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

MISSILEBORNE GAS OPERATED POWER SUPPLY TESTS  
(PNEUMATIC AND HOT GAS)

1. OBJECTIVE

The objective of this procedure is to ascertain pertinent characteristics of missileborne gas operated power supplies.

2. BACKGROUND

Gas operated power supplies usually are operated by compressed air or hot gas and are used in missileborne applications to motivate the control systems, drive electrical power supplies, or both. Pneumatic power supplies, at one time widely used in missileborne applications, largely have been supplanted by hot gas power supplies. Since the hot gas power supply stores no pressure until just prior to launch, no long-term leakage problems arise. The same operational and testing principles apply to both types of power supplies.

Engineers and other personnel actively engaged in the testing and evaluation of power supplies have developed over a long period of time certain standard procedures for testing. Properly used, these procedures readily determine the acceptability of power supply for an intended use. The power supply must adhere to design parameters and manufacturer's specifications to be accepted.

3. REQUIRED EQUIPMENT

- a. Pressure Actuated Electrical Switch
- b. Electrical Timer or Mechanical Timer
- c. Dummy Load (electrical resistor bank, actual missile components, or in the case of a simple power supply: mechanical globe valve).
- d. Pressure Transducer
- e. Oscillograph (four channel capability)
- f. Amplifier (capable of step or ramp inputs)
- g. Flow Meter
- h. Thermocouple
- i. Centrifuge
- j. Tachometer
- k. Vibrating Table
- l. Pneumatic Tester
- m. Voltmeter

4. REFERENCES

- A. AF Manual 52-31, Guided Missiles Fundamentals, Dept. of the Air Force, Washington, D. C., 20 September 1957

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- B. Shepherd, D.G., Principles of Turbomachinery, The Macmillan Company, New York
- C. Van Nostrand, D., International Dictionary of Physics and Electronics, D. Van Nostrand Co., Inc., New York

5. SCOPE

5.1 SUMMARY

This MTP describes the following tests:

- a. Starting Time Test - A test to determine the time required for the power supply to attain the rated operational speed.
- b. Pressure Regulation Tests - Tests of the ability of the pneumatic system to maintain a uniform pressure.
- c. Power Capability Tests - Tests to determine if the unit will produce adequate power under variable load conditions.
- d. Fuel Consumption and Onboard Run Time Test - Tests to determine the length of time the unit will produce adequate power.
- e. Operating Life and Wear Resistance Test - A test of the durability of the power supply.
- f. Operating Positions Test - A test to determine the effect of acceleration on the power supply operation.
- g. Resonant Spectrum Test - A test to determine the effect of vibrational frequencies on the power supply operation.
- h. Leakage Test - A test to determine the extent of valve and fitting leakage.
  - 1. Relief Valve Test - A test to determine the relief valve opening and closing pressures.
  - j. Hydrostatic Test - A test to determine the maximum pressure the unit will withstand.
  - k. Overspeed Test - A test to determine the maximum intermittent rotational speed the unit will safely withstand.

5.2 LIMITATIONS

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

6. PROCEDURES

6.1 PREPARATION FOR TEST

- a. Testing personnel shall be familiar both with the power supplies they are to test and the test equipment to be utilized in the aforementioned testing.
- b. Prior to the test, all pertinent technical manuals, manufacturer's specifications/drawings, etc. shall be reviewed to permit a proper selection of test equipment and accessories.
- c. The individual items of test and monitoring equipment required must be selected with due consideration of the requirements and capabilities of the power supply being tested.

NOTE: In general, test equipment and accessories shall have an accuracy of at least ten times that of the unit being tested.

d. The desired test conditions shall be selected.

NOTE: The test conditions that may be required for gas operated power supply evaluation are classified in three general categories:

1. Tests conducted at laboratory room ambient conditions.
2. Tests conducted in a specified environment and then compared to the results of similar tests previously conducted at laboratory room ambient conditions.
3. Tests conducted in a specified environment and then repeated at laboratory room ambient conditions.

## 6.2 TEST PROCEDURES

### 6.2.1 Starting Time, Fuel Consumption, and Running Time Tests

a. The equipment shall be arranged as shown in Figure 1.

