Chapter 6 Quantities, units and symbols

6.1 The SI-system

Since 1964 SI has been the Swedish standard within the area of quantities and units where fundamental information can be found in SIS 01 61 18 (General principles and writing rules) and SIS 01 61 26 (Prefixes for multiple units) and SIS 01 61 32 (SI-units, derived and additional units).

Units are divided into four different classes:

Base units
Supplementary units
Derived units
Additional units

If a prefix (micro, milli, kilo, mega, etc.) is placed before a unit, the formed unit is then called a multiple unit.

Base units, supplementary units and derived units are called *SI units* and multiple units formed by SI units are called *units in SI*. Note that additional units and not units in SI.

Base units are one of the established, independent units in which all other units can be expressed.

There are 7 base units in SI:

for length	metre	m
for mass	kilogram	kg
for time	second	s
for electrical current	ampere	A
for temperature	kelvin	K
for luminous intensity	candela	cd
for the amount of substance	mole	mol

Supplementary units are units of a basic nature, but are not classified as base units or derived units.

Two supplementary units are included in SI:

for plane angles	radian	rad
for solid angles	steradian	sr

Derived units and formed as a power or products of powers of one or more base units and / or supplementary units according to physical laws for the relation between different units.

15 derived units have been given their own names:

Quantity	Designation	Symbol	Expressed in other SI units	Expressed in base and supplementary units
frequency	hertz	Hz	-	s^{-1}
force	newton	N	-	m x kgxs^{-2}
pressure, mechanical stress	pascal	Pa	N/m^2	m^{-1} x kg x s^{-2}
energy, work	joule	J	N x m	m^2 x kg x s^{-2}
power	watt	W	J/s	m^{-2} x kg x s^{-3}
electrical quantity, charge	coulomb	C	A x s	s x A
electrical voltage	volt	V	W/A	m^2 x kg x s^{-3} x A^{-1}
capacitance	farad	F	C/V	m^{-2} x kg^{-1} x s^4 x A^{-2}
resistance	ohm	W	V/A	m^2 x kg x s^{-3} x A^{-2}
conductivity	siemens	S	A/V	m^{-2} x kg^{-1} x s^3 x A^2
magnetic flux density	tesla	T	Wb/m^2	kg x s^{-2} x A^{-1}
magnet flux	weber	Wb	V x s	m^2 x kg x s^{-2} x A^{-1}
inductance	henry	H	Wb/A	m^2 x kg x s^{-2} x A^{-2}
luminous flux	lumen	lm	cd x sr	cd x sr
light	lux	lx	lm/m^2	cd x sr x m^2

Additional units. There are a number of units outside of SI, which for different reasons cannot be eliminated despite that corresponding units in principle can be expressed in SI units. A number of these units have been selected to be used with the units in SI and are called additional units.

There are also a further four additional units primarily for use within astronomy and physics. All of these additional units are approved by Comité International des Poids et Mesures (CIPM) 1969 and are used together with SI units.

The following additional units for technical use occur:

Quantity	Additional unit		Remarks
	Designation	Symbol	
plane angle	degree	...°	$1° = \frac{\pi}{180}$ rad
plane angle	minute	...'	$1' = \frac{1°}{60}$
plane angle	second	..."	$1" = \frac{1'}{60}$
volume	litre	l	1 l = 1 dm^3
time	minute	min	1 min = 60 sec
time	hour	h	1 h = 60 min = 3.600 sec
time	day	d	1 d = 24 h
mass	tonne (metric)	t	1 t = 1.000 kg
pressure	bar	bar	1 bar = 10^5 Pa = 10^5 N/m^2

Multiple units. A multiple unit is formed by an SI unit or an additional unit by the unit being preceded by a prefix that involves the multiplication by the power of ten. Fourteen such prefixes are stated in international recommendations (standards) as set out in the table below.

