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Recommended Practice

Methods and Equipment for Calibration of Variable Area Meters (Rotameters)

ISA-RP16.6 — Methods and Equipment for Calibration of Variable Area Meters (Rotameters)

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Preface

This Recommended Practice has been prepared as a part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value this report should not be static, but should be subject to periodic review. Toward this end the Society welcomes all comments and criticisms, and asks that they be addressed to the Standards and Practices Board Secretary, ISA, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, North Carolina 27709, e-mail: standards@isa.org.

This report was prepared by the 8D-RP16 Committee of the Production Processes Standard Division on Variable Area Meters.

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The assistance of those who aided in the preparation of this Recommended Practice by answering questionnaires, offering suggestions, and in other ways is gratefully acknowledged.

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1 Purpose

This Recommended Practice is intended to provide a useful guide for the general considerations important to the calibration of variable area meters (rotameters).

2 History and development

The need for this Recommended Practice was established by a survey of instrument users sent out initially in September, 1954, to about two-hundred-and-fifty meter users and manufacturers.

3 Scope

This Recommended Practice has been prepared to describe the methods and equipment used for calibrating the glass and metal metering tube area meters (rotameters) covered in RP16.1.2.3. Nomenclature and terminology for extension devices are included in ISA-RP16.4. Installation, operation and maintenance instructions are included in ISA-RP16.5.

4 Methods and equipment

When calibrating a rotameter, certain techniques for determining the proper equipment and procedures must be considered. Care should be taken in selecting equipment for controlling flows, measuring volumes and time intervals, etc., with acceptable accuracies of measurement.

The use of the rotameter dictates the accuracy of calibration required. When the rotameter is used as a flow indicating device and repeatability of readings is of paramount importance the rotameter can usually be calibrated with a reference liquid such as water and corrections for density can be made using the formulas presented in Paragraph 4.1.1.

To determine whether the viscosity of the metering liquid will permit calibration with a reference liquid, refer to Chart, Figure RP16.6.1.

If absolute accuracy of measurement is most important, the rotameter should be calibrated with the process fluid that it will eventually handle or kinematic simulation should be employed to assure highest absolute accuracy. (Refer to Paragraph 4.2)

4.1 Three basic methods are employed in the calibration of rotameters. They are volumetric, gravimetric and comparison.

4.1.1 Volumetric

In these methods the volume of fluid flowing is accurately measured and timed as it passes through the rotameter into the collecting chamber at a controlled rate. Instruments in this group include gasometers, burettes, and stand pipe systems which provide measurements directly in basic volumetric terms.

Liquids

For liquid calibrations, the collecting chamber may vary from a small Bureau of Standards certified burette for calibrating very small rotameters to large accurately calibrated receiving tanks for calibrating larger instruments. (Refer to Figure RP16.6.2)

Formula used with Figure RP16.6.2 — Liquid Calibration

$$Q_m = \frac{V_c}{Sec} \times 60 \times \sqrt{\frac{(\rho_f - \rho_m)\rho_c}{(\rho_f - \rho_c)\rho_m}}$$

Where:

Q_m = Volumetric flow rate of liquid to be metered in units per minute

V_c = Volume of calibrating liquid collected in units consistent with Q_m

Sec = Collection time in seconds

ρ_f = Density of metering float in grams/cc

ρ_m = Density of liquid to be metered in grams/cc

ρ_c = Density of calibrating liquid in grams/cc

Liquid to Gases

Rotameter sizes 1/2" and larger may be calibrated volumetrically using water as the flowing medium. GPM of liquid, specific gravity 1.0 times 4.15 equals SCFM gas, specific gravity 1.0, when metered at 0 psig and 70°F.

Gases

For calibrating rotameters with gases, a gasometer as illustrated in Figure RP16.6.3 is recommended. In this method, gas at controlled flow rate, temperature, and pressure flows through the rotameter and is collected in the inverted bell.

