer for a minimum null voltage (V_o). The quadrature voltage (e_q) is calculated from the formula:

$$e_q = \frac{V_o}{E}$$

This procedure is repeated over the Actual Electrical Travel until a maximum value is obtained.

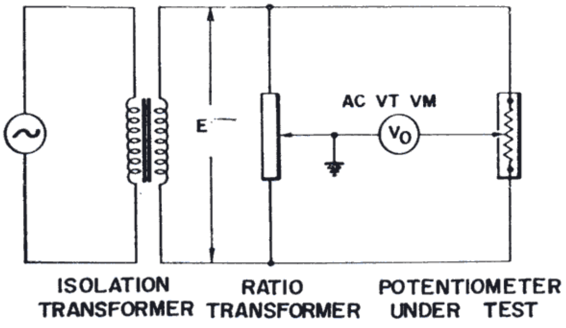


FIGURE 7.3A Quadrature voltage measurement

Note: Wiring must be arranged to provide minimum possible stray capacitances.

7.3.2 🟦 QUADRATURE VOLTAGE — NONWIREWOUND

7.3.2.1 🟦 OBJECT To measure the maximum value of that portion of the output voltage which is ±90° out of time phase with the input voltage, expressed as volts per volt applied, at a specified input voltage and frequency.

7.3.2.2 🟦 EQUIPMENT

AC voltage source	1.2.13
Ratio transformer	1.2.14
AC vacuum tube voltmeters	1.2.15
Potentiometer mounting fixture	1.1.1

7.3.2.3 🟦 TEST PROCEDURE The potentiometer is mounted in the potentiometer mounting fixture and connected in the circuit shown in Figure 7.3A. Set the test pot to a position on the Theoretical Electrical Travel (3.8). Adjust the ratio transformer for a minimum null voltage (V_o). The quadrature voltage (e_q) is calculated from the formula:

$$e_q = \frac{V_o}{E}$$

This procedure is repeated over the Theoretical Electrical Travel until a maximum value is obtained.

Note: Wiring must be arranged to provide minimum possible stray capacitances.

7.4.1 ■ OBJECT To measure the phase difference between the sinusoidal input and output voltages at a specified input voltage and frequency with the shaft at a specified position.

7.4.2 ■ EQUIPMENT

AC voltage source	1.2.13
Ratio transformer	1.2.14
AC vacuum tube voltmeters	1.2.15
Potentiometer mounting fixture	1.1.1

7.4.3 ■ TEST PROCEDURE Phase Shift in a precision potentiometer varies in magnitude with shaft position (see Figure 7.4A). The figure shows the relationship between Phase Shift, Quadrature Voltage (7.3) and shaft position for normal conditions and indicates that Phase Shift becomes maximum at essentially zero output, a somewhat meaningless value. A more valuable measure of Phase Shift can be described at the point of maximum Quadrature Voltage, and for the purposes of this document Phase Shift will be measured in terms of Quadrature Voltage.

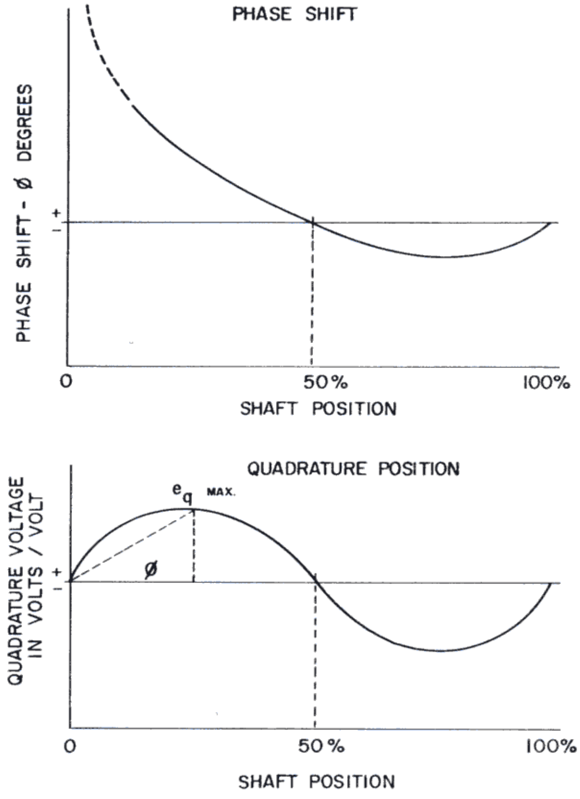


FIGURE 7.4A Phase shift determination

Since Quadrature Voltage is expressed in terms of volts/volt, Phase Shift can be calculated from:

$$\text{Phase Shift} = \tan^{-1}(e_q)$$

Therefore, Phase Shift is determined by measuring the Quadrature Voltage and calculating as above using e_q maximum unless otherwise specified.

