12 July 1968

Materiel Test Procedure 5-2-539
White Sands Proving Ground

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

MISSILEBORNE ELECTRICAL POWER SUPPLY TESTS

1. OBJECTIVE

The objective of this Materiel Test Procedure is to determine the ability of missileborne electrical power supplies to meet specified requirements, based on a comprehensive evaluation of their performance characteristics and limitations.

2. BACKGROUND

The acceptability of a power supply for a given function or usage depends ultimately on its ability to reliably satisfy design parameters and equipment specifications under a variety of dynamic conditions. Power supply tests such as those contained herein allow the engineer to effectively evaluate the performance of a given power supply in order to ensure proper design, eliminate problem areas and maintain quality throughout production.

3. REQUIRED EQUIPMENT

a. AC Ammeter
b. AC Voltmeter
c. AC Wattmeter
d. DC Ammeter
e. DC Voltmeter
f. Oscilloscope
g. Wave Analyzer
h. Interval Timer
i. Phase Meter
j. Frequency Counter
k. Time Printer
l. Marker Filter Network
m. Low Pass Filter
n. Power Switch
o. 5-Position Switch
p. AC/DC Differential Voltmeter
q. AC/DC VTVM with recorder output terminals
r. 2-Channel direct writing recorder
s. Voltmeter with high voltage probe
t. Ohmmeter or Impedance Bridge
u. Sawtooth Wave Generator
v. Square Wave Generator
w. Variable Primary Power Source
x. Load Resistor Network, Non Inductive, Rated at 25%, 50%, 75% and 100% of full load.
y. Relay, Sensitive to SQ WF Output
z. Reactive Load Network Similar to LSR.

4. REFERENCES

A. ASA Z32.13.1950, Abbreviations For Use On Drawings, American Standards Association, New York, New York, 1950.
B. Kuehn, Martin H., Mathematics For Electricians, McGraw-Hill Book Company, Inc., New York, New York, 1949.
C. Packard, Charles A., Relay Engineering, Struthers-Dunn, Inc., Phila., Pa., 1954.
D. Laws, Frank A., S.B., Electrical Measurements, McGraw-Hill Book Company, Inc., New York, New York, 1938.

5. SCOPE

5.1 SUMMARY

This Materiel Test Procedure describes the following subtests applicable to missileborne electrical power supplies:

a. Power supply warm-up subtest - The objective of this subtest is to measure the time lapse between the application of primary power and the attainment of stable operation. (Not applicable to batteries).
b. Power supply accuracy and stability subtest - The objective of this subtest is to measure the variation in output voltage over a given time period. (Not applicable to radio frequency power supplies and batteries.)
c. Power supply output voltage regulation subtest - The objective of this subtest is to measure the ability of a power supply to compensate for variations of input voltage and output load resistance.
d. Power supply efficiency subtest - The objective of this subtest is to measure the output power of a power supply compared to the input power.
e. Power supply harmonic distortion subtest - The objective of this subtest is to measure the variations from a pure sine wave of the AC output of a power supply.
f. Power supply ripple content subtest - The objective of this subtest is to measure the ability of filtering components to remove electrical noise from the DC output of a power supply.
g. Relay functions subtest - The objective of this subtest is to measure the amount of delay caused by relay response time and the electrical resistance as measured across the contacts of a power control relay.
h. Power supply frequency stability subtest - The objective of this subtest is to measure the variations in the output frequency of a D-C to A-C power supply or inverter.
i. Power supply frequency analysis subtest - The objective of this subtest is to measure the relative amplitude of various inverter output frequencies.
j. Power supply phase unbalance subtest - The objective of this subtest is to measure the relative amplitude of each output phase of an inverter.
k. Power supply phase angle subtest - The objective of this subtest is to detect the phase displacement in inverter outputs.
l. Battery life subtest - The objective of this subtest is to measure the length of time a battery will produce an acceptable output under load.

5.2 LIMITATIONS

Due to the wide variety of electrical power supplies, this MTP will be restricted to testing methods quite general in nature; however, they may be adapted as required to accommodate specified units.

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 Pretesting Procedures

a. Personnel responsible for conducting the test should ensure that applicable design specifications and instructions are available.

b. Operating instructions for test instruments to be used in the conduct of the test should be obtained and available to test personnel.

c. A test log book or folder should be prepared and utilized to record data during tests.

d. Ensure that all test instruments have been calibrated to within desired tolerances and possess a current calibration tab.

e. Ensure that test personnel are familiar with power supplies they are to test and fully qualified in the use of the associated test equipment.

f. Brief test personnel on the purpose of the test, responsibilities of each, functions to be performed during testing, and the degree of accuracy expected.

g. Ensure that the input impedence of monitoring equipment is high enough to avoid circuit loading.