Power	Prefix		Example	
	Designation	Symbol		
10^{12}	tera	T	1 terajoule	1 TJ
10^{9}	giga	G	1 gigawatt	1 GW
10^{6}	mega	M	1 megavolt	1 MV
10^{3}	kilo	k	1 kilometre	1 km
10^{2}	hectoh	h	1 hectogram	1 hg
10^{1}	deca	da	1 decalumen	1 dalm
10^{-1}	deci	d	1 decimetre	1 dm
10^{-2}	centi	c	1 centimetre	1 cm
10^{-3}	milli	m	1 milligram	1 mg
10^{-6}	micro	μ	1 micrometre	1 μm
10^{-9}	nano	n	1 nanohenry	1 nH
10^{-12}	pico	p	1 picofarad	1 pF
10^{-15}	femto	f	1 femtometre	1 fm
10^{-18}	atto	a	1 attosecond	1 as

Pressure					
Pa=N/m²	**bar**	**kp/cm²**	**Torr**	**m vp**	**mm vp**
1	10^{-5}	1.02×10^{-5}	7.5×10^{-3}	1.02×10^{-4}	0.102
10^{5}	1	1.02	750	10.2	1.02×10^{4}
9.81×10^{4}	0.981	1	735	10	10^{4}
133,3	1.33×10^{-3}	1.36×10^{-3}	1	1.36×10^{-2}	13,6
9.81×10^{3}	9.81×10^{-2}	0.1	73.5	1	10^{3}
9.81	9.81×10^{-5}	10^{-4}	7.35×10^{-2}	10^{-3}	1
Energy					
J	**kJ**	**kWh**	**kpm**	**kcal**	
1	10^{-3}	2.78×10^{-7}	0.102	2.39×10^{-4}	
1000	1	2.78×10^{-4}	102	0.239	
3.6×10^{6}	3.6×10^{3}	1	3.67×10^{5}	860	
9.81	9.81×10^{-3}	2.72×10^{-6}	1	2.39×10^{-3}	
4.19×10^{3}	4.19	1.16×10^{-3}	427	1	
Power					
W	**kpm/s**	**kcal/s**	**kcal/h**	**hk**	
1	0.102	0.239×10^{-3}	0.860	1.36×10^{-3}	
9.81	1	2.34×10^{-3}	8.43	1.33×10^{-2}	
4.19×10^{3}	427	1	3.6×10^{3}	5.69	
1.163	0.119	0.278×10^{-3}	1	1.58×10^{-3}	
735	75	0.176	632	1	

6.2 Drawing symbols

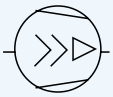

Air filter


Silencer


Diffusor


Compensator


Damper valve


Screw compressor


Non-return valve


Stop valve


Safety valve

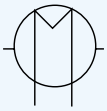
Manual valve


Pressure closing valve


Pressure opening valve


Oil separator

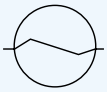

Ejector


Water cooled cooler

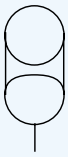
Water separator

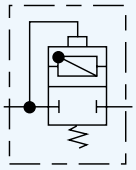

Condensation receiver

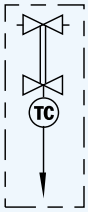

Direction of flow


Air cooled cooler

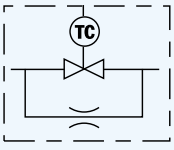

Fan


Expansion vessel


Minimum pressure valve

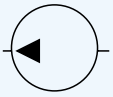


Thermostat valve

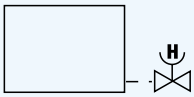


Thermostat valve

Fluid filter



Fluid pump

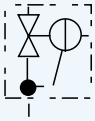


Oil tank with manual drainage

Restrictor

Bypass

Pressure regulator



Oil stop valve

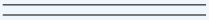
Air

Oil

Water

Drainage

Ventilation ducting

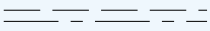


Mechanical connection

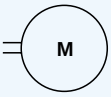
Signal air

Electrical signal

Border line



Electrical energy

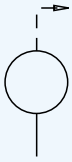


Electric motor

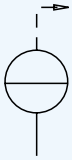
Electrical distribution box

Motor coupling

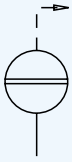
Blind flange



Sensor for pressure, temperature, etc.