8 *mechanical characteristics*

8.1 ■ SHAFT RUNOUT

8.1.1 ■ OBJECT To measure the eccentricity of the shaft diameter with respect to the rotational axis of the shaft and measured at a specified distance from the end of the shaft. The body of the potentiometer is held and the shaft is rotated with a specified load applied radially to the shaft.

8.1.2 ■ EQUIPMENT

Dial indicator	1.1.5
Dial indicator holding fixture	1.1.6
Potentiometer mounting fixture	1.1.1
Dead weight load	1.1.9
Cylindrical shaft adaptor	1.1.8
Surface plate or equivalent firm surface	

8.13 ■ TEST PROCEDURE (SEE FIGURE 8.1A) Mount the potentiometer firmly with the shaft axis in a horizontal position and hold rigid with respect to the dial indicator. Position the dial indicator such that its probe contacts the shaft within 1/8 inch from the end of the shaft or the edge of any interruption of the smooth cylindrical shaft surface. This measurement requires that the shaft be a smooth cylindrical surface at the point of measurement and when specified, shafts with noncylindrical surfaces such as flats, slots, or splines will require the use of the cylindrical shaft adaptor. Depress the probe sufficiently to insure a proper positive and negative indication of the dial. Apply 1/2 pound load radially to the shaft to remove Shaft Radial Play and position as close to the indicator probe as is practical. For small diameter shafts reduce the magnitude of the load applied such that it never exceeds that which would cause the shaft to permanently deform. Then rotate the shaft slowly through 360° or through its Total Mechanical Travel (3.1), whichever is less. The Shaft Runout is the total indicated reading determined by adding the maximum positive and negative readings without regard to algebraic signs.

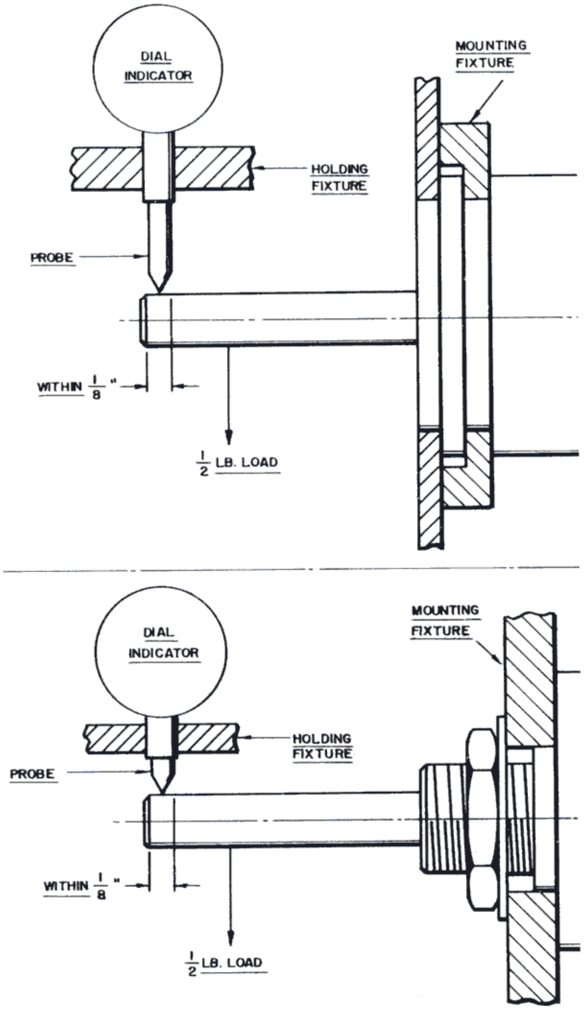


FIGURE 8.1A Measurement of shaft runout

8.2 ■ LATERAL RUNOUT

8.2.1 ■ OBJECT To measure the perpendicularity of the mounting surface of the potentiometer with respect to the rotational axis of the shaft measured on the mounting surface at a specified distance from the outside edge of the mounting surface. The shaft is held and the body of the potentiometer is rotated while specified loads are applied radially and axially to the body of the potentiometer.

