

DEVELOPMENT TEST
OF AIRCRAFT ENGINES

A. APPLICABLE SPECIFICATIONS.

A-1. There are no general specifications applicable to this specification.

B. TYPE.

B-1. This specification covers the requirements of the Procuring Agency for a development test for all types of aircraft engines. This test includes the inspection before test, calibration, 50-hour endurance test, power check after test, tear-down inspection and preparation of the report.

C. MATERIAL AND WORKMANSHIP.

C-1. Not applicable to this specification.

D. GENERAL REQUIREMENTS.

D-1. Not applicable to this specification.

E. DETAIL REQUIREMENTS.

E-1. Not applicable to this specification.

F. METHOD OF INSPECTION AND TEST.

F-1. This specification covers the scope and procedure for conducting a development test of an aircraft engine. This test includes the required performance calibrations to determine whether the engine meets its design requirements and a sufficient endurance test to indicate whether or not the design warrants further development and sufficient testing to indicate what minor changes should be incorporated in a successful design of engine prior to submission of an engine to the type test.

F-2. Aircraft engines and test apparatus shall be subject to inspection by authorized Government Inspectors who shall be given all necessary facilities to determine conformance with this specification.

F-3. Before calibration, and after preliminary tests, the engine shall be completely dismantled for inspection of all parts. In all cases, dimensions shall be recorded of the following major parts:

F-3a. Pistons.- Piston ring land dimensions in the thrust and anti-thrust planes, piston skirts at the top and bottom in the thrust and anti-thrust planes. Piston pin holes in the propeller and anti-propeller holes parallel and perpendicular to the major axis of the piston. Piston ring gap clearance and groove side clearance.

F-3b. Piston and Knuckle Pins.- Maximum and minimum diameters of piston pins at the propeller end, center and anti-propeller end.

F-3c. Cylinder bores at the top, bottom and center in both the thrust and anti thrust planes.

F-3d. Connecting rod bearings and piston pin bushings at the propeller and anti-propeller ends, parallel and perpendicular to the axis of the connecting rod. Link pin bushings attached to the connecting rod at the propeller and anti-propeller ends, in and perpendicular to the line of thrust of the link rod or rods.

F-3e. Crankshaft(When Plain Main Bearings Are Used).- Main bearing journals, parallel and perpendicular to No. 1 crank cheeks at the propeller and anti-propeller ends. Connecting rod journals, parallel and perpendicular to the crank cheeks at the propeller and anti propeller ends.

F-3f. Main Bearings (When Plain Bearings are Used.).- Measurements to be taken at the propeller and anti-propeller ends as near a vertical and horizontal plane in the normal position of the engine as the parting surface of the bearing will permit.

F-3g. Valves.- Maximum and minimum intake and exhaust valve stem diameters at the top, center and bottom and total valve length.

F-3h. Valve Guides.- Inside diameters of intake and exhaust valve guides in the thrust and anti-thrust planes, at the top, center and bottom.

F-3i. Valve Springs.- Tension of each intake and exhaust valve spring when compressed to the valve open and valve closed length.

F-4. Power Absorption.- Calibration shall be conducted on a type of power absorption dynamometer acceptable to the Procuring Agency such as an electric cradle dynamometer or water brake. The endurance test may be conducted on a reaction test stand, rigid test stand, electric cradle dynamometer, or water brake.

F-5. Prior to submitting an engine to all the tests specified in this development test the contractor shall conduct necessary tests to determine that the engine has proper timing, compression ratio, degree of supercharging, cooling, lubrication, satisfactory vibrational characteristics, and all other features required to satisfactorily undertake the tests called for in this specification.

F-6. After all preliminary contractor's tests have been completed and the engine is considered ready for the development test, the inspection specified in Paragraph F-3 shall be conducted and the following calibrations shall be accomplished before the endurance test.

F-6a. Fuel Determination.- A mixture control run shall be made with the throttle fixed at rated speed and rated power with the fuel and fuel consumption specified by the Procuring Agency. Without changing the throttle position, the mixture control shall be gradually moved to the lean position, maintaining constant speed. Readings shall be taken at each 3 percent decrement of fuel flow until the engine does not operate smoothly. If the engine will not operate satisfactorily at rated power and speed with the specified fuel and a fuel consumption 10 percent less than that specified by the Procuring Agency, then the Procuring Agency shall be consulted. Curves shall be prepared showing, vs. fuel flow:

- (1) Actual brake horsepower
- (2) Specific fuel consumption
- (3) Maximum head and barrel temperatures (air cooled)
- (4) Cooling liquid flow
- (5) Cooling liquid temperature rise.

F-6b. Power Determination.- A calibration shall be made at rated power and speed and with the same throttle setting, the power shall be determined from 105 percent rated speed to 60 percent rated speed at intervals of 100 R.P.M. These runs shall be accomplished with the mixture control set "Full Rich," "Best Power" and "Best Setting" at each speed. If in the opinion of the Procuring Agency or contractor it is impossible to satisfactorily operate the engine at "Best Setting", or "Best Power", these readings may be omitted but the Procuring Agency shall be informed of the reasons for the omission. Curves shall be prepared showing, vs. speed:

- (1) Actual and corrected brake horsepower
- (2) Actual and corrected brake mean effective pressure
- (3) Fuel flow
- (4) Specific fuel consumption
- (5) Intake manifold pressure.
- (6) Oil flow through the engine
- (7) Oil pressure from the pressure pump and from the scavenging pump and oil pressure normally taken on the engine if not from the pressure pump.
- (8) Oil temperature rise
- (9) Cooling liquid flow
- (10) Cooling liquid temperature rise
- (11) Pressure at carburetor inlet

F-6c. Supercharger Test: If the engine is equipped with an integral supercharger capable of maintaining rated power at an altitude of 3000 ft. or more, then the following supercharger test shall be accomplished. At 80 percent, 90 percent, 100 percent and 105 percent rated speed with the same throttle setting used for rated power and rated speed, the weight of air being consumed by the engine shall be measured by a method approved by the Procuring Agency. At each of these speeds and corresponding air flows the pressure of the fuel-air mixture or air leaving the supercharger shall be determined. The cylinders or cylinder banks, pistons, connecting rods and all necessary drives not required for operating the supercharger and oiling system, shall then be removed and proper balance weights placed on the crankshaft, if necessary, in order that the engine may be motored. An ample collector ring or pipe shall then be attached to all supercharger outlet pressures, speeds and air flows, the following readings shall be taken:

- (1) Pressure of air entering the supercharger.
- (2) Temperature of air entering the supercharger.
- (3) Pressure of air leaving the supercharger.
- (4) Temperature of air leaving the supercharger.
- (5) All necessary pressures and temperatures of air entering and leaving the measuring device required for computing the weight of the air used.
- (6) Horsepower required to drive the supercharger and all accessories.

At the completion of the above runs, the supercharger impeller shall be removed and a check run made at the same speeds to determine friction horsepower other than that required to compress the air. From the above runs there shall be plotted, vs. engine speed, the following curves:

- (1) Horsepower required to compress the quantity of air used by the engine. (Item 6 less the friction run above.)
- (2) Weight of air passing through the compressor.
- (3) Ratio of absolute supercharger outlet pressure to absolute supercharger inlet pressure.
- (4) Ratio of absolute supercharger outlet temperature to absolute supercharger inlet temperature.
- (5) Air temperature rise passing through the supercharger.
- (6) Adiabatic air temperature rise through the supercharger using the same initial temperature and pressure ratio obtained on test with an exponent of compression of 1.40.
- (7) Ratio of the adiabatic temperature rise to the actual temperature rise.

If the supercharger compresses only air, then all of the above tests may be accomplished with the engine in operation, since the fuel-air mixture will not disturb the test results. Under these conditions, propeller load supercharger data shall also be obtained from rated power and speed to one-half rated speed at intervals of 100 R.P.M.

F-7. At the option of the contractor of the Procuring Agency tear-down inspection may be made at the conclusion of or during the runs covered by the above calibration and with the approval of the Government Inspector parts may be replaced.

F-8. Endurance Test.- Following the calibrations the engine shall be given the following 50-hour endurance test.

F-8a. The fifty hours shall be divided into ten periods of 5 each, the first 1/2 hour to be accomplished at rated power and rated speed, the speed varying not more than plus or minus 2 percent, and the remaining 4-1/2 hours shall be at 90 percent power and 97 percent speed, except for the last hour of the last period, which shall be at rated power and rated speed. During the endurance run, the following data shall be recorded at 15 minute intervals:

- (1) Reading number.
- (2) Total elapsed time of operation.
- (3) Actual time of day.
- (4) Revolutions per minute of crankshaft.
- (5) Torque (if on a torque stand or dynamometer).
- (6) Manifold pressure positive or negative.
- (7) Air vacuum at inlet to carburetor.
- (8) Air temperature at inlet to carburetor.
- (9) Air temperature, wet bulb.
- (10) Air temperature, dry bulb.
- (11) Liquid coolant temperature at inlet to pump.
- (12) Liquid coolant temperature leaving engine.
- (13) Liquid coolant pressure at inlet to pump.
- (14) Liquid coolant pressure leaving engine.
- (15) Liquid coolant flow, lbs. per minute (every hour).
- (16) Oil temperature at inlet to pump.
- (17) Oil temperature leaving engine.
- (18) Oil pressure.
- (19) Oil consumed in pounds per hour.
- (20) Oil flow through the engine, lbs. per minute (every hour).
- (21) Fuel used in pounds per hour.
- (22) If air-cooled, the cylinder head and base temperatures of all cylinders.

F-8b. The date, compression ratio, type of carburetor, fuel and oil specification number, type spark plugs, and engine number shall be recorded on each log sheet.

F-8c. The barometer shall be read and recorded at 2-hour intervals.

F-8d. Notes shall be placed on the log sheets of all incidents of the run, such as oil leaks, vibration, change of spark plugs, tappet adjustments and any other irregularity of functioning of engine or instruments.

F-8e. The Procuring Agency will be sole judge as to permissible adjustments of the engine and as to what constitutes a major failure which will terminate the test and what constitutes a major part.

F-8f. Intervals of endurance test operation of less than one hour duration, terminated by an engine failure, shall not be credited to the required test time. Endurance test time less than 30 minutes duration shall not be credited.

F-8g. The endurance test shall be considered completed when every major part of the engine has completed the entire 50-hour development test. At the discretion of the Procuring Agency, redesign and retesting may be required of any part which fails or indicates weakness after having completed its endurance test but is retained in the engine to complete the endurance testing on other parts. Parts which fail shall be replaced with redesigned parts or one of different material unless the Procuring Agency authorizes the installation of a new part of the original design and material for one which failed due to faulty material or workmanship.

F-9. After completion of the endurance test, check calibration shall be made to determine change in performance. This shall be composed of the tests required by Paragraph F-6b.

F-10. The fuel and oil shall conform to the Procuring Agency's specifications required by the contract or specification under which the engines are tested or built. The fuel and oil consumption shall conform to the specification or contract applicable.

F-11. Fuel, oil and torque scales shall be calibrated before the initial engine calibration, before the endurance test and before the final calibration.

F-12. Upon completion of the above tests, the engines shall be completely dismantled for inspection of all parts. All measurements required in Section F, 3, shall again be taken and tables made which show the wear of all parts measured.

F-13. Definitions.

F-13a. Normal Rated Speed.- Normal rated speed is the speed so designated by the contractor and accepted by the Procuring Agency. (This speed will be the same for sea level and altitude.)

F-13b. Normal Rated Power.- Normal rated power is the power so designated by the contractor and accepted by the Procuring Agency.

F-13c. Normal sea level power is the power developed under standard sea level conditions with normal rated speed and normal rated manifold pressure.

F-13d. Normal Rated Altitude.- Normal rated altitude is the altitude at which normal rated power is developed at normal rated speed with full throttle under standard altitude conditions. (An engine with a two-speed or two-stage supercharger has two normal rated altitudes.)

F-13e. Manifold Pressure.- Manifold pressure is the absolute pressure in inches of mercury measured at the point specified by the accepted installation drawing of the engine. All test values shall be on a basis of dry absolute manifold pressure which is obtained by subtracting the vapor pressure from the observed absolute manifold pressure. (All manifold pressures shall be determined on test by a mercury barometer alone or with a mercury manometer.)

F-13e(1). In the case of an altitude engine, a manifold pressure higher than normal rated manifold pressure will be required to develop normal rated power on the test block.

F-13f. Normal Rated Manifold Pressure.- Normal rated manifold pressure is the absolute manifold pressure obtained with full throttle at normal rated speed and normal rated altitude under standard altitude conditions. (An engine with a two-speed or two-stage supercharger may have two normal rated manifold pressures.)

F-13g. Sea Level Engine.- A sea level engine is an engine which is designed for extended periods of full throttle operation at sea level.

F-13h. Altitude Engine.- An altitude engine is an engine which is designed for extended full throttle operation at altitude and for which full throttle operation at sea level is restricted or prohibited.