NOTE: The load illustrated can be either the actual missile components or a bank of resistors of suitable power ratings. In the case of a simple power supply, a globe valve will suffice. The timer may be either electrical or mechanical, depending upon the time durations and tolerances involved.

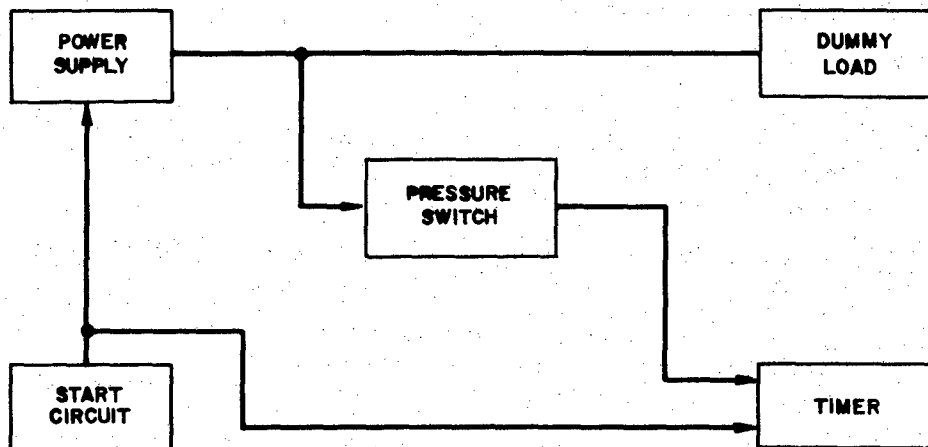


FIGURE 1. STARTING TIME TEST CONFIGURATION

b. The dummy load shall be adjusted to the value expected in flight conditions.

NOTE: Firing test data shall be used to arrive at logical load values and frequencies.

c. The power supply shall be started by application of the start signal.

d. The time interval between the application of the start signal and the occurrence of the specified output pressure of the power supply shall be measured and recorded.

e. The length of time that power supply pressure satisfies specification requirements shall be determined and recorded.

f. Turn power supply off.

g. Repeat steps c through f nine more times.

NOTE: Starting Time, Fuel Consumption, and Running Time Tests are combined in the above procedures in order to reduce the number of runs required and to allow a correlation between starting time and running time.

#### 6.2.2 Operating Life and Wear Resistance Test

a. Determine and record the number of times the combination of tests outlined in paragraph 6.2.1 can be conducted before the power supply output fails to meet the specifications.

b. After the power supply serviceability has dropped below acceptable standards, the wear as indicated by the change in fit of mating moving parts shall be noted and recorded.

#### 6.2.3 Pressure Regulation Tests

##### 6.2.3.1 Static Test

a. A static load, consisting of a resistance bank of specified value, shall be connected across the output of the alternator.

b. Instrumentation shall be set up to measure and record the output pressure and voltage of the power supply.

NOTE: An oscillograph shall be used to record the measured gas pressure and output voltage.

c. The power supply shall be operated at a steady state condition and the gas pressure and output voltage shall be recorded.

d. The resistance of the resistance bank shall be changed to simulate another static load condition.

e. Steps c and d shall be repeated until the gas pressure has been monitored and recorded at all desired static load conditions.

f. The oscillograph recordings shall be removed from the oscillograph.

g. Repeat the above test two more times.

#### 6.2.3.2 Dynamic Test

- a. An amplifier using step or ramp inputs shall be placed across the output of the alternator.
- b. Instrumentation shall be set up to measure and record the output pressure and voltage of the power supply.

NOTE: An oscillograph shall be used to record the measured gas pressure and output voltage.

- c. Frequency response shall be tested by driving the servo amplifiers in a frequency response representative of flight conditions.
- d. The output pressure of the power supply shall be monitored and recorded.
- e. The oscillograph recordings shall be removed from the oscillograph.
- f. Repeat the above test two more times.

