Calculation Basics

deltaflow
made by systec

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Welcome to systec Controls

The deltaflow dynamic pressure probe you have purchased is a highly precise measurement tool of superior quality. You can count on it for the very best performance even under the most adverse conditions.

Accurate evaluation of all measurements and precise calculation of flow are integral factors contributing to the high degree of precision.

This booklet contains all information you will need in order to achieve optimal measurement results with your deltaflow.

Table of Contents

Basics / Units of Measurement

All units of measurement used in this booklet are SI units. If you use a different unit system, we recommend that you convert your values to SI units before performing calculations and then afterwards convert them back to the unit system you are using.

Pressure p in Pa	
Unit	SI Unit Pa
hPa	1hPa = 100 Pa
kPa	1kPa = 1,000 Pa
MPa	1Mpa = 1,000,000 Pa
mbar	1mbar = 100 Pa
bar	1bar = 100,000 Pa
Torr	1 Torr = 133.3224 Pa
at	1 at = 98,066.65 Pa
atm	1 atm = 101,325 Pa
mWS	1 mWS = 9806.65 Pa
mmWS	1 mmWS = 9.80665 Pa
mmHG	1 mmHG = 133.322 Pa
psi (lbf/in^2)	1 psi = 6,894.76 Pa

In this booklet, the pressure unit should always be interpreted as absolute pressure (index *abs*). If gauge pressure values are the only values which are available (index ü or g), then the current or average ambient pressure at the sampling site must be added. The average ambient pressure at sea level is 101,325Pa.

Temperature T in K	
Unit	SI Unit K
°C	K=°C+273.15
°F	K=((°F-32)*5/9)+273.15

Differential Pressure dp in Pa	
Unit	SI Unit Pa
hPa	1hPa = 100 Pa
kPa	1kPa = 1,000 Pa
mbar	1mbar = 100 Pa
bar	1bar = 100,000 Pa
mWS	1 mWS = 9806.65 Pa
mmWS	1 mmWS = 9.80665 Pa
mmHG	1 mmHG = 133.322 Pa
psi (lbf/in^2)	1 psi = 6,894.76 Pa

Mass Flow qm in kg/s	
Unit	SI Unit kg/s
t/d	1 t/d = 1,000/86,400 kg/s
t/h	1 t/h = 1,000/3,600 kg/s
t/min	1 t/min = 1,000/60 kg/s
t/s	1 t/s = 1,000 kg/s
kg/h	1 kg/h = 1/3,600 kg/s
kg/min	1 kg/min = 1/60 kg/s
lb/d	1 lb/d = 5.249911*10e-6 kg/s
lb/h	1 lb/h = 125.99786*10e-6 kg/s
lb/min	1 lb/min = 7.5598*10e-3 kg/s
lb/s	1 lb/s = 0,45359237 kg/s

Instructions for converting the mass flow into volume flow, standard volume flow, or speed are described later in this booklet.

Diameter d in m	
Unit	SI Unit m
mm	1 mm = 0.001 m
cm	1 cm = 0.01 m
ft	1 ft = 0.3048 m
in	1 in = 0.0254 m

Medium Density ρ in kg/m³	
Unit	SI Unit m
kg/dm³	1 kg/dm³= 1,000 kg/m³
g/cm³	1 g/cm³ = 1,000 kg/m³
kg/l	1 kg/l = 1,000 kg/m³

General Basic Calculation Information

The way flow is calculated with the deltaflow is similar to the way flow is calculated according to EN ISO 5167-1 (formerly DIN 1952). The following formula applies to flow:

$$q_m = \sqrt{\frac{1}{\zeta}}\varepsilon\frac{\pi}{4}d^2\sqrt{2dp\rho_B} \qquad (1)$$

Formula Symbol	Measurement	SI Unit
q_m	Mass flow	kg/s
ζ	Probe-specific resistance coefficient (blockage factor)	-
ε	Expansion Number (for incompressible media =1)	-
d	Conduit interior diameter	m
dp	Differential pressure	Pa
ρ_B	Medium density under operating conditions	kg/m³

Index	Meaning
N	Standard conditions (101,325 Pa, 273.15K)
B	Operating conditions (current pressure and current temperature inside the conduit)
D	Design conditions (pressure and temperature settings incorporated into the deltaflow design, identified on the calculation sheet)

Resistance Coefficient

You will find the resistance coefficient ζ (Zeta) on your deltaflow calculation sheet. In some documents the probe factor K ("K number") is used instead of ζ. There is a simple correspondence between ζ and the K number, and conversion between the two is easy:

$$K = \sqrt{\frac{1}{\zeta}} \quad \text{or} \quad \zeta = \frac{1}{K^2}$$

In contrast to many other primary elements, the deltaflow's resistance coefficient in turbulent flow is not dependent on the flow itself or on the medium (Reynolds).

