

H 2 Works Standards

The instruction manual only contains those Works Standards which are listed in the following table:

During the preparation of this manual the current version of the standard was added.

The standards are not subject to change control.

Pressure and tightness tests of pressurized hollow spaces	026.00.1
Surface cleanliness of pressure vessels and piping	033.21.2 P1
Cleanliness and cleaning of process piping at site prior start-up of machines	033.21.2 P2
Preservation of pressure vessels, piping and fittings	033.23.5
Lubricants	790.21.2
Screw tightening torque	903.99.0
Field welding of pipes (Quality assurance documents)	QSV-WQ-04e
Execution of hydrostatic and pneumatic pressure and tightness test. (Quality assurance documents)	QSV-QP-07e

Pressure and tightness tests of pressurised hollow spaces

ATLAS COPCO ENERGAS
GmbH

Works Standard
ENG 026.00.1 - en

(Original version: german-revision C/02.98)

1. General

Pressurised vessels and hollow spaces incorporated in parts of ACE products are subjected to pressure tests and, if required, tightness tests to verify their stability and tightness and for reasons of safety to avoid danger to persons, in particular operators, animals and the environment. The tests are aimed at ruling out dangers entailed by bursting pressurised spaces and/or leakages of toxic, inflammable or radioactive fluids.

The pressurised spaces of these components may be filled with different fluids (liquid, gas, vapour). The following components and part groups are subjected to pressure tests: pressure vessels, pipes (Works Standard ENG 036.00.2), casings, suction nozzles and miscellaneous parts (complete plants, machine groups, ...) as per order book or customer requirement.

This Works Standard describes the scope of pressure and tightness tests carried out in ACE as a function of the dangerous nature of the fluid handled.

It is not applicable to supplier-purchased parts and customer-provided parts which, however, have to meet the statutory regulations and have to be executed and tested/inspected as per the standards and specifications shown in the order.

2. Definitions

Pressure tests: To check stability and tightness of components (see item 3).

Hydraulic tightness test: To verify tightness (see item 3.1).

Pneumatic tightness test: Corresponds to safety check (see item 3.2) as to nature and scope; it is, however, carried out in an open test basin and at reduced test pressure. The formation of foam or bubbles is an indication of leakages. For calculation of test pressure as per AD Instruction Sheet HP20 refer to the Handling Manual.

Helium sniffing test: The probe of the measuring instrument registers any helium leakages escaping from the pressurised space on the surface of the specimen.
(direct probing - tightness test)

Helium enveloping test: The probe of the measuring instrument registers any helium leakages escaping from the pressurised space in the gas-tight space between the test specimen and the plastic enclosure surrounding it.
(tightness test)

Helium vacuum test: The probe of the measuring instrument registers any traces of helium that enter the evacuated space of the test specimen.
(tightness test)

3. Pressure tests

3.1 Hydraulic pressure test

Components that include pressurised spaces are subjected to hydraulic (hydrostatic) pressure tests to verify stability and tightness depending on the conditions of the application and their function. The test pressure is calculated for each component on the basis of the standard applicable to the individual component, refer to Handling Manual.

Operating state	Applications	Standards
Internal overpressure:	• Pressure vessels, pipes	to AD Instruction Sheet HP 20
Internal overpressure:	• Machine parts (e.g. casing)	to ASME CODE VIII, API 672
External overpressure or negative pressure:	• Pressure vessels, machine parts	to standard ACE test procedure *)

Issued:	Standard dept.	Revision	Reason of revision
Date	11.1985	C/09.1998	General revision
Name	Hobeth	KSN/Némorin	

- *) The ACE test procedure specifies that these components be subjected to a hydraulic pressure test at an internal test pressure of 2 bar for reasons of safety (to verify tightness).

Hydraulic pressure tests are carried out by pressurising the space with conditioned water as test fluid.

For more details on hydraulic pressure tests refer to Written Procedure QSV-QP-7.

3.2 Safety check

Whenever the need of carrying out pneumatic pressure tests is specified for the fluid handled in requirement classes A2 to C (refer to table in item 4.1), ACE requires a safety check to immediately precede the pneumatic pressure test to protect the staff in charge of the test from any danger. This pneumatic safety check incorporates the test specimen being immersed in water in a closed pressure test basin. It is, however, not part of the prescribed test inspection of the component. For calculation of test pressure (overpressure) refer to Handling Manual.

For more details on the safety check refer to Written Procedure QSV-QP-7.

4. Tightness tests as function of the dangerous nature of the fluid handled

4.1 Requirement classes and test scopes

Depending on the dangerous nature of the fluid handled, the pressurised component is tested for tightness after it has passed the stability test and safety check (refer to item 3). If the fluid handled is a liquid (e.g. water, oil), the component just has to pass the hydraulic pressure test to verify its stability. If the fluid handled is a gas or a vapour, additional tightness tests have to be carried out in most cases. Refer to the subsequent table for the requirement classes applicable to specific fluids, test scopes of tightness tests and ACE code.

Requirement classes		Applications Fluids, description	Test scope	
Description	Code		Test type	Test fluid
Normal	A1	• Non-hazardous gases or vapours such as air, N ₂ and water vapour	Hydraulic test	Conditioned water
Increased	A2	• Slightly hazardous (non-inflammable and non-toxic) gases or vapours such as CO ₂ , • Casings made of aluminium alloy • Customer requirement	See A1, plus pneumatic test	Dry air or N ₂
High	B	• Hazardous (inflammable and/or toxic) gases or vapours such as refrigerants (R134a, ...), propane, polypropylene, ..., • Customer requirement	See A1, plus pneumatic test	Helium or He/N ₂ -mixture with helium content of 10%
Extreme	C1	• Very hazardous (inflammable/explosive and/or highly toxic/radioactive) gases or vapours • Customer requirement	See A2, plus helium sniffing test	Helium in tested space
	C2		See A2, plus helium enveloping test	Helium in tested space
	C3		See A2, plus helium vacuum test	Helium applied from outside

Note: For gas mixtures refer to item 4.2.2.

For more details on tightness tests refer to Written Procedures QSV-QP-2 and QP-7.

4.2. **Classification of some fluids with regard to their dangerous nature**

4.2.1 **Gases and vapours**

	Fluids handled (applicable also to higher contents in gas mixtures)	Classification as per requirement class (code) or evaluation
1-	Air	A1
	N ₂ (nitrogen)	
	Water vapour	
	CO ₂ (carbon dioxide)	
	O ₂ (oxygen)	A2
	Refrigerants (R134a, FHC)	
	CO (carbon monoxide)	B
	NH ₃ (ammonia)	
	Olefins (ethylene, propylene, ...)	
	Paraffins (methane, ethane, propane, natural gas, ...)	
	SO ₂ (sulphur dioxide)	
	H ₂ (hydrogen) Content < 5%	
	H ₂ (hydrogen) Content ≥ 5%	C1
2-	Chloric gases and all other gases and vapours (non-hazardous, inflammable, toxic, highly toxic, ...)	As per regulation on hazardous substances or as agreed by departments Engineering and Quality Control

4.2.2 **Gas mixtures**

	Fluid handled: Gas mixtures containing fluids	Classification as per requirement class (code) or evaluation
1-	 of different requirement classes	
	Composition Content	
	B+C1 C1-content <5%	B
	B+C1 C1-content ≥5%	C1
	B + (C1)+C2 C2-content <3%	
2-	B + (C1)+C2 C2-content ≥3%	C2
	...of the same requirement class and any other gas mixtures (non-hazardous, inflammable, toxic, highly toxic, ...)	As per regulation on hazardous substances or as agreed by departments Engineering and Quality Control

5. **Engineering**

5.1 **Sealing places: gaskets and sealing surfaces**

The execution of sealing surfaces (e.g. groove, V-type groove, flat) and surface quality are determined as a function of requirement class, sealing type and the individual application (e.g. temperature). Seals and sealing surfaces must be selected and/or designed in keeping with the applicable standards.

For instance:

- for seals → Works Standard ENG 040.00.0
- for sealing surfaces → Works Standard ENG 033.00.0 and DIN 4760

5.2 Test references on drawings

For instance: Pressure and tightness tests as per Works Standard ENG 026.00.1
Fluid handled of requirement class A2 for a 1200-litre vessel.

On drawing: Pressure and tightness tests as per Works Standard ENG 026.00.1
Requirement class A2, 1200 l

Test pressures: $P_{hyd.}$ (for stability)
 $P_{pneum.}$ (for safety during testing)
 $P_{2pneum.}$ (for tightness)

Note: volume to be shown only for vessels.

6. Indication on test specimen: identification

After the test specimen has passed the pressure and tightness tests, it must be identified with the test status. For more associated information refer to Written Procedure QSV-QP-7.

7. Some important data

Tightness measurement using helium:

Measuring instrument: Helium leakage detector, smallest leakage rate to be detected: 10^{-3} mbar.l/s
(detection limit)

Leakage rate: reference values: normal 10^{-3} to 10^{-4} mbar.l/s
extreme reactors $\approx 10^{-4}$ mbar.l/s
ACE: feasible 10^{-4} to 10^{-3} mbar.l/s
Sniffing sensitivity 10^{-3} to 10^{-2} mbar.l/s

We recommend to determine the required leakage rate with the customer as a function of the annual gas loss to be expected in each individual application.

Generation of vacuum (to the extent technically feasible):
(Vacuum technique DIN 28400-2)

Pressure: reference values: technically feasible $\approx 10^{-11}$ mbar
in ACE lowest feasible $\approx 10^{-4}$ mbar
Standard 10^{-1} to 10^{-3} mbar

8. References

Deviations in form	DIN 4760
Technical surfaces, roughness	ENG 033.00.0
Tests of piping	ENG 036.00.2
Seals to be used for flange connections	ENG 040.00.00
Turbocompressors, expansion turbines	Handling Manuals
Hydraulic and pneumatic pressure and tightness tests	QSV-QP-7
Tightness tests using helium leakage detector	QSV-QP-2
Regulation governing hazardous substances	GefStoffV
First test of pressure vessels, type test and pressure test	AD Instruction Sheet HP 20
Pressure Vessels	ASME CODE VIII
Packaged, integrally geared centrifugal air compressors....	API 672
Vacuum technique, descriptions and definitions: vacuum pumps	DIN 28400-2