Sensor for pressure, temperature, etc.



Sensor for pressure, temperature, etc.

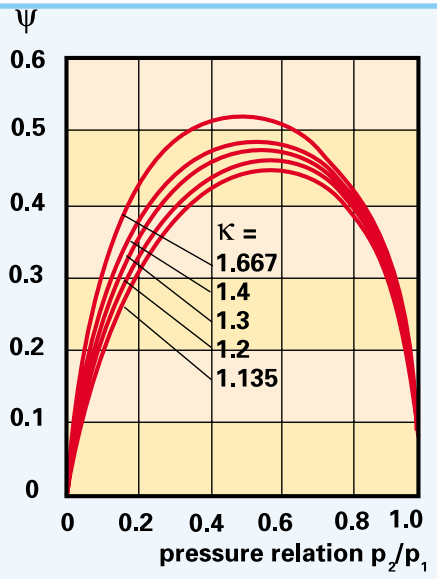
6.3 Diagrams and tables

Material	J/kg x K
air (atmospheric pressure)	1 004
aluminium	920
copper	390
oil	1 670-2 140
steel	460
water	4 185
zinc	385

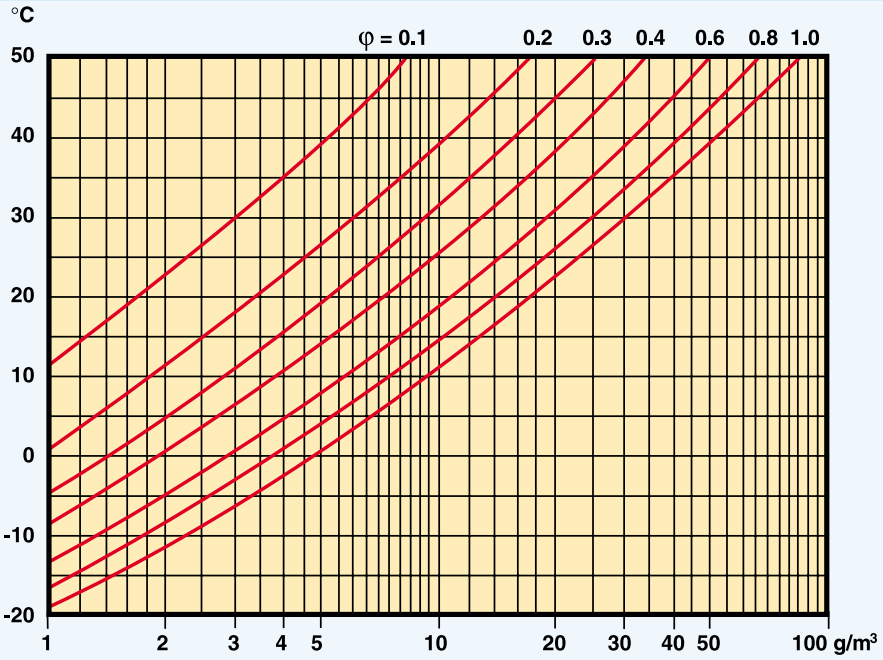
Heat capacity for some materials.

boiling point	78.8	K
critical pressure (a)	37.66	bar
critical temperature	132.52	K
specific weight	1.225	kg\m^3
dynamic viscosity	17.89×10^{-6}	Pa x s
freezing point	57-61	K
gas constant	287.1	J\(kg x K)
kinematic viscosity	14.61×10^{-6}	m /s^2
molar weight	28.964	(dimensionless)
heat capacity at:		
constant pressure	1.004	kJ\(kg x K)
specific heat capacity ratio	1.40	(dimensionless)
speed of sound	340.29	m\s
thermal conductivity	0.025	W\(m x K)