6.1.2 Preparation of Test Log

Data to be recorded in the test log prior to testing shall include but not be limited to the following:

a. Name of particular subtest
b. Nomenclature and serial number of the test item
c. Characteristics to be measured

6.2 TEST CONDUCT

6.2.1 Power Supply Warm-up Subtest

a. Connect equipment according to the test configuration, shown in the appendix, appropriate for the particular power supply being tested.

b. Allow sufficient warm-up time for the test equipment and primary power source to permit stable operation.

c. Monitor the output of the power supply under test with an appropriate meter; oscilloscope or other device.

d. Measure the time lapse between the initial application of primary power to the test power supply and the appearance of an output stable in amplitude and/or frequency.

e. Record the time required to attain stability.

f. Repeat the above procedures a minimum of three times.

6.2.2 Power Supply Accuracy and Stability Subtest

a. Connect equipment according to the test configuration used in 6.2.1.

b. Following the warm-up subtest, monitor the output of the power supply under test with an appropriate voltmeter for twenty minutes.

c. Measure and record the output voltage of the power supply under test every 30 seconds.

NOTE: The above subtest is not applicable to RF power supplies and batteries.

6.2.3 Power Supply Voltage Regulation Subtest

a. Connect equipment according to test configuration used in 6.2.1.

b. Turn equipment on and allow sufficient time for warm-up and stabilization of test power supply output.

c. Monitor and record the output voltage of the test power supply under full load conditions with the specified input voltage applied.

d. Vary the load resistance from full load to an open circuit condition.

e. Measure and record the output voltage of the test power supply for each load condition.

f. Decrease the input voltage to the test power supply by 10% steps.

g. Measure and record the output voltage of the test power supply for each load condition.

NOTE: If a noticeable variation in output voltage is noted in g. above, the input voltage is decreased in increments of 1% and recorded in each load condition until normalcy occurs.

h. Repeat steps f & g for 10% increases in input voltage.

NOTE: These procedures (6.2.3) are not applicable to batteries.

6.2.4 Power Supply Efficiency Subtest

a. Connect equipment according to test configuration used in 6.2.1.

b. Turn equipment on and allow sufficient time for warm-up and stabilization of test power supply output.

c. Measure and record the input power to the test supply.

d. Measure and record the output power of the test power supply.

e. Vary the input power in 10% steps, a minimum of 10 times and repeat procedures c. and d. above.

NOTE: The above procedures are not applicable to batteries.

6.2.5 Power Supply Harmonic Distortion Subtest

a. Connect equipment according to test configuration used in 6.2.1.

b. Turn equipment on and allow sufficient time for warm-up and stabilization of test power supply output.

c. Adjust the wave analyzer to the fundamental frequency of the power supply.

d. Measure and record, with the wave analyzer, the output voltage and frequency of the test power supply.

e. Increase the wave analyzer frequency until another peak output occurs.

f. Measure and record the output voltage and frequency of the test power supply.

g. Repeat steps e. and f. until no further peaks occur.

NOTE: The above procedures are applicable only to power supplies producing an AC output.

6.2.6 Power Supply Ripple Content Subtest

a. Select an appropriate test configuration from the appendix according to the output of the test power supply and connect equipment as indicated.

b. Turn on equipment and allow sufficient time for warm-up.

c. Measure and record the amplitude of the power supply output ripple voltage with an oscilloscope while the test power supply is operating under full load.

d. Measure and record the DC output voltage of the test power supply while the power supply is operating under full load.

e. Decrease the load in 25% increments down to no load and repeat procedures c. & d. above.

NOTE: The above procedures are not applicable to power supplies producing A-C outputs.

6.2.7 Relay Functions Subtest

a. Connect equipment according to the configurations shown in the appendix for power supply relays.

b. Isolate the test item (power control relay or transfer switch) from all other circuits.

c. Energize the test item.

d. Measure and record the resistance across the contacts of the test item with an ohmmeter with the relay contacts in the open position.

e. Repeat step d. above with the relay contacts in the closed position.

f. Monitor and record, with an oscilloscope using a delayed sweep mode, the relay response time.

6.2.8 Power Supply Frequency Stability Subtest

a. Connect equipment according to the configuration shown in the appendix for an inverter, or other DC to AC power supply.

b. Connect a frequency counter across the load resistor.

c. Turn equipment on and allow sufficient warm-up time.

d. Measure and record, with the frequency counter connected as in c. above, the frequency across the load resistor at 30 second intervals during a 5 minute period.