8.2.2 ■ EQUIPMENT

Dial indicator	1.1.5
Dial indicator holding fixture	1.1.6
Potentiometer shaft holding fixture	1.1.7
Two dead weight loads	1.1.9
Surface plate or equivalent firm surface	

8.2.3 ■ TEST PROCEDURE (SEE FIGURE 8.2A) Make the measurement with the potentiometer mounted firmly in the shaft holding fixture and with the shaft axis in a vertical position. Clamp the shaft within 1/8 inch of the front surface of the potentiometer without interference and hold rigid with respect to the dial indicator. The potentiometer body is to remain free to rotate. Care should be taken to insure that the shaft is not distorted in any way due to the mode of clamping or the inherent weight of the potentiometer body. Position the dial indicator such that its probe contacts the smooth portion of mounting surface of the potentiometer less than 1/8 inch from the outside edge of the mounting surface. The probe should be depressed sufficiently to insure a proper positive and negative indication. A 1/2 pound load is applied normal to the centerline of the shaft axis on the potentiometer body within 1/8″ of the mounting surface. Simultaneously, a 1/2 pound load is applied axially on the centerline of the potentiometer. The loads serve to remove the Shaft Radial and End Plays. For small diameter shafts the magnitude of the load applied shall be reduced such that it never exceeds that which would cause the shaft to permanently deform. The body of the potentiometer is then slowly rotated through 360° or through the Total Mechanical Travel (3.1), whichever is less. The Lateral Runout is the total indicated reading determined by adding the maximum positive and negative readings without regard to algebraic signs.

8.3 ■ PILOT DIAMETER RUNOUT

8.3.1 ■ OBJECT To measure the eccentricity of the pilot diameter with respect to the rotational axis of the shaft indicated on the pilot diameter. The shaft is held and the body of the potentiometer is rotated while a specified load is applied radially to the body of the potentiometer.

LEGEND:

☐ WIREWOUND
■ WIREWOUND AND NONWIREWOUND

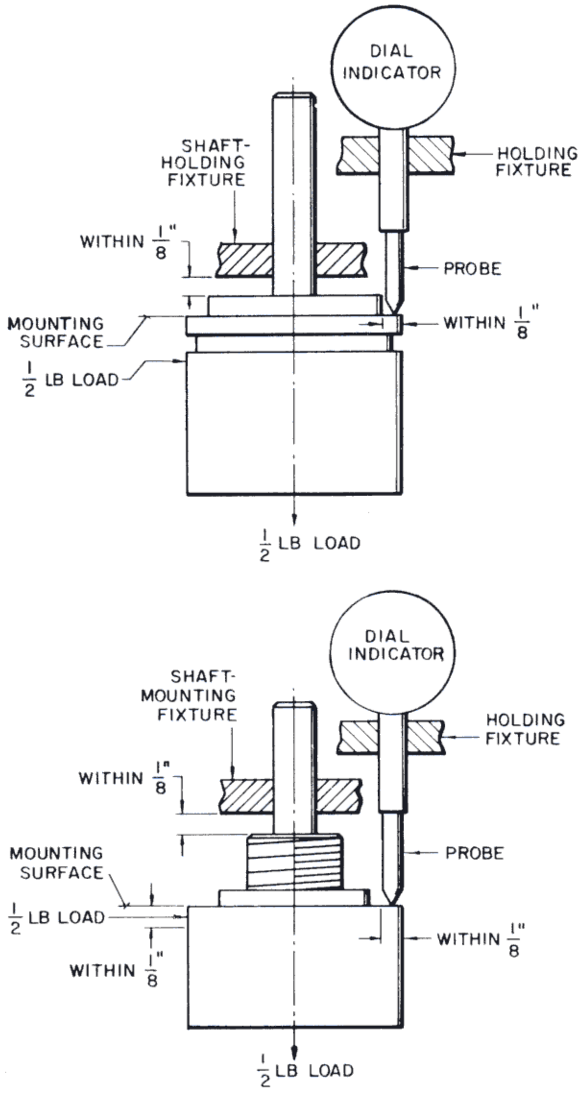


FIGURE 8.2A Measurement of lateral runout

8.3.2 ■ EQUIPMENT

Dial indicator	1.1.5
Dial indicator holding fixture	1.1.6
Potentiometer shaft holding fixture	1.1.7
Two dead weight loads	1.1.9
Surface plate or equivalent firm surface	