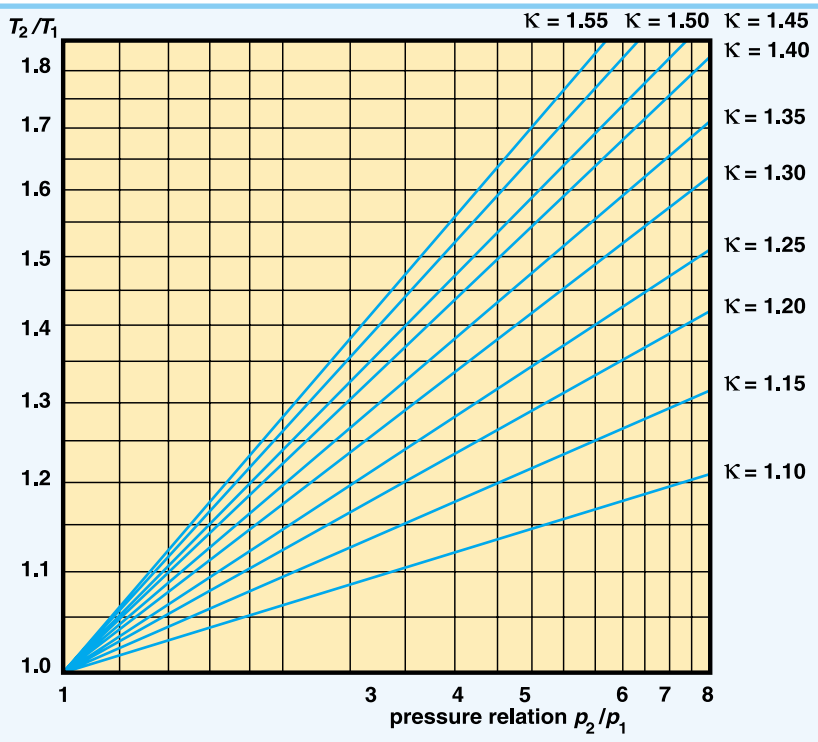
Some physical constants for dry air at sea level (=15°C and 1013 bar).



Flow coefficients as a function of the pressure relation for different κ-values.



Water content in air at different relative vapour pressures (φ).
The maximum water content is doubled with each temperature rise of 11 K.



The diagram show the temperature relationship T_2/T_1 for different gases with different κ-values during isentropic compression.

t °c	Ps mbar	ρw g/m³	t °c	Ps mbar	ρw g/m³
-40	0.128	0.119	5	8.72	6.80
-38	0.161	0.146	6	9.35	7.26
-36	0.200	0.183	7	10.01	7.75
-34	0.249	0.225	8	10.72	8.27
-32	0.308	0.277	9	11.47	8.82
-30	0.380	0.339	10	12.27	9.40
-29	0.421	0.374	11	13.12	10.01
-28	0.467	0.413	12	14.02	10.66
-27	0.517	0.455	13	14.97	11.35
-26	0.572	0.502	14	15.98	12.07
-25	0.632	0.552	15	17.04	12.63
-24	0.689	0.608	16	18.17	13.63
-23	0.771	0.668	17	19.37	14.48
-22	0.850	0.734	18	20.63	15.37
-21	0.937	0.805	19	21.96	16.31
-20	1.03	0.884	20	23.37	17.30
-19	1.14	0.968	21	24.86	18.34
-18	1.25	1.06	22	26.43	19.43
-17	1.37	1.16	23	28.09	20.58
-16	1.51	1.27	24	29.83	21.78
-15	1.65	1.39	25	31.67	23.05
-14	1.81	1.52	26	33.61	24.38
-13	1.98	1.65	27	35.65	25.78
-12	2.17	1.80	28	37.80	27.24
-11	2.38	1.96	29	40.06	28.78
-10	2.60	2.14	30	42.43	30.38
-9	2.84	2.33	31	44.93	32.07
-8	3.10	2.53	32	47.55	33.83
-7	3.38	2.75	33	50.31	35.68
-6	3.69	2.99	34	53.20	37.61
-5	4.02	3.25	35	56.24	39.63
-4	4.37	3.52	36	59.42	41.75
-3	4.76	3.82	37	62.76	43.96
-2	5.17	4.14	38	66.28	46.26
-1	5.62	4.48	39	69.93	48.67
0	6.11	4.85	40	73.78	51.19
1	6.57	5.19	41	77.80	53.82
2	7.06	5.56	42	82.02	58.56
3	7.58	5.95	43	86.42	59.41
4	8.13	6.36	44	91.03	62.39