* * *

Atlas Copco Atlas Copco Energas GmbH	Surface cleanliness of pressure vessels and piping	Works Standard 033.21.2 E part 1						
1. 2. 2.1 2.2 3.	<u>Scope of application</u> The requirements contained in this Works Standard are applicable to internal surfaces of pressure vessels, piping, and their accessory which come into contact with industrial gases, except for oxygen 1). The same requirements are applicable to pressure vessels and piping which are filled with lubricating oil. <u>Execution:</u> Internal surfaces must be free of ferrous oxides such as rust, annealing and welding scales, and solid matter such as sand, slag, welding beads, turning and grinding chips. <u>Blanks</u> Blanks such as sheets and pipes etc. must be cleaned to the bare metal prior to machining. Parts contaminated by rust or scale must be blast-cleaned (degree of de-rusting 3 to DIN 8202). Parts protected by paint or preservatives must be cleaned to the bare metal in the area of welds. Foreign parts such as tacked or adhesive-bonded labels etc. must be carefully removed. <u>Finished parts (functional groups)</u> Finished parts must be cleaned of welding beads, slag etc. by grinding or blast-cleaning after welding. On parts made of stainless austenitic steels coloration come about by contacting and slag must be removed by pickling after welding. Pressure vessels and piping which cannot be mechanically cleaned by grinding or blasting etc. after welding must be pickled or acidified in accordance with the following Works Standards: <table> <tr> <td>033.15.0 E</td><td>for stainless austenitic steels</td></tr> <tr> <td>033.15.1 E</td><td>" " " "</td></tr> <tr> <td>033.15.2 E</td><td>for unalloyed and low-alloy steels</td></tr> </table> <u>Drying</u> After completion of flushing after pickling or acidifying and/or hydraulic pressure testing, the water remaining in the vessel after draining must be blown out by means of compressed air. After that, the internal spaces must be checked for cleanliness. Vessels and piping made of unalloyed or low-alloy steels shall be subsequently dried by blowing hot air through them until a temperature of at least + 50 °C is obtained at the coldest place. Do not dry spaces which contain cooling water or brine. 1) For surface cleanliness of oxygen plants refer to 033.21.0 E.	033.15.0 E	for stainless austenitic steels	033.15.1 E	" " " "	033.15.2 E	for unalloyed and low-alloy steels	
033.15.0 E	for stainless austenitic steels							
033.15.1 E	" " " "							
033.15.2 E	for unalloyed and low-alloy steels							

For cleanliness and cleaning of process piping on site prior to machine commissioning refer to Works Standard 033.21.2 E, part 2.

issued	TNW	Revision No.				
Date	5/85	A/10.90				
Name	Ma.	<i>Ami</i>				

Works Standard 033.21.2E, part 1

 Atlas Copco Energas GmbH	Cleanliness and cleaning of process piping on site prior to machine commissioning - GUIDELINE -	Works Standard 033.21.2 E part 2														
Cleanliness and cleaning of process piping on site prior to machine commissioning. 1. Clean piping and plant parts supplied by ACE as laid down in Works Standard 033.21.2 E, part 1. Preserve to Works Standard 033.23.5 E. For oxygen plants, Works Standard 033.21.0 E must be additionally complied with. 2. Surface cleanliness of piping connected to machines and units supplied by ACE should also meet requirements described in Works Standards 033.21.2 E, part 1. 3. If requirements laid down in Works Standards 033.21.2 E, part 1 are not met, all pipes supplied by the customer must be cleaned by blowing-off prior to machine commissioning. Always purge machine inlet pipes. Only for short suction pipes, which draw in air from the atmosphere, can blowing-off be done without, if equivalent methods are applied (brushing, wiping, drawing off) to make sure that major solid particles do not enter the machine. 3.1 To blow off, remove pipes from the machine and install a pipe branch leading into the atmosphere or into a pressure-less room. Secure the outlet area. If necessary, install a quick-opening shut-off device into the branch. All people working near the machine are to wear ear protection. 3.2 Blow off pipes under identical or stricter conditions (speeds, pressures, temperatures) compared to subsequent operation. Normally, dry, oil-free air is used as blow-off medium. As a substitute, a medium similar to the fluid handled can be used, if the corresponding safety rules are complied with. If continuous blowing-off is not possible, admit operating pressure to pipes to the extent possible and relieve of pressure all at once. 3.3 Blow off at least three times. In between the individual processes, subject the pipe to ambient conditions. The duration of the single blowing-off process should not be less than one minute. 3.4 To check the degree of cleanliness, fasten a high-polish stainless steel baffle plate (18 % Cr, 9 % Ni or similar) of about 100 cm² and 2 mm thickness in vertical direction to the direction of outlet flow in the outlet gas flow during blowing-off. 3.5 Stop blowing-off, if - the baffle plate has not become mat, - single impacts have a minimum distance of 2 cm, - no single impact has created a crater of bigger than 1 mm in diameter. Continuation page 2																
<table border="1"> <tr> <td>Issued</td> <td>TNW</td> </tr> <tr> <td>Date</td> <td>90-10-16</td> </tr> <tr> <td>Name</td> <td><i>[Signature]</i></td> </tr> </table>	Issued	TNW	Date	90-10-16	Name	<i>[Signature]</i>	<table border="1"> <tr> <td colspan="4">Revision No.</td> </tr> <tr> <td> </td> <td> </td> <td> </td> <td> </td> </tr> </table>	Revision No.								Works Standard 033.21.2 E, part 2
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Date	90-10-16															
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Revision No.																

Nur zur Information
Für Information only

Customer: US Steel Kosice
AC doc.-no.: IM_57237318_en
Plant code: ASU Kosice

Rev.: 0.0 dated: 24.06.2005

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Works Standard 033.21.2 E, part 2

- 3.6 Immediately after blowing-off, re-connect the pipes to the machine or close them in a way that dirt cannot enter the pipes.
4. In addition, we recommend to install a strainer of mesh size 200 μ m in the inlet pipe and cover it with spun-bonded tissue during initial operation until the plant is free of impurities.

For surface cleanliness of pressure vessels and piping
see Works Standard 033.21.2 E, part 1.

Nur zur Information
Für Information only

 Atlas Copco Energas GmbH	Preservation of pressure vessels, pipes and fittings	Works Standard 033.23.5E																
1. <u>Scope of application:</u> This Works Standard is applicable for all pressure vessels *1), pipes, and accessories used for operation with technical gases, except for oxygen *2). 2. <u>Surface cleanness:</u> Execution to Works Standard 033.21.2 3. <u>Execution:</u> 3.1 Cleaned and tested parts will be assembled to the extent permitted by packing and/or transport possibilities. 3.2 <u>Closing and sealing parts:</u> 3.2.1 Closing devices to Works Standard 507.91.4 must be used for flanges, flange connections, welded nozzles, etc. 3.2.2 Welded nozzles and sleeves with internal thread and other threaded connections must be sealed with threaded plugs to Works Standard 903.53.0 and sealing rings to Works Standard 909.00.2. 3.3 Fill-in connection for nitrogen to Works Standard 531.61.0 (Material No. 6915 2605 07). 3.4 <u>Warning sign:</u> All parts filled with nitrogen must be provided with warning sign material No. 6915 2605 05 to Works Standard 569.61.0. The warning sign is not expressly referred to in the single items of "Execution". 4 <u>Execution:</u> 4.1 <u>Pressure vessels, pipes, and accessories for operation with gas:</u> 4.1.1 Pressure vessels, pipes and similar made of CrNi steel must be sealed as described in 3.2.1 and 3.2.2 on all sides. Pressure vessels, pipes and similar made of non-alloy or low-alloy steel (referred to as C-steel in the following) must additionally be filled with nitrogen at 0.3 bar through the fill-in connection (3.3). 4.1.2 Suction and discharge-side connections of pressure vessels, pipes and similar, which are completely mounted as package unit together with the core unit, will be sealed as described in 3.2.1 and 3.2.2; the entire internal space must be filled with nitrogen at 0.3 bar through the fill-in connection (3.3). Continuation on page 2																		
<table border="1"> <tr> <td>Issued</td> <td>TNW</td> </tr> <tr> <td>Date</td> <td>89-12-08</td> </tr> <tr> <td>Name</td> <td><i>Mi.</i></td> </tr> </table>	Issued	TNW	Date	89-12-08	Name	<i>Mi.</i>	<table border="1"> <tr> <td colspan="5">Revision No.</td> </tr> <tr> <td> </td> <td> </td> <td> </td> <td> </td> <td> </td> </tr> </table>	Revision No.										Works Standard 033.23.5E
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Date	89-12-08																	
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Works Standard 033.23.5 E

4.2 Pressure vessels, pipes, and accessories for the oil loop:

- 4.2.1 Internal surfaces of oil tanks and oil coolers must be greased with anticorrosive oil *3); these vessels must be closed as described in 3.2.1/3.2.2 or filled with nitrogen at 0.3 bar through the fill-in connection (3.3).
- 4.2.2 After drying, pipes must be greased with oil for factory assembly; in case of longer storage or erection work on site, they must be greased with anticorrosive oil *3); openings must be closed as described in 3.2.1/3.2.2.
- 4.2.3 Smaller pipe sections and pipes of smaller dimensions must be treated as described in 4.2.2; instead of closing them, they must be welded into a vapour seal enclosure.

4.3 Other pipes:

- 4.3.1 Pipe sections such as control pipes and similar must be welded into a vapour seal enclosure. Pipes made of C-steel must additionally be greased with anticorrosive oil *3).
- 4.3.2 Apply anticorrosive oil on internal surfaces and boiled linseed oil on external surfaces of C-steel pipes shipped as pipe lengths. All pipe lengths made of C-steel, CrNi steel, NE metal and similar must be closed with protective plugs or caps to Works Standard 923.93.0 and/or 923.93.1 to avoid pollution of internal surfaces.

4.4 Fittings

Internal surfaces of fittings must be greased with anticorrosive oil *3).
Connecting flanges and welded nozzles must be closed with protective plugs to Works Standard 923.93.0.

4.5 Connections for spaces filled with cooling water:

These connections are protected against pollution by closing them with protective plugs or caps to Works Standard 923.93.0 and/or 923.93.1.

4.6 Proceed accordingly for parts not expressly mentioned.

- *1) In this context, pressure vessel shall mean all coolers, separators etc.
- *2) For preservation instructions covering oxygen plants see Works Standard 033.21.0 .
- *3) Anticorrosive oil, material No. 6915 1353 16.
De-greasing not required, compatible with usual lubricants.

Atlas Copco

Lubricants for ACT turbomachinery

ATLAS COPCO ENERGAS
GmbHWorks Standard
ENG 790.21.2 - en(Original version: German - revision F/01.2002;)
(Other versions: en, es, fr, it, nl)

The Atlas Copco - List of Lubricants, 1985, and older editions are withdrawn.

1. Application

Lubricating oils for turbomachinery manufactured by Atlas Copco "Applied Compressor and Expander Technique" (ACT) must be suited for the following applications:

- Lubrication/cooling of
 - bearings
 - gear systems
 - mechanical seals
 - electric motors, generators
 - steam turbines including control circuits
 - gas turbines
- Lubrication of oil-filled gear couplings

2. Requirements

The lubricating oil must correspond to DIN 51515, part 1 (turbine oils). For minimum requirements refer to the table on page 3.

If the lubricant manufacturer does not provide all required data or if not all data comply with our requirements, ACT must be contacted for permission to use such a lubricant.

The correct lubrication of the ACT equipment is essential to equipment life. Therefore only highly-refined, paraffinic-type base oils with excellent viscosity/temperature behaviour should be selected. The base oil should contain additives to prevent oxidation and corrosion. The additives must not react with components within the oil circulation system.

All additives must remain homogeneously dissolved in the base oil at all temperatures between pour point and 175 °C. The compatibility of the additive system to other approved oils must be guaranteed. The oil appearance must remain always clear. No solid contaminants must be formed. Filtration (by 1µ filter) or centrifuging the oil must not change the guaranteed values.