Formulas used with Figure RP16.6.3 — Gas Calibration

To determine the calibration of the rotameter undergoing test, use the following formulas:

1. $$QStd = \frac{V_g}{Sec} \times \frac{60 \times S_c \times (P_b + P_g) \times 530}{S_o \times 14.7 \times T_g} \times \sqrt{\frac{V_c}{V_1}}$$

2. $$QAct = \frac{V_g}{Sec} \times \frac{60 \times S_c \times (P_b + P_g) \times 530 \times V_1}{V_1 \times 14.7 \times T_g \times 13.35} \times \sqrt{\frac{V_c}{V_1}}$$

3. $$W = \frac{V_g}{Sec} \times \frac{60 \times 0.075 \times S_c \times (P_b + P_g) \times 530}{14.7 \times T_g} \times \sqrt{\frac{V_c}{V_1}}$$

Where:

QStd = Std. CFM at 14.7 psia & 70°F.

QAct = Actual CFM (volume at metering temperature and pressure)

W = PPM Flow Rate

Vg = Volume gas collected in cu. ft.

Sec = Collection time, seconds

T_g = Gasometer temperature, degrees Rankine (460 + °F.)

P_b = Barometric pressure at calibration (psia)

P_g = Static pressure of Gasometer (psi) (in. H_2O x .0361)

S_c = Specific Gravity of calibrating gas at 14.7 psia and 70°F. (Air=1.0)

S_o = Specific Gravity of gas to be metered at 14.7 psia and 70°F.

*V_c = Specific Volume of calibrating gas at calibration temperature and pressure, cu. ft./lb.

*V_1 = Specific Volume of gas to be metered at metering temperature and pressure, cu. ft./lb.

*For perfect gases

$$V_c = 13.35 \times \frac{14.7}{P_c} \times \frac{T_c}{530} \times \frac{1}{S_c}$$

Where:

P_c = metering pressure at calibration, psia

T_c = metering temperature at calibration, degrees Rankine (460 + °F.)

$$V_1 = 13.35 \times \frac{14.7}{P_1} \times \frac{T_1}{530} \times \frac{1}{S_o}$$

Where:

P_1 = operating metering pressure, psia

T_1 = operating metering temperature, degrees Rankine (460 + °F.)

NOTE: Standard conditions in rotameter industry usually stated as 14.7 psia and 70°F.

4.1.2 Gravimetric

In this method the liquid at controlled flow rates passes through the rotameter under test and is collected in a receiving tank. The weight of liquid is accurately measured by a precision scale or other weighing device. Flowing time is accurately recorded and flow rate in gravimetric units computed directly by deciding scale readings by time. Automatic operation may be achieved by means of photocell or mercury contact timing devices. Equipment for this method of measurement weighs the liquid passing through the rotameter under test and provides flow rate readings in gravimetric or weight units. Unlike volumetric systems, the readings taken from the gravimetric systems are independent of density or viscosity of the fluid. (Refer to Figure RP16.6.4)

Formula used with Figure RP16.6.4 — Liquid Calibration

$$W_m = \frac{W_c \times 60}{Sec} \sqrt{\frac{(\rho_f - \rho_m)\rho_m}{(\rho_f - \rho_c)\rho_c}}$$

Where:

W_m = Mass flow rate of fluid to be metered in pounds per minute

W_c = Weight of calibrating fluid collected in pounds

Sec = Collection time in seconds

ρ_f = Density of metering float

ρ_m = Density of liquid to be metered

ρ_c = Density of calibrating liquid

4.1.3 Comparison

In this method, liquid and gas calibrations are made by comparing the rotameter under test against an accurately calibrated flow measuring instrument (See Figure RP16.6.5). Calibration accuracy will depend entirely on the accuracy of the calibrated flow measuring instrument serving as a secondary standard.

