# (R) DIESEL INJECTION PUMP TESTING— PART 2: ORIFICE PLATE FLOW MEASUREMENT

*Foreword*—This SAE Recommended Practice is similar to ISO 7440/2.

**1. Scope**—This part of SAE J968 specifies the flow measuring system, including the fixture, to be used for flow testing the single hole orifice plates used in an orifice plate type nozzle and holder assembly (described in SAE J968/1) which is intended for testing and setting diesel fuel injection pumps on test benches.

The flow measuring system and fixture ensure accurate flow testing of the entire range of orifices from 0.4 to 0.8 mm diameter as specified in SAE J968/1. It is intended primarily for use by the manufacturers of single hole orifice plates.

**2. References**

**2.1 Applicable Documents**—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

**2.1.1 SAE PUBLICATIONS**—Available from SAE, 400 Commonwealth Dr., Warrendale, PA 15096-0001.

SAE J967—Calibration Fluid for Diesel Injection Equipment

SAE J968/1—Calibrating Nozzle and Holder Assemblies

**2.1.2 ISO PUBLICATIONS**—Available from ANSI, 11 West 42nd Street, New York, NY 10036.

ISO 7440/2—Road vehicles—Fuel injection equipment testing—Part 2: Orifice plate flow measurement

**3. Orifice Plate Flow Measuring System**

**3.1 General Description**—An orifice plate flow measuring system shall comprise:

  a. Orifice Plate Holding Fixture (shown in Figure 1);

  b. Fluid Supply Circuit and Flow Measuring Device (an example is shown in Figure 2);

  c. Flow Overcheck Device—OPTIONAL. (This device is for periodic overchecking of the accuracy of the primary flow measurement device in (b) and is specified in Appendix A).

The system shall be designed and constructed to minimize fluid evaporation, contamination, aeration, and instability of pressure and temperature.

Flow values obtained by alternative systems shall require correlation with values determined using the above system.

**3.2 Orifice Plate Holding Fixture**—The functionally critical details and dimensions of the fixture are shown in Figure 1. Dimensions not specified and construction techniques are left to the discretion of the manufacturer of the fixture, but shall be such that the fixture has unrestricted and undisturbed flow.

### 4. Flow Measuring Procedure

#### 4.1 General Requirements

    a. The orifice plates shall be clamped in a fixture conforming to Figure 1.

    b. The following monitoring points shall be provided and the values measured or verified:

        (1) orifice inlet temperature

        (2) orifice inlet pressure

        (3) orifice outlet pressure

    c. The fluid shall enter the orifice through the entry cone.

    d. The flow through each orifice plate shall be measured individually.

    e. The fluid in the flow circuit shall conform to SAE J967. Viscosity and specific gravity shall be measured frequently and the fluid shall be discarded if it ceases to conform to SAE J967.

#### 4.2 Reference Conditions—The orifice plate flow values stated in Part 1 of this document refer to volumetric flow rate measured (or adjusted to) 40 °C. The other reference conditions shall be as follows:

    a. Inlet pressure minus outlet pressure = 100 bar

    b. Outlet pressure = ambient pressure

    c. Inlet temperature of fluid = 40 °C

    d. Dynamic viscosity at 40 °C = $2.1 \times 10^{-3}$ Ns/m$^2$

    e. Density at 40 °C = 0.808 g/cm$^3$

NOTE—Dynamic viscosity at 40 °C = kinematic viscosity at 40 °C × density at 40 °C.

#### 4.3 Accuracy of Measurement

4.3.1 Measurements shall be taken with the following accuracies

    a. Orifice volumetric flow rate at 40 °C: ± 0.2% of reading;

    b. Temperature of volume measured: ± 0.5 °C;

    c. Dynamic viscosity at 40 °C: $\pm\ 0.1 \times 10^{-3}$ Ns/m$^2$;

    d. Density at 40 °C and at atmospheric pressure: ± 0.001 g/cm$^3$;

NOTE—Density is preferably measured at ambient temperature and is adjusted to 40 °C as follows in Equation 1:

$$\rho_{m40} = \rho_a - 0.00068 \, (40 - t_a) \quad \text{g/cm}^3 \tag{Eq. 1}$$

4.3.2 The following supply conditions shall be maintained taking into account gauge error:

    a. Temperature of fluid at inlet: ± 1 °C;

    b. Inlet Pressure: ± 0.1 bar;

    c. Maximum cyclic fluctuation in inlet pressure: ± 1 bar.