#### 6.2.4 Power Capability Tests

- a. A static load in excess of flight value, consisting of a resistance bank of specified value, shall be connected across the output of the alternator.
- b. Instrumentation shall be set up to measure and record the gas velocity, gas temperature, gas pressure, and output voltage of the power supply.

NOTE: The gas velocity is measured by a flow meter and the gas temperature is measured by a thermocouple.

- c. The power supply shall be operated and the gas velocity, gas temperature, gas pressure, and output voltage shall be measured and recorded simultaneously.
- d. Turn power supply off.
- e. Repeat b and c two more times.

#### 6.2.5 Operating Position Test

- a. A preselected load shall be connected across the output of the alternator.
- b. Mount the power supply and its rated load on a centrifuge.
- c. Align the reference axis (RA) of the power supply in one of the seven relationships with the centrifuge acceleration axis (CA) shown in Figure 2.
- d. Instrument the power supply to measure and record the gas pressure, gas temperature, gas velocity, and output voltage.
- e. Monitor and record the gas pressure, gas temperature, gas velocity, and output voltage of the power supply at a gravity (g) magnitude corresponding to flight conditions.
- f. Repeat steps c and d for each of the other six axis orientations.
- g. Repeat the above test two more times.

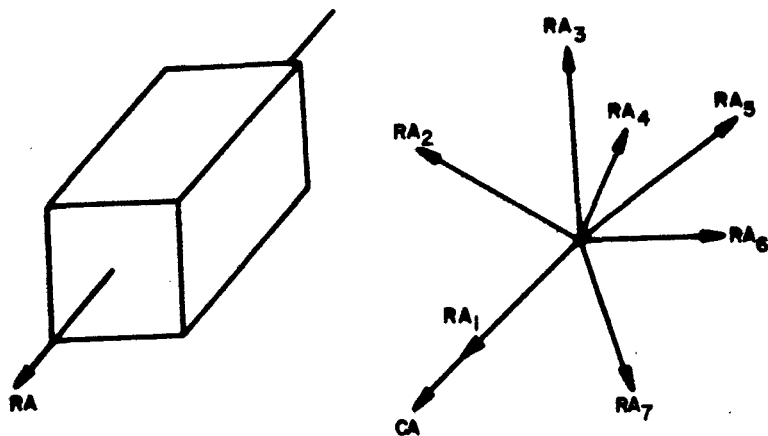


FIGURE 2. AXIS ORIENTATION FOR POSITION TESTING

6.2.6 Resonant Spectrum Test

- a. Connect a preselected load across the output of the alternator.
- b. Mount the power supply and its rated load on a vibrating table.
- c. Instrument the power supply to measure and record the gas pressure, gas temperature, gas velocity, and output voltage.
- d. Operate power supply and vibrating table.
- e. Monitor and record the gas pressure, gas temperature, gas velocity and output voltage at all vibrational frequencies normally occurring in flight.
- f. Note and record the resonant frequencies and their amplitudes.
- g. Turn power supply and vibrating table off.
- h. Repeat the above test two more times.

6.2.7 Leakage Test

- a. Connect a flow meter to the power supply as shown in Figure 3.
- b. Operate power supply.

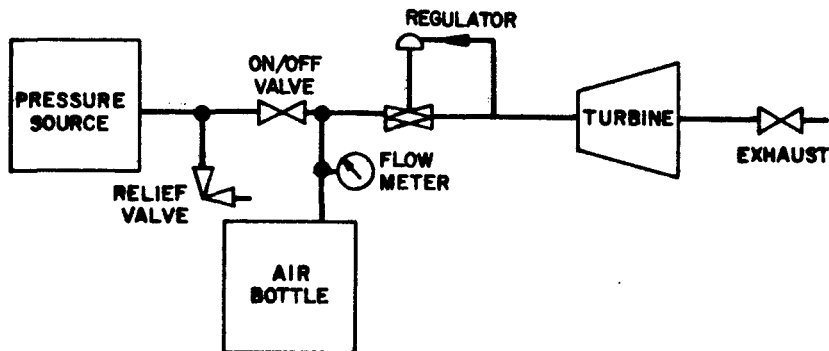


FIGURE 3. LEAKAGE TEST CONFIGURATION

- c. Compare the flow meter reading with the specifications and record the difference as leakage.
- d. Turn off power supply.
- e. Repeat steps b through d two more times.

6.2.8 Relief Valve Test

- a. Remove the relief valve from the power supply and connect it to a pneumatic tester.
- b. Note and record the pressures at which the valve opens and closes. Record the pressure spread (bandwidth) of the relief valve.
- c. Repeat above test two more times.

6.2.9 Hydrostatic Test

- a. Fill the space normally occupied by gas with either water or oil and build up pressure to the proof test limit of the power supply.
- b. Examine the unit for evidence of yielding or elongation and record the result.

NOTE: Since liquids are very slightly compressible at the pressures normally encountered in these tests, hydrostatic testing allows pressure to be increased to the bursting point with little impetus being imparted to fragments. Thus, the bursting point of pressurized components can be established in relative safety.

- c. Repeat the above test two more times.

6.2.10 Overspeed Test

WARNING

This is a dangerous test and must be conducted in an area which provides the testing personnel with protection from fragmentation and escaping pressurized gas.

- a. Operate power supply at normal operating speed as allowed by specifications.
- b. Record voltage output with voltmeter.
- c. Increase power supply speed to highest surge speed allowed by the specifications for the time duration expected in flight.
- d. Record voltage output.
- e. Reduce speed of power supply to normal operating speed as specified in a.
- f. Record voltage output.
- g. Turn power supply off.
- h. Repeat a through g two more times.
- i. Dismantle the unit and inspect the components for damage.
- j. Record any evidence of failure and, if applicable the failure point.
- k. Operate a similar power supply (not the same one) in an increasing overspeed condition and record the burst point.

6.3 TEST DATA

6.3.1 Preparation for Test

Record test condition (s) as described in 6.1.d.

6.3.2 Starting Time, Fuel Consumption, and Onboard Run Time Tests

Record the following:

- a. Time interval in seconds between the application of the start signal and the occurrence of the specified output of the power supply for each test in a series of ten tests.
- b. Length of time in seconds that power supply pressure satisfies specification requirements for each test in a series of ten tests.

6.3.3 Operating Life and Wear Resistance Test

Record the following:

- a. Total number of times the combination of tests described in paragraph 6.2.1 can be conducted before the power supply output fails to meet specifications.
- b. Record any observations of component wear.

6.3.4 Pressure Regulation Tests

6.3.4.1 Static Test

- a. Record all static loads used in ohms.
- b. Retain all oscillograph power supply output pressure and voltage recordings recorded at all desired static load conditions for each test in a series of three tests.

6.3.4.2 Dynamic Test

Retain all pressure and voltage oscillograph recordings for each test in a series of three tests.

6.3.5 Power Capability Tests

- a. Record static load used in ohms.
- b. Retain all pressure, velocity, temperature, and voltage oscillograph recordings for each test in a series of three tests.

6.3.6 Operating Position Test

- a. Record static load used.
- b. Record the gravity (g) magnitude corresponding to flight conditions.
- c. Retain pressure, temperature, velocity and voltage oscillographs recorded at each of the 7 axis orientations shown in Figure 2 for each test in a series of three tests.



6.3.7 Resonant Spectrum Test

- a. Record preselected load in ohms.
- b. Retain all pressure, temperature, velocity and voltage oscillographs recorded at all vibrational frequencies in each test in a series of three tests.
- c. Record resonant frequency in cps for each test in a series of three tests.

6.3.8 Leakage Test

Record flow meter reading to power supply in cubic feet per second for each test in a series of three tests.

6.3.9 Relief Valve Test

For each test in a series of three tests record:

- a. Pressure in psi at which the relief valve opens.
- b. Pressure in psi at which the relief valve closes.

6.3.10 Hydrostatic Test

Record any evidence of yielding or elongation in inches for each test in a series of three tests.

6.3.11 Overspeed Test

- a. Record the following for each test in a series of three tests:
  - 1) Normal operating speed of power supply in rpm
  - 2) Voltage output
  - 3) Maximum surge speed in rpm
  - 4) Voltage output
  - 5) Voltage output when power supply speed is reduced from maximum surge speed to normal operating speed.
- b. Record any evidence of failure.
- c. Record burst point in rpm of similar power supply (not the same one).