6.2.9 Frequency Analysis Subtest

a. Select the appropriate test configuration in the appendix and connect equipment as indicated.

b. Connect a wave analyzer across the load resistor.
c. Turn equipment on and allow sufficient warm-up time.
d. Measure and record all frequencies present on the wave analyzer.

6.2.10 Power Supply Phase Unbalance Subtest

a. Arrange and connect equipment according to procedure given in 6.2.9 a.
b. Energize equipment.
c. Measure and record, using a VTVM with recorder terminals and a recorder, the voltage amplitude of each output phase of the inverter under each load condition. (Zero to full load in 10% increments).
d. Substitute reactive loading components for the purely resistive network and monitor and record as in c. above.
e. Mark the recorder tape to identify each combination of phase and loading.

6.2.11 Power Supply Phase Angle Test

a. Connect equipment according to procedure given in 6.2.9 a.
b. Use a phase meter or oscilloscope to measure the phase angles under load conditions in 6.2.10.
c. Record measured phase angles.

6.2.12 Battery Life Test

a. Charge battery (if applicable) according to manufacturers instructions.
b. Arrange and connect equipment according to figure 11 page A-6 shown in the Appendix.
c. Energize equipment.
d. Measure and record the time the circuit is connected to the battery.
e. Measure and record the time the output voltage or current drops below an acceptance level.

6.3 TEST DATA

6.3.1 Power Supply Warm Up Subtest

a. Record the time lapse, between the initial application of primary power to the test power supply and the appearance of a stable output, in seconds.
b. Record each repetition.

6.3.2 Power Supply Accuracy and Stability Subtest

Record the output voltage, of the power supply under test, in volts every 30 seconds.

6.3.3 Power Supply Voltage Regulation Subtest

a. Record the output voltage in volts, of the test power supply, under full load conditions with the specified input voltage applied.
b. Record the output voltage in volts, of the test power supply, under each load condition, (full load to no load), with the specified input voltage applied.

c. Record the output voltage in volts, of the test power supply, for each load condition in b. above, as the input voltage is decreased by 10% steps.

d. Record as above in c. for increases of input voltage by 10% steps.

6.3.4 Power Supply Efficiency Subtest

a. Record the input power to the test power supply in watts.

b. Record the output power of the test power supply in watts.

c. Repeat recordings in a. & b. above as the input power is varied in 10% steps a minimum of 10 times.

6.3.5 Power Supply Harmonic Distortion Subtest

a. Record the output voltage in volts at the fundamental frequency.

b. Record the fundamental frequency in cp's from the wave analyzer.

c. Record output voltage in volts at each successive frequency.

d. Record each successive frequency in cp's until no further peaks occur.

6.3.6 Power Supply Ripple Content Subtest

a. Record the amplitude in volts of the test power supply output ripple voltage as indicated on the oscilloscope, while the test power supply is operating under full load conditions.

b. Record the D-C output voltage in volts, of the test power supply while operating under full load conditions.

c. Repeat recordings as in a. & b. above as the load is decreased in 25% increments down to no load.

6.3.7 Relay Functions Subtest

a. Record the resistance,in ohms, across the contacts of the test item with the relay contacts in the open position.

b. Record the resistance, in ohms, across the contacts of the test item with the relay contacts in the closed position.

c. Record in seconds, the relay response time.

6.3.8 Power Supply Frequency Stability Subtest

Record the frequency across the load resistor, measured by the frequency counter, in cycles per second, at 30 second intervals during a 5 minute period.

6.3.9 Frequency Analysis Subtest

Record in cycles per second, all frequencies present on the wave analyzer.

6.3.10 Power Supply Phase Unbalance Subtest

a. Record, using a VTVM with recorder terminals and a recorder, the voltage amplitude of each output phase of the inverter under each load condition, (0 to full load), in volts.

b. Record as above, the voltage amplitude of each output phase of the inverter in volts, under each load condition, when the resistive network load is replaced by reactive loading components.

6.3.11 Power Supply Phase Angle Test

Record measured phase angles for each load condition (0 to full load).

6.3.12 Battery Life Test

Record the elapsed time in seconds, between the time of initial closing of the battery circuit and the time at which output voltage or current drops below an acceptable level.

6.4 DATA REDUCTION AND PRESENTATION

6.4.1 Power Supply Warm-Up Subtest Data

a. Determine from data recorded in 6.3.1, the average warm-up time for the test Power Supply.

b. Compare average warm-up time, as determined above, with the prescribed warm-up time for the particular power supply being tested and determine if tolerances are adhered to.