Saturation pressure (P_S) and density (ρ_W) for saturated water vapour.

Gas	Volume %	Weight %
nitrogen N_2	78.084	75.520
oxygen O_2	20.947 6	23.142
argon Ar	0.934	1.288
carbon dioxide CO_2	0.031 4	0.047 7
neon Ne	0.001 818	0.001 267
helium He	0.000 524	0.000 072 4
krypton Kr	0.000 114	0.000 330
xenon Xe	0.000 008 7	0.000 039
hydrogen H_2	0.000 05	0.000 003
methane CH_4	0.000 2	0.000 1
nitrous oxide N_2O	0.000 05	0.000 08
ozone O_3	summer: 0 to 0.000 007	0 to 0.000 01
	winter: 0 to 0.000 002	0 to 0.000 003
sulphur dioxide SO_2	0 to 0.000 1	0 to 0.000 2
nitrogen dioxide NO_2	0 to 0.000 002	0 to 0.000 003
ammonia NH_3	Ca 0	Ca 0
carbon monoxide CO	Ca 0	Ca 0

Composition of clean, dry air at sea level. This composition is relatively constant up to a height of 25 km.

Machine type and size	Air requirement max. l/s
Drilling machines, Ø = bit diameter (mm)	
Small Ø < 6.5	**6.0**
Medium 6.5 < Ø = < 10	**7.5**
Large 10 < Ø < 16	**16.5**
Thread cutters	**6**
Screwdriver, d = screw size	
Small d < M6	**5.5**
Medium M6 < d < M8	**7.5**
Impact wrench, d = bolt size	
Small d < M10	**5.0**
Medium M10 < d < M20	**7.5**
Large d ≥ M20	**22.0**
Filing machine	**7.5**
Polishers/Die grinders, e = power (kW)	
Small e < 0.5	**8.0**
Large e > 0.5	**16.5**
Grinders, e = power (kW)	
Small 0.4 < e < 1.0	**20.0**
Medium 1,0 < e < 2	**40.0**
Large e > 2	**60.0**
Chipping hammers	
Light	**6.0**
Heavy	**13.5**
Air hoists t = lifting tonnage	
t < 1 tonne	**35**
t > 1 tonne	**45**
Scaler	**5.0**
Cleaning nozzle	**6.0**
Nutrunner, d = bolt size	
d ≤ M8	**9**
d ≥ M10	**19**

Some examples of air consumption for some common power tools and machines based on experience. These values from the basis for calculating the requisite compressor capacity.