If for some reason you do not receive a calculation sheet with your deltaflow, you can order one from systec Controls by providing the serial number from your unit. Or you can use the free deltacalc software, which can be downloaded from the systec Controls website at www.systec-controls.de.

Expansion Number ε

The expansion number ε (Epsilon) defines the effect of the pressure loss and the resulting change in the density of the medium on the flow measurement.

In the case of incompressible media (liquids), pressure loss at the primary element does not result in any change in density, so the expansion number is 1.

In the case of compressible media (gasses, steam), the expansion number varies proportionally from 1 as the amount of pressure loss at the primary element increases and as the static pressure within the conduit decreases.

Because the deltaflow causes only a very minor pressure loss, the expansion number is usually very close to 1. You will find the expansion number at the design point ε_D listed on your deltaflow calculation sheet.

When calculating flow, the expansion number is often assumed to be a constant. To do this, the expansion number is generally calculated as 2/3 of the maximum flow qmax ($\varepsilon_{2/3}$). For deltaflow purposes it is very easy to calculate $\varepsilon_{2/3}$ from ε_D:

$$\varepsilon_{2/3} = 1 - \frac{4}{9}(1 - \varepsilon_D)$$

For applications in which the expansion number varies significantly from 1, calculating the actual current expansion number can increase the accuracy of the quantity measurement. The actual current expansion number ε_B can be calculated from the design expansion number ε_D as follows:

$$\varepsilon_B = 1 - \left[\frac{p_D \cdot dp_B}{p_B \cdot dp_D} \cdot (1 - \varepsilon_D) \right]$$

Conduit Interior Diameter Conduit d

The interior diameter of the conduit has a great impact on the accuracy of the flow calculation. For this reason we recommend that you determine the exact interior diameter measurement at the sampling point when conducting measurements which require a high degree of accuracy. The mathematical average from multiple measurements can be used when dealing with non-round conduits.

The interior diameter can change at high temperatures due to the thermal expansion of the material. For this reason, the calculation sheet of your deltaflow specifies the "warm" interior diameter of your conduit. This means that it is only necessary—and practical—to calculate the actual interior diameter at a given moment (d_B) if the process temperatures change dramatically during the course of operation. The warm interior diameter is calculated as follows:

$$d_B = d_D \cdot (1 + \alpha(T_B - T_D))$$

In this formula, α represents the vertical (length) expansion coefficient of the conduit material. For most steels, the value of α falls between 10*10e-6 and 16*10e-6. A temperature increase of 100K, for example, would result in an increased diameter measurement of 0.13% based on the material, and the flow would be increased by 0.26%.

A table containing the vertical expansion coefficient values of various materials is located in the Appendix.

Measured Differential Pressure dp

As you can see in Equation (1), the differential pressure is located below the radical when calculating flow. Many differential pressure transducers can automatically extract the root given the measured differential pressure signal. The output signal from this type of transducer is then no longer proportional to the differential pressure, but is instead proportional to the root of the differential pressure.

It is therefore extremely important to be aware of whether or not the root extraction is automatically performed within the transducer when evaluating the measurement signals from differential pressure transducers.

Current Operational Density ρ_B

The density of a medium depends upon its composition, the temperature, and the pressure which is applied to it.

The density of liquids is only affected in a very slight way by the pressure. For this reason, liquids are also referred to as "incompressible media." Likewise, the effect that temperature has on liquids is substantially less than the effect it has on gasses or steams.

There are basically two principal approaches to calculating the density of media: calculation based on tables and calculation based on equations.

Calculating density based on tables is very simple and exact, but it does require that a density table exist and be available. Density tables for many common media can be found in the appendix of this booklet. It is permissible to construct a linear interpolation between sampling points when there is no phase transition (i.e. boiling or melting point) located between the sampling points.

There are many formulas for calculating density based on equations. These formulas vary in their ease of use and in their accuracy. A few common formulas are detailed below.