F-13i. Actual Brake Horsepower.- Actual brake horsepower is the actual horsepower output of the engine under the prevailing test conditions. This is sometimes referred to as "observed brake horsepower."

F-13j. Standard Conditions.- Standard conditions are the values of air temperature and pressure given in N.A.C.A. Technical Report No. 218. The standard of humidity, for the purposes of this specification, is zero vapor pressure at all altitudes. Standard conditions shall apply to carburetor or air throttle entrance pressure, temperature and humidity, and exhaust pressure.

F-13k. Carburetor or Air Throttle Entrance Pressure.- Carburetor or air throttle entrance pressure is the static absolute air pressure at the entrance (before the screen) to the carburetor or air throttle. It shall be determined on test by a mercury barometer alone or with a water or mercury manometer.

F-13l. Specific Fuel and Oil Consumption. - Specific fuel consumption is the weight in pounds of fuel consumed per actual brake horsepower per hour, and specific oil consumption is the weight in pounds of oil consumed per actual brake horsepower per hour.

F 13m. Mixture Adjustment. - The following definitions apply to any given speed and throttle position. "Full rich" mixture adjustment is the adjustment in which the mixture control lever is in the position giving maximum fuel flow. "Best power" setting is the setting which gives the least fuel flow when maximum power is developed. "Best setting" is that setting which results in a one percent drop in power from "best power" caused by a reduction in fuel flow.

F-13n. Maximum Power. - Maximum power is the maximum actual brake horsepower which the engine will develop at any given speed and throttle position with optimum mixture strength.

F-13o. Propeller Load. - Propeller load horsepower is the horsepower represented by a curve drawn through the point of developed horsepower at designated speed and varying directly as the cube of the speed.

F-14. Corrections.

F-14a. To compensate for the variations in the temperature of the air entering the engine the manifold pressure required to develop the actual power output specified shall be calculated on the assumption that with constant manifold pressure the actual horsepower is inversely proportional to the square root of the absolute carburetor or air throttle entrance temperature. An alternative temperature correction may be used if based on substantiating test data acceptable to the Procuring Agency.

F-14b. All test values shall be on a basis of dry absolute manifold pressure which is obtained by subtracting the vapor pressure from the observed absolute manifold pressure.

F-14c. Correction of the Barometer or Mercury Manometer for Temperature. - The observed reading of a mercury column varies not only with changes in the applied pressure, but also with changes in the temperature of the mercury and of the scale. The observed readings must, therefore, be corrected to the values they would have if the mercury and scale were maintained at their standard temperature. The correction given in Table I corresponding to the observed height of the mercury column and to the temperature indicated by a thermometer attached to the column, is to be added to or subtracted from the observed height to obtain the true height or, in the case of a barometer, the true barometric pressure. This correction shall be made for all readings greater than ten inches. Only the true barometer reading shall be recorded on the log sheet.

F-15. Reports.

F-15a. The Procuring Agency will designate the number of copies of the report that will be prepared and where they will be sent.

F-15b. The report shall contain the following items, in the order given:

- (1) Title page.
- (2) Index.
- (3) Object.
- (4) Conclusions and recommendations.
- (5) Introduction.
- (6) Description. Complete and detailed description of the engine shall be made covering the lubrication system, induction system, cooling system, description of cylinders, description of crankcase, description of connecting rod and piston assembly, description of valve gear and description of all other features not covered in the above. The following table shall be compiled in addition to the above description:

(a) Manufacturer:

Name
Location of factory

(b) Model and rating of engine:

Model
Rating brake horsepower at R.P.M.

(c) General form:

Bore
Stroke
Number of cylinders
Total piston displacement
Cylinder arrangement
Cooling
Compression volume ratio

(d) Crankshaft:

Material
Journal diameter
Crank pin diameter.
Number of bearings
Number of crank throws
Counterweight:
1. Integral or separate
2. Number
3. Method of attachment

(e) Propeller hub:

Type
Dimensions - sufficient for propeller design.

(f) Connecting rods:

Length center to center
Type, solid or split cap
Material
Bearing in rod
Type
Weight of piston end, crankshaft end,
master rod, auxiliary rod.

- (g) Bearings:
 - Material
 - Miscellaneous data

- (h) Pistons:
 - Material
 - Type - Sketch sectional view of pistons which will show clearly the general form, number of rings and relative dimensions.
 - Weight with rings, pins and pin retainers.