#### 4.4 Correction Procedure—To compensate for the effects of temperature, density and viscosity, the empirical formula in Equation 2 shall be used:

$$\text{Flow} = \text{Flow}_{(measured)} \times \frac{\left[1.7\sqrt{\dfrac{\rho_{m40}}{\rho}}\right] \times \left[1 - \left[\dfrac{\mu - \mu_{m40}}{\mu K}\right]\right]}{[1 + \gamma \, (t_m - 40)]} \tag{Eq. 2}$$

where:

$\rho$      is the reference density = 0.808 g/cm³

$\rho_{m40}$   is the fluid density (g/cm³)in the circuit at 40 °C

$\mu$      is the reference dynamic viscosity = 2.1 × 10⁻³ Ns/m²

$\mu_{m40}$   is the dynamic viscosity (Ns/m²) of fluid in the circuit at 40 °C

$\gamma$      is the coefficient of volumetric expansion of the fluid, equal to 0.000824 °C⁻¹

$t_m$     is the fluid temperature (°C) in the flow measuring device

$t_a$     is the fluid temperature (°C) at which density is measured

and

K = 88 for 0.4 orifices

K = 100 for 0.5 orifices

K = 114 for 0.6 orifices

K = 135 for 0.7 orifices

K = ∝ for 0.8 orifices

## 5. Notes

**5.1 Marginal Indicia**—The (R) is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

PREPARED BY THE SAE DIESEL FUEL INJECTION EQUIPMENT
STANDARDS COMMITTEE

Dimensions in millimetres
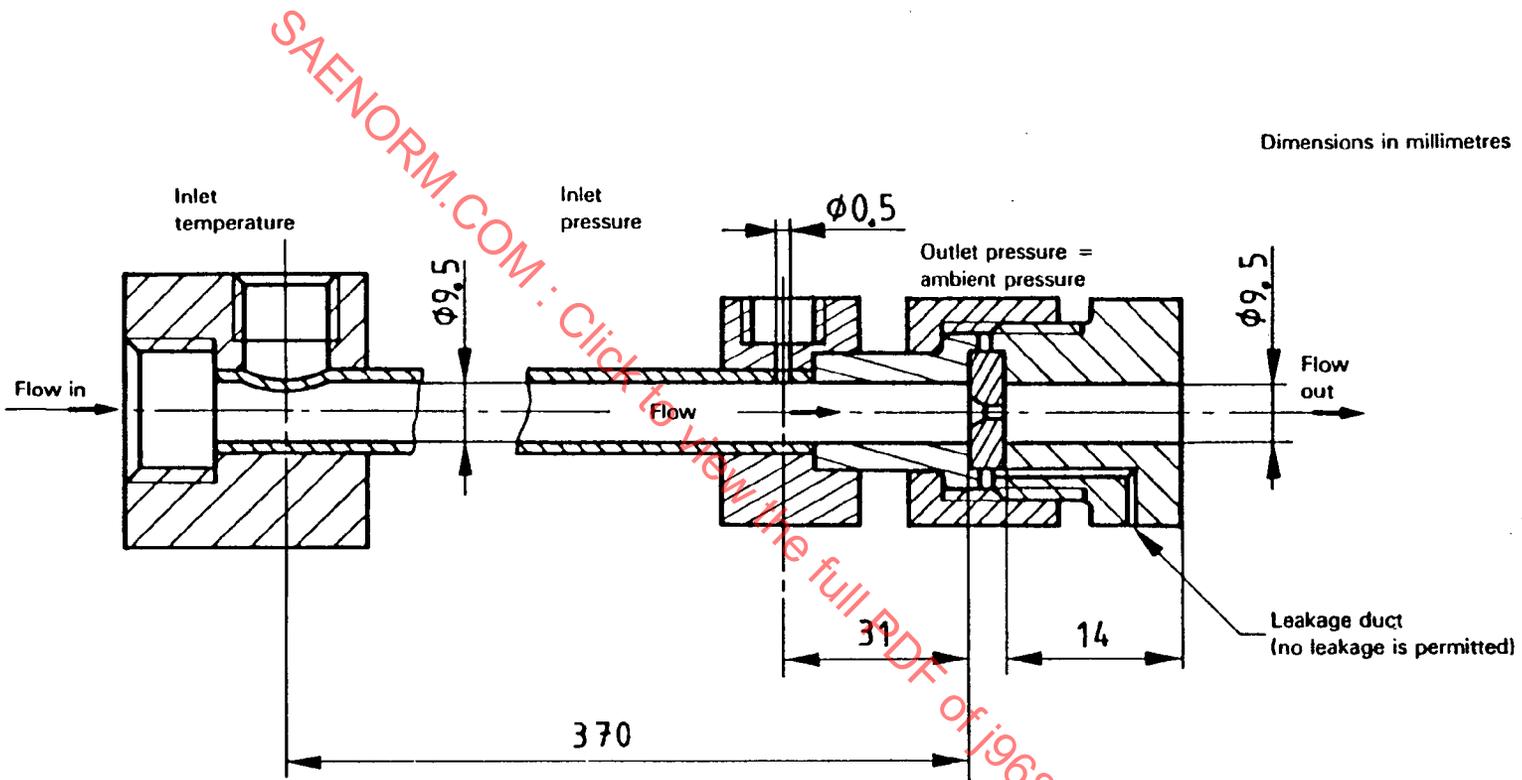


FIGURE 1—ORIFICE PLATE HOLDING FIXTURE FOR FLOW MEASUREMENT

Inlet temperature

Inlet pressure

Ø0.5

Ø9.5

Outlet pressure = ambient pressure

Ø9.5

Flow in

Flow

Flow out

Leakage duct (no leakage is permitted)

31

14

370

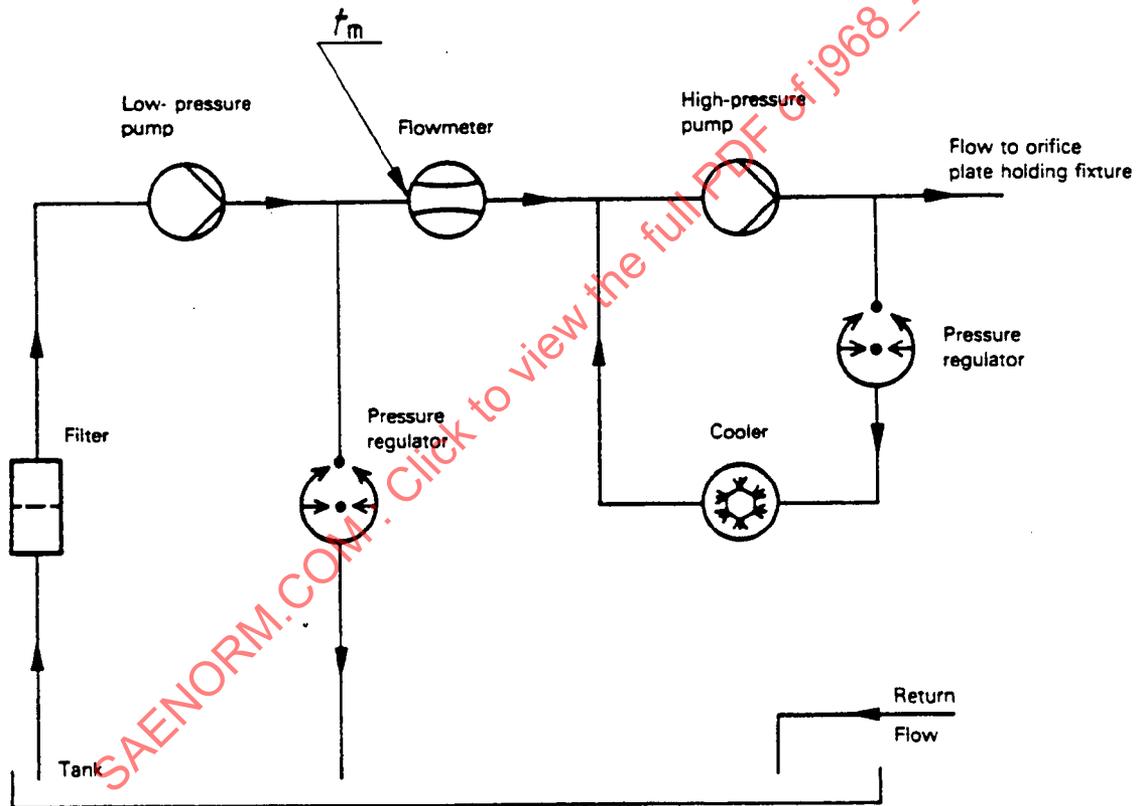# Example of fluid supply circuit and flow-measuring device