8.3.3 ■ TEST PROCEDURE (SEE FIGURE 8.3A) Make the measurement with the potentiometer mounted firmly in the shaft holding fixture and with the shaft axis in a vertical position. Clamp the shaft within 1/8 inch of the front surface of the potentiometer without interference and hold rigid with respect to the dial indicator. The potentiometer body is to remain free to rotate. Take care to insure that the shaft is not distorted in any way due to the mode of clamping or the inherent weight of the potentiometer body. Position the dial indicator such that its probe contacts the periphery of the pilot surface near the mid-point of the surface. Depress the probe sufficiently to insure a proper positive and negative indication. A 1/2 pound load is applied normal to the centerline of the shaft axis on the potentiometer body within 1/8 inch of the mounting surface to remove the Shaft Radial Play. For small diameter and/or long shafts reduce the magnitude of the load applied such that it never exceeds that which would cause the shaft to permanently deform. The body of the potentiometer is then slowly rotated through 360° or through the Total Mechanical Travel (3.1), whichever is less. The Pilot Diameter Runout is the total indicated reading determined by adding the maximum positive and negative readings without regard to algebraic signs.

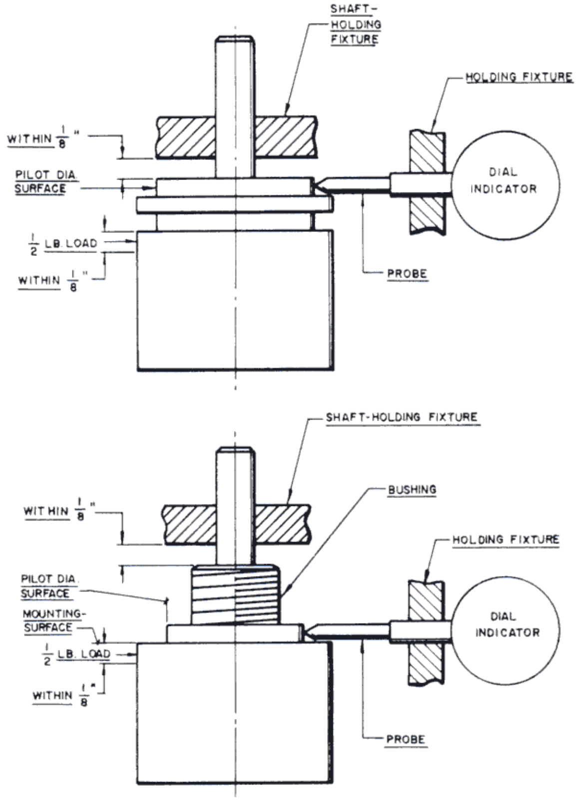


FIGURE 8.3A Measurement of pilot diameter runout

8.4 ■ SHAFT RADIAL PLAY

8.4.1 ■ OBJECT To measure the total radial excursion of the shaft with respect to the pilot diameter, indicated at a specified distance from the front surface of the potentiometer, with a specified radial load applied alternately in opposite directions at a specified point.