For the lubrication of ACT equipment no oils with EP (extreme pressure) properties are allowed. EP-additives are aimed to reduce wear. EP-oils contain heavy-duty additives which should improve the load carrying ability of the lubricating film.

The additives allowed for the only approved non EP-Type lubricants must not contain any metal-organic, sulphur/phosphorous or zinc containing compounds. Even traces of these materials may form deposits mainly in high temperature zones (bearings/seals), which finally may lead to operating problems.

3. Oil control during operation

Usually the oil quality supplied by well recognized lubricant manufacturers exceeds the minimum requirements in the Lubricant Recommendation Sheet on page 2.

A comparison of the data in the table to the information on the oil quality provided by the manufacturer may allow an estimation of an extended oil drain interval.

For the recommended viscosity group please refer to the instruction manual.

If the regular used-oil analysis shows that the oil in service does no longer fulfill the minimum requirements, the oil must be changed. Should this oil change become necessary in less than 2 years or 16.000 hours, the oil supplier must be contacted. ACT is of course also willing to give the user advice in such a case.

Oil samples must be taken at least every 12 months or 8.000 hours usually during operation after a minimum operating time of 1 hour. The oil sample should be taken from the circulating system.

The sample volume should be at least 1 litre or to the requirements of the laboratory. It should be filled into a clean container which should be closed immediately.

Issued:	Standard dept.	Revision	Reason of revision
Date	07.1988	F/01.2002	General revision
Name	Castor A.	KCAN/Némorin	

ACE Works Standard ENG 790.21.2 - en page 1 of 2

4. Discolouration of metal surfaces

Please check oil wetted parts e.g. gear teeth or bearings on regular intervals for discolouration.

Mainly at long term use of the oil at elevated temperatures discolouration of gear teeth surfaces may be experienced. This discolouration with colours ranging from yellow to brown and blue, similar to annealing colours, is formed by a reaction layer of the oil additives or the oxidation products of the oil. The formation of this very thin reaction layer depends on the composition of the additives, temperatures and pressures at the location, service life of the oil and air humidity.

Although this reaction layer appears to be stable usually it will be continuously removed and rebuilt by the oil components.

As long as no black deposits or hard residues are found, the discolouration of metal parts does not have a negative impact on the operating condition.

* * *

Lubricant Recommendation Sheet

For the lubrication of turbomachinery, lubricating oils according to DIN 51515-1 (Turbine Oils) with viscosity group ISO VG 32 or ISO VG 46 according to DIN 51519 are recommended. This table shows the requirements.

Synthetic lubricants are not required in most cases. For special applications it may be necessary to use synthetic oils. Such recommendations are given in the instruction manuals of the machine.

		Requirements		Standard
Turbine oil		TD 32	TD 46	DIN 51502
ISO viscosity Group		ISO VG 32	ISO VG 46	DIN 51519 ISO 3448
Viscosity at 40 °C (mm ² /s)	min max	28.8 35.2	41.4 50.6	DIN 51562 ISO 3104 ASTM D 445
Viscosity index VI		≥ 90		DIN ISO 2909 ASTM D 2270
Density at 15 °C (g/ml)		≤ 0.9		DIN 51757 ISO 3675 ASTM D 1298
Flash point COC (°C) (°F)		≥ 175 ≥ 347	≥ 185 ≥ 365	DIN ISO 2592 ASTM D 92
Pour point (°C) (°F)	2	≤ -6 ≤ 21.2		DIN ISO 3016 ASTM D 97
Neutralization number (TAN) (mg KOH/g)	3	≤ 0.2		DIN 51558-1 ISO 6618 ASTM D 664
Oxide ash (g/100 g)		≤ 0.01		DIN EN ISO 6245, ASTM D 874
Solid contaminants (% wt)		< 0.05		ISO 4406
Water content (% wt)		< 0.05		DIN ISO 3733 ASTM D 95
Water separation (seconds)		≤ 300		DIN 51589-1 ASTM D 1401
Air release time at 50 °C (minutes)		≤ 5		DIN 51381 ASTM D 3427

..... (continuation)

		Requirements		Standard
Turbine oil		TD 32	TD 46	DIN 51502
Foaming tendency: Foam quantity – Foam stability	S1/S2/S3	≤ 450-10 / 50-0 / 450-10		ISO 6247 ASTM D 892
Copper corrosion (stage)		≤ 2 - 100 A3		DIN EN ISO 2160, ASTM D 130
Steel corrosion (synthetic sea water) (stage)		0 - A		DIN ISO 7120 ASTM D 665
TOST-Test; 1000 hours to increase the TAN (mg KOH/g)		≤ 2.0		DIN 51587 ISO DIS 4263 ASTM D 943
FZG-Test (A/8.3/90)	4)	≥ 5	≥ 6	DIN 51354
1) For special applications, oils of viscosity group 10, 22 and 68, (oils of viscosity group 10 and 22 are CL-type oils according to DIN 51517 part 2) are recommended. In this case refer to the details in the instruction manual. 2) In case of extreme low ambient temperatures oils with a lower pour point have to be used 3) Used oil limit value: max 0.2 mg KOH/g above fresh oil value 4) FZG = Research Institut for the Manufacture of Toothed Wheels and Gears, Munich.				

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Atlas Copco Atlas Copco Energies GmbH	Tightening torques Mt for screws (For dynamometric keys)	Works Standard 903.99.0E																				
This Works Standard is an excerpt from VDI guideline 223D and deals with screw connections designed to transmit static or varying operating forces. The determinations laid down in this guideline apply to steel screws in a temperature range from -40 °C to +300 °C, where neither cold embrittlement nor creeping of screw steels are to be expected. The following rules apply to screws and nuts tightened by means of dynamometric keys. Tightening torques indicated in the subsequent table result in a utilization of the elastic screw limit stress $\sigma_{0.2}$ of 90 % as a function of friction. Surface friction between screw head or nut on the one hand and tensioned part on the other hand depends on surface quality and lubrication. Coefficients of friction for various surface and lubricating states <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="text-align: center;">Surface Contact of screw head or nut</th> <th colspan="3" style="text-align: center;">Lubrication</th> </tr> <tr> <th></th> <th style="text-align: center;">MoS₂ paste</th> <th style="text-align: center;">Oil</th> <th style="text-align: center;">dry</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;"> $\leq 16 \mu\text{m}$ Smooth surfaces, e. g. turned, ground, milled. Spiral-type machining screws such as countersinking of U-type disks and similar. </td> <td style="text-align: center;">0.100</td> <td style="text-align: center;">0.125</td> <td style="text-align: center;">0.160</td> </tr> <tr> <td style="text-align: center;"> $> 16 \text{ to } \leq 100 \mu\text{m}$ Perceptible cross-type machining screws such as turning screws of milled surfaces (sheet) and similar. </td> <td style="text-align: center;">0.125</td> <td style="text-align: center;">0.160</td> <td style="text-align: center;">-</td> </tr> <tr> <td style="text-align: center;"> $> 100 \mu\text{m}$ Rough cross-type machining screws such as rough turning screws or forged surfaces and similar. </td> <td style="text-align: center;">0.160</td> <td style="text-align: center;">-</td> <td style="text-align: center;">-</td> </tr> </tbody> </table> In the subsequent tables, the tightening torques for the individual strength classes and coefficients of friction are indicated. Tightening torques for screws, which are not included in the table, must be calculated to formulae mentioned on page 2 and registered on the drawings. Screws 8.8 and C7 of DIN flanges must only be tightened with the torque of screw 5.6.			Surface Contact of screw head or nut	Lubrication				MoS ₂ paste	Oil	dry	$\leq 16 \mu\text{m}$ Smooth surfaces, e. g. turned, ground, milled. Spiral-type machining screws such as countersinking of U-type disks and similar.	0.100	0.125	0.160	$> 16 \text{ to } \leq 100 \mu\text{m}$ Perceptible cross-type machining screws such as turning screws of milled surfaces (sheet) and similar.	0.125	0.160	-	$> 100 \mu\text{m}$ Rough cross-type machining screws such as rough turning screws or forged surfaces and similar.	0.160	-	-
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Tightening torques M_t for screws
(For dynamometric keys)

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Tightening torques M_A are calculated to VDI guideline 2230. M_A for cylindrical screws

$$M_A = \frac{0.9 \cdot \sigma_{0.2}}{\sqrt{1 + 3 \left[\frac{4}{1 + d_3/d_2} \left(\frac{P}{\pi \cdot d_2} + 1.155 \mu \right) \right]^2}} \cdot A_S \left[0.16 P + \mu_{ges} \left(0.58 d_2 + \frac{D_{km}}{2} \right) \right]$$

 M_A for necked-down bolts

$$M_A = \frac{0.9 \cdot \sigma_{0.2}}{\sqrt{1 + 3 \left[\frac{2 d_2}{d_0} \left(\frac{P}{\pi \cdot d_2} + 1.155 \mu \right) \right]^2}} \cdot A_T \left[0.16 P + \mu_{ges} \left(0.58 d_2 + \frac{D_{km}}{2} \right) \right]$$

 P = lead d_0 = smallest shaft diameter d_2 = pitch diameter d_3 = core diameter μ_{ges} = coefficient of friction at thread and screw head or nut μ = coefficient of friction at thread A_T = reduced shaft cross section = $\frac{d_0^2 \pi}{4}$ A_S = tension cross section = $\frac{\pi}{4} \cdot \left(\frac{d_2 + d_3}{2} \right)^2$ D_{km} = effective diameter for moment of friction at the contact point of screw head or nut $\sigma_{0.2}$ = elastic screw limit, i. e. 0.2 % of screw material yield strength
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Tightening torques Mt for screws
(For dynamometric keys)