6.4.2 Power Supply Accuracy and Stability Subtest Data

a. Plot a graph with time on the horizontal axis and recorded output voltages on the vertical axis.

b. Examine curve to determine if the output voltage fluctuates within tolerable limits.

6.4.3 Power Supply Output Voltage Regulation Subtest Data.

a. Plot graphs for each load condition, showing input voltage on the x-axis and output voltage on the y-axis.

b. Calculate the % of regulation as follows:

$$\% \text{ Regulation} = \frac{E_{NL} - E_L}{E_L} \times 100$$

Where: E_{NL} = Output without load

E_L = Output with load

and % Regulation

c. Examine graphs to determine if output voltages and regulation are within acceptable limits.

6.4.4 Power Supply Efficienty Subtest

a. Calculate the % efficiency of the test power supply from data recorded in 6.3.4 as follows:

$$\% \text{ Efficiency} = \frac{\text{output power}}{\text{input power}} \times 100$$

b. Compare calculated % efficiency with system prescribed values and determine whether acceptable.

6.4.5 Power Supply Harmonic Distortion Subtest Data

a. Calculate the % of harmonic distortion (d), from data recorded in 6.3.5, as follows:

$$\% (d) = \frac{a_2^2 + a_3^2 + a_n^2}{a_1} \times 100$$

Where: a = Amplitude of the fundamental frequency

a_2, a_3, a_n, etc = Amplitude of

b. Plot a graph on the amplitude of the harmonics versus the frequency showing the harmonic number on the x-axis and the amplitude on the y-axis.

c. Compare the calculated % distortion and the graph of the harmonics to prescribed tolerances and determine if within acceptable limits.

6.4.6 Power Supply Ripple Content Subtest Data

a. Compute the % ripple voltage for each load condition using data recorded in 6.3.6, as follows:

$$\% \text{ Ripple voltage} = \frac{E_R \times 100}{E_{DC}}$$

Where: E_R = Peak to peak amplitude of ripple voltage

E_{DC} = d-c output voltage

b. Compare % ripple voltage calculated to % ripple voltage prescribed for test item and determine if within acceptable limits.

6.4.7 Relay Functions Subtest Data

Compare recorded resistance and relay response time to manufacturer's specifications to determine if within acceptable limits.

NOTE: Normal Relay action produces a waveform similar to that shown below:

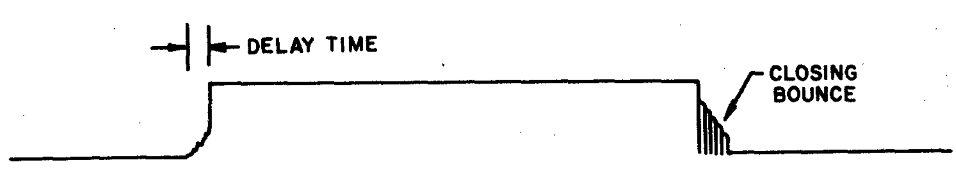


Figure 1. (Typical Relay Operation Waveform)

6.4.8 Power Supply Frequency Stability Subtest Data

a. Plot a graph showing time on the x-axis and frequency on the y-axis, with data recorded in 6.3.8.
b. Compare plotted curve with prescribed data to determine is stability is acceptable.

6.4.9 Power Supply Frequency Analysis Subtest Data

a. Plot a graph showing frequency on the x-axis and amplitudes on the y-axis.
b. Same as 6.4.8 b. above.

6.4.10 Power Supply Phase Unbalance Subtest Data

Compare data recorded in 6.3.10 with system tolerances to determine if outputs are acceptable.

6.4.11 Power Supply Phase Angle Subtest Data

Compare recorded phase angles for various loading conditions with phase angles prescribed for the system and determine if discrepancies are within acceptable limits.

6.4.12 Battery Life Subtest Data

Compare battery life as recorded in 6.3.12 with the specified life time to determine if acceptable.

APPENDIX

POWER SUPPLY TEST CONFIGURATIONS

A. A-c to A-c Power Supplies

A-c to a-c power supplies are designed to convert the output of a primary a-c power source to an a-c voltage and current of values different from the source. A suggested test configuration to be used to perform the tests is shown in Figure 2.