8.4.2 ■ EQUIPMENT

Dial indicator	1.1.5
Dial indicator holding fixture	1.1.6
Potentiometer mounting fixture	1.1.1
Dead weight load	1.1.9
Surface plate or equivalent firm surface	

8.4.3 ■ TEST PROCEDURE (SEE FIGURE 8.4A) Mount the potentiometer firmly with the shaft axis in a horizontal position and hold rigid with respect to the dial indicator. Position the dial indicator such that its probe contacts the shaft within 1/8 inch of the front surface of the potentiometer body. Depress the probe sufficiently to insure a proper positive and negative indication of the dial. A 1/2 pound load is applied normal to the shaft at a point 1/2 inch from the front surface of the potentiometer (or at the end of the shaft for shaft extensions less than 1/2 inch) in two opposite directions, one at a time, along the axis of the dial indicator probe (or perpendicular to the stylus if a pivot pointer indicator is used). Then rotate the plane of application of load 90° relative to the potentiometer body without rotating the shaft and then repeat procedure. For small diameter and/or long shafts reduce the magnitude of the load applied such that it never exceeds that which would cause the shaft to permanently deform. The Shaft Radial Play is the largest total indicated reading for either of the two readings. The total indicated reading is determined by adding the maximum positive and negative readings without regard to algebraic signs.

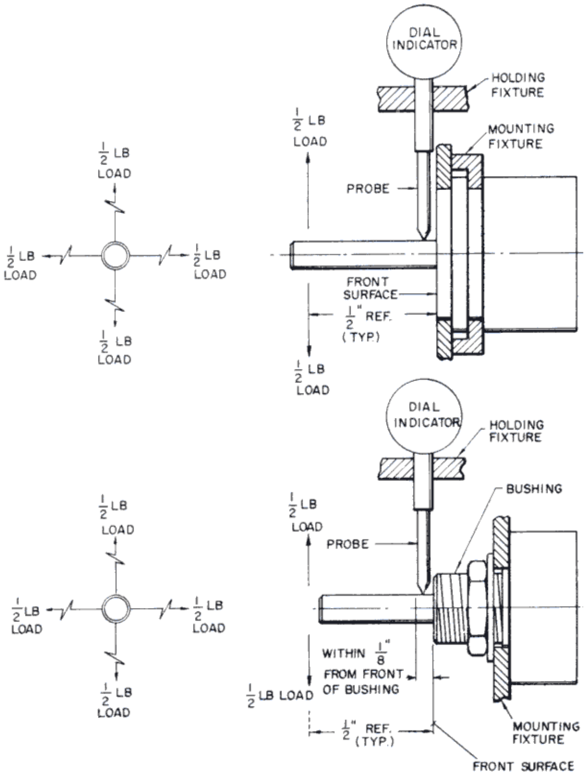


FIGURE 8.4A Measurement of shaft radial play

8.5 ■ SHAFT END PLAY

8.5.1 ■ OBJECT To measure the total axial excursion of the shaft with respect to the potentiometer body, indicated at the end of the shaft with a specified axial load applied alternately in opposite directions.

8.5.2 ■ EQUIPMENT

Dial indicator	1.1.5
Dial indicator holding fixture	1.1.6
Potentiometer mounting fixture	1.1.1
Dead weight load	1.1.9
Surface plate or equivalent firm surface	

8.5.3 ■ TEST PROCEDURE (SEE FIGURE 8.5A) The potentiometer is mounted firmly by its normal means with the shaft axis in a vertical position and held rigid with respect to the dial indicator, leaving the shaft free to rotate.

The dial indicator is positioned with its probe parallel (or normal if pivot pointer indicator is used) to the axis of the shaft and in contact with the end of the shaft on the centerline. The probe is depressed sufficiently to insure a proper positive and negative indication. A 1/2 pound load is applied alternately in opposite directions along the axis of the shaft. The Shaft End Play is the total indicated reading determined by adding the maximum positive and negative readings without regard to algebraic signs.

8.6 ■ STARTING TORQUE

8.6.1 ■ OBJECT To measure the maximum moment in the clockwise and counterclockwise directions required to initiate shaft rotation anywhere in the Total Mechanical Travel.

8.6.2 ■ EQUIPMENT

Potentiometer mounting fixture	1.1.1
Load device	1.1.4

8.6.3 ■ TEST PROCEDURE Mount the potentiometer firmly by its normal mounting means. Connect the load device to the potentiometer shaft so as to prevent relative movement between the two. A torque is applied through the load device and about the axis of the potentiometer shaft until shaft rotation is initiated. Care should be exercised to avoid applying radial or axial loads that will cause the shaft to deform or influence the measurement.

The procedure is followed for each direction of rotation at each obvious point of mechanical or electrical junction (e.g., ends of dead space, taps and shorts) and at three randomly selected points over the Total Mechanical Travel (3.1). The Starting Torque is the maximum indicated reading of the load device.