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Strength class or material		4.6		5.6		6.8		10.9		12.9		14.5		17.0		20.0		24.0		27.0		30.0		35.0		40.0		45.0		50.0		55.0		60.0		65.0		70.0		75.0		80.0		85.0		90.0		95.0		100.0		105.0		110.0		115.0		120.0		125.0		130.0		135.0		140.0		145.0		150.0		155.0		160.0		165.0		170.0		175.0		180.0		185.0		190.0		195.0		200.0		205.0		210.0		215.0		220.0		225.0		230.0		235.0		240.0		245.0		250.0		255.0		260.0		265.0		270.0		275.0		280.0		285.0		290.0		295.0		300.0		305.0		310.0		315.0		320.0		325.0		330.0		335.0		340.0		345.0		350.0		355.0		360.0		365.0		370.0		375.0		380.0		385.0		390.0		395.0		400.0		405.0		410.0		415.0		420.0		425.0		430.0		435.0		440.0		445.0		450.0		455.0		460.0		465.0		470.0		475.0		480.0		485.0		490.0		495.0		500.0		505.0		510.0		515.0		520.0		525.0		530.0		535.0		540.0		545.0		550.0		555.0		560.0		565.0		570.0		575.0		580.0		585.0		590.0		595.0		600.0		605.0		610.0		615.0		620.0		625.0		630.0		635.0		640.0		645.0		650.0		655.0		660.0		665.0		670.0		675.0		680.0		685.0		690.0		695.0		700.0		705.0		710.0		715.0		720.0		725.0		730.0		735.0		740.0		745.0		750.0		755.0		760.0		765.0		770.0		775.0		780.0		785.0		790.0		795.0		800.0		805.0		810.0		815.0		820.0		825.0		830.0		835.0		840.0		845.0		850.0		855.0		860.0		865.0		870.0		875.0		880.0		885.0		890.0		895.0		900.0		905.0		910.0		915.0		920.0		925.0		930.0		935.0		940.0		945.0		950.0		955.0		960.0		965.0		970.0		975.0		980.0		985.0		990.0		995.0		1000.0		1005.0		1010.0		1015.0		1020.0		1025.0		1030.0		1035.0		1040.0		1045.0		1050.0		1055.0		1060.0		1065.0		1070.0		1075.0		1080.0		1085.0		1090.0		1095.0		1100.0		1105.0		1110.0		1115.0		1120.0		1125.0		1130.0		1135.0		1140.0		1145.0		1150.0		1155.0		1160.0		1165.0		1170.0		1175.0		1180.0		1185.0		1190.0		1195.0		1200.0		1205.0		1210.0		1215.0		1220.0		1225.0		1230.0		1235.0		1240.0		1245.0		1250.0		1255.0		1260.0		1265.0		1270.0		1275.0		1280.0		1285.0		1290.0		1295.0		1300.0		1305.0		1310.0		1315.0		1320.0		1325.0		1330.0		1335.0		1340.0		1345.0		1350.0		1355.0		1360.0		1365.0		1370.0		1375.0		1380.0		1385.0		1390.0		1395.0		1400.0		1405.0		1410.0		1415.0		1420.0		1425.0		1430.0		1435.0		1440.0		1445.0		1450.0		1455.0		1460.0		1465.0		1470.0		1475.0		1480.0		1485.0		1490.0		1495.0		1500.0		1505.0		1510.0		1515.0		1520.0		1525.0		1530.0		1535.0		1540.0		1545.0		1550.0		1555.0		1560.0		1565.0		1570.0		1575.0		1580.0		1585.0		1590.0		1595.0		1600.0		1605.0		1610.0		1615.0		1620.0		1625.0		1630.0		1635.0		1640.0		1645.0		1650.0		1655.0		1660.0		1665.0		1670.0		1675.0		1680.0		1685.0		1690.0		1695.0		1700.0		1705.0		1710.0		1715.0		1720.0		1725.0		1730.0		1735.0		1740.0		1745.0		1750.0		1755.0		1760.0		1765.0		1770.0		1775.0		1780.0		1785.0		1790.0		1795.0		1800.0		1805.0		1810.0		1815.0		1820.0		1825.0		1830.0		1835.0		1840.0		1845.0		1850.0		1855.0		1860.0		1865.0		1870.0		1875.0		1880.0		1885.0		1890.0		1895.0		1900.0		1905.0		1910.0		1915.0		1920.0		1925.0		1930.0		1935.0		1940.0		1945.0		1950.0		1955.0		1960.0		1965.0		1970.0		1975.0		1980.0		1985.0		1990.0		1995.0		2000.0		2005.0		2010.0		2015.0		2020.0		2025.0		2030.0		2035.0		2040.0		2045.0		2050.0		2055.0		2060.0		2065.0		2070.0		2075.0		2080.0		2085.0		2090.0		2095.0		2100.0		2105.0		2110.0		2115.0		2120.0		2125.0		2130.0		2135.0		2140.0		2145.0		2150.0		2155.0		2160.0		2165.0		2170.0		2175.0		2180.0		2185.0		2190.0		2195.0		2200.0		2205.0		2210.0		2215.0		2220.0		2225.0		2230.0		2235.0		2240.0		2245.0		2250.0		2255.0		2260.0		2265.0		2270.0		2275.0		2280.0		2285.0		2290.0		2295.0		2300.0		2305.0		2310.0		2315.0		2320.0		2325.0		2330.0		2335.0		2340.0		2345.0		2350.0		2355.0		2360.0		2365.0		2370.0		2375.0		2380.0		2385.0		2390.0		2395.0		2400.0		2405.0		2410.0		2415.0		2420.0		2425.0		2430.0		2435.0		2440.0		2445.0		2450.0		2455.0		2460.0		2465.0		2470.0		2475.0		2480.0		2485.0		2490.0		2495.0		2500.0		2505.0		2510.0		2515.0		2520.0		2525.0		2530.0		2535.0		2540.0		2545.0		2550.0		2555.0		2560.0		2565.0		2570.0		2575.0		2580.0		2585.0		2590.0		2595.0		2600.0		2605.0		2610.0		2615.0		2620.0		2625.0		2630.0		2635.0		2640.0		2645.0		2650.0		2655.0		2660.0		2665.0		2670.0		2675.0		2680.0		2685.0		2690.0		2695.0		2700.0		2705.0		2710.0		2715.0		2720.0		2725.0		2730.0		2735.0		2740.0		2745.0		2750.0		2755.0		2760.0		2765.0		2770.0		2775.0		2780.0		2785.0		2790.0		2795.0		2800.0		2805.0		2810.0		2815.0		2820.0		2825.0		2830.0		2835.0		2840.0		2845.0		2850.0		2855.0		2860.0		2865.0		2870.0		2875.0		2880.0		2885.0		2890.0		2895.0		2900.0		2905.0		2910.0		2915.0		2920.0		2925.0		2930.0		2935.0		2940.0		2945.0		2950.0		2955.0		2960.0		2965.0		2970.0		2975.0		2980.0		2985.0		2990.0		2995.0		3000.0		3005.0		3010.0		3015.0		3020.0		3025.0		3030.0		3035.0		3040.0		3045.0		3050.0		3055.0		3060.0		3065.0		3070.0		3075.0		3080.0		3085.0		3090.0		3095.0		3100.0		3105.0		3110.0		3115.0		3120.0		3125.0		3130.0		3135.0		3140.0		3145.0		3150.0		3155.0		3160.0		3165.0		3170.0		3175.0		3180.0		3185.0		3190.0		3195.0		3200.0		3205.0		3210.0		3215.0		3220.0		3225.0		3230.0		3235.0		3240.0		3245.0		3250.0		3255.0		3260.0		3265.0		3270.0		3275.0		3280.0		3285.0		3290.0		3295.0		3300.0		3305.0		3310.0		3315.0		3320.0		3325.0		3330.0		3335.0		3340.0		3345.0		3350.0		3355.0		3360.0		3365.0		3370.0		3375.0		3380.0		3385.0		3390.0		3395.0		3400.0		3405.0		3410.0		3415.0		3420.0		3425.0		3430.0		3435.0		3440.0		3445.0		3450.0		3455.0		3460.0		3465.0		3470.0		3475.0		3480.0		3485.0		3490.0		3495.0		3500.0		3505.0		3510.0		3515.0		3520.0		3525.0		3530.0		3535.0		3540.0		3545.0		3550.0		3555.0		3560.0		3565.0		3570.0		3575.0		3580.0		3585.0		3590.0		3595.0		3600.0		3605.0		3610.0		3615.0		3620.0		3625.0		3630.0		3635.0		3640.0		3645.0		3650.0		3655.0		3660.0		3665.0		3670.0		3675.0		3680.0		3685.0		3690.0		3695.0		3700.0		3705.0		3710.0		3715.0		3720.0		3725.0		3730.0		3735.0		3740.0		3745.0		3750.0		3755.0		3760.0		3765.0		3770.0		3775.0		3780.0		3785.0		3790.0		3795.0		3800.0		3805.0		3810.0		3815.0		3820.0		3825.0		3830.0		3835.0		3840.0		3845.0		3850.0		3855.0		3860.0		3865.0		3870.0		3875.0		3880.0		3885.0		3890.0		3895.0		3900.0		3905.0		3910.0		3915.0		3920.0		3925.0		3930.0		3935.0		3940.0		3945.0		3950.0		3955.0		3960.0		3965.0		3970.0		3975.0		3980.0		3985.0		3990.0		3995.0		4000.0		4005.0		4010.0		4015.0		4020.0		4025.0		4030.0		4035.0		4040.0		4045.0		4050.0		4055.0		4060.0		4065.0		4070.0		4075.0		4080.0		4085.0		4090.0		4095.0		4100.0		4105.0		4110.0		4115.0		4120.0		4125.0		4130.0		4135.0		4140.0		4145.0		4150.0		4155.0		4160.0		4165.0		4170.0		4175.0		4180.0		4185.0		4190.0		4195.0		4200.0		4205.0		4210.0		4215.0		4220.0		4225.0		4230.0		4235.0		4240.0		4245.0		4250.0		4255.0		4260.0		4265.0		4270.0		4275.0		4280.0		4285.0		4290.0		4295.0		4300.0		4305.0		4310.0		4315.0		4320.0		4325.0		4330.0		4335.0		4340.0		4345.0		4350.0		4355.0		4360.0		4365.0		4370.0		4375.0		4380.0		4385.0		4390.0		4395.0		4400.0		4405.0		4410.0		4415.0		4420.0		4425.0		4430.0		4435.0		4440.0		4445.0		4450.0		4455.0		4460.0		4465.0		4470.0		4475.0	
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Tightening torques Mt for screws
(For dynamometric keys)

(Works Standard 903.99.0e)