Dew point °C	g/m³	Dew point °C	g/m³	Dew point °C	g/m³	Dew point °C	g/m³
+100	588.208	+58	118.199	+16	13.531	−25	0.55
99	569.071	57	113.130	15	12.739	26	0.51
98	550.375	56	108.200	14	11.987	27	0.46
97	532.125	55	103.453	13	11.276	28	0.41
96	514.401	54	98.883	12	10.600	29	0.37
95	497.209	53	94.483	11	9.961	30	0.33
94	480.394	52	90.247	10	9.356	31	0.301
93	464.119	51	86.173	9	8.784	32	0.271
92	448.308	50	82.257	8	8.243	33	0.244
91	432.885	49	78.491	7	7.732	34	0.220
90	417.935	48	74.871	6	7.246	35	0.198
89	403.380	47	71.395	5	6.790	36	0.178
88	389.225	46	68.056	4	6.359	37	0.160
87	375.471	45	64.848	3	5.953	38	0.144
86	362.124	44	61.772	2	5.570	39	0.130
85	340.186	43	58.820	1	5.209	40	0.117
84	336.660	42	55.989	0	4.868	41	0.104
83	324.469	41	53.274			42	0.093
82	311.616	40	50.672	−1	4.487	43	0.083
81	301.186	39	48.181	2	4.135	44	0.075
80	290.017	38	45.593	3	3.889	45	0.067
79	279.278	37	43.508	4	3.513	46	0.060
78	268.806	36	41.322	5	3.238	47	0.054
77	258.827	35	39.286	6	2.984	48	0.048
76	248.840	34	37.229	7	2.751	49	0.043
75	239.351	33	35.317	8	2.537	50	0.038
74	230.142	32	33.490	9	2.339	51	0.034
73	221.212	31	31.744	10	2.156	52	0.030
72	212.648	30	30.078	11	1.96	53	0.027
71	204.286	29	28.488	12	1.80	54	0.024
70	196.213	28	26.970	13	1.65	55	0.021
69	188.429	27	25.524	14	1.51	56	0.019
68	180.855	26	24.143	15	1.38	57	0.017
67	173.575	25	22.830	16	1.27	58	0.015
66	166.507	24	21.578	17	1.15	59	0.013
65	159.654	23	20.386	18	1.05	60	0.011
64	153.103	22	19.252	19	0.96	65	0.0064
63	146.771	21	18.191	20	0.88	70	0.0033
62	140.659	20	17.148	21	0.80	75	0.0013
61	134.684	19	16.172	22	0.73	80	0.0006
60	129.020	18	15.246	23	0.66	85	0,00025
59	123.495	17	14.367	24	0.60	90	0.0001

The water content in the air at different dew points.

6.4 Compilation of current standards and norms

Here follows a compilation of current (1997) standards and norms within the compressed air field. The compilation refers to Swedish regulations, but in most cases there are equivalent national regulations in other countries. The listed standards are all, with some exceptions, European or international. Pneurop documents are usually issued with a parallel CAGI issue for the American market.

It is always important to check with the issuing body that the latest issue is being used, unless the requirement / demand refers to a dated issue.

6.4.1 Safety related regulations and standards

6.4.1.1 Machine safety

EU directive 89/392/EEG, Machinery directive. In Sweden this has been made law as AFS 93:10 (modified as AFS 94:48). National Swedish Board of Occupational Safety and Health regulations for machinery

EN 1012-1 Compressors and vacuum pumps – Safety demands – Del 1: Compressors

EN 1012-2 Compressors and vacuum pumps – Safety demands – Del 2: Vacuum pumps

6.4.1.2 Pressure safety

Directive 87/404/EEG, Simple pressure vessels. In Sweden this has been made law as AFS 93:41 I (modified as AFS 94:53) National Swedish Board of Occupational Safety and Health regulations for simple pressure vessels

Directive 76/767/EEG Covers common legislation for pressure vessels and methods of inspecting. Directive 97/23/EG for pressure equipment (applies from 1999-11-29)

AFS 86:9 (modified as AFS 94:39)) National Swedish Board of Occupational Safety and Health regulations for pressure vessels and other pressure equipment

EN 764 Pressure equipment - Terminology and symbols - Pressure, temperature.