Calculating the Density of Liquids Using a Volume Expansion Coefficient

One simple method of calculating the medium density of liquids is to use constant volume expansion coefficients.

$$\rho_B = \rho_{20°C} \frac{1}{(1 + \gamma(T_B - 293.15K))}.$$

Example: Water at 50°C and 1 bar

$$\rho_{70°C} = 998.2 \frac{kg}{m^3} \frac{1}{\left(1 + 20.7 * 10e - 5 \frac{1}{K}(30K)\right)} = 992.0 \frac{kg}{m^3}.$$

Consult a volume of tables, and you will find an actual density of 988.0 kg/m³ at 1 bar and 50°C. The error in the density calculation in this example equals 0.4%, and the resulting error in the flow calculation will amount to 0.2%.

You will find the volume expansion coefficients of several liquids in the appendix of this booklet.

Other Formulas for Calculating the Density of Liquids

The densities of supercooled liquids and overheated gasses, hydrocarbons, and mixtures of materials are frequently calculated by using the model equations of Lee and Kessler (Lee, B.I. and M.G. Kessler: AICHE J.21 (1975) pg.510). The calculation model is described in detail in the *VDI-Wärmeatlas* (Association of Engineers Thermal Atlas). You will find extensive tables with calculation constants necessary for many different types of media in the same reference source.

Calculating the Density of Steam and Water

The IAPWS Equation is used for the exact calculation of the density (and other state variables) of water and water steam. (IAPWS is the International Assosiation for the Properties of Water and Steam: www.iapws.org.)

The IAPWS Equation requires a considerable amount of numerical and mathematical process. The precise definition has been documented in an extensive publication (W. Wagner and A. Pruss, "The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use," *J. Phys. Chem. Ref. Data*, **31**, 387-535 (2002)). Various pre-programmed source codes or libraries are available for purchase (see www.ruhr-uni-bochum.de/thermo/Forschung/Seiten/Zustandsgln/IAPWS-95.htm).

If the operational position is not too far from the design point, the density of water can be roughly calculated by using a constant volume expansion coefficient (see description above). The density of overheated steam can be calculated by using the ideal gas equation (see description below) at small distances from the design point.

It is simple matter to calculate density by using tables (refer to the Water/Steam Table in the Appendix). Interpolating beyond the boiling point, however, could result in large discrepancies and is not recommended.

Calculating the Density of Gasses

Calculating the density of gasses by means of tables is also a simple and precise procedure.

If no tables are available, or if the medium in question is a mixture of gasses, then various calculation equations are available, among them van der Waals, Redlich Kwong, and many others. Various calculation models are described in detail in the *VDI-Wärmeatlas*. You will also find extensive tables with necessary calculation constants for many different types of media in the same reference source.

The ideal gas equation is a very simple equation which often provides sufficient accuracy when calculating density within short distances from the design point.

$$\rho_B = \rho_D \frac{p_B \cdot T_D}{p_D \cdot T_B}$$

The more operational pressure and temperature deviate from the design point, the more unreliable the calculation. This is especially true when the operational level approaches the boiling point of the gas. When this happens, the pressure increases and the temperature decreases. At greater distances from the boiling point, the ideal gas equation generally provides fairly accurate calculations.

The ideal gas equation can also be used for overheated steam. The same conditions apply as for other gasses.

Example:

$$p_D = 2.00 MPa (20 bar)$$
$$T_D = 553.15 K (280°C)$$
$$\rho_D = 8.330 kg/m^3$$
$$p_B = 2.15 MPa$$
$$T_B = 543.15 K (270°C)$$
$$\rho_B = 8.330 kg/m^3 \frac{2.15 \cdot 554.15}{2.00 \cdot 543.15} = 9.136 kg/m^3$$

According to the IAPWS 95, the actual density at 2.15 Mpa and 543.15K is 9.221 kg/m³. The error in density calculation, then, is 0.92%, and the resulting error in the flow measurement equals approximately 0.46%.

Density Correction for Water-laden Gasses

Gases can absorb water (humidity). Mixtures of gas and water have a different density than “pure,” or dry, gasses. The amount of water a gas is able to absorb increases with the temperature of that gas. Very hot gasses that have been run through a wash can sometimes absorb a considerable amount of water and their fluid data can then be significantly different from those of dry gasses.

The process for calculating the density of water-laden gasses and making the necessary corrections to the flowmetering is detailed in the VDI / VDE 2040, Part 4.