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Strength class or material S	Kp/mm ² N/mm ²	Tightening torque M _k (Kp, Nm) of cylindrical screws DIN 913, 915, 912, 7984, 939 and similar												Cr X20Cr13V	GnI X10CrNiTi189	5Cr X5CrMnNi1105						
		4.6			5.6			6.8			10.9						12N19V			G 24CrMo5V		
		Kp		Nm	Kp		Nm	Kp		Nm	Kp		Nm				Kp		Nm		Kp	Nm
		24	240	30	300	64	640	90	900	43	430	45	450				50	500	21			
Coarse thread		of fric.	Kp	Nm	Kp	Nm	Kp	Nm	Kp	Nm	Kp	Nm	Kp	Nm	Kp	Nm	Kp	Nm	Kp	Nm		
M 20	0.100	43.53	426.86	54.41	533.58	116.07	1138.30	163.23	1600.74	77.98	764.80	81.61	800.37	90.68	889.30	38.09	373.51	126.98	1245.02			
M 30	0.125	50.54	485.86	63.18	619.57	134.76	1321.76	189.54	1858.72	90.56	888.08	94.77	928.36	105.30	1032.82	44.23	433.70	144.57	1445.67			
M 30	0.160	58.89	577.51	73.61	721.89	157.04	1540.03	220.84	2185.66	105.51	1034.71	110.42	1082.83	122.69	1203.15	51.53	505.32	171.76	1684.41			
M 33	0.100	59.12	578.73	73.90	724.67	157.64	1545.85	221.69	2174.00	105.92	1038.69	110.84	1087.00	123.16	1207.78	51.73	507.27	172.42	1690.89			
M 33	0.125	68.86	675.24	88.07	844.05	183.81	1800.64	258.21	2532.15	123.37	1209.81	128.10	1258.08	143.45	1406.75	60.25	590.84	200.83	1989.45			
M 33	0.160	80.48	789.03	100.57	986.28	214.56	2104.07	301.72	2958.85	144.15	1413.87	150.86	1479.43	167.62	1643.81	70.40	690.40	234.67	2301.33			
M 36	0.100	75.73	742.62	94.66	928.27	201.94	1980.32	283.97	2784.82	135.68	1330.53	141.99	1392.41	157.76	1547.12	66.26	649.79	220.87	2165.97			
M 36	0.125	88.06	863.80	110.08	1078.50	234.83	2302.83	330.34	3238.50	157.78	1547.28	165.12	1619.25	183.46	1798.17	77.05	755.65	258.85	2518.83			
M 36	0.160	102.75	1007.63	128.44	1259.54	274.00	2687.02	385.31	3776.62	184.09	1805.34	192.66	1888.31	214.06	2099.23	89.81	881.68	299.86	2938.93			
M 38	0.100	97.90	960.09	122.38	1200.12	261.07	2560.25	367.13	3600.35	175.41	1720.17	183.57	1800.18	203.96	2000.20	85.66	840.08	285.55	2800.27			
M 38	0.125	114.14	1119.30	142.67	1395.13	304.37	2984.61	428.01	4197.39	204.50	2005.42	214.01	2098.69	237.78	2331.88	99.87	979.39	332.90	3264.63			
M 38	0.160	133.49	1309.06	168.86	1636.32	355.96	3490.82	500.58	4908.96	238.16	2345.40	250.29	2454.48	278.19	2721.20	118.80	1145.43	389.34	3818.09			
M 42	0.100	120.90	1185.58	151.12	1481.97	322.39	3161.54	453.36	4445.91	216.60	2124.16	226.68	2222.96	251.87	2479.96	105.78	1037.38	352.94	3457.94			
M 42	0.125	140.74	1380.22	175.93	1725.28	375.32	3680.60	527.79	5175.84	252.17	2472.90	263.89	2587.82	293.22	2875.47	123.15	1207.70	410.50	4025.86			
M 42	0.160	164.38	1612.07	205.46	2015.09	438.36	4298.86	616.45	6045.28	284.52	2808.29	308.22	3022.63	342.47	3358.46	143.64	1410.56	479.46	4701.87			
M 45	0.100	150.79	1478.77	188.49	1848.46	402.11	3943.39	565.47	5545.39	270.17	2649.47	282.74	2772.70	314.15	3080.77	131.94	1293.92	439.81	4313.08			
M 45	0.125	175.92	1725.19	219.90	2156.49	469.12	4600.52	659.70	6469.48	315.19	3090.37	329.85	3234.74	366.50	3594.16	153.93	1509.55	513.10	5031.82			
M 45	0.160	205.86	2018.98	257.35	2523.73	549.01	5383.96	772.05	7571.19	368.87	3617.35	386.02	3785.59	428.91	4206.21	180.14	1766.61	600.48	5888.70			
M 48	0.100	196.10	1923.06	245.12	2403.82	522.93	5128.14	735.36	7211.46	351.34	3445.47	367.68	3605.73	408.54	4006.37	171.58	1682.67	571.95	5608.97			
M 48	0.125	228.02	2245.88	286.27	2807.35	610.71	5989.02	858.81	8422.06	410.32	4023.87	429.41	4211.03	477.12	4678.90	200.39	1965.15	667.86	6550.49			
M 48	0.160	268.53	2633.42	335.67	3291.78	716.09	7022.45	1007.00	9875.33	481.12	4718.21	503.50	4937.68	559.45	5486.29	234.97	2304.24	783.22	7680.81			

Tightening torques Mt for screws
for dynamometric keys)

(Works Standard 903.99.0e)

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Strength class or material	S	Kp/mm² N/mm²	Tightening torque M_A (Kp·m, Nm) of cylindrical screws DIN 931, 933, 912, 798A, 939 and similar												CNI X10CNI1189	SCr XSCrMA1189														
			4,6		5,6		8,8		10,9		KS 12N18V		G 24CMA6V				Cz X20Cz13V													
			Nm	Kp·m	Nm	Kp·m	Nm	Kp·m	Nm	Kp·m	Nm	Kp·m	Nm	Kp·m			Nm	Kp·m	Nm	Kp·m										
M 10 x 1,5	0,100	67,82	6,82	8,64	84,77	18,44	180,85	25,93	254,32	12,39	121,51	12,97	127,16	14,41	141,29	15,34	153,4	16,84	165,17	18,75	183,66	20,83	204,28	22,91	225,58	25,99	254,32	28,07	277,13	30,15
M 10 x 1,5	0,125	79,28	10,11	11,85	116,20	21,42	211,42	30,32	297,30	14,48	142,05	15,16	148,65	16,84	165,17	18,75	183,66	20,83	204,28	22,91	225,58	25,99	254,32	28,07	277,13	30,15	297,30	32,23	313,37	34,31
M 10 x 1,5	0,160	92,98	8,48	92,98	118,20	25,28	247,89	35,55	348,60	16,98	166,55	17,77	174,30	19,75	193,66	21,62	212,91	23,50	231,29	25,37	250,06	27,25	270,85	29,12	290,44	31,00	308,60	32,87	326,73	34,75
M 10 x 1,5	0,100	98,06	10,00	12,50	122,57	26,66	261,48	37,50	367,71	17,91	175,68	18,75	183,66	20,83	204,28	22,91	225,58	25,99	254,32	28,07	277,13	30,15	297,30	32,23	313,37	34,31	333,33	36,39	359,49	38,47
M 10 x 1,5	0,125	114,98	11,72	14,56	143,72	31,27	306,51	43,37	421,17	21,01	206,00	21,62	212,91	23,50	231,29	25,37	250,06	27,25	270,85	29,12	290,44	31,00	308,60	32,87	326,73	34,75	347,50	36,62	365,62	38,50
M 10 x 1,5	0,160	135,20	13,79	17,23	169,00	36,76	360,53	51,70	507,00	24,70	242,23	25,37	250,06	27,25	270,85	29,12	290,44	31,00	308,60	32,87	326,73	34,75	347,50	36,62	365,62	38,50	385,00	40,37	399,49	42,25
M 20 x 1,5	0,100	138,8	13,88	17,35	170,14	37,01	362,95	52,05	510,42	24,87	243,87	25,37	250,06	27,25	270,85	29,12	290,44	31,00	308,60	32,87	326,73	34,75	347,50	36,62	365,62	38,50	385,00	40,37	399,49	42,25
M 20 x 1,5	0,125	163,1	16,31	20,39	199,98	43,51	426,85	61,18	598,86	28,23	278,66	28,84	284,27	30,71	302,84	32,58	320,91	34,45	340,58	36,32	358,71	38,19	379,98	40,06	398,17	41,93	417,00	43,80	435,09	45,67
M 20 x 1,5	0,160	188,57	18,86	24,04	235,71	51,28	502,85	72,11	707,14	34,45	337,85	35,06	346,11	36,93	364,06	38,80	385,19	40,67	402,80	42,54	420,91	44,41	442,02	46,28	460,93	48,15	480,06	50,02	499,15	51,89
M 22 x 1,5	0,100	181,28	18,12	22,62	222,53	49,30	483,45	69,32	678,84	33,12	324,81	33,68	332,46	35,55	351,19	37,42	371,81	39,28	391,40	41,14	410,91	43,00	429,77	44,86	448,33	46,72	466,80	48,58	484,88	50,44
M 22 x 1,5	0,125	213,51	21,35	27,22	266,89	58,06	569,36	81,65	800,66	39,01	382,54	40,62	402,33	42,48	424,61	44,34	443,61	46,20	461,77	48,06	480,22	49,92	497,08	51,78	515,83	53,64	534,39	55,49	553,24	57,34
M 22 x 1,5	0,160	252,09	25,21	32,13	315,12	68,55	672,25	96,40	945,35	46,06	451,87	46,72	464,27	48,58	483,45	50,44	502,85	52,30	520,91	54,16	540,11	56,02	558,97	57,88	577,73	59,69	596,54	61,50	613,85	63,31
M 24 x 1,5	0,100	239,25	23,92	30,50	299,06	65,06	637,89	91,49	897,18	43,71	428,65	44,34	442,02	46,20	461,77	48,06	480,22	49,92	497,08	51,78	515,83	53,64	534,39	55,49	553,24	57,34	571,19	59,19	589,04	61,00
M 24 x 1,5	0,125	282,29	28,23	35,88	352,87	76,78	752,78	107,95	1058,60	51,57	505,78	52,14	516,29	53,97	529,30	55,78	549,61	57,64	575,51	59,50	593,81	61,36	611,91	63,22	630,67	65,08	649,03	66,94	667,79	68,79
M 24 x 1,5	0,160	333,89	33,39	42,58	417,38	90,78	890,38	127,68	1252,09	61,00	598,22	61,62	606,84	63,49	625,05	65,34	641,57	67,20	669,61	69,06	688,51	70,92	707,77	72,78	726,63	74,64	745,49	76,50	763,85	78,36
M 20 x 2	0,100	130,36	13,04	16,82	162,96	35,45	347,64	49,85	488,87	23,82	233,57	24,38	240,06	25,25	250,06	26,12	261,17	27,00	270,85	28,87	288,51	30,71	305,86	32,58	323,73	34,45	342,08	36,32	360,23	38,19
M 20 x 2	0,125	152,10	15,21	19,39	190,13	41,36	405,61	56,18	550,39	27,78	272,52	28,34	280,06	29,20	290,44	30,71	307,08	32,23	313,37	33,74	333,89	35,25	352,87	36,76	367,71	38,27	382,72	39,78	397,73	41,29
M 20 x 2	0,160	178,03	17,80	22,69	222,53	48,41	474,73	66,08	647,60	32,53	318,96	33,10	328,62	34,04	338,80	35,91	350,11	37,82	378,81	39,73	397,00	41,64	415,59	43,55	434,50	45,41	453,36	47,27	472,22	49,13
M 24 x 2	0,100	231,17	23,12	29,07	288,96	62,86	616,44	88,40	868,87	42,23	414,17	42,84	434,44	44,71	446,59	46,58	467,66	48,45	485,50	50,32	501,17	52,19	520,04	54,06	539,89	55,92	558,74	57,78	577,63	59,61
M 24 x 2	0,125	271,03	27,10	34,55	338,79	73,70	722,75	103,64	1016,37	49,52	485,50	50,14	501,17	52,00	519,81	53,87	537,72	55,71	556,56	57,60	574,91	59,48	593,63	61,36	612,51	63,22	631,37	65,08	649,93	66,94
M 24 x 2	0,160	318,67	31,87	40,82	402,62	86,65	849,79	121,86	1195,02	58,22	570,95	58,84	598,51	60,71	606,84	62,60	624,61	64,50	643,01	66,39	662,80	68,28	681,63	70,17	700,48	72,06	719,33	73,94	738,25	75,82
M 30 x 2	0,100	465,57	46,57	59,34	581,96	126,60	1241,52	178,03	1745,89	85,06	834,15	85,68	872,95	88,02	899,94	90,39	921,81	94,71	934,06	97,06	962,31	99,48	1017,00	103,89	105,31	107,73	110,15	112,57	114,99	117,41
M 30 x 2	0,125	548,67	54,87	69,84	685,83	148,20	1463,11	208,81	2057,51	100,24	983,03	100,86	1028,75	103,22	1058,19	105,66	1088,11	111,08	1138,06	115,50	1184,91	120,92	1239,84	126,33	1298,75	132,14	1356,66	138,55	1424,56	145,94
M 30 x 2	0,160	648,21	64,82	82,62	810,26	176,26	1728,56	247,87	2430,79	118,43	1161,38	119,05	1215,39	121,46	1245,81	123,87	1276,22	130,28	1336,63	135,69	1397,04	141,10	1451,45	146,56	1505,91	152,97	1570,36	160,42	1648,77	166,88
M 36 x 3	0,100	780,05	78,01	99,43	975,07	212,12	2080,15	298,29	2925,20	142,52	1397,60	143,14	1462,60	145,55	1497,05	148,96	1531,51	155,36	1596,01	162,21	1670,46	167,02	1714,91	171,87	1769,36	181,82	1873,81	192,77	1988,26	203,72
M 36 x 3	0,125	932,26	93,26	118,58	1143,22	248,70	2438,88	348,73	3429,67	167,08	1638,62	167,70	1714,91	169,11	1741,12	170,54	1786,75	181,99	1862,40	187,44	1928,81	194,89	2005,20	202,92	2085,61	211,64	2176,05	220,36	2266,47	229,08
M 36 x 3	0,160	1075,33	107,53	137,07	1344,16	292,41	2867,54	411,20	4032,48	196,46	1926,63	197,08	2016,24	200,49	2054,81	201,90	2099,41	213,33	2208,84	218,76	2278,27	223,68	2327,69	228,59	2397,10	234,41	2446,51	240,32	2495,93	246,23
M 39 x 3	0,100	1003,72	100,37	127,94	1254,65	272,94	2676,59	389,82	3763,95	183,38	1798,33	183,99	1891,97	189,60	1944,96	190,21	1999,47	203,63	2108,88	207,08	2158,29	211,49	2208,70	215,80	2259,21	220,01	2309,72	224,22	2360,23	228,33
M 39 x 3	0,125	1179,12	117,91	150,30	1473,98	330,63	314,32	450,86	441,70	213,75	2102,30	214,36	2208,70	215,97	2235,11	217,18	2291,59	231,59	2397,00	235,59	2442,41	239,50	2490,91	244,39	2539,30	249,28	2587,70	254,17	2636,10	259,06
M 39 x 3	0,160	141,63	141,63	177,04	1730,14	377,68	3703,77	531,11	5208,43	253,75	2488,47	254,36	2604,21	255,97	2620,02	257,18	2676,03	269,19	2761,44	271,20	2817,35	275,11	2863,26	280,96	2909,17	285,72	2955,08	291,47	2990,99	300,00