EN 286-1 Simple unfired pressure vessels designed to contain air or nitrogen - Part 1: Design, manufacture and testing

EN 286-2 Simple unfired pressure vessels designated to contain air or nitrogen - Part 2: Pressure vessels for air braking and auxiliary systems for motor vehicles and their trailers

EN 286-3 Simple unfired pressure vessels designed to contain air or nitrogen - Part 3: Steel pressure vessels designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock

EN 286-4 Simple unfired pressure vessels designed to contain air or nitrogen - Part 4: Aluminum alloy pressure vessels designed for air braking equipment and auxiliary pneumatic equipment for railway rolling stock

6.4.1.3 Environment

Pneurop PN8NTCI, Noise test code for compressors. ISO 84/536/EC. Sound level demands for machinery. A special standard for sound measurements is being drawn up within ISO.

For the emission of exhaust fumes from combustion engines a decision is expected according to "EU stage 1'

6.4.1.4 Electrical safety

ELSAK-FS 1994:9 National Swedish Board of Electrical Safety's regulations for electrical material.

ELSAK-FS 1994:7 National Swedish Board of Electrical Safety's regulations for heavy current installations (equivalent to IEC 364)

EU directive 89/336/EEG Electromagnetic compatibility

ELSAK-FS 1995:5 National Swedish Board of Electrical Safety's regulations for electromagnetic compatibility

EN 60204-1 Machinery, Electrical safety instructions

EN 60439-1 Low-voltage switchgear and control gear assemblies

6.4.2 Technical related standards and norms

6.4.2.1 Standardization

SS 1796 Compressed air technology - Terminology

ISO 3857-1 Compressors, pneumatic tools and machines - Vocabulary - Part 1: General

ISO 3857-2 Compressors, pneumatic tools and machines - Vocabulary - Part 2: Compressors

ISO 5390 Compressors - Classification

ISO 5941 Compressors, tools and machines Preferred pressures

6.4.2.2 Specifications

SS-ISO 1217 Compressed air technology – displacement compressors – delivery tests

ISO 5389 Turbo-compressors - Performance test code ISO 7183-1 Compressed air dryers - Part 1: Specifications and testing

ISO 7183-1 Compressed air dryers - Part 2: Performance ratings

ISO 8010 Compressors for the process industry - Screw and related types - Specifications and data sheets for their design and construction

ISO 8011 Compressors for the process industry - Turbo types - Specifications and data sheets for their design and construction

ISO 8012 Compressors for the process industry - Reciprocating types - Specifications and data sheets for their design and construction

SS-ISO 8573-1 Compressed air for general use - Part 1: Contaminants and quality classes. For enforcement of the current national Swedish regulations there are:

Pressure vessel norms 1987
Piping norms 1978
Air container norms 1991
Issued by the Pressure vessel standardization
EG directive 73/23/EEG Low voltage directive

6.4.2.3 Measurements

ISO 8573-2 Compressed air for general use Part 2: Test methods for oil aerosol content

(Draft) ISO 8573-3 Compressed air - Part 3: Measurement of humidity

(Draft) ISO 8573-4 Compressed air - Part 4: Measurement of solid particles

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Notes

What sets Atlas Copco apart as a company is our conviction that we can only excel in what we do if we provide the best possible know-how and technology to really help our customers produce, grow and succeed.

There is a unique wayof achieving that - we simply call it the Atlas Copco way. It builds on **interaction**, on long-term relationships and involvement in the customers' process, needs and objectives. It means having the flexibility to adapt to the diverse demands of the people we cater for.

It's the **commitment** to our customers' business that drives our effort towards increasing their productivity through better solutions. It starts with fully supporting existing products and continuously doing things better, but it goes much further, creating advances in technology through **innovation**. Not for the sake of technology, but for the sake of our customers' bottom line and peace-of-mind.

That is how Atlas Copco will strive to remain the first choice, to succeed in attracting new business and to maintain our position as the industry leader.

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