Calculating the Density of Natural Gas

Natural gas is actually a mixture of various gasses in varying combinations. The primary elements are usually methane and nitrogen as well as other hydrocarbons and pollutants.

There are various calculation models available for determining gas density. The ideal gas equation is often used for basic control purposes.

Custody transfer applications and measurements which require a high degree of precision are usually calculated using the AGA or the GERG Equation.

The AGA NX family of equations the standard in most non-European countries. This equation is described in the VDI / VDE 2040, Part 4.

The GERG88 Equation was developed by European gas suppliers and is widely-used within the European region as a standard for calculating gas quantities. The GERG88 is described in the DVGW Worksheet G486. (DVGW is he *German Technical and Scientific Association for Gas and Water* and is headquartered in Bonn, Germany.)

Simplified Calculation Equations

The following simplified calculation equations can be used for applications with limited demand for precision such as in-house volume measurements and for adjustment purposes.

Flowmetering of Liquids

Prerequisite conditions for simplification:
Constant density, incompressible liquid, constant conduit interior diameter.

$$q_m = q_{m,D} \cdot \sqrt{\frac{dp_B}{dp_D}}$$

In this instance, $q_{m,D}$ represents the mass flow according to the calculation sheet of your deltaflow. The radical term corresponds to the output signal of a root extracting differential pressure transducer.

If the final value of the transducer is set to correspond with the calculation sheet of your deltaflow, then the root extracted output signal of the dp-transducer is proportional to the flow measurement.

Flowmetering of Gasses and Steam

Prerequisite conditions for simplification:
Constant expansion number, ideal gas behavior, constant conduit interior diameter.

$$q_m = q_{m,D} \cdot \sqrt{\frac{p_B \cdot T_D}{p_D \cdot T_B}} \cdot \sqrt{\frac{dp_B}{dp_D}}$$

Again in this equation, the last radical term corresponds to the output signal of a root-extracting differential pressure transducer. The flow measurement, therefore, results from the designed mass flow multiplied by the output signal of a root-extracting transmitter. The density correction is handled by the middle radical term, which incorporates the operational pressure and temperature as well as the design pressure and temperature.

You will find the design data (Index D) on the calculation sheet for your deltaflow.

The simplified flow equation for gasses can also be used to make a rough calculation of the volume measurement of overheated steam.

Converting the Mass Flow to Other Units

Conversion to Standard Volume Flow

The standard volume flow is primarily used in calculating gas volumes. The standard state of a gas is usually based on 273.15K (0°C) and 10135.5 Pa (1.01325 bar). The standard volume flow is calculated from the mass flow as follows:

$$q_N = q_M \frac{1}{\rho_N}$$

A table containing various standard densities is located in the Appendix.

Conversion to Volume Flow

The volume flow is used quite often for liquids. The volume flow is calculated using the following equation:

$$q_B = q_M \frac{1}{\rho_B}$$

The process of determining operational density is described above in the section "Current Operational Density."

Conversion to Velocity

The process for identifying the average velocity within conduits is often used to determine pressure loss. The velocity of a medium can be calculated using the following formula:

$$v = q_M \frac{1}{\rho_B} \cdot \frac{4}{\pi \cdot d^2}$$

flowcom Flow Calculator

The medium data for a whole series of gasses are stored in the memory of the flowcom Flow Calculator. The flowcom performs the calculations as described in this information booklet and does so in a reliable and precise manner.

In particular, the flowcom uses extensive tables to calculate the medium densities and, for natural gas, it comes pre-equipped with the GERG88 functional equation.

The flowcom allows for the effects of the expansion number, the thermal conduit expansion, as well as other nonlinear characteristics of flowmeters.

Even when used independently from the deltaflow, the flowcom can calculate and compensate for the influences of pressure and temperature on virtually any other flowmetering system.

Because it uses a freely definable unit system, a user can input and output any and all data in whatever units he is comfortable with.

flowcom is easy to set up under Windows.

Detailed information about the flowcom product can be found at: www.systec-controls.de.

Questions?