- (i) Wrist pin:
 - Diameter
 - Retaining device
 - Material

- (j) Cylinders:
 - Material
 - Description - brief
 - Sketch sectional view showing general form of the cylinder valve location and combustion chamber shape.

- (k) Valve seats:
 - Material
 - Form

- (l) Valves:
 - Number per cylinder
 - Form
 - Material
 - Seat angle
 - Lift
 - Diameter
 - Internal cooling

- (m) Valve springs:
 - Type
 - Number per valve
 - Stress - valve open, valve closed
 - Length - free, valve open, valve closed
 - Material

- (n) Valve timing: (Static)
 - Inlet open
 - Inlet closed
 - Exhaust open
 - Exhaust closed
 - Provisions for adjusting

- (o) Camshaft:
 - Number
 - Diameter
 - Valve operating means - rocker arm or direct contact
 - Number of cams on shaft
 - Cam lift and valve travel diagram
 - Radius of heel of cam

- (p) Camshaft gear train:
 - Simple sketch showing the arrangement and ratios of the camshaft, gun control drives, oil, water and fuel pump gears.

- (q) Gun control drive:
 - Description

- (r) Ignition:
 - Type and description
 - Timing

- (s) Carburetor:
 - Number
 - Vendor
 - Type
 - Altitude mixture control means
 - Settings
 - Heater, type

- (t) Intake manifolds:
 - Sketch showing the general arrangement and form of the passage leading from the cylinders to the carburetor chamber.
 - Velocity of air through manifold at rated speed and power.

- (u) Crankcase:
 - General form.
 - Method of securing crankshaft journals.
 - Sketch of general arrangement of the engine shall be furnished in two views; front and side. This sketch will show the following dimensions:
 - Center to center of engine bearers
 - Overall length
 - Overall height
 - Overall width

- (v) Coolant pump:
 - Type
 - Ratio of crankshaft speed to pump speed
 - Packing gland type
 - Sketch of driving train in accordance with Section F-15, b, (6) (p).

- (v) Oil pump:
 - Type
 - Sketch of driving train in accordance with Section F-15, b, (6) (p).
 - Capacity at rated speed
- (x) Blower:
 - Type
 - Size
 - Ratio of speed to crankshaft speed
 - Gearing
 - Coupling, clutch, spring, et cetera
- (y) Fuel pump:
 - Type
 - Speed
 - Capacity
- (z) Generators:
 - Flange
 - Type of gear

A complete weight table shall be included in accordance with the standard method of designating engine weights.

- (7) Method of Test. - General description of test equipment and methods used in conducting the test.
- (8) Record of Test. - Chronological history of all events in connection with all of the testing.
- (9) Analysis of Results. - A complete discussion of all phases of the test, such as probable reasons for failure and unusual wear, comparison in performance with previous models and analysis of general operation.
- (10) In addition to the data required in Section F-6a, F-6b and F-6c, each curve sheet shall include average carburetor air temperature, type of spark plugs, ignition advance, carburetor main jet size, economizer jet size and venturi diameter, as well as the type of carburetor.
- (11) Graphic Log of Endurance Test. - A graphic log of the endurance test, plotted at 15-minute intervals, shall be prepared, showing:
 - (a) Engine speed in R.P.M.
 - (b) Engine horsepower B.H.P. actual (if tested on dynamometer or torque stand)

- (c) Engine horsepower B.H.P. corrected (if tested on dynamometer or torque stand)
 - (d) Fuel consumption in pounds per hour.
 - (e) Specific fuel consumption (if tested on dynamometer or torque stand)
 - (f) Oil consumption in pounds per hour.
 - (g) Specific oil consumption (if tested on dynamometer or torque stand)
 - (h) Oil pressure
 - (i) Manifold pressure
 - (j) Carburetor air temperature
 - (k) Oil temperature in and out of engine
 - (l) Maximum and minimum head and barrel temperatures (designating cylinder)
 - (m) Liquid coolant temperature in and out of engine.
 - (n) Barometer.
- (12) Tables showing parts measurements before and after test and wear.
- (13) Photographs. - Photographs of the full front, full rear, top, bottom, right and left sides of the engine shall be taken. Photographs shall also be included showing failures and condition of the major parts of the engine at the completion of the test.

G. PACKING AND MARKING.

G-1. Not applicable to this specification.

H. NOTES.

H-1. NOTICE: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

(Copies of this specification may be obtained from the Chief, Materiel Division, Air Corps, Wright Field, Dayton, Ohio.)

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