4.2 Kinematic simulation

When it is impractical to calibrate rotameters directly because of viscosity considerations, hazards to the operator or equipment, or for economic reasons, kinematic simulation of fluid properties is employed. Through the use of a variety of fluid media and by maintaining controlled temperature conditions, viscosities and densities over a wide range can be achieved to match those physical properties of the fluid for which the rotameter is designed.

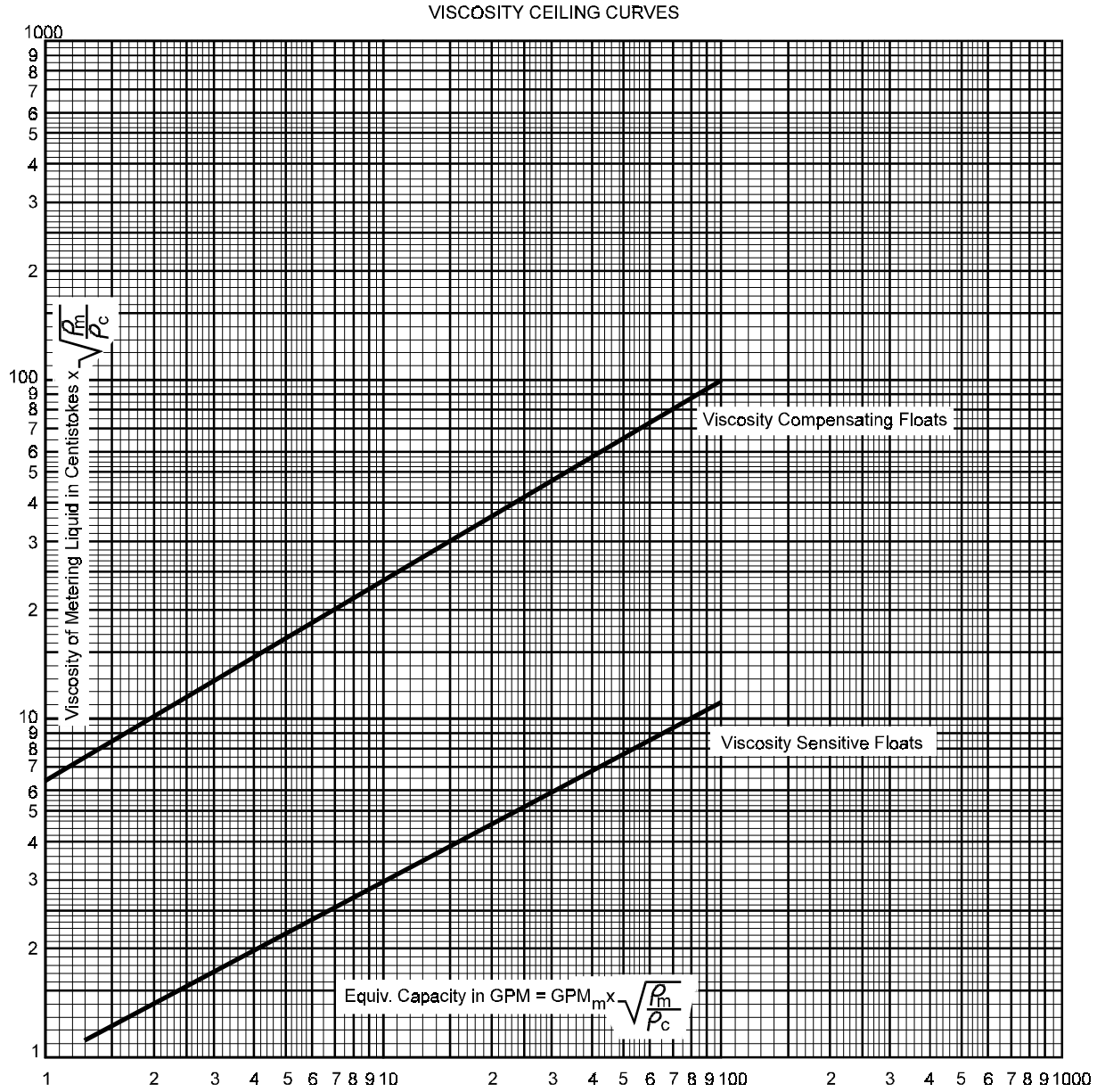
Formulas used are the same as those under 4.1.