Tightening torques Mt for screws
(For dynamometric keys)

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Strength class or material	S N/mm²	Tightening torque Mt (Kp, Nm) of cylindrical screws DIN 913, 912, 7984, 939 and similar										CNI X100N/MT189		SCr XSCr/MT189	
		4,6	5,6	6,6	8,6	10,9	K8 12N19V	G 24CrMo5V	Cr X20Cr13V	Kp	Nm	Kp	Nm	Kp	Nm
M 42 X 3	0,100	128,55	150,69	175,79	342,80	482,06	230,32	241,03	267,81	262,82	262,82	12,48	1103,05	374,93	3876,85
M 42 X 3	0,125	151,26	180,07	215,15	403,35	567,21	271,00	283,61	315,12	309,02	315,12	132,35	1297,91	441,17	4328,36
M 42 X 3	0,160	178,44	223,05	277,60	475,83	668,14	319,70	334,57	371,75	364,58	371,75	156,13	1531,14	520,44	5103,81
M 45 X 3	0,100	159,53	199,41	234,99	425,41	598,23	285,82	299,12	332,35	325,92	332,35	139,59	1368,89	465,29	4562,96
M 45 X 3	0,125	187,99	234,99	280,42	501,30	691,32	338,81	352,48	391,84	384,07	391,84	164,48	1613,09	548,30	5376,98
M 45 X 3	0,160	222,08	277,60	333,75	592,21	832,79	397,89	416,40	462,86	453,18	462,86	184,32	1805,62	647,73	6352,05
M 48 X 3	0,100	195,11	243,89	291,75	520,30	731,57	349,58	365,84	406,48	398,62	406,48	170,72	1674,23	569,08	5580,75
M 48 X 3	0,125	230,22	287,78	343,22	613,92	863,33	412,48	431,66	479,63	470,52	479,63	201,44	1975,48	671,48	6584,93
M 48 X 3	0,160	272,30	340,38	428,32	728,14	1021,13	487,87	510,57	567,28	556,35	567,28	238,26	2338,57	794,21	7788,56
M 52 X 3	0,100	249,65	312,06	369,59	665,73	935,19	447,29	468,09	520,10	5100,48	520,10	218,44	2142,21	728,15	7140,69
M 52 X 3	0,125	295,01	368,77	443,27	786,88	1106,28	528,56	553,14	614,60	6027,16	614,60	258,13	2531,41	860,44	8438,03
M 52 X 3	0,160	348,41	436,77	534,08	931,77	1310,30	628,03	655,15	727,34	7136,70	727,34	305,74	2998,26	1019,12	9994,18
M 56 X 4	0,100	318,93	398,66	480,55	850,48	1185,99	571,42	588,00	664,44	6515,93	664,44	278,06	2736,69	930,22	9122,30
M 56 X 4	0,125	375,48	469,23	571,34	1001,29	1408,06	672,74	704,03	782,28	7671,32	782,28	328,55	3221,95	1095,18	10738,85
M 56 X 4	0,160	443,27	554,08	683,57	1182,04	1682,25	794,19	831,12	923,47	9055,15	923,47	387,86	3803,99	1282,86	12678,62
M 60 X 4	0,100	392,44	480,55	589,84	1046,52	1471,66	703,13	735,83	817,59	8017,82	817,59	343,39	3367,48	1144,63	11224,95
M 60 X 4	0,125	462,65	578,32	702,89	1233,74	1734,95	828,82	867,47	963,88	9452,23	963,88	404,82	3969,94	1349,40	13233,12
M 60 X 4	0,160	548,86	683,57	848,82	1458,28	2050,71	979,78	1025,35	1139,28	11172,34	1139,28	478,50	4692,47	1594,99	15641,55
M 64 X 4	0,100	476,41	589,84	714,39	1270,42	1786,53	853,56	893,26	982,52	9733,25	982,52	416,86	4087,96	1389,52	13626,54
M 64 X 4	0,125	562,31	702,89	868,82	1499,49	2108,66	1007,47	1054,33	1171,48	11480,27	1171,48	492,02	4825,07	1640,07	16083,58
M 64 X 4	0,160	665,39	831,73	1034,96	1774,36	2495,20	1182,15	1247,60	1386,22	13594,19	1386,22	582,21	5709,56	1840,71	18031,88
M 68 X 4	0,100	571,51	714,39	870,55	1524,04	2143,17	1023,98	1071,59	1190,65	11676,30	1190,65	500,07	4904,05	1666,91	16346,84
M 68 X 4	0,125	675,28	844,10	1034,96	1800,76	2544,20	1209,88	1266,16	1406,84	13796,39	1406,84	580,87	5784,48	1869,58	18314,95
M 68 X 4	0,160	798,86	998,83	1234,96	2132,97	2999,49	1433,08	1499,74	1668,38	16341,81	1668,38	689,88	6863,48	2332,93	22878,27
M 72 X 4	0,100	678,45	848,07	1034,96	1800,76	2544,20	1215,56	1272,10	1413,44	13861,14	1413,44	593,65	5821,68	1978,82	19405,62
M 72 X 4	0,125	802,41	1003,01	1234,96	2133,76	2999,49	1433,08	1504,52	1671,59	16393,64	1671,59	702,11	6885,33	2340,36	22951,11
M 72 X 4	0,160	951,29	1189,11	1461,18	2538,77	3567,33	1704,39	1793,88	1981,85	19435,31	1981,85	832,38	8162,84	2774,59	27209,45
M 80 X 4	0,100	930,60	1163,25	1407,55	2481,59	3489,74	1667,32	1744,87	1938,74	19012,59	1938,74	814,27	7985,29	2714,24	26617,84
M 80 X 4	0,125	1102,44	1378,05	1651,10	2939,85	4134,16	2087,08	2087,08	2298,76	22533,50	2298,76	984,64	9458,87	3215,46	31532,92
M 80 X 4	0,160	1308,98	1636,83	1986,24	3480,65	4908,73	2345,28	2454,37	2727,07	26743,45	2727,07	1145,37	11232,25	3817,90	37440,83

Tightening torques Mt for screws
(For dynamometric keys)

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Strength class or 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Tightening torques Mt for screws
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Page 8

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Tightening torques M_t for screws
(For dynamometric keys)

(Works Standard 903.99.0e)

