IEC 60534-2-3

Edition 3.0 2015-12

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Industrial-process control valves –
Part 2-3: Flow capacity – Test procedures

Vannes de régulation des processus industriels –
Partie 2-3: Capacité d'écoulement – Procédures d'essai

IEC 60534-2-3:2015-12(en-fr)

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FOREWORD

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International Standard IEC 60534-2-3 has been prepared by subcommittee 65B: Measurement and control devices, of IEC technical committee 65: Industrial-process measurement, control and automation.

The third edition cancels and replaces the second edition published in 1997, of which it constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Addition of informative Annexes B, C, D, E and F.
b) Organizational and formatting changes were made to group technically related subject matter.

The text of this standard is based on the following documents:

FDIS	Report on voting
65B/1025/FDIS	65B/1028/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60534 series, published under the general title *Industrial-process control valves*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INDUSTRIAL-PROCESS CONTROL VALVES –

Part 2-3: Flow capacity – Test procedures

1 Scope

This part of IEC 60534 is applicable to industrial-process control valves and provides the flow capacity test procedures for determining the following variables used in the equations given in IEC 60534-2-1:

a) flow coefficient C;

b) liquid pressure recovery factor without attached fittings F_L;

c) combined liquid pressure recovery factor and piping geometry factor of a control valve with attached fittings F_{LP};

d) piping geometry factor F_P;

e) pressure differential ratio factors x_T and x_{TP};

f) valve style modifier F_d;

g) Reynolds number factor F_R.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60534-1, *Industrial-process control valves – Part 1: Control valve terminology and general considerations*

IEC 60534-2-1:2011, *Industrial-process control valves – Part 2-1: Flow capacity – Sizing equations for fluid flow under installed conditions*

IEC 60534-8-2, *Industrial-process control valves – Part 8-2: Noise considerations – Laboratory measurement of noise generated by hydrodynamic flow through control valves*

IEC 61298-1, *Process measurement and control devices – General methods and procedures for evaluating performance – Part 1: General considerations*

IEC 61298-2, *Process measurement and control devices – General methods and procedures for evaluating performance – Part 2: Tests under reference conditions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60534-1, IEC 60534-2-1, IEC 61298-1, and IEC 61298-2 apply.

4 Symbols

Symbol	Description	Unit
C	Flow coefficient (K_v, C_v)	Various (see IEC 60534-1)
C_R	Flow coefficient at rated travel	Various (see IEC 60534-1)
d	Nominal valve size (DN)	mm
F_d	Valve style modifier	1
F_F	Liquid critical pressure ratio factor	1
F_L	Liquid pressure recovery factor of a control valve without attached fittings	1
F_{LP}	Combined liquid pressure recovery factor and piping geometry factor of a control valve with attached fittings	1
F_P	Piping geometry factor	1
F_R	Reynolds number factor	1
F_γ	Specific heat ratio factor	1
M	Molecular mass of flowing fluid	kg/kmol
N	Numerical constants (see Table 3)	Various (see Note 1)
p_c	Thermodynamic critical pressure	kPa or bar (see Note 2)
p_v	Vapour pressure of liquid at inlet temperature	kPa or bar
p_1	Inlet absolute static pressure measured at the upstream pressure tap	kPa or bar
p_2	Outlet absolute static pressure measured at the downstream pressure tap	kPa or bar
Δp	Differential pressure ($p_1 - p_2$) between upstream and downstream pressure taps	kPa or bar
Δp_{max}	Maximum pressure differential	kPa or bar
$\Delta p_{max(L)}$	Maximum effective Δp without attached fittings	kPa or bar
$\Delta p_{max(LP)}$	Maximum effective Δp with attached fittings	kPa or bar
Q	Volumetric flow rate	m^3/h (see Note 3)
Q_{max}	Maximum volumetric flow rate (choked flow conditions)	m^3/h
$Q_{max(L)}$	Maximum volumetric flow rate for incompressible fluids (choked flow conditions without attached fittings)	m^3/h
$Q_{max(LP)}$	Maximum volumetric flow rate for incompressible fluids (choked flow conditions with attached fittings)	m^3/h
$Q_{max(T)}$	Maximum volumetric flow rate for compressible fluids (choked flow conditions without attached fittings)	m^3/h
$Q_{max(TP)}$	Maximum volumetric flow rate for compressible fluids (choked flow conditions with attached fittings)	m^3/h
Re_v	Valve Reynolds number	1
T_1	Inlet absolute temperature	K
t_s	Reference temperature for standard conditions	°C
X	Ratio of pressure differential to inlet absolute pressure ($\Delta p/p_1$)	1
x_T	Pressure differential ratio factor of a control valve without attached fittings for choked flow	1
x_{TP}	Pressure differential ratio factor of a control valve with attached fittings for choked flow	1
Y	Expansion factor	1
Z	Compressibility factor (Z = 1 for gases that exhibit ideal gas behaviour)	1
γ	Specific heat ratio	1
ν	Kinematic viscosity	m^2/s (see Note 4)
ζ	Velocity head loss coefficient of a reducer, expander or other fitting attached to a control valve	1
ρ_1/ρ_o	Relative density (ρ_1/ρ_o = 1 for water at 15 °C)	1