6.4 DATA REDUCTION AND PRESENTATION

The results of tests presented in this MTP will be in the form of charts, graphs, tables, recorder tapes, or such other forms as may apply. The evaluation of test data is not based upon a single test, but instead, upon an average of a group of similar tests which will present more indicative results and reduce the possibility of erroneous conclusions.

The extent of equipment evaluation usually will be limited to comparing the actual test results to the manufacturer's specifications and/or the requirements as imposed by the intended usage.

6.4.1 Starting Time, Fuel Consumption and Running Time

- a. Compute the average starting time from the data collected in 6.3.2.a.
- b. The average starting time computed above should be less than the time specified in the specifications.

NOTE: Starting time usually is one to five seconds, with a tolerance of 0.5 second (excessive starting time could result in a waste of fuel).

- c. Compute the average length of time that the power supply pressure satisfies specification requirements based on test data collected in 6.3.2.b.

6.4.2 Operating Life and Wear Resistance

- a. In determining the significance of the number of power runs conducted before the power supply output failed to meet specifications the following criterion shall be noted: A test model of power supply which will repeatedly withstand as many as ten full power runs under test can reasonably be expected to perform satisfactorily for one missile flight.
- b. Any wear noted which is enough to justify rejecting the power supply shall be indicated.

NOTE: Wear-prone areas detected by this test, while not weak enough to justify rejecting the power supply, should be documented to provide for improvement in subsequent power supply production.

6.4.3 Pressure Regulation

- a. Based on oscillograph recordings collected in 6.3.4.1 and 6.3.4.2 ensure that the pressure and voltage are at all times equal to or greater than specification values.
- b. Based on the above oscillograph recordings ensure that the output voltage and pressure remain within specified tolerances.
- c. Based on the above oscillograph recordings ensure that the frequency of the oscillations in the output pressure and voltage are higher than the resonant frequency of any of the respective pressure and electrical components.

6.4.4 Power Capabilities

- a. From the oscillographs of gas pressure, velocity, and temperature collected in 6.3.5.b calculate gas power and plot it against time in seconds.
- b. Ensure that the plot of power is free of unusual oscillations or vibration for the normal flight duration time.
- c. Ensure that the plot of gas power exceeds or equals flight specification values for the normal flight duration time.
- d. From the oscillographs of the voltage across the alternator output and the known electrical load compute electrical power and plot it as a function of time.
- e. Ensure that the plot of electrical power is free of unusual oscillation or fluctuations for the normal flight duration time.

f. Ensure that the plot of power exceeds or equals flight specification values for the normal flight duration time.

#### 6.4.5 Operating Position

a. From the pressure, temperature, velocity and voltage oscillograph recordings collected in 6.3.6 compute average values of pressure, temperature, velocity and voltage for each of the seven axis orientations shown in Figure 2.

NOTE: The oscillograph recordings must not indicate any excess fluctuations in magnitude at each of the seven positions.

b. From the average values of pressure, temperature, and velocity compute average gas power at each of the seven positions.

c. Compare each of these seven values with each other.

NOTE: Each of the values must be within specification tolerance of the others.

d. From the average values of voltage at each of the seven positions and the known electrical load compute average electrical power at each of the seven positions.

e. Compare each of the seven values with each other.

NOTE: Each of the values must be within specification tolerance of the others.

#### 6.4.6 Resonant Spectrum

a. From the pressure, temperature, velocity and voltage oscillograph recordings collected in 6.3.7 compute average pressure, temperature, velocity, and voltage at each vibration frequency.

NOTE: The oscillograph recordings must not indicate any excess fluctuations in magnitude at any of the vibration frequencies.

b. From the average value of pressure, temperature and velocity compute average gas power at each of the vibrational frequencies.

c. Compare each of the above average gas power values to each of the other average gas power values.