FIGURE 2—FLUID SUPPLY CIRCUIT WITH PRESSURE AND TEMPERATURE CONTROL AND FLOW-MEASURING DEVICE

## Appendix A
## An Overcheck Device for the Flow Measuring System—OPTIONAL

*A.1 Requirements*—The device as illustrated in Figure A1 shall have the following features:

**A.1.1 Measuring Chamber (1)**—The volume of the sample shall be measured in a chamber with the following specifications:

    a. 4 liters capacity minimum

    b. minimum internal wetted surface

    c. conical upper and lower surfaces

    d. vertical graduated tube of 25 mm diameter maximum extending upwardly from the top surface of the chamber

    e. graduations in 1 mL increments and correct at 50 °C to ± 2 mL after draining for 1 min

    f. chamber made from low thermal expansion material, or appropriate allowance for differential expansion to be made in the measured flow correction formula (see 4.4)

    g. a 25 mm effective diameter drain valve in the center of the base

    h. independent upwardly facing fluid inlet

    i. the measuring chamber shall have a temperature sensor in a central position lying on the axis of the inlet connection

**A.1.2 Level Sensor (2)**—A level sensor looking through the graduate shall stop the sample collection and timer simultaneously.

**A.1.3 Three-Port Valve (3)**—A symmetrical power operated three-port valve with zero leakage (or two separate similar two-port valves operating in "push-pull" mode) shall be arranged to connect the orifice outlet to either the measuring cylinder or to a separate chamber having the same height. This valve shall have an equivalent port area of between 6 mm and 8 mm diameter and shall have fast response time (<50 ms) and equal in both directions.

**A.1.4 Slave Chamber (4)**—The second "slave" chamber shall have an overflow at the same level as the sensor in A.1.2 (see Figure A1), and the measuring chamber shall have an overflow at a higher level.

**A.1.5 Drain Return (5)**—The drain return shall be separate from the overflow lines to ensure full and complete drainage.

**A.1.6 Control Unit (6)**—A control unit shall incorporate a second timer with a six figure display reading to three decimal places and having an accuracy of ± 0.001 s. Controls shall be provided to:

    a. deliver the flow to the measuring chamber and start the timer simultaneously.

    b. drain and reset the timer.

    c. manually select and hold either direction of flow (to test for leakage).

The sensor shall reverse the valve mode and stop the timer simultaneously.

**A.1.7 Fluid Passageway (7)**—This fluid passageway, because it must run downward, shall have a bore size large enough to produce no back pressure and small enough to carry entrained air downward with the smallest orifice flow rate, e.g., between 7 and 8 mm bore.

*A.2 Schematic Diagram*—Figure A1 shows the device for calibrating and checking a different type of faster acting primary meter. The arrangement of overflow levels with respect to the orifice height and the arrangement of the fluid passageways shall be observed.