Kinematic simulation follows the equation:

$$\text{Centistokes cal. fluid} = \text{Centistokes Metering Fluid} \times \sqrt{\frac{\text{Fluid density metering fluid}}{\text{Fluid density calibration fluid}}}$$

4.3 Field check

Any of the above methods may be used to check rotameters. Tank gaging may be used for checking liquid handling rotameters and liquid displacement methods may be used for rotameters handling gases. Actual results will be commensurate with the care employed in the calibration and the precision of the facilities.



To determine whether the viscosity of the metering liquid will permit calibration with a reference liquid, calculate equivalent capacity in GPM and plot capacity vs viscosity on above curve. If this point falls below the viscosity ceiling curve for the float being used, calibration with the reference medium is permissable. If the point is above the curve, calibration by hydraulic simulation or the actual metering liquid is required.

Figure RP16.6.1

TYPE --- Volumetric. Liquid at controlled flow rate flows thru rotameter into accurately calibrated burette. Time is accurately measured.

RANGE OF FLOWS - Fraction of c.c. Up to thousands of G.P.M.

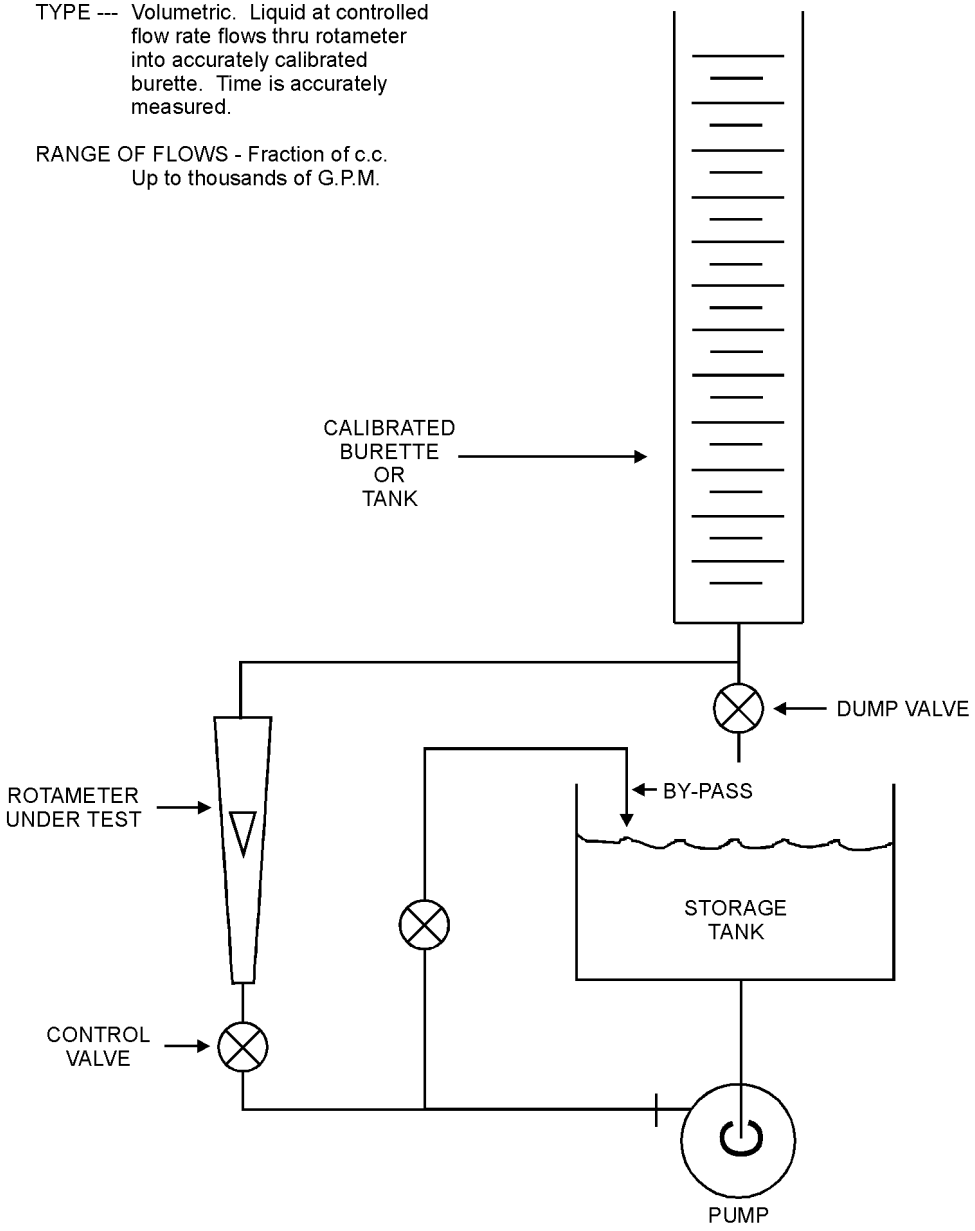
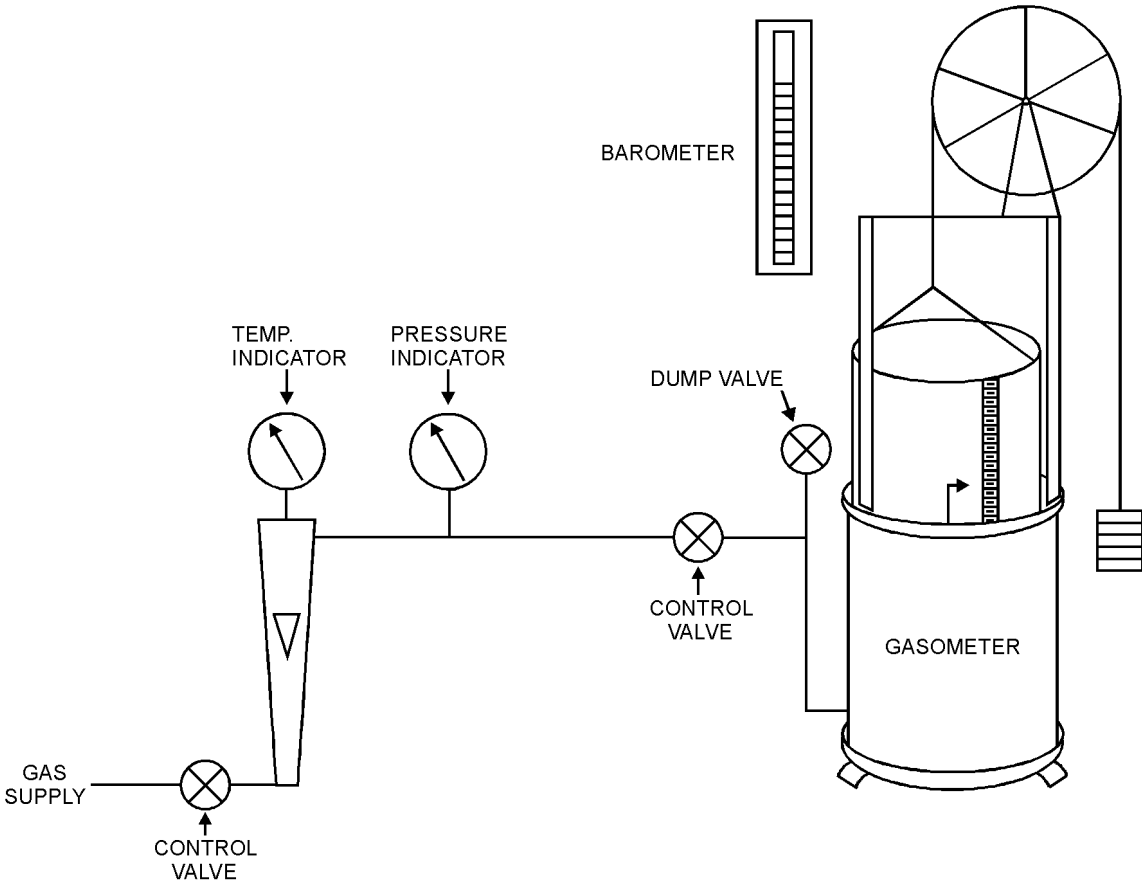