NOTE 1 To determine the units for the numerical constants, dimensional analysis may be performed on the appropriate equations using the units given in Table 1.

NOTE 2 1 bar = 10^2 kPa = 10^5 Pa.

NOTE 3 Compressible fluid volumetric flow rates in m^3/h, identified by the symbol Q, refer to standard conditions which are an absolute pressure of 101,325 kPa (1,013 25 bar) and a temperature of either 0 °C or 15 °C (see Table 3).

NOTE 4 1 centistoke = 10^{-6} m^2/s.

5 Test system

5.1 Test specimen

The test specimen is any valve or combination of valve, pipe reducer, and expander or other devices attached to the valve body for which test data are required. See Annex A for additional examples of test specimens representative of typical field installations.

Additional considerations apply when testing certain styles of high-capacity control valves, e.g., ball or butterfly valves. These valves may produce free jets in the downstream test section impacting the location of the pressure recovery zone. See Clause 6 for expected accuracies.

Fractional C valves (valves where $C << N_{18}$) are addressed in 8.1.2.

Physical or computer-based modelling of control valves as the basis for flow coefficient determination is permissible but is outside the scope of this standard. When modelling, it is incumbent on the practitioner to employ suitable modelling techniques to validate the model and scaling relationships to actual flow data, and to document the nature of the model.

5.2 Test section

A basic flow test system is shown in Figure 1.