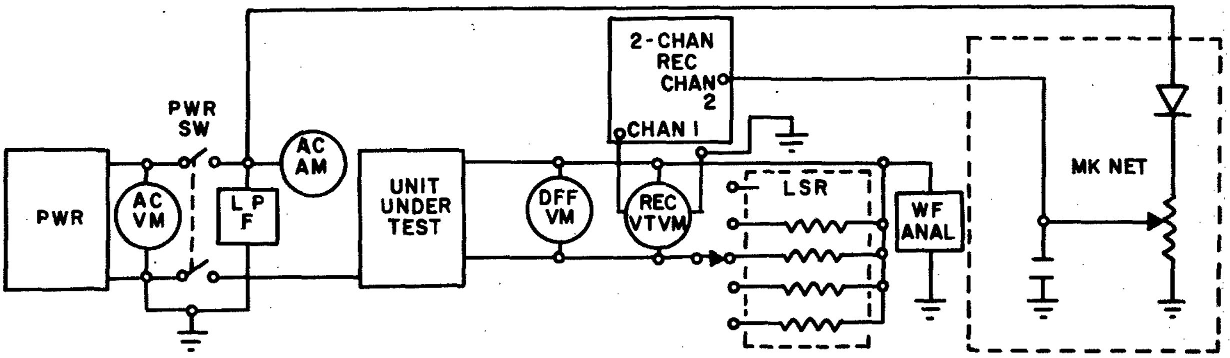


Figure 2. A-c to A-c Power Supply Test Configuration

B. A-c to D-c Power Supplies

A-c to d-c power supplies are designed to convert the output of a primary a-c power source to d-c power of the proper voltage and current values. A suggested test configuration to be used to perform the tests is shown in Figure 3.

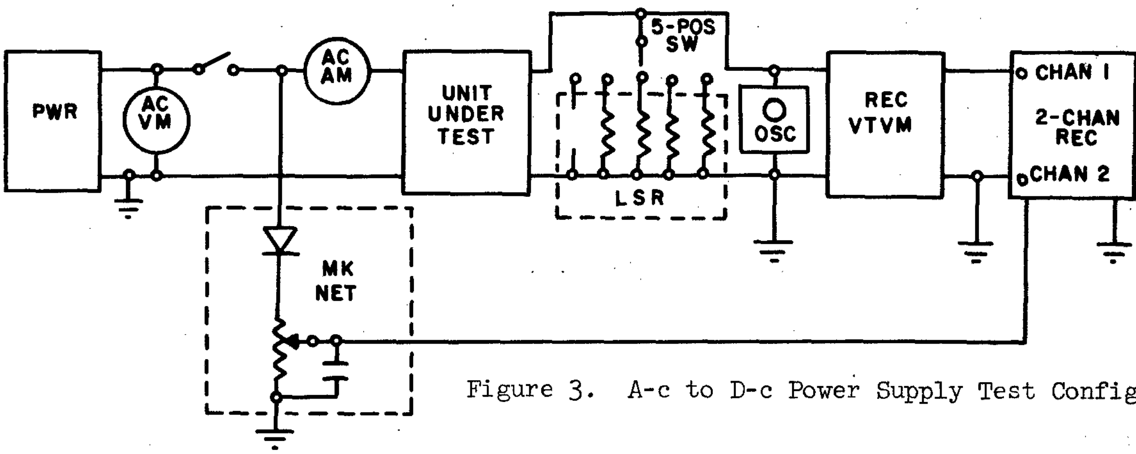


Figure 3. A-c to D-c Power Supply Test Configuration

C. D-c to A-c Power Supplies

D-c to a-c power supplies are designed to convert the output of a primary d-c power source to a-c power of the desired voltage, frequency, and current. Both the mechanical type (choppers and vibrators) and the electronic type (multi-vibrators and oscillators) can be tested by using these procedures. A suggested test configuration to be used to perform the tests is shown in Figure 4.

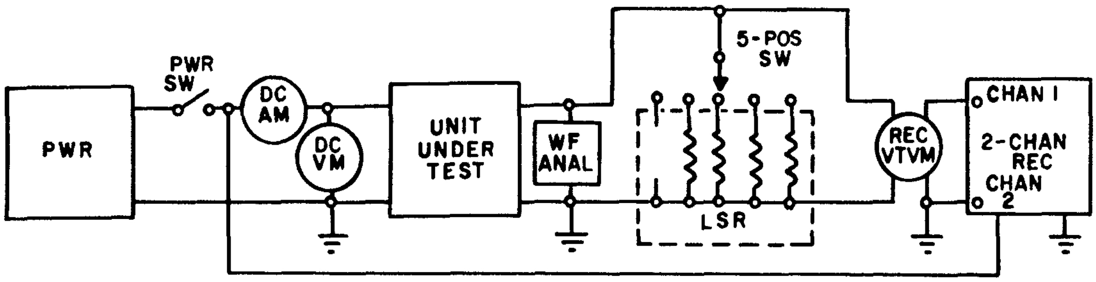


Figure 4. D-c to A-c Power Supply Test Configuration

D. D-c to D-c Power Supplies

D-c to d-c power supplies are designed to convert the output of a primary d-c power source to a different level of d-c. With the exception of a rectified and filtered output, they are similar to the d-c to a-c power supplies. A suggested test configuration to be used to perform the tests shown in Figure 5.

