Society of Automotive Engineers, Inc.
29 West 39th Street
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AERONAUTICAL RECOMMENDED PRACTICE

ARP 24

PROCEDURE FOR TESTING PRESSURE DROP IN AIRCRAFT ACCESSORIES

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Revised

I. PURPOSE: These recommendations are intended to outline good practice in pressure drop testing of accessories in the hydraulic, fuel, oil and coolant systems of aircraft. A brief explanation of fundamental formulas in their relation to pressure drop testing is incorporated.

II. EQUIPMENT: The equipment for pressure drop testing should be so constructed that continuous controlled operation can be maintained throughout the test period.

A. Tank: The tank should contain means for controlling temperature variations. The fluid temperatures during pressure drop runs should be held in the following ranges:

Hydraulic Oil	90 to 100 F
Engine Oil	160 to 180 F
Fuel	70 to 90 F

Baffles or other devices to remove turbulence and entrained air at the pump suction should be provided. Evidence that there is no entrained air should be observed at a transparent tube section in the supply line between the pressure tap and the test specimen.

B. Pump: A reliable means of variable flow control should be used. Throttling is not considered sufficiently reliable. It is desirable to mount the pump close to the tank to minimize suction losses. Speed of the pump should not be exceptionally high.

C. Flowmeters: Equipment used for flow measurement must give accurate and reproducible results. Flow measuring instruments must be checked periodically by weighing the flow. A good test installation will enable flow measurements to be made to an accuracy of 1% or better.

D. Pressure Taps: Pressure taps should be carefully made and installed at the same height in the system. Figures 1 and 2 show two simple and acceptable designs. All drillings and flow passages should be smooth with clean intersections.

E. Pressure Differential Measurement: The means of measuring pressure differential between taps may vary with the pressure, fluid and accuracy required. Accurate gages, mercury manometers, and air-test fluid manometers all have application. Air fluid columns are usually the most accurate, but the columns become bulky at higher pressures. Valves and other means should be provided to allow thorough and positive venting of the manometer connections to eliminate trapped air.

F. Test Fluid: Accessories should be tested on the fluid with which they will be used. Stoddard Solvent or safety fluid may be used as a standard test fluid for gasoline equipment.

III. PROCEDURE: The test sample should be mounted between pressure taps with straight smooth tubing. At least 20 diameters of smooth straight tubing of the same diameter as the ports on the test specimen should be connected between taps and sample. A minimum of 40 diameters of this same diameter straight tubing should be installed between the upstream pressure tap and the nearest upstream fitting. Before taking readings, all air should be bled from the system and instrument lines. Readings should be duplicated with flow increasing and decreasing over the range of test. The pressure drop through the tubing and taps alone should be measured in the same manner and subtracted from the total pressure drop obtained in testing the unit.

IV. GENERAL:

A. Fundamental Information: Pressure drop for straight tubing may be computed from the basic pressure drop equation:

$$PD = \frac{\rho f L V^2}{2gd}$$

1. Laminar Flow.- From this equation the following equations are derived where the flow is known to be laminar (Reynolds number less than approximately 2000):

(a) velocity unit of measure:

$$PD\ (psi) = .006912\ \frac{\mu L V}{d^2}$$

(b) volumetric unit of measure:

$$PD\ (psi) = .0088\ \frac{\mu L Q}{d^4}, \text{ where } Q = AV$$

$$\text{or } V = \frac{Q}{A} = \frac{Q}{\frac{\pi d^2}{4}}$$

(c) mass unit of measure:

$$PD\ (psi) = .0088\ \frac{\mu L M}{\rho d^4}, \text{ where } M = Q\rho$$

$$\text{or } Q = \frac{M}{\rho}$$

2. Turbulent Flow.- Where flow is known to be turbulent (Reynolds number greater than approximately 3000), the following equations should be used:

(a) velocity unit of measure:

$$PD\ (psi) = .00003417\ \frac{\mu^{.25}\ \rho^{.75} V^{1.75} L}{d^{1.25}}$$

(b) volumetric unit of measure:

$$PD\ (psi) = .00005217 \frac{\mu^{.25} \rho^{.75} Q^{1.75} L}{d^{4.75}}, \text{ where } Q = AV$$

$$\text{or } V = \frac{Q}{A} = \frac{Q}{\frac{\pi d^2}{4}}$$

(c) mass unit of measure:

$$PD\ (psi) = .00005207 \frac{\mu^{.25} M^{1.75} L}{\rho d^{4.75}}, \text{ where } M = Q\rho$$

$$\text{or } Q = \frac{M}{\rho}$$

where: μ = absolute viscosity, lbs. per ft.-sec.

ρ = density, lbs. per cu. ft.

V = velocity, ft. per sec.

d = inside diameter of pipe, ft.

M = weight per unit time, lbs. per sec.

Q = volume per unit time, cu. ft. per sec.

L = length of tube, ft.

g = gravity acceleration, 32.2 ft. per sec. per sec.

constants shown in these equations include such constants as π, conversion factors, and constants in the friction factor.

Referring back to the original basic pressure drop equation, f may be computed from either of the following equations:

For laminar flow: $f = \frac{64}{R}$

For turbulent flow: $f = \frac{.3164}{R^{.25}}$

where: R (Reynolds number) = $\frac{dV\rho}{\mu}$

It will be noted that English units of measure were specified in the above equations. If metric units or a combination of metric and English units are used throughout as a unit of measure, the constants in these equations will change. Care should be taken to properly compensate for any change in units of measure from those given above.

B. <u>Conversion</u>: Conversion of pressure drop results from test to service fluid: pressure drop for any fitting, bend or accessory can be calculated for many service fluids from the experimental results obtained with a given test fluid with the aid of certain fundamental relationships. This calculation or conversion can only be made if the flow patterns for both fluids are in the same region, whether laminar or turbulent flow. The pressure drop with the test fluid can be expressed in terms of equivalent length of straight tubing by substituting, as shown in formula IV 2 C under turbulent flow of the preceeding paragraph. Conversion to the service fluid can then be made by substituting this equivalent length of tubing in the same formula with the new constants for the service fluid. The Reynolds number for both fluids must be calculated to determine whether laminar or turbulent flow exists for both fluids. This conversion process is quite accurate for low pressures and fluids of similar viscosity and density. Viscosity changes due to high pressures and wide differences in viscosity of the fluids under comparison reduce the accuracy of conversion.

C. <u>Accuracy of Pressure Drop Testing</u>: Due to the extensive range of conditions and objectives of pressure drop testings it is not possible to set allowable limits for the accuracy of tests. Good practice in testing should generally enable the duplication of test results to plus or minus 5% or better.