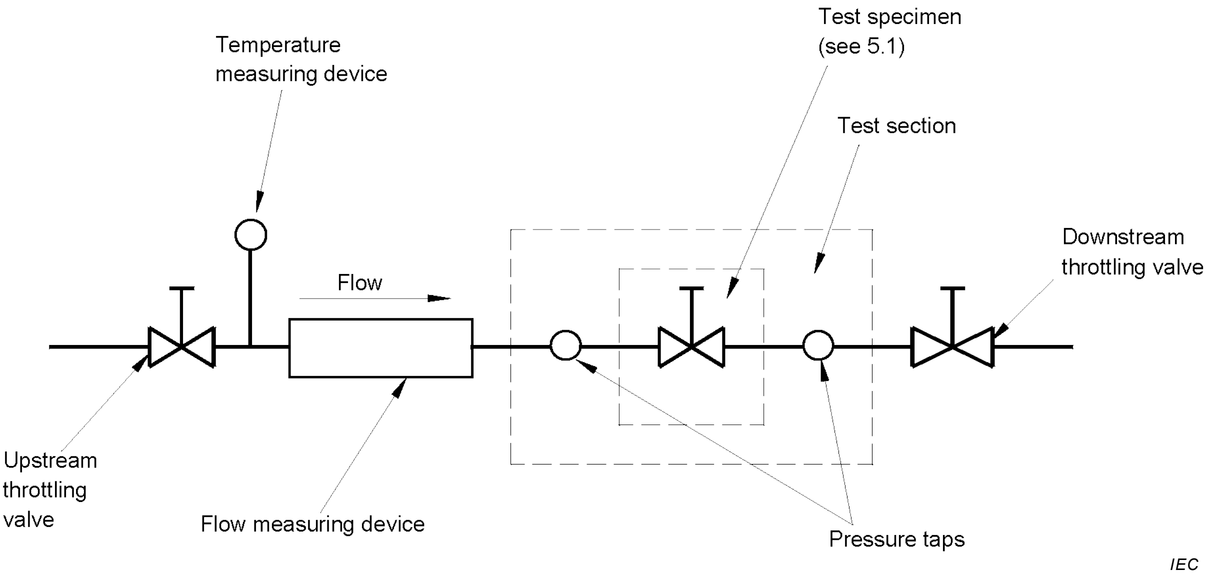


Figure 1 – Basic flow test system

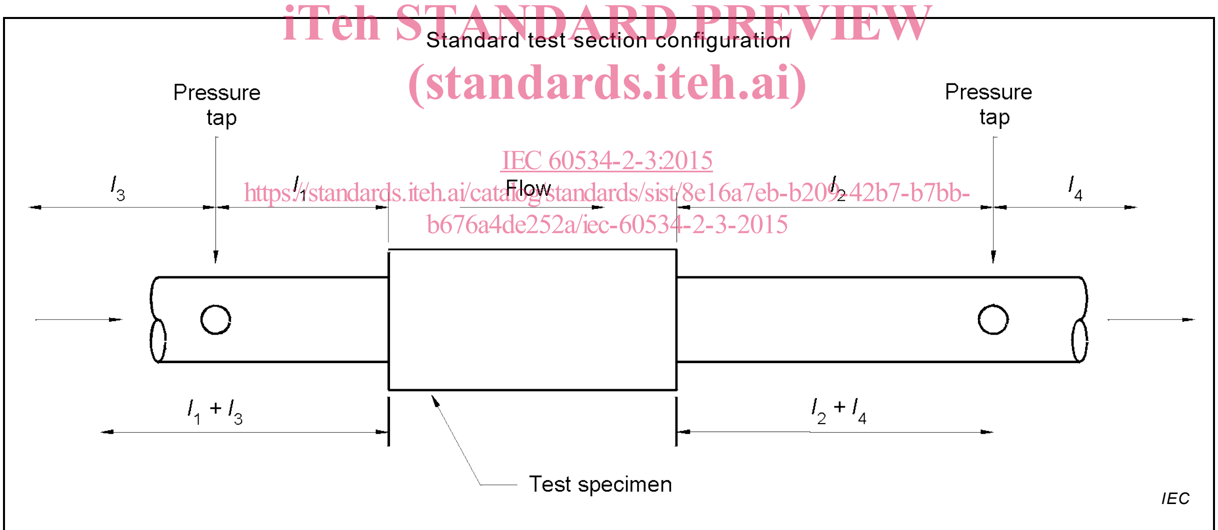
The upstream and downstream piping adjacent to the test specimen should conform to the nominal size of the test specimen connection and to the straight length requirements of Figure 2. The inlet and outlet piping shall be suitable for the maximum respective pressures that can be applied by the test system (Table B.3 provides data for commonly used pipe).

The inside diameter (ID) of the pipe normally should be within ± 2 % of the actual inside diameter of the inlet and outlet of the test specimen for all valve sizes. As the C/d^2 ratio (of the test valve) increases, the mismatch in diameters becomes more problematic. Potential pressure losses associated with the inlet and outlet joints become significant in comparison to the loss associated the valve. Also, a significant discontinuity at the valve outlet could affect the downstream (p_2) pressure measurement. One indication of the significance of mismatched diameters is the value of the piping geometry factor (F_P) based on the internal diameters. This value approaches unity for a standard test, i.e., for equal line and specimen inside diameters. Therefore, to ensure the proper accuracy for the test, it shall be demonstrated by either calculation or test that $0,99 \leq F_P \leq 1,01$. If $F_P < 0,99$, or $F_P > 1,01$ it shall be so noted in the test data (see 8.1.5 or 10.1.5). See Annex F for a sample calculation.