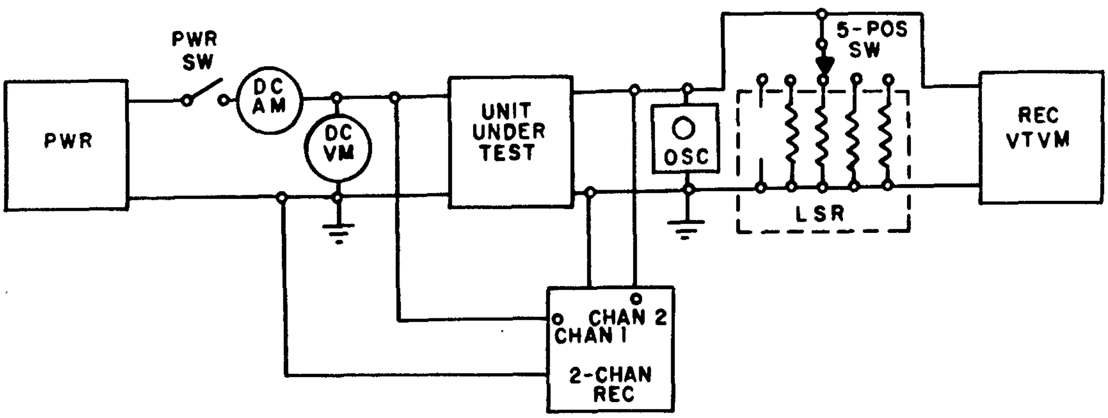


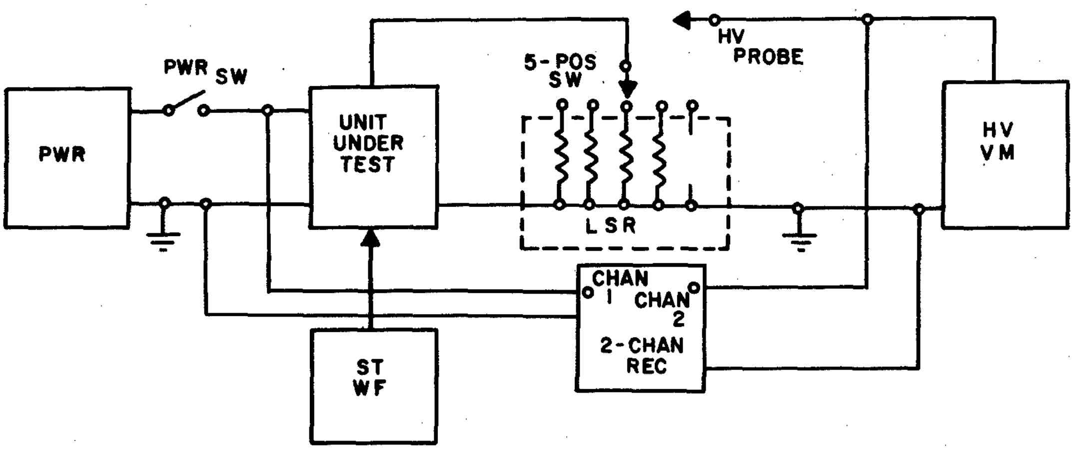
Figure 5. D-c to D-c Power Supply Test Configuration

E. RF Power Supplies

An RF power supply uses a local oscillator operating at radio, frequencies to provide the electronic equipment with the required operating potentials. The generated voltage is coupled through a transformer to a rectifier and a filter circuit to produce the desired d-c output. Either a conventional RF power supply, a triggered RF power supply, or a flyback power supply may be tested by using the procedures outlined in this MTP. A suggested test configuration to be used to perform the tests is shown in Figure 6.

WARNING

Severe electrical shock and RF burn can result from close proximity to high voltage contacts (direct contact is unnecessary, since the voltages are capable of arcing several inches).



Note

Sawtooth wave generator may be omitted when testing power supplies with self-contained oscillators.

Figure 6. Radio Frequency Power Supply Test Configuration

F. Motor Generators

The three types of motor generators are the dynamotor, rotary converter, and inverter.