No one knows the deltaflow better than we do! Please take advantage of our know-how—
we are more than pleased to be of assistance. Within Germany we have a network of field representatives, and our distributors in other countries are also pleased to help you. You can find out who is located in your area by referring to our web page:

http://www.systec-controls.de

Or simply place a telephone call to our headquarters in Puchheim, Germany:

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Appendix

Densities ρ of Various Liquids at 20°C in kg/l

Acetone		0.791
Ammonia, liquid	(24%)	0.910
	(35%)	0.882
Benzene		0.879
Carbon tetrachloride		1.594
Chloroform		1.489
Crude oil		0.74...0.94
Diesel fuel		0.85...0.88
Diethyl ether		0.714
Ethyl alcohol (Ethanol)		0.789
Gasoline,	Automotive	0.78
	Aviation	0.72
Glycerine		1.261
Heating oil		0.95...1.08
Hydrochloric acid	(40%)	1.195
Maschine oil		approx. 0.9
Mercury		13.546
Methyl alcohol		0.7915
Milk, whole		1.032
Mineral oil,	Lubricant	approx. 0.85
	Drum	0.93
Nitric acid	(50%)	1.31
	(100%)	1.512
Octane		0.702
Olive oil		0.91
Paraffin oil		0.9...1.0
Petroleum		0.81
Potash, caustic	(40%;15 -C)	1.395
Ricinus oil		0.96
Spirit		0.83
Sulfuric acid	(50%)	1.40
	(100%)	1.834
	Silicone oil	0.76...0.97
Terpentine spirits		0.855
Toluene		0.8669
Transformer oil		0.87
Water		0.9982
Water, heavy		1.105

Densities ρ of Various Gasses at 20°C and 1013.25 bar in kg/m

Air	1.2929
Ammonia	0.7714
Argon	1.784
Butane	2.703
Carbon dioxide	1.9769
Carbon monoxide	1.250
Chlorine	3.214
Dimethyl ether	2.1098
Helium	0.1785
Hydrogen	0.08988
Hydrogen chloride	1.6392
Krypton	3.744
Methane	0.7168
Neon	0.9002
Nitrogen	1.2505
Oxygen	1.42895
Propane	2.0096
Town gas	approx. 0.6
Water vapor	0.768
Xenon	5.897

Length Expansion Coefficients α of Solid Materials at 20°C in 10e-6/K

Aluminium		23.8
Aluminum oxide, sintered		6
	Soapstone	9…10
Amber		54
Antimony		10.9
Asphalt		approx. 200
Bakelite		30
Beryllium		12.3
Bismuth		13.5
Brass		18
Bronze		17.5
Caesium		97
Casein plastic		60…80
Cast iron		11.8
Celluloid		101
Chrome		6.6
Cobalt		13
Constantan		15
Copper		16.8
Diamond		1.3
Duralumin		23
Elektron		24
Fats		approx. 100
Fiber, vulcanized		5
Germanium		6
Glass,	flint	7.9
	crown	9.5
Glass, Jena		
	3 891 (Suprax)	3.2
	8330 (Duranglas 50)	3.2
	8409 (Supermax 56)	3.7
	Pyrex	3.2
	Quartz	0.45
Glass, sintered		
	16111	8.07
	59111	5.9
	1565 111	3.45
	2 877 (Lab. glass 20)	4.5
	2954111	6.28
Gold		14.3
Granite		3.8
Graphite		7.9
Grog (Molochite)		5
Ice (0°C)		0.502
Indium		56
Invar		1.5…2
Iridium		6.6
Iron		12.1
Lead		29
Lime, powdered		20
Lithium		58
Magnesium		26
Manganese		23
Manganine		18
Marble		11
Mica		9
Molybdenum		5.2
Naphthaline		94
Nickel		12.8
Palladium		11
Paper, laminated		10
Phenol		290
Phosphorus, white		124
Piaeryl (Plexiglass)		70…100
Platinum		9.0
Platinum-Iridium (101/>,)		8.9
Platinum-Rhodium (10%)		9
Polyamide (Perlon, Nylon)		100 to 140
Polyethylene		200
Polystyrene		60…80
Polyvinylchloride (PVC)		150…200
Porcelain		3…4
Potassium		84
Potassium nitrate		78
Potassiumchlorid		33
Resin		212
Rosin		45
Rubber, hard (vulcanite)		75…100
Salt, rock (crystal)		40
Sandstone		7…12
Silicone carbide	(Carborundum)	6.6
Silver		19.7
Sodium		71
Sodium chloride		40
Steel,	Chroni-	10.0
	soft	11
	nickel	12
	V2A-	16
Sugar cane		83
sulfur, rholl-11).		90
Suprainvar		0.3
Tantalum		6.5
Teflon		60…100
Thallium		29
Thorium		11
Tin		27
Titanium		9
Tungsten		4.3
Zinc		27

Volume Expansion Coefficients γ of Liquids at 20°C in 10e-5/K

Acetic acid	107
Acetone (Propanon)	149
Aniline	84
Benzene	124
Bromine	113
Bromoform	91
Carbon tetrachloride	123
Chlorobenzene	98
Chloroform	128
Cyanhydride (prussic acid)	193
Diethyl ether	162
Dioxane	109
Ethyl acetate	138
Ethyl alcohol	110
Ethyl benzene	88
Formic acid	102
Gasoline	106
Glycerine	50
Glycol	64
Heptane	124
Hexane	135
Mercury	18.1
in quartz glass	17.9
in sintered glass 16 111	15.7
Methanol	120
Methylene chloride	137
Nitric acid	124
Nitrobenzene	83
Octane	114
Olive oil	72
Pentane	160
Pentanol	90
Petroleum	96
Pyridine	112
Sulfuric acid	57
Silicone oil	90...160
Tetraline	78
Toluene	111
Turpentine, spirits	97
Water	20.7
Xylene	98

Volume Expansion Coefficients γ of Gasses at 0..100°C in 10e-5/K

Air	367
Ammonia	377
Argon	368
Carbon dioxide	373
Carbon monoxide	367
Chlorine	383
Ethane	375
Ethine	373
Helium	366
Hydrogen	366
Hydrogen chloride	372
Krypton	369
Methane	368
Neon	366
Nitrogen	367
Nitrogen monoxide	368
Oxygen	367
Sulfur dioxide	385
Water vapor	394
Xenon	372

Density ρ of Air in kg/m³ Relative to Pressure and Temperature

	bar								
°C	**0.96**	**0.97**	**0.98**	**0.99**	**1**	**1.01**	**1.01**	**1.02**	**1.03**
0	1.224	1.237	1.25	1.263	1.275	1.288	1.293	1.301	1.314
2	1.216	1.228	1.24	1.253	1.266	1.279	1.283	1.291	1.304
4	1.207	1.219	1.232	1.244	1.257	1.27	1.274	1.282	1.295
6	1.198	1.211	1.223	1.236	1.248	1.26	1.265	1.273	1.285
8	1.19	1.202	1.214	1.227	1.239	1.252	1.256	1.264	1.276
10	1.181	1.193	1.206	1.218	1.23	1.243	1.247	1.255	1.267
12	1.173	1.185	1.197	1.21	1.222	1.234	1.238	1.246	1.258
14	1.165	1.177	1.189	1.201	1.213	1.225	1.229	1.238	1.25
16	1.157	1.169	1.181	1.193	1.205	1.217	1.221	1.229	1.241
18	1.149	1.161	1.173	1.185	1.2	1.209	1.212	1.221	1.232
20	1.141	1.153	1.165	1.177	1.188	1.2	1.204	1.212	1.224
22	1.133	1.145	1.157	1.169	1.18	1.192	1.196	1.204	1.216
24	1.126	1.137	1.149	1.161	1.172	1.184	1.188	1.196	1.208
26	1.118	1.13	1.141	1.153	1.165	1.176	1.18	1.188	1.2
28	1.111	1.122	1.134	1.145	1.157	1.168	1.172	1.18	1.192
30	1.103	1.115	1.126	1.138	1.149	1.161	1.164	1.172	1.184
32	1.096	1.107	1.119	1.13	1.142	1.153	1.157	1.165	1.176
34	1.085	1.098	1.11	1.122	1.135	1.147	1.151	1.159	1.172