The inside surfaces shall be reasonably free of flaking rust or mill scale and without irregularities that could cause excessive fluid frictional losses.

5.3 Throttling valves

The upstream and downstream throttling valves are used to control the pressure differential across the test section pressure taps and to maintain a specific upstream or downstream pressure. There are no restrictions as to style of these valves. However, the downstream valve should be of sufficient capacity, and may be larger than the nominal size of the test specimen, to ensure that choked flow can be achieved at the test specimen for both compressible and incompressible flow. Vaporization at the upstream throttling valve shall be avoided when testing with liquids.



Key

l_1 Two times nominal pipe diameter

l_2 Six times nominal pipe diameter

l_3 Eighteen times nominal pipe diameter minimum

l_4 One times nominal pipe diameter minimum

NOTE 1 Straightening vanes may be used where beneficial. If employed, the length l_3 may be reduced to not less than eight times the nominal pipe diameter. Information concerning flow conditioning can be found in ASME Performance Test Code PTC 19.5-2004, "Flow Measurement".

NOTE 2 The location of the pressure taps are upstream and downstream of the test specimen as a whole. The test specimen may be simply the control valve or the control valve with any combination of attached fittings (see Annex A).

NOTE 3 If upstream flow disturbance consists of two elbows in series and they are in different planes, additional flow conditioning is required. See ASME Fluid meters for additional guidelines for line length.

Figure 2 – Test section piping requirements

5.4 Flow measurement

The flow measuring instrument may be located upstream or downstream of the test section, and may be any device which meets the specified accuracy. The accuracy rating of the instrument shall be ±2 % of actual output reading. The resolution and repeatability of the instrument shall be within ±0,5 %. The measuring instrument shall be calibrated as frequently as necessary to maintain specified accuracy. All guidelines specific to the flow-measuring instrument regarding flow conditioning (e.g., the number of straight pipe diameters, upstream and downstream of the instrument, etc.) shall be followed.

5.5 Pressure taps

Pressure taps shall be provided on the test section piping in accordance with the requirements listed in Figure 3. These pressure taps shall conform to the construction illustrated in Figure 3. The edge of of the pressure tap hole shall be clean and sharp (i.e., check for corrosion and/or erosion) or slightly rounded, free from burrs, wire edges or other irregularities. In no case shall any fitting protrude inside the pipe.

Orientation:

Incompressible fluids – Tap centrelines should be located horizontally to reduce the possibility of air entrapment or dirt collection in the pressure taps.

Compressible fluids – Tap centrelines should be oriented horizontally or vertically above pipe to reduce the possibility of dirt or condensate entrapment.

For butterfly and other rotary valves, the pressure taps shall be aligned (parallel) to the main shaft of the valve to reduce the effect of the velocity head of the flowing fluid on the pressure measurement.

Multiple pressure taps can be used on each test section for averaging pressure measurements. Each tap shall conform to the requirements in Figure 3.

See 5.9 for other installation guidelines.

5.6 Pressure measurement

All pressure and pressure differential measurements shall be made using instruments with an accuracy rating of ±2 % of actual output reading. Pressure-measuring devices shall be calibrated as frequently as necessary to maintain specified accuracy.

If individual pressure measurements (p_1, p_2) are used in lieu of a single differential pressure measurement (Δp), care shall be taken to select instruments which are accurate enough that the calculated pressure differential value ($p_1 - p_2$) is known with an accuracy at least as good as the accuracy rating stated above for pressure differential measurements.

5.7 Temperature measurement

The fluid temperature shall be measured using an instrument with an accuracy rating of ±1 °C (±2 °F) of actual output reading. The temperature measuring probe should be chosen and positioned to have minimum effect on the flow and pressure measurements. Thermocouples used for temperature measurement should be at least Class B according to IEC 60751.

The inlet fluid temperature shall remain constant within ±3 °C (±5 °F) over the time interval during which the test data is recorded for each specific test point. The flowing system should be allowed to stabilize for a period of time that exceeds the time constant of the measuring device to ensure that the correct temperature is being recorded.

5.8 Valve travel

The valve travel shall be fixed within ±0,5 % of the rated travel during any one specific flow test.