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Strength class or material		5.6		8.8		10.9		12Ni19V		G 24CrMoV		Cr X2Cr13V		C41 X10CrNi189		5Cr X5CrNiNi189	
S	Ko/mm² N /mm²	30 300	64 640	64 640	90 900	43 430	45 450	50 500	21 210	70 700	d _f = D ₉ e. g. Works Standard 010.31.0						
Fine thread		Tightening torque M _A (Kpa, Nm) of necked-down bolts															
of fric μ	d _f	Nm		Kpm		Nm		Kpm		Nm		Kpm		Nm		Kpm	
		Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm		
12.7	M 16 x 1.5	6.33	62.07	13.50	132.42	18.99	186.22	9.07	88.97	9.49	93.11	10.55	103.45	4.43	43.45	14.77	144.83
	M 16 x 1.5	7.33	71.85	15.63	153.27	21.98	215.54	10.50	102.88	10.98	107.77	12.21	119.75	5.13	50.28	17.09	167.64
	M 16 x 1.5	8.48	83.14	18.09	177.37	25.43	249.43	12.15	119.17	12.72	124.71	14.13	138.57	5.93	58.20	19.78	194.00
	M 18 x 1.5	9.25	90.72	19.73	193.53	27.75	272.16	13.26	130.03	13.88	136.08	15.42	151.20	6.48	63.50	21.58	211.68
14.5	M 18 x 1.5	10.74	105.38	22.92	224.77	32.23	316.08	15.40	151.01	16.12	158.04	17.81	175.60	7.52	73.75	25.07	245.84
	M 18 x 1.5	12.47	122.31	26.61	260.92	37.42	366.93	17.88	175.31	18.71	183.46	20.79	203.85	8.73	85.62	29.10	285.39
	M 20 x 1.5	13.49	132.28	28.78	282.19	40.47	396.83	19.33	189.60	20.23	198.42	22.48	220.46	9.44	92.59	31.47	308.65
	M 20 x 1.5	15.73	154.28	33.56	329.08	47.19	462.77	22.55	221.10	23.59	233.58	26.22	257.09	11.01	107.98	36.70	359.93
16.6	M 20 x 1.5	18.34	179.88	39.13	383.70	55.02	536.58	26.29	257.80	27.51	268.78	30.57	299.77	12.84	125.90	42.78	419.67
	M 22 x 1.5	17.58	172.37	37.50	367.73	52.73	517.12	25.19	247.07	26.37	258.56	29.30	287.29	12.30	120.66	41.01	402.20
	M 22 x 1.5	20.52	201.25	43.78	429.32	61.56	603.74	28.41	288.45	30.78	301.87	34.20	335.41	14.36	140.87	47.88	469.57
	M 22 x 1.5	23.95	234.83	51.08	500.86	71.84	704.48	34.32	336.58	35.92	352.24	39.91	391.38	16.76	164.38	55.87	547.93
20.0	M 24 x 1.5	23.30	228.45	49.70	487.37	69.89	685.36	33.39	327.45	34.94	342.68	38.83	380.76	16.31	159.92	54.36	533.06
	M 24 x 1.5	27.25	267.26	58.14	570.16	81.78	801.79	39.06	383.08	40.88	400.89	45.42	445.44	18.08	187.08	63.59	623.61
	M 24 x 1.5	31.86	312.45	67.97	666.58	95.58	937.35	45.67	447.84	47.79	468.67	53.10	520.75	22.30	218.71	74.34	729.05
	M 20 x 2	12.21	119.70	26.04	255.36	36.62	359.10	17.50	171.57	18.31	179.55	20.34	199.50	8.54	83.79	28.48	279.30
15.8	M 20 x 2	14.10	138.30	30.09	295.05	42.31	414.91	20.21	198.23	21.15	207.45	23.51	230.51	9.87	96.81	32.91	322.71
	M 20 x 2	16.29	159.79	34.76	340.89	48.98	478.38	23.36	229.04	24.44	239.69	27.16	266.32	11.41	111.85	38.02	372.85
	M 24 x 2	21.73	213.07	46.35	454.56	65.18	639.22	31.14	305.41	32.59	319.61	36.21	355.12	15.21	149.15	50.70	497.17
	M 24 x 2	25.23	247.41	53.82	527.80	75.69	742.22	36.16	354.61	37.84	371.11	42.05	412.34	17.66	173.18	58.87	577.28
19.3	M 24 x 2	28.28	287.14	62.46	612.56	87.94	861.42	41.97	411.57	43.92	430.71	48.80	478.56	20.50	201.00	68.32	669.99
	M 30 x 2	44.93	440.59	95.84	939.92	134.78	1321.76	64.40	631.51	67.39	660.88	74.88	734.31	31.45	308.41	104.83	1028.03
	M 30 x 2	52.48	514.64	111.96	1097.81	157.44	1543.93	75.22	737.66	78.72	771.96	87.48	857.74	36.74	360.25	122.45	1200.83
	M 30 x 2	61.26	600.75	130.69	1281.80	183.78	1802.25	87.81	861.07	91.86	901.12	102.10	1001.25	42.88	420.52	142.94	1401.75
24.8	M 36 x 3	73.62	721.93	157.05	1540.11	220.85	2165.78	105.52	1034.76	110.42	1082.89	122.69	1203.21	51.53	505.35	171.77	1684.50
	M 36 x 3	85.48	838.38	182.38	1788.50	258.47	2515.08	122.53	1201.65	128.23	1257.54	142.48	1397.27	59.84	586.85	198.47	1956.17
	M 36 x 3	95.24	933.16	211.70	2076.08	297.71	2918.48	142.24	1394.87	148.85	1459.75	165.39	1621.84	68.46	681.22	231.55	2270.72
	M 39 x 3	96.01	941.54	204.82	2006.61	288.03	2824.61	137.61	1349.54	144.02	1412.30	160.02	1569.23	67.21	659.08	224.02	2196.92
31.8	M 36 x 3	111.76	1096.01	238.43	2338.15	335.28	3288.03	160.19	1570.95	167.84	1644.01	188.27	1826.68	78.23	767.21	260.78	2557.36
	M 36 x 3	130.04	1275.24	277.41	2720.50	390.11	3825.71	186.39	1827.84	195.06	1912.85	216.73	2125.39	91.03	892.67	303.42	2975.55

Tightening torques M_t for screws
(For dynamometric keys)

(Works Standard 903.99.0e)

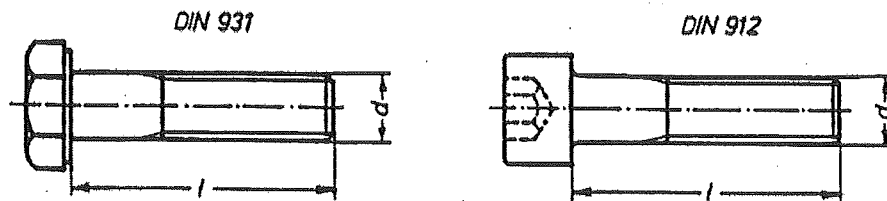
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Strength class of material S N/mm ²	Fine thread	Coeff. of fric μ	Reduced shaft			Tightening torque M_t (Kpm, Nm) of necked-down bolts $d_f = 0,9 \cdot d_k$ e. g. Works Standard 010.31.0			G			C ₂			C ₁			C ₀		
			5,6	6,8	10,9	12,9	12,9	12,9	24CrMo5V	24CrMo5V	24CrMo5V	20Cr13V	20Cr13V	20Cr13V	20Cr13V	20Cr13V	20Cr13V	20Cr13V	20Cr13V	20Cr13V
			Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm
M 42 X 3	0.100		121,17	1188,25	258,49	2534,93	363,50	3564,74	173,87	1703,15	181,75	1782,37	201,95	1980,41	84,82	831,77	282,72	2772,57	831,77	2772,57
M 42 X 3	0.125		141,30	1385,64	301,43	2958,02	423,89	4156,91	202,52	1988,08	211,94	2078,45	235,49	2309,39	98,91	969,94	328,69	3233,15	98,91	969,94
M 42 X 3	0.160		164,67	1614,91	351,31	3445,14	494,02	4844,73	236,03	2314,70	247,01	2422,36	274,46	2691,52	115,27	1130,44	384,24	3766,12	115,27	1130,44
M 45 X 3	0.100		151,89	1488,58	324,04	3177,78	455,69	4468,74	217,72	2135,07	227,84	2234,37	253,16	2482,64	106,33	1042,71	354,42	3475,69	106,33	1042,71
M 45 X 3	0.125		177,45	1740,19	378,56	3712,41	532,35	5220,57	254,35	2494,27	266,17	2610,28	295,75	2900,32	124,21	1216,13	414,05	4060,44	124,21	1216,13
M 45 X 3	0.160		207,18	2031,76	441,98	4334,43	621,55	6095,28	286,96	2812,19	310,77	3047,64	345,30	3386,27	145,03	1422,23	483,43	4740,78	145,03	1422,23
M 48 X 3	0.100		186,36	1827,55	397,56	3898,77	559,07	5482,63	267,11	2619,48	279,54	2741,32	310,60	3045,91	130,45	1279,28	434,83	4264,27	130,45	1279,28
M 48 X 3	0.125		218,02	2138,02	463,10	4561,11	634,05	6214,07	312,49	3064,50	327,03	3207,03	363,36	3563,37	152,81	1496,62	508,71	4988,72	152,81	1496,62
M 48 X 3	0.160		254,88	2499,55	543,75	5332,38	764,65	7488,66	365,33	3582,69	382,32	3749,33	424,81	4165,92	178,42	1749,69	594,73	5832,29	178,42	1749,69
M 52 X 3	0.100		240,52	2358,68	513,11	5031,98	721,56	7076,08	344,75	3380,79	360,78	3538,04	400,87	3931,15	168,36	1651,08	561,21	5503,62	168,36	1651,08
M 52 X 3	0.125		281,86	2764,26	601,34	5897,14	845,64	8292,86	404,03	3962,14	422,82	4146,43	469,80	4607,14	197,32	1935,00	657,72	6450,00	197,32	1935,00
M 52 X 3	0.160		330,11	3237,30	704,24	6906,24	990,34	9711,91	473,16	4640,13	495,17	4855,95	550,19	5395,50	231,08	2266,11	770,26	7553,71	231,08	2266,11
M 56 X 4	0.100		291,79	2861,49	622,49	6104,51	875,37	8584,47	418,23	4101,46	437,59	4292,23	486,32	4769,14	204,25	2003,04	680,84	6676,80	204,25	2003,04
M 56 X 4	0.125		340,13	3335,53	725,61	7115,81	1020,39	10008,61	487,52	4780,94	510,20	5003,30	566,88	5559,23	238,09	2334,88	793,64	7782,91	238,09	2334,88
M 56 X 4	0.160		396,17	3886,10	845,16	8288,22	1188,51	11655,30	567,84	5569,65	594,26	5827,66	660,28	6475,17	277,32	2719,57	924,40	9065,24	277,32	2719,57
M 60 X 4	0.100		361,30	3543,10	770,76	7558,62	1083,89	10629,30	517,86	5078,45	541,94	5314,64	602,16	5905,17	252,91	2480,17	843,02	8267,24	252,91	2480,17
M 60 X 4	0.125		421,80	4138,46	899,84	8824,45	1265,41	12409,39	604,59	5928,83	632,70	6204,69	703,00	6894,10	295,26	2895,52	984,20	9651,75	295,26	2895,52
M 60 X 4	0.160		492,02	4825,10	1049,85	10293,55	1476,07	14475,30	705,23	6915,98	738,04	7237,65	820,04	8041,84	344,42	3377,57	1148,05	11258,57	344,42	3377,57
M 64 X 4	0.100		440,97	4324,41	940,73	9225,42	1322,90	12973,25	632,05	6198,33	661,45	6486,62	734,96	7207,36	308,68	3027,09	1028,93	10090,31	308,68	3027,09
M 64 X 4	0.125		515,52	5055,55	1099,76	10785,16	1546,57	15166,65	738,92	7246,29	773,28	7583,32	859,20	8425,91	360,87	3538,69	1202,89	11796,28	360,87	3538,69
M 64 X 4	0.160		602,13	5904,89	1284,55	12597,12	1806,40	17714,70	863,06	8463,69	903,20	8857,35	1003,55	9841,50	421,49	4133,43	1404,97	13778,09	421,49	4133,43
M 68 X 4	0.100		541,92	5314,45	1156,10	11337,51	1625,77	15943,38	776,76	7617,39	812,89	7971,69	903,21	8857,43	379,35	3720,12	1264,49	12400,41	379,35	3720,12
M 68 X 4	0.125		634,74	6224,63	1354,10	13279,21	1904,21	18673,89	909,79	8921,97	953,10	9336,95	1057,89	10374,36	444,32	4357,24	1481,05	14524,14	444,32	4357,24
M 68 X 4	0.160		742,89	7285,22	1584,82	15541,80	2228,66	21855,67	1064,80	10442,14	1114,33	10927,82	1236,14	12142,03	520,02	5099,66	1733,40	16986,85	520,02	5099,66
M 72 X 4	0.100		635,89	6235,96	1356,57	13303,40	1907,68	18707,91	911,45	8938,23	953,84	9353,95	1059,82	10393,29	445,12	4365,18	1483,75	14550,60	445,12	4365,18
M 72 X 4	0.125		745,22	7308,10	1589,80	15590,63	2235,66	21924,33	1068,15	10474,85	1118,83	10962,16	1242,03	12180,17	521,95	5115,68	1738,85	17052,25	521,95	5115,68
M 72 X 4	0.160		872,49	8556,18	1861,31	18253,19	2617,46	25668,55	1250,57	12303,86	1308,73	12834,27	1494,15	14260,30	610,74	5989,33	2035,81	19964,43	610,74	5989,33
M 80 X 4	0.100		880,82	8637,93	1879,09	18427,60	2642,48	25913,83	1262,52	12381,05	1321,24	12956,90	1469,04	14396,56	616,58	6046,55	2055,26	20155,19	616,58	6046,55
M 80 X 4	0.125		1034,31	10143,13	2208,53	21638,68	3102,94	30429,41	1482,51	14539,49	1551,47	15214,70	1723,85	16905,23	724,02	7100,20	2413,39	23667,31	724,02	7100,20
M 80 X 4	0.160		1213,29	11898,27	2568,34	25382,99	3639,86	35684,84	1739,04	17054,19	1819,93	17847,40	2022,14	19830,45	849,30	8328,80	2831,00	27782,65	849,30	8328,80