8.7 ■ RUNNING TORQUE

8.7.1 ■ OBJECT To measure the maximum moment in the clockwise and counterclockwise directions required to sustain uniform shaft rotation at a specified speed throughout the Total Mechanical Travel.

8.7.2 ■ EQUIPMENT

Potentiometer mounting fixture	1.1.1
Load device	1.1.4

8.7.3 ■ TEST PROCEDURE Mount the potentiometer firmly by its normal mounting means. Connect the load device to the potentiometer shaft so as to prevent relative movement between the two. Sufficient torque is applied through the load device and about the axis of the potentiometer shaft until a sustained uniform shaft rotation of 4 RPM is achieved. Care should be exercised to avoid applying radial or axial loads that will cause the shaft to deform or influence the measurement. This procedure is followed over the Total Mechanical Travel (3.1) in both the clockwise and counterclockwise directions. The Running Torque is considered to be the maximum reading of the load device.

8.8 ■ MOMENT OF INERTIA

8.8.1 ■ OBJECT To measure the mass Moment of Inertia of the rotating element of the potentiometer about its rotational axis.

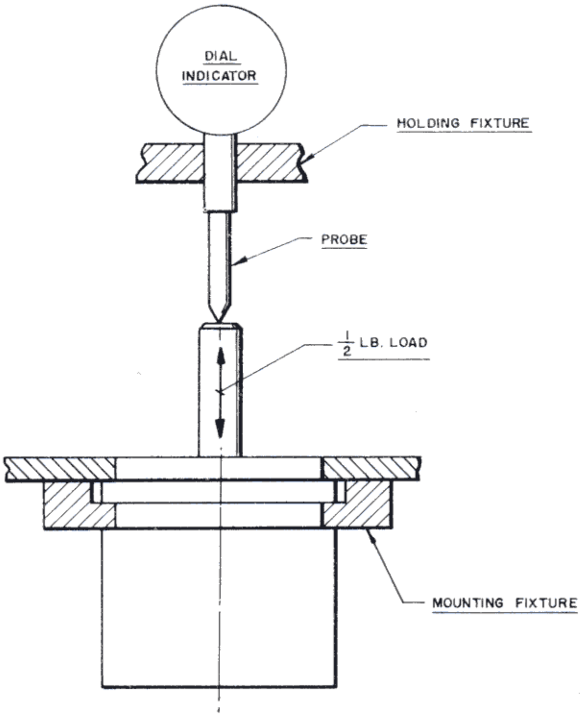


FIGURE 8.5A Shaft end play

Note: This procedure requires dismantling of the potentiometer and in this sense is considered destructive. Furthermore, it does not include the inertia of the inner races of ball bearings.

8.8.2 ■ EQUIPMENT

Steel wire (music wire)	
Moment of inertia adaptor	1.1.13
Mass of known inertia	1.1.14
Timing clock	1.1.15

8.8.3 ■ TEST PROCEDURE Suspend mass of known moment of inertia from the wire and adaptor such that the centerline of the known mass coincides with the centerline of the wire. With the wire attached to a rigid point, twist the known mass such that oscillation about the centerline will occur. Measure the period of oscillation. The system should be so located that air circulation of vibrations will not cause any swaying of the pendulum. Remove the known mass and connect the rotating elements of the potentiometer in the same manner to the wire and measure its period of oscillation. The Moment of Inertia of the rotating member of the potentiometer may then be determined from the following equation.

$$I_P = (I_S + I_A)\left(\frac{T_P}{T_S}\right)^2 - I_A$$

I_P = Moment of inertia of the rotating member in gm — cm²
I_S = Moment of inertia of the known mass in gm — cm²
I_A = Moment of inertia of the adaptor in gm — cm²
T_P = Period of rotating member of the potentiometer and adaptor in seconds
T_S = Period of known mass of adaptor in seconds

8.9 ■ STOP STRENGTH

8.9.1 ■ STATIC STOP STRENGTH

8.9.1.1 ■ OBJECT To determine the ability of the stop mechanism to withstand static load for a specified period of time without permanent change of the stop positions greater than specified.