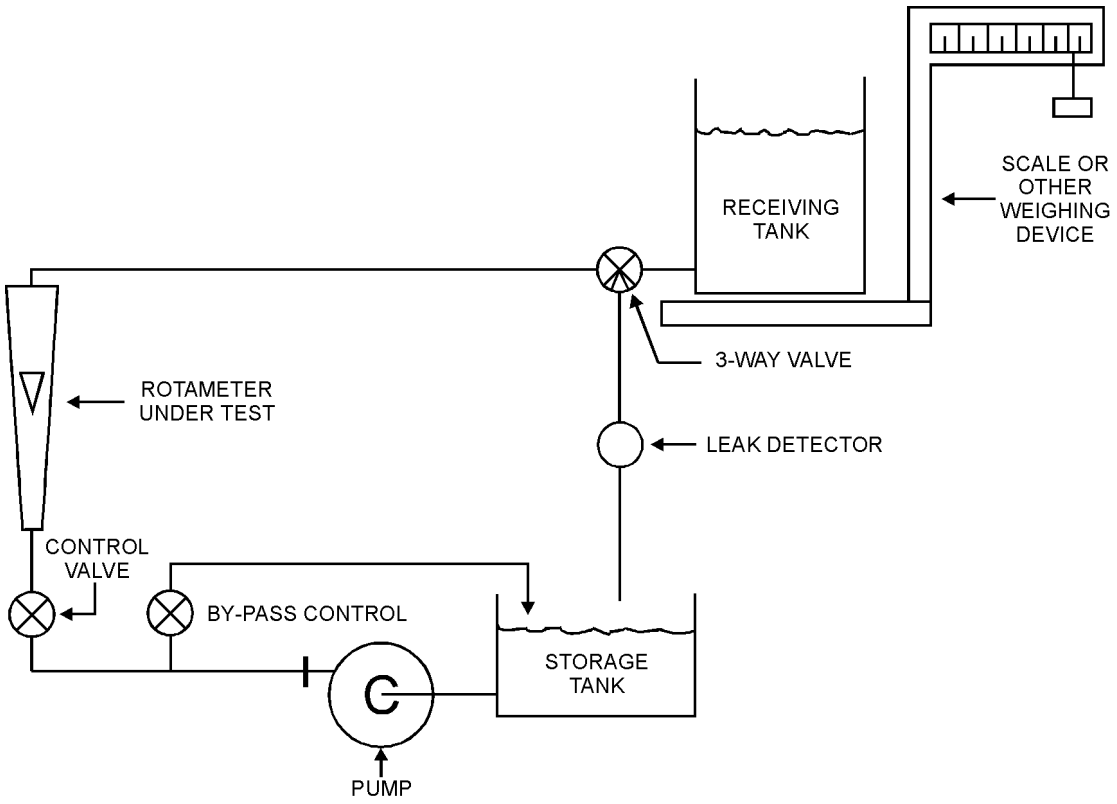
Figure RP16.6.2



TYPE ---- Volumetric Gasometer. Gas at controlled flow rate, temperature and pressure flows thru rotameter under test and is collected in inverter bell gasometer. Back pressure in bell is maintained at 2 " H_2O col. or less. Volume of gas flowing is read from scale on bell. Flowing time is recorded by accurate timer.