NOTE: Each of the values must be within specification tolerance of the others.

d. From the average values of voltage at each of the vibrational frequencies and the known electrical load compute average electrical power at each vibrational frequency.

e. Compare each of the average electrical power values to each other.

NOTE: Each of the values must be within specification

tolerance of the others.

f. Compute mechanical resonant frequency of the power supply and its amplitude for each of the three runs of the test and establish an average.

NOTE: The amplitude of the resonant frequencies must not be great enough to cause fatigue or a prohibitive degree of system excitation.

#### 6.4.7 Leakage Tests

- a. Compute average flow meter reading from data collected in 6.3.8.
- b. Determine leakage by taking the difference between the average flow meter reading computed above and the specifications.

NOTE: Excessive leakage usually is caused by loose fittings, fatigue, defective seals, torque maladjustment, and/or deterioration. The resultant loss of reserve pressure can terminate the power supply operation prematurely.

#### 6.4.8 Relief Valve

- a. Compute from data collected in 6.3.9.a the average pressure at which the relief valve opens.
- b. Compute from data collected in 6.3.9.b the average pressure at which the relief valve closes.
- c. Based on a and b above determine average pressure spread in psi between the relief opening and closing points.
- d. In evaluating the result obtained in c the following criteria should be observed:
  - 1) Too large a pressure spread (based upon specifications) between the relief valve opening and closing points will waste power and impair system response.
  - 2) Too narrow a spread (based upon specifications) will produce high frequency vibration which can cause fatigue failure in the valve.

#### 6.4.9 Hydrostatic Pressure

Compare yielding or elongation of units noted in 6.3.10 with specification values.

#### 6.4.10 Overspeed Test

The following criteria shall be observed when analyzing data obtained in 6.3.11:

- a. The unit shall be capable of operating at intermittent overspeed conditions as specified without damage and load recovery must be complete in each instance.

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b. The establishment of burst speed provides data by which to adjust the relief valve. The burst speed represents failure of the speed control mechanism.

APPENDIX A

(a) Simple Gas Operated Power Supply

A simple gas operated power supply, as used to drive missile control surfaces, consists of a pressure source, a pressure regulator, a relief valve, and an on-off valve, as shown in Figure A-1. It acts as the "muscles" of the missile guidance system.

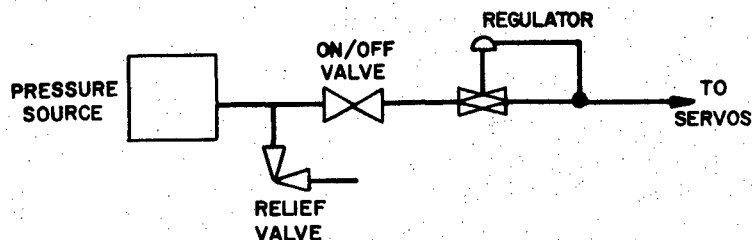


FIGURE A-1. SIMPLE GAS OPERATED POWER SUPPLY

(b) Complex Gas Operated Power Supply

The simple gas operated power supply becomes more complex when it is required to generate electrical power as well as motivate missile control surfaces. In addition to the components of the basic power supply, an alternator, a gas turbine, and a speed control system are required, as shown in Figure A-2.

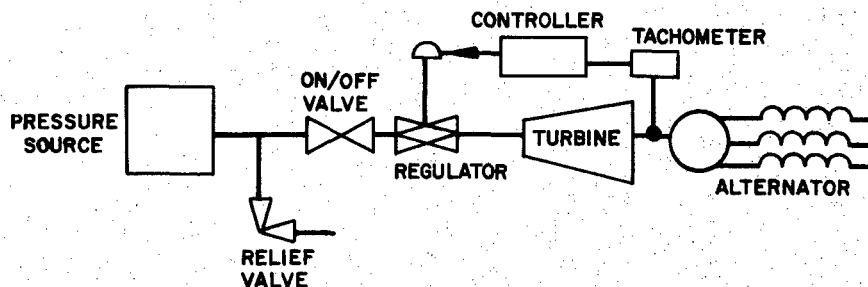


FIGURE A-2. COMPLEX GAS OPERATED POWER SUPPLY