1. Dynamotors -- A dynamotor is a motor driven generator used to convert a d-c input voltage to a higher or lower level of d-c. The armature windings of the motor and the generator are wound on the same rotor, each electrically independent. Both motor and generator use the same stator field winding. One set of brushes is used as the input and the other is used as the output. The input-to-output voltage ratio is directly proportional to the turns ratio of the armature windings of the motor and the generator. The output must be filtered to remove brush noise. A suggested test configuration to be used to perform the tests is shown in Figure 7.

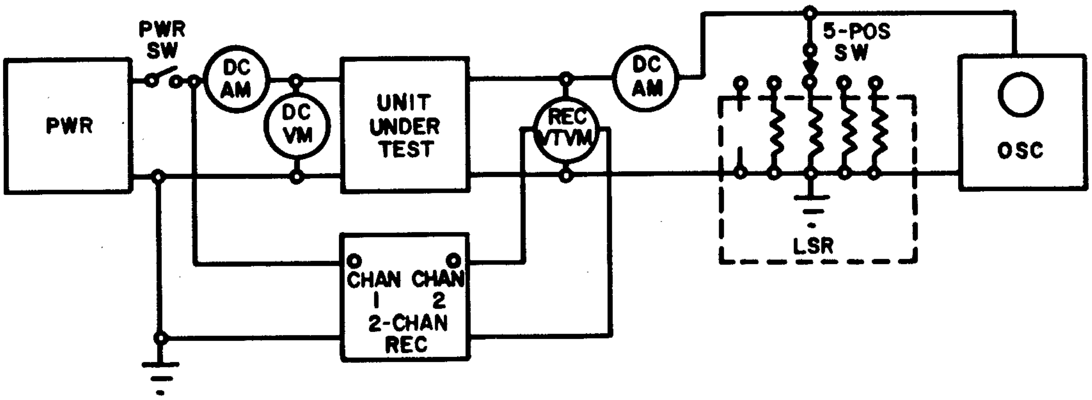


Figure 7. Dynamotor Test Configuration

2. Rotary Converters -- A rotary converter, as used to change a-c to d-c, consists of an a-c motor and a generator, with the armature windings wound separately on the same rotor and operating in the same stator field. It operates at its rated rotational speed as a synchronous motor, using either single phase or polyphase a-c. The a-c input is applied to the motor through slip rings, while the d-c output is taken from the commutator by brushes. By taking the output from a second set of slip rings, rather than brushed, either a single phase or polyphase a-c output is available, of the same or a different frequency as determined by the design of the converter. A suggested test configuration to be used to perform the tests is shown in Figure 8.

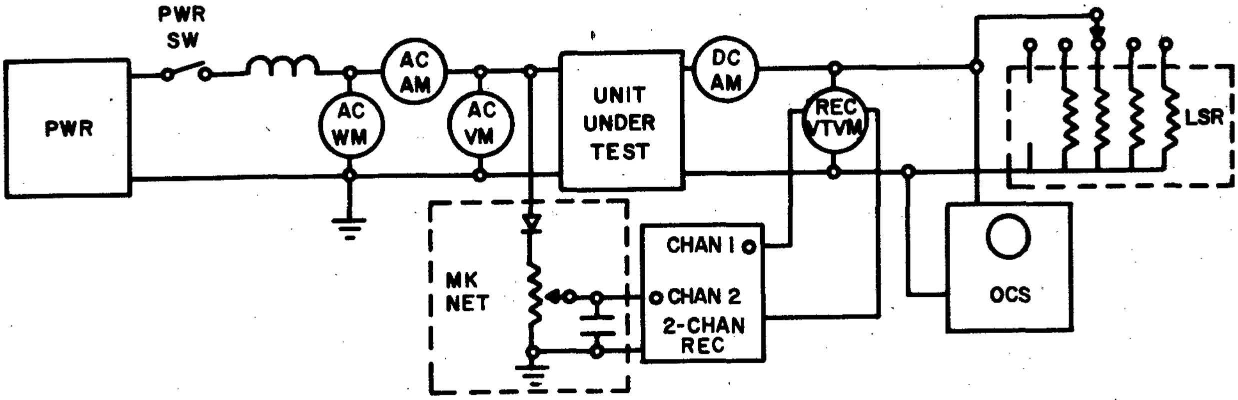


Figure 8. Rotary Converter Test Configuration

3. Inverters -- An inverter is used to change d-c to a-c. It consists of a d-c motor and a-c generator with armature windings wound separately on the same rotor; however, they operate in two different stator fields. It also can produce either single phase or polyphase a-c voltage. An inverter can operate with a single stator field; however, the rotational speed and frequency are not as stable; therefore the single stator field is not normally used in military applications. A suggested test configuration is to be used to perform the tests is shown in Figure 9.