RANGE OF FLOWS - Spirometers and gasometers are available for flow ranges from 10 cc/min to more than 200 SCFM.

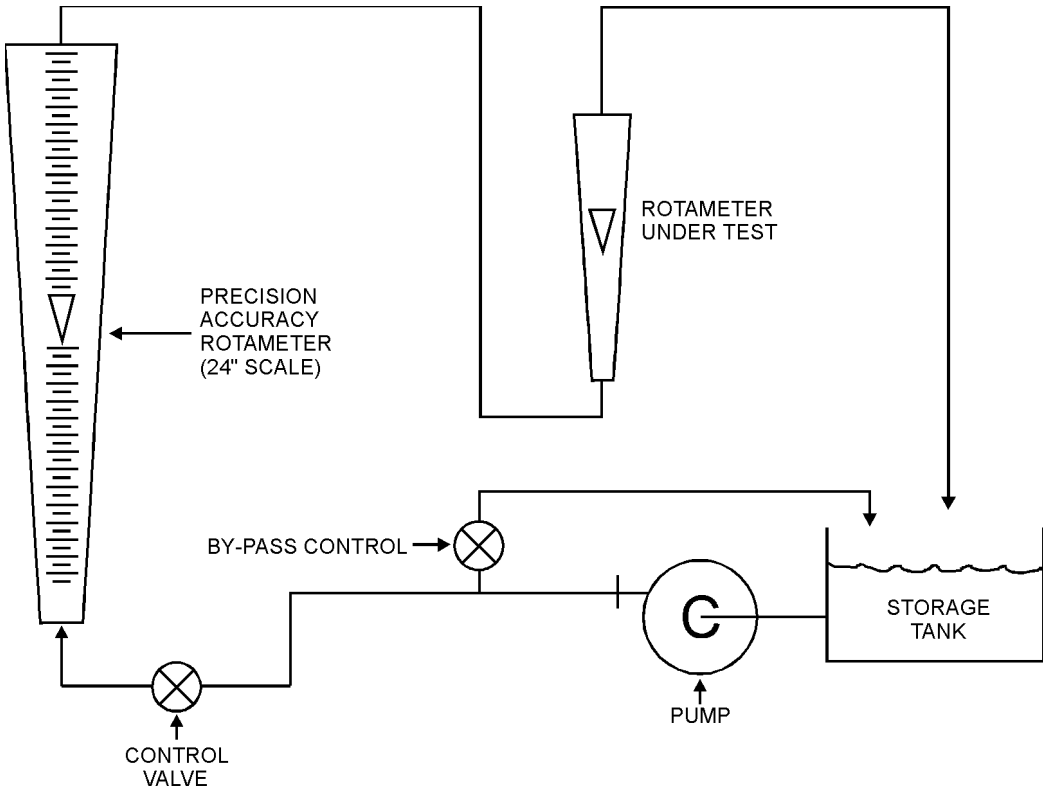
Figure RP16.6.3



TYPE ---- Gravimetric. Liquid at controlled flow rate pass thru meter and is collected in receiving tank. Weight of liquid is accurately measured by scale or other weighing device flowing time is accurately recorded.

RANGE OF FLOWS - 10 P.P.H. up

Figure RP16.6.4



TYPE ---- Comparison Method. Rotameter under test is connected in series with accurately calibrated rotameter. Fluid is pumped thru system. Readings from precision rotameter and corresponding reading from rotameter under test are recorded.

RANGE OF FLOWS - 0.1 to 150 GPM

Figure RP16.6.5

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