Tightening torques M_t for screws
(For dynamometric keys)

(Works Standard 903.99.0e)

Page 11



Subsequently indicated values of tightening torques M_t for screws of

Strength class A2 DIN 267 part 11 (edition 1/80)

represent a completion of indications contained in pages 1 to 10. The calculation is based on the following values:

0.2 % yield strength $R_{p0.2}$ in N/mm^2 min., strength class 70

for thread diameters $d \leq 20$ mm 450 N/mm^2 min.

$d > 20$ to ≤ 30 mm 250 N/mm^2 min. 1)

Values apply for standard hexagon and hexagon socket screws with nominal lengths exceeding 3 up to including 8 times the thread diameter. For screws with bigger nominal lengths and/or deviating forms strength values must be agreed upon when ordering.

1) Values apply only for thread diameters up to 30 mm, if entire screws are tested.

Values of strength class 50 ($R_{p0.2} = 210 N/mm^2$) apply for thread diameters exceeding 30 mm.

Tightening torques for cylindrical screws

Kgm
Nm

Thread $\varnothing$	Coefficient of friction		
	0.100	0.125	0.160
M 5	0.360 3.520	0.400 4.030	0.480 4.660
M 6	0.600 5.950	0.690 6.820	0.790 7.860
M 8	1.470 14.410	1.690 16.570	1.950 19.120
M 10	2.880 28.270	3.310 32.700	3.840 37.600
M 12	4.990 48.910	5.740 56.350	6.640 65.190
M 16	12.240 120.040	14.170 139.080	16.480 161.710

Thread $\varnothing$	Coefficient of friction		
	0.100	0.125	0.160
M 20	23.800 233.380	27.570 270.360	32.050 314.290
M 24	22.770 223.320	26.380 258.670	30.660 300.700
(M 27)	33.350 327.060	38.780 380.370	45.250 443.840
M 30	45.330 444.610	52.640 516.270	61.330 601.530
(M 33)	51.730 507.260	60.240 590.830	70.390 690.280
M 36	66.260 649.780	77.050 755.650	89.900 881.670

For coefficients of friction see Works Standard 903.99.0e page 1

Units of quantity contained in the table:

Upper line: kgm

Lower line: Nm

Atlas Copco	Written Procedure	Sheet 1 of 7
QSV-WQ-4e	Field welding of pipes: Prerequisites, execution, inspections	04-03-1997

Index

1. Purpose
2. Application
3. Responsibilities
4. Description
5. Enclosures: yes (X) no (...)

	All users of Written Procedures are obliged to check - on the basis of the index of Manual 7.2 - whether they are in possession of the valid version of the Written Procedure in question. Manuals are filed in the departments Engineering, Quality Control, Quality Assurance and Documentation. The current date of the index is available in SAP.
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Rev.	Date	Issued by	Checked by	Note
0	04-03-97	<i>Udo Jank</i>	<i>[Signature]</i>	First edition

Distribution:

MTD	QA	WK	WQ	WP	WPA	WFS	AS	ASI	

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Atlas Copco	Written Procedure	Sheet 2 of 7
QSV-WQ-4e	Field welding of pipes: Prerequisites, execution, inspections	04-03-1997

1. **Purpose:** This Written Procedure governs the activities and responsibilities related to field welding of pipes (process-, seal- and leakage gas, oil, water) and the associated prerequisites and inspections.
2. **Application:** This Written Procedure is applicable to all departments (in particular Service) that are dealing with the above mentioned welding.
3. **Responsibilities:**
 - *Issue of required instructions (WPS, PQR):* ACE welding engineer and/or ACE welding expert or welding supervisor of the expert company that is ordered to weld the pipes.
 - *Selection of qualified welders in the field:* Service (service technician/site supervisor), if necessary after discussion with the ACE welding engineer/welding expert.
 - *Supervision and inspection of field welding:* Service (service technician/site supervisor)
 - *Documentation of welds:* Service (service technician/site supervisor)
 - *Support of service technician in the field:* ACE welding engineer/welding expert in cooperation with Quality Control
4. **Description:**
 - 4.1 **General:** This procedure contains a description of the prerequisites for welding the different piping systems in the field. Compliance with these prerequisites, supervision of actual welding and subsequent inspection of the piping systems are designed to ascertain their good quality and operability. This applies in particular to the process gas pipes, failure of which (bursting, leakages in the presence of toxic and inflammable fluids) might present a considerable safety risk to people. The distinctions that have been made were basically fixed by the risk existing in the event of damage. Should there still be any queries, ACE's Quality Control and/or the ACE welding engineer/ welding expert must be contacted in any case.
 - WPS ⇒ Welding procedure specification
 - PQR ⇒ Procedure qualification record
 - WPQ ⇒ Welding operator performance qualification
 - 4.2 **Fluid „water“, $p \leq 10$ bar, $t \leq 65$ °C**
 - **Approved welding methods:** GTAW (gas tungsten arc welding), GTAW/SMAW (shielded metal arc welding), OFW (oxy-fuel [gas] welding) (just „welding to the right permitted“). To obtain maximum tightness seams must always be welded in at least two passes.
 - **Filler metal:** Only those welding filler metals must be employed that have been qualified for the corresponding application (e.g. by VdTÜV).
 - **Welders:** Only welders that are qualified for the individual application must be employed (as per EN287 or ASME section 9). If such qualification is not available, it may be checked by a part-specific test weld which is subsequently subjected to a visual inspection by the service technician.
 - **Inspections:** The execution of a 100-percent visual inspection of welds to EN25817 (refer also to the enclosure) and a pressure and tightness test at maximum possible system pressure is mandatory.
 - 4.3 **Fluid „water“, $p > 10$ bar and/or $t > 65$ °C**
 - Whenever welds have to be made in the field, an order-specific instruction is issued by the welding engineer and Quality Control based on the procedure described in item 4.2.

Bye Bye AC Welding Procedure

Atlas Copco	Written Procedure	Sheet 3 of 7
QSV-WQ-4e	Field welding of pipes: Prerequisites, execution, inspections	04-03-1997

4.4 Fluid „oil“, $p \leq 10$ bar, $t \leq 65$ °C

- Approved welding methods: GTAW (gas tungsten arc welding), GTAW/SAW (shielded metal arc welding), OFW (oxy-fuel [gas] welding) (just „welding to the right permitted“). To obtain maximum tightness seams must always be welded in at least two passes. When welding pipes made of CrNi-steel, make sure that the maximum interpass temperature is 250 °C.
- Filler metal: Only those welding filler metals must be employed that have been qualified for the corresponding application (e.g. by VdTÜV).
- Welders: Only welders that are qualified for the individual application must be employed (as per EN287 or ASME section 9). If such qualification is not available, it may be checked by a part-specific test weld which is subsequently subjected to a visual inspection by the service technician.
- Inspections: The execution of a 100-percent visual inspection of welds to EN25817 (refer also to the enclosure) and a hydraulic pressure and tightness test at maximum possible system pressure is mandatory. The ID of pipes with lesser diameter must be checked for any drop-through at the root. Where visual inspection is not feasible, flow tests must be carried out.

4.5 Fluid „oil“, $p > 10$ bar and/or $t > 65$ °C

- Whenever welds have to be made in the field, an order-specific instruction is issued by the welding engineer and Quality Control based on the procedure described in item 4.4.

4.6 Fluid „gas“

- Approved welding methods: GTAW (gas tungsten arc welding), GTAW/SAW (shielded metal arc welding), GMAW (gas metal arc welding). When welds are made by external expert companies, the associated Welding Procedures must be checked as per EN288 or ASME section 9 (WPS and PQR must be available) or welders are obliged to weld as per ACE's specifications (in this context, refer to „standard welding plan“). To obtain maximum tightness seams must always be welded in at least two passes. When welding pipes made of CrNi-steel, make sure that the maximum interpass temperature is 250 °C.
- Filler metal: Only welding filler metals that have been qualified for the corresponding application must be employed (e.g. by VdTÜV).
- Welders: Only qualified welders must be employed (as per EN287 or ASME section 9). WPQ must be available.
- Inspections: The execution of a 100-percent visual inspection of welds to EN25817 (refer also to the enclosure) and a hydraulic pressure test at 1.5-fold maximum operating pressure is mandatory. After approval by Quality Control, the test pressure may be reduced to 1.3-fold operating pressure on a case-to-case basis. The welded seams must also be subjected to a 100-percent radiographic inspection. Exceptions from this rule may only be authorised by Quality Control.

When dangerous fluids are employed (toxic, inflammable, harmful to the environment: CO, ammonia, refrigerant, natural gas, ethylene or similar), the execution of an additional pneumatic tightness test is mandatory. If possible, this tightness test should be carried out at 1.1-fold maximum operating pressure. The fluid to be employed may be nitrogen, a nitrogen-helium mixture may be used from case to case. Quality Control should be contacted whenever dangerous fluids are involved.

- 4.7 **Documentation:** The enclosed certificate must be completed by the service technician/site supervisor to document the welds and the inspections that were made in the field and passed on to Quality Control/Documentation via the installation supervisor in the framework of final handling of site documentation. One separate certificate must be made out for each and every existing pipe type (water, oil, process-, seal- and leakage gas) which, however, may contain all welds made on this pipe type.
Welds (at least process-, seal- and leakage gas) must be permanently marked to enable allocation of welds to welders.

First Sample/C 1458/04/02/04/03/04/04/05/06/07/08/09

Atlas Copco	Written Procedure	Sheet 4 of 7
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4.8 **Higher requirements:** Any national or customer-specific requirements for execution and inspection of welds on pressurised pipes that exceed those contained in this Welding Procedure will always have priority. Such countries, where this is or may be the case, are e.g. Sweden, Finland, Norway and sