Basic principles

Q = Upper range value quantity unit per time unit

Liquids:

Q_v Flow measurement
Q_m Weight measurement (flow measurement x density)

Gases:

Q_n Flow measurement of gases in operating condition and scaling in standard condition
Q_n Flow measurement of gases in operating condition and scaling in operating condition
Q_m Weight measurement of gases in operating condition and scaling in standard condition (flow measurement x density)

Quantity unit:

e.g. m^3; l (dm^3), ml (cm^3)

Time unit:

e.g. h , min., sec.

Here a few examples: Conversion of the measuring units to l/h or m^3/h

Abbreviation	Factor in l/h	Factor in m^3/h
m3/h	1000	1
l/h	1	0.001
ml/h	0.001	0.000001
ml/min	0.06	0.00006
ml/s	3.6	0.0036
l/min	60	0.06
l/s	3600	3.6
hl/h	100	0.1
hl/min.	6000	6
cm3/h	0.001	0.000001
cm3/min	0.06	0.00006
cm3/s	3.6	0.0036
dm3/h	1	0.001
dm3/min	60	0.06
dm3/s	3600	3.6
m3/min	60000	60
US-Gal /min	227.1	0.2271
US-Gal /h	3.785	0.003785

The operating data in water or air are converted for calibration of the measuring equipment. The values are scaled **up to** limit value of 3000 in e. g. 300 – 3000 l/h and scaled **above** a limit value of 3000 e. g. 0.4 – 4 m³/h.

VDI/VDE Directive 3513 sheet 1 describes the procedure for the calculation of scales of rotameter flowrate metering equipment. For this, all substances and flow parameters e.g. density, viscosity, pressure and temperature are considered.

Conversion of the customer medium into a calibration medium

Calibration condition corresponds with the flowrate values stated on the type sheet

For	liquids:	for gases:
Medium:	Water	air
Density:	1 kg/l	1.293 kg/m³
Viscosity:	1 mPa.s	0.0181 mPa.s
Temperature:	20 °C	20 °C
Pressure:	p_{abs} 1.013 bar	p_{abs} 1.013 bar

Example for liquids :

Density:

Density of operating liquids in kg/l	0.5	0.6	0.7	0.8	0.9	1.0
Factor	0.68	0.75	0.82	0.88	0.94	1.00
Density of operating liquids in kg/l	1.1	1.2	1.3	1.4	1.5	1.6
Factor	1.06	1.10	1.17	1.22	1.27	1.32

Customer medium 10 m³/h with a density of 1.4 kg/l

corresponds with a flowrate in the type sheet of 12.2 m³/h

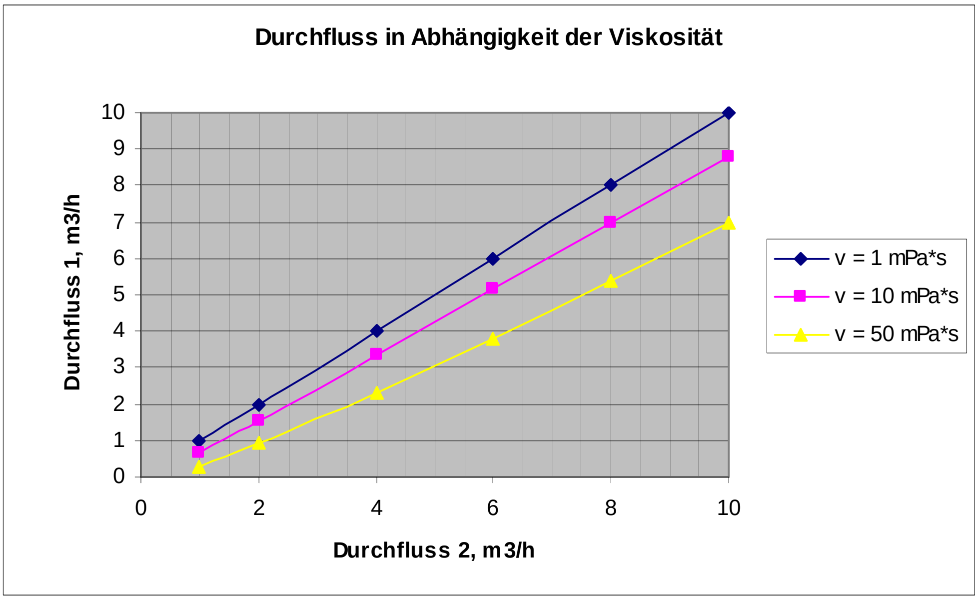
From this it follows that: customer density smaller — factor under 1
customer density greater — factor above 1

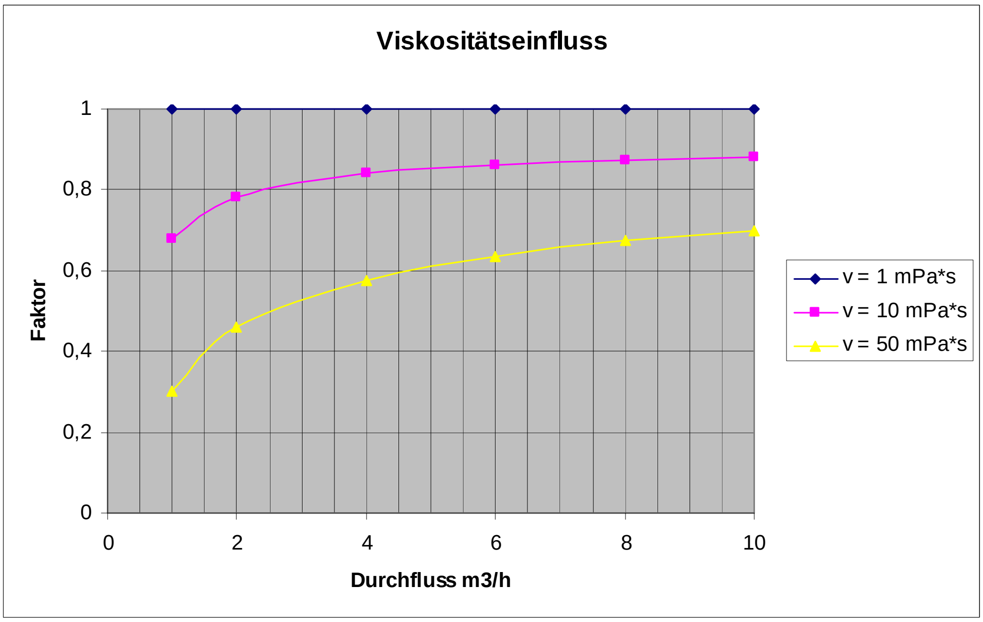
Temperature:

is considered via the density

Viscosity:

For the viscosity, no factor can be stated over the entire measuring range!
Viscosity depends on speed!





Example for gases:

Density:

Medium	Air	Oxygen	Nitrogen	Ammonia	Chloric gas	Hydrogen	Carbon dioxide	Propane
Density of operating gas in kg/m³	1.293	1.429	1.251	0.771	3.220	0.089	1.977	2.020
Factor	1.00	1.05	0.98	0.77	1.58	0.26	1.24	1.25

Customer medium 10 m³/h ammonia:

corresponds with a flowrate in the type sheet of 7.7 m³/h

From this it follows that: customer density smaller — factor under 1
customer density greater — factor above 1

Temperature:

Temperature of operating gas in °C	0	10	20	30	40	50	60
Factor	0.97	0.98	1.00	1.02	1.03	1.05	1.07

From this it follows that: customer temperature smaller — factor under 1
customer temperature greater — factor above 1

Pressure:

Pressure of operating gas in bar **absolute**	0.5	1.01	3	5	10	20	40
Factor	1.42	1.00	0.58	0.45	0.32	0.23	0.16

Customer pressure 5 bar absolute (pe 4 bar) with 10 m³/h

corresponds with a flowrate in the type sheet of 4.5 m³/h

From this it follows that: Pressure smaller — factor above 1
Pressure greater — factor under 1

Mecon GmbH
Zieglerstraße 10 – 16
D - 52078 Aachen

Phone 0241 (41369)241 41369 – 0
Fax 0241 (41369)241 41369 – 40

www.mecon.de
E.mail: info@mecon.de

Registered Office of the Company and Register Court Cologne - HRB-No. 52534 - VAT.-IdNo.: DE813470098 - Tax-IdNo.: 204 / 5735 / 1489 - Managing Director Grad. Eng., Dirk Hamböcker

Accuracy classes

According to Directive VDE/VDE 3513, sheet 2, the measuring accuracy for flowrate measuring equipment is defined into various accuracy classes. Depending on the flow, the following measurement uncertainties, measured in % of the measuring value or in % of the upper range value, are permissible.

A measuring uncertainty is assigned to each accuracy class, which must not be exceeded anywhere along the measuring range. This range is created as the sum of the two following indexing errors:

1. Indexing error: 3/4 of the figure stated as the accuracy class is the error as a percentage of the measured value

2. Indexing error: 1/4 of the figure stated as the accuracy class is the error as a percentage of the full-scale value

The total deviation can be calculated according to the following formula:

$$\text{Positionsfehler} = \left(\frac{3}{4}\,Messwert + \frac{1}{4}\,Endwert\right) \times \frac{K}{100}$$

with K as the stated figure for the accuracy class

Mecon GmbH
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D - 52078 Aachen

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Fax 0241 (41369)241 41369 – 40

www.mecon.de
E.mail: info@mecon.de

Registered Office of the Company and Register Court Cologne - HRB-No. 52534 - VAT.-IdNo.: DE813470098 - Tax-IdNo.: 204 / 5735 / 1489 - Managing Director Grad. Eng., Dirk Hamböcker

Flow in %	Accuracy class 0.4 1. indexing error	0.4 2. indexing error	0.4 overall error	0.6 1. indexing error	0.6 2. indexing error	0.6 overall error	1 1. indexing error	1 2. indexing error	1 overall error	1.6 1. indexing error	1.6 2. indexing error	1.6 overall error
100	0,30	0,10	0,40	0,45	0,15	0,60	0,75	0,25	1,00	1,20	0,40	1,60
90	0,27	0,10	0,37	0,41	0,15	0,56	0,68	0,25	0,93	1,08	0,40	1,48
80	0,24	0,10	0,34	0,36	0,15	0,51	0,60	0,25	0,85	0,96	0,40	1,36
70	0,21	0,10	0,31	0,32	0,15	0,47	0,53	0,25	0,78	0,84	0,40	1,24
60	0,18	0,10	0,28	0,27	0,15	0,42	0,45	0,25	0,70	0,72	0,40	1,12
50	0,15	0,10	0,25	0,23	0,15	0,38	0,38	0,25	0,63	0,60	0,40	1,00
40	0,12	0,10	0,22	0,18	0,15	0,33	0,30	0,25	0,55	0,48	0,40	0,88
30	0,09	0,10	0,19	0,14	0,15	0,29	0,23	0,25	0,48	0,36	0,40	0,76
20	0,06	0,10	0,16	0,09	0,15	0,24	0,15	0,25	0,40	0,24	0,40	0,64
10	0,03	0,10	0,13	0,05	0,15	0,20	0,08	0,25	0,33	0,12	0,40	0,52

Flow in %	Accuracy class 2,5 1. indexing error	2,5 2. indexing error	2,5 overall error	4 1. indexing error	4 2. indexing error	4 overall error	6 1. indexing error	6 2. indexing error	6 overall error	10 1. indexing error	10 2. indexing error	10 overall error
100	1.88	0.63	2.50	3.00	1.00	4.00	4.50	1.50	6.00	7.50	2.50	10.00
90	1.69	0.63	2.31	2.70	1.00	3.70	4.05	1.50	5.55	6.75	2.50	9.25
80	1.50	0.63	2.13	2.40	1.00	3.40	3.60	1.50	5.10	6.00	2.50	8.50
70	1.31	0.63	1.94	2.10	1.00	3.10	3.15	1.50	4.65	5.25	2.50	7.75
60	1.13	0.63	1.75	1.80	1.00	2.80	2.70	1.50	4.20	4.50	2.50	7.00
50	0.94	0.63	1.56	1.50	1.00	2.50	2.25	1.50	3.75	3.75	2.50	6.25
40	0.75	0.63	1.38	1.20	1.00	2.20	1.80	1.50	3.30	3.00	2.50	5.50
30	0.56	0.63	1.19	0.90	1.00	1.90	1.35	1.50	2.85	2.25	2.50	4.75
20	0.38	0.63	1.00	0.60	1.00	1.60	0.90	1.50	2.40	1.50	2.50	4.00
10	0.19	0.63	0.81	0.30	1.00	1.30	0.45	1.50	1.95	0.75	2.50	3.25

In addition, the accuracy of the measuring devices in percent % can

Depending on the flow, the following measurement uncertainties, measured in % of the upper range value, are permissible along the entire display range.

Flow in %	Measuring accuracy: 1.6	2	3	4	5
100	1.60	2.00	3.00	4.00	5.00
90	1.60	2.00	3.00	4.00	5.00
80	1.60	2.00	3.00	4.00	5.00
70	1.60	2.00	3.00	4.0	5.00
60	1.60	2.00	3.00	4.00	5.00
50	1.60	2.00	3.00	4.00	5.00
40	1.60	2.00	3.00	4.00	5.00
30	1,60	2.00	3.00	4.00	5.00
20	1.60	2.00	3.00	4.00	5.00
10	1.60	2.00	3.00	4.00	5.00

Rotameter flowrate measuring devices generally have a vertical pipe that continuously extends towards the top, in which a specially shaped rotameter can move freely up and down.

The measuring substance flows from bottom to top through the pipe. In doing so, it lifts the rotameter until an annular gap between the pipe wall and the rotameter is formed, whereby the forces acting on the rotameter are balanced.

Three main forces act on the rotameter:

- the constant force of gravity
- the hydrostatic buoyancy, which is also constant if the density of the measuring substance is constant, according to the Archimedes Principle.
- force S, with which the flow lifts the rotameter.

Flowrate measuring devices, which work according to the principle of flotation, use a vertical conical measuring pipe made of glass, metal or plastic, in which a specially shaped rotameter can move freely up and down. When flowing from bottom to top, the rotameter adjusts itself such that the buoyancy and its form resistance are in equilibrium with the mass. The flowrate values are read off on the scale at the measuring edge of the rotameter

Each flowrate value therefore corresponds with a defined annular gap. This results from the conical shape of the measuring pipe at a certain height position of the rotameter.

The flowrate value for glass cones can be directly read off on a scale at the reading edge of the rotameter.

For metal cones the position of the rotameter is magnetically transferred to a display.