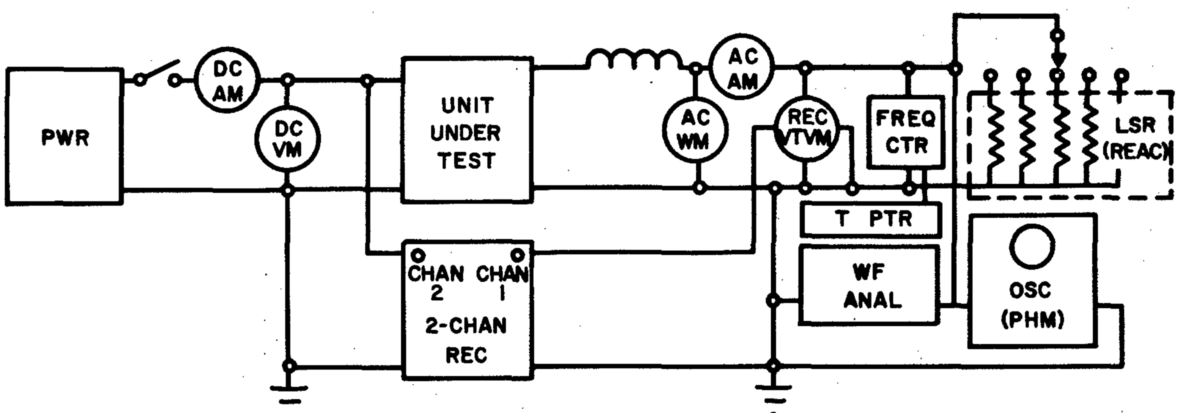


Figure 9. Inverter Test Configuration

G. Relays

A relay or transfer switch is often used to delay the connection of an electrical load until the motor generator has attained its normal operating speed. This ensures that the electrical components, served by the motor generator, will not be subjected to incorrect voltages or frequencies. A suggested test configuration to be used to perform the tests is shown in Figure 10.

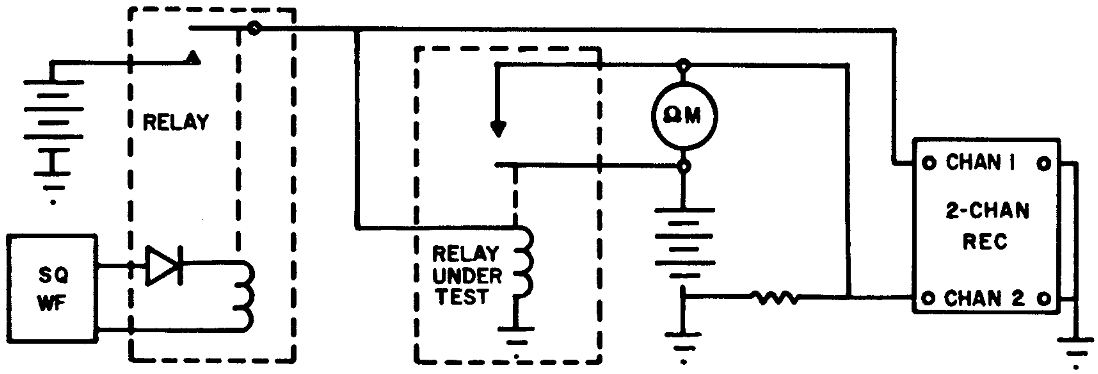


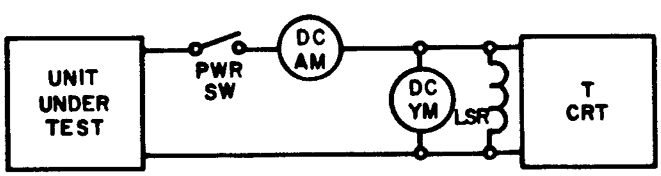
Figure 10. Power Control Relay Test Configuration

H. Battery Power Supplies

Battery power supplies consist of chemically charged cells. They may be either of the dry cell type or of the type which uses a wet electrolyte.

1. Dry Cells -- Dry cells are always energized, and usually have a long shelf life when stored under the proper conditions of temperature and humidity. They are not rechargeable.

2. Wet Cells -- Wet cell batteries may be stored for extremely long periods when separated from the electrolyte. In many wet batteries, the chemical action which takes place during discharge can be reversed by applying a charging current to flow in the direction opposite to the discharge current. A suggested test configuration to be used to perform the test is shown in Figure 11.



Figur 11. Battery Test Configuration