The accuracy rating of the travel-measuring instrument shall be ±0,2 % of rated travel.

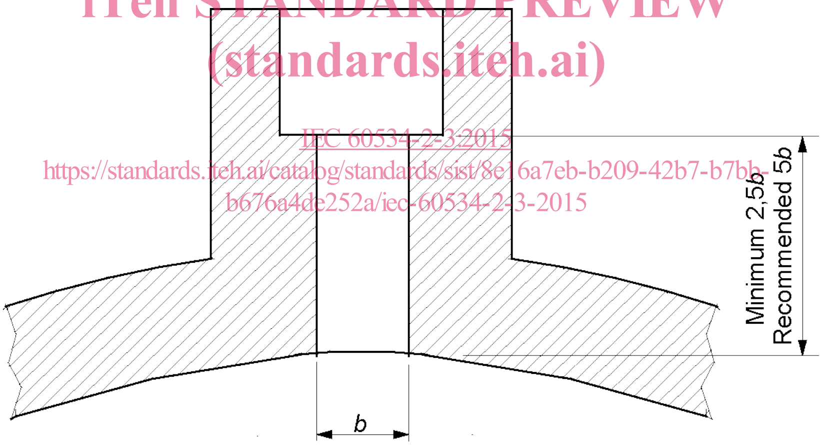
5.9 Installation of test specimen

Alignment between the centreline of the test section piping and the centreline of the inlet and outlet of the test specimen shall be within (see Table 1 and Figure 3):

Table 1 – Test specimen alignment

Pipe size	Allowable misalignment
DN 15 through DN 25	0,8 mm
DN 32 through DN 150	1,6 mm
DN 200 and larger	0,01 nominal pipe diameter

The inside diameter of each gasket shall be sized and the gasket positioned so that it does not protrude inside the pipe.



b = pressure tap diameter

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NOTE 1 Any suitable method of making the physical connection is acceptable if above recommendations are adhered to.

NOTE 2 Reference: ASME Performance Test Code PTC 19.5-1972, "Applications. Part II of Fluid Meters, Interim Supplement on Instruments and Apparatus."

Size of pipe	"*b*" Not exceeding	"*b*" Not less than
Less than 50 mm	6 mm	3 mm
50 mm to 75 mm	9 mm	3 mm
100 mm to 200 mm	13 mm	3 mm
250 mm and greater	19 mm	3 mm

Figure 3 – Recommended pressure tap connection

6 Accuracy of tests

Valves having an $\frac{C}{N_{18}d^2} < 0{,}047$ and x_T < 0,84 at tested travel will have a calculated flow coefficient, C, of the test specimen within a tolerance of ± 5 %. The tolerance for valves that do not meet these criteria may exceed 5 %. These accuracy statements apply when fully turbulent flow can be established. See Annex D for further information when this is not the case.

See cautions presented in 5.1.

7 Test fluids

7.1 Incompressible fluids

Fresh water that is free of appreciable entrained solids (i.e., < 1 000 × 10^{-6} dissolved salts; < 1 000 × 10^{-6} entrained solids) shall be the basic fluid used in this procedure. Inhibitors may be used to prevent or retard corrosion and to prevent the growth of organic matter. The aggregate effect of additives and all contaminants on density or viscosity shall be evaluated by computation using the equations in this standard. The sizing coefficient shall not be affected by more than 0,1 %. Test fluids other than fresh water may be required for obtaining F_R and F_F. Test fluid temperature range for fresh water should be 5 °C to 40 °C.

7.2 Compressible fluids

Air or some other compressible fluid shall be used as the basic fluid in this test procedure. The test fluid shall fall in the ideal gas behaviour range under test conditions, and therefore shall have a ratio of specific heats that falls in the range 1,2 ≤ γ ≤ 1,6 (see Cunningham, Driskell, in the Bibliography). Vapours that may approach their condensation points at the vena contracta of the specimen are not acceptable as test fluids. Care should be taken to avoid internal icing during the test.