Density ρ of Water in kg/m³ Relative to Pressure and Temperature

Pressure	**Temperature in °C**							
bar	**0.0**	**25.0**	**50.0**	**75.0**	**100.0**	**150.0**	**200.0**	**250.0**
1.00	999.8	997.1	988.0	974.9	0.5896	0.5164	0.4604	0.4156
5.00	1000.0	997.2	988.2	975.0	958.6	917.1	2.3537	2.1083
10.00	1000.3	997.5	988.4	975.3	958.8	917.4	4.8566	4.8566
20.00	1000.8	997.9	988.5	975.7	959.3	917.9	865.1	8.9757
30.00	1001.3	998.4	989.3	976.2	959.8	918.5	865.9	14.172
40.00	1001.8	998.8	989.7	976.6	960.2	919.1	866.6	799.1
50.00	1002.3	999.3	990.2	977.0	960.7	919.6	867.4	800.3
60.00	1002.8	999.7	990.6	977.5	961.1	920.2	868.1	801.4
70.00	1003.3	1000.1	991.0	977.9	961.6	920.7	868.8	802.6
80.00	1003.8	1000.6	991.5	978.4	962.1	921.2	869.6	803.7
90.00	1004.3	1001.0	991.9	978.8	962.5	921.8	870.3	804.8
100.00	1004.8	1001.5	992.3	979.2	963.0	922.4	871.0	805.9
150.00	1007.3	1003.7	994.4	981.4	965.3	925.1	874.6	811.2
200.00	1009.7	1005.3	996.5	983.5	967.5	927.7	873.0	816.3
250.00	1012.1	1008.0	998.6	985.6	968.7	930.4	881.4	821.1
300.00	1014.5	1010.1	1000.7	987.7	971.9	932.9	884.7	825.7
350.00	1016.9	1012.2	1002.7	989.7	974.0	935.4	887.9	830.2
400.00	1019.2	1014.3	1004.7	991.8	976.1	937.9	891.0	834.4
450.00	1021.5	1016.4	1006.7	993.8	978.2	940.3	894.0	838.6
500.00	1023.8	1018.4	1008.7	995.8	980.3	942.7	897.0	842.5
600.00	1028.3	1022.4	1012.6	999.7	984.3	947.4	902.8	850.1
700.00	1031.7	1026.4	1016.4	1003.5	988.3	951.9	908.3	857.3
800.00	1037.0	1030.3	1020.1	1007.3	992.2	956.3	913.6	864.1
900.00	1041.2	1034.1	1023.8	1011.0	996.0	960.6	918.8	870.5
1000.00	1045.3	1037.8	1027.4	1014.6	999.7	964.8	923.7	876.7

Pressure	**Temperature in °C**							
bar	**300**	**350**	**400**	**450**	**500**	**600**	**700**	**800**
1	0.3790	0.3483	0.3223	0.2999	0.2805	0.2483	0.2227	0.2019
5	1.9137	1.7540	1.6200	1.5056	1.4066	1.2437	1.1149	1.0105
10	3.8771	3.5402	3.2617	3.0623	2.8241	2.4932	2.2331	2.0228
20	7.9713	7.2169	6.6142	6.1153	5.6926	5.0101	4.4794	4.0531
30	12.326	11.047	10.065	9.2708	8.6076	7.5512	6.7390	6.0908
40	17.000	15.052	13.623	12.497	11.571	10.117	9.0121	8.1360
50	22.073	19.255	17.299	15.798	14.586	12.709	11.299	10.189
60	27.662	23.687	21.102	19.179	17.653	15.326	13.599	12.249
70	33.944	28.384	25.045	22.646	20.776	17.970	15.914	14.316
80	41.226	33.394	29.143	26.202	23.957	20.642	18.242	16.391
90	713.36	38.776	33.411	29.855	21.198	23.341	20.584	18.474
100	715.58	44.611	37.867	33.611	30.305	26.068	22.941	20.564
150	725.87	87.191	63.889	54.200	48.077	40.154	34.943	31.124
200	735.02	600.78	100.54	78.732	67.711	55.039	47.319	41.871
250	743.32	625.74	166.63	109.09	89.904	70.794	60.080	52.803
300	750.93	644.27	358.05	148.45	115.26	87.481	73.234	63.919
350	757.99	659.30	474.89	201.63	144.43	105.15	86.779	75.214
400	764.58	672.10	523.67	270.91	177.97	123.81	100.71	86.682
450	770.78	683.33	554.78	343.37	215.87	143.44	115.01	98.312
500	776.64	693.39	577.99	402.28	256.95	163.99	129.64	110.09
600	787.51	710.93	612.45	479.87	338.44	207.20	159.77	134.02
700	797.44	726.00	633.83	528.62	405.76	251.73	190.65	158.30
800	806.62	739.31	659.27	563.69	456.99	295.45	221.74	182.72
900	815.18	751.29	677.05	591.14	496.53	336.53	252.48	207.03
1000	823.21	762.21	692.58	613.80	528.21	373.93	282.36	231.03