This test is performed primarily for design evaluation and is not considered a routine inspection test. Therefore the measurements taken for Static Stop Strength have no relationship to the specified limits of other parameters such as Total Mechanical Travel, Mechanical Overtravel, etc.

8.9.1.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Load device	1.1.4
Shaft load adaptor	1.1.10

8.9.1.3 ■ TEST PROCEDURE Mount the potentiometer in the travel measuring device and securely lock the shaft to the travel indicator. The absolute readings are recorded at each end of the Total Mechanical Travel (3.1). Then apply the specified Static Stop Strength load to the stops and hold against the stop for 10 seconds at each end of the mechanical travel. The point of application of the load to the shaft should be within 1/8 inch of the front mounting surface of the potentiometer to avoid applying unwanted moments or load to the shaft. Final readings of the absolute values of the ends of Total Mechanical Travel are then taken in the same manner as the initial values. The differences between the final readings and their corresponding initial readings are the permanent changes of the stop positions. The permanent change should be no greater than 1° or 0.005″.

Note 1: It is realized that it may be difficult (if not impossible) to apply the Static Stop Strength load while the shaft remains locked to the travel measuring indicator. However, it is necessary for the purpose of this test not to disturb this relationship so that a change in relationship between the shaft and the resistance element can be detected. This change can be caused by a twisting or elongating of the shaft or a movement of the wiper mechanism relative to the shaft when the load is applied.

To accomplish this a coupling may be devised to connect the travel indicator to the pot shaft or modified shaft load adaptor in such a manner that the two may be disconnected and reconnected without losing the desired relationship. This assumes that the body of the potentiometer remains fixed throughout the test.

Note 2: A permanent attachment to the shaft may be required to permit large loads to be applied and prevent otherwise damaging the shaft. In this sense the test is considered destructive.

8.9.2 ■ DYNAMIC STOP STRENGTH

8.9.2.1 ■ OBJECT To determine the ability of the stop mechanism to withstand a specified inertia load, at a specified shaft velocity for a specified number of impacts, without a permanent change of the stop position greater than specified.

This test is performed primarily for design evaluation and is not considered a routine inspection test. Therefore the measurements taken for Dynamic Stop Strength have no relationship to the specified limits of other parameters such as Total Mechanical Travel, Mechanical Overtravel, etc.

8.9.2.2 ■ EQUIPMENT

Travel measuring device	1.1.3
Inertia load	1.1.11
Shaft load adaptor	1.1.10

8.9.2.3 ■ TEST PROCEDURE Mount the potentiometer in the travel measuring device and securely lock the shaft to the travel indicator. The absolute readings are recorded at each end of the Total Mechanical Travel (3.1). Without disturbing the relationship of the shaft and the travel indicator (see Note 1), the potentiometer is coupled to the specified inertia load. The point of application of the load to the shaft should be within 1/8 inch of the front mounting surface of the potentiometer to avoid applying unwanted moments or loads to the shaft. The load is then caused to move toward one stop at a specified constant velocity. The input energy is removed just prior to the pot shaft reaching the stop such that the inertia load may freely move into the stop without excessive external braking or energy input. The direction of displacement of the load is reversed and the procedure repeated. This procedure is repeated for a total of 100 impacts at each stop. At the conclusion the absolute values of the ends of the Total Mechanical Travel are again measured and recorded. The differences between the final readings and their corresponding initial readings are the permanent changes of the stop positions. The permanent change should be no greater than 1° or 0.005″.

Note 1: It is realized that it may be difficult (if not impossible) to apply the Dynamic Stop Strength load while the shaft remains locked to the travel measuring indicator. However, it is necessary for the purposes of this test not to disturb this relationship, so that a change in relationship between the shaft and the resistance element can be detected. This change can be caused by a twisting or elongating of the shaft or a movement of the wiper mechanism relative to the shaft when the load is applied.

To accomplish this a coupling may be devised to connect the travel indicator to the pot shaft or modified shaft load adaptor in such a manner that the two may be disconnected and reconnected without losing the desired relationship. This assumes that the body of the potentiometer remains fixed throughout the test.

Note 2: A permanent attachment to the shaft may be required to permit large loads to be applied and prevent otherwise damaging the shaft. In this sense, the test is considered destructive.

■ □ ■