8 Test procedure for incompressible fluids

8.1 Test procedure for flow coefficient *C*

8.1.1 Install the test specimen without attached fittings in accordance with piping requirements in Figure 2.

8.1.2 Flow tests shall include flow measurements at three widely spaced pressure differentials (but not less than 0,1 bar) within the turbulent, non-vaporizing region. The suggested differential pressures are

a) just below the onset of cavitation (incipient cavitation) or the maximum available in the test facility, whichever is less (see IEC 60534-8-2);

b) about 50 % of the pressure differential of a);

c) about 10 % of the pressure differential of a).

The pressures shall be measured across the test section pressure taps with the valve at the selected travel.

For very small valve capacities, non-turbulent flow may occur at the recommended pressure differentials. In this case, larger pressure differentials shall be used to ensure turbulent flow. Flow tests should be conducted at conditions where the valve Reynolds Number, Re_v, (see equation (13)) is 100 000 or higher. If it is not possible to attain a minimum valve Reynolds Number of 100 000, then a compressible flow coefficient test should be considered (also see Annex D). Deviations and reason for the deviations from standard requirements shall be recorded.

For large valves where flow source limitations are reached, lower pressure differentials may be used optionally as long as turbulent flow is maintained. Deviations from standard requirements shall be recorded and the reasons for the deviations shall be indicated.

8.1.3 In order to keep the downstream portion of the test section filled with liquid and to prevent vaporization of the liquid, the absolute upstream pressure shall be maintained at a minimum of $2\Delta p/F_L^2$ or p_{atm}+0,14 bar, whichever is greater. If the liquid pressure recovery factor, F_L, of the test specimen is unknown, a conservative (i.e. low) estimate may be used. See Annex E of IEC 60534-2-1: 2011 for typical F_L values. Table 2 provides the minimum upstream pressures for selected values of Δp and F_L. The line velocity should not exceed 13,7 m/s to avoid vaporization in fresh water.

8.1.4 Flow tests shall be performed to determine:

a) the rated flow coefficient C_R using 100 % of rated travel;

b) inherent flow characteristics (optional), using 5 %, 10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 %, 90 % and 100 % of rated travel.

NOTE To determine the inherent flow characteristic more fully, flow tests may be performed at travel intervals less than 5 % of rated travel.

Table 2 – Minimum inlet absolute test pressure in kPa (bar) as related to F_L and Δp

	Minimum inlet absolute test pressure – kPa (bar)								
Δp kPa (bar)→ F_L↓	35 (0,35)	40 (0,40)	45 (0,45)	50 (0,50)	55 (0,55)	60 (0,60)	65 (0,65)	70 (0,70)	75 (0,75)
0,5	280 (2,8)	320 (3,2)	360 (3,6)	400 (4,0)	440 (4,4)	480 (4,8)	520 (5,2)	560 (5,6)	600 (6,0)
0,6	190 (1,9)	220 (2,2)	250 (2,5)	270 (2,7)	300 (3,0)	330 (3,3)	360 (3,6)	380 (3,8)	410 (4,1)
0,7	150 (1,5)	160 (1,6)	180 (1,8)	200 (2,0)	220 (2,2)	240 (2,4)	260 (2,6)	280 (2,8)	300 (3,0)
0,8	150 (1,5)	160 (1,6)	160 (1,6)	170 (1,7)	170 (1,7)	190 (1,9)	200 (2,0)	220 (2,2)	230 (2,3)
0,9	150 (1,5)	160 (1,6)	160 (1,6)	170 (1,7)	170 (1,7)	180 (1,8)	180 (1,8)	190 (1,9)	190 (1,9)

NOTE 1 For large valves where flow source limitations are reached, lower pressure differentials may be used optionally as long as turbulent flow is maintained and differential pressure measurement accuracy is within specification.

NOTE 2 For pressures not listed, use the following equation to calculate the upstream pressure: $p_{1,min} = 2\Delta p/F_L^2$.

8.1.5 Record the following data:

a) valve travel;

b) inlet pressure p_1;

c) pressure differential ($p_1 - p_2$) across the pressure taps;

d) fluid inlet temperature T_1;

e) volumetric flow rate Q;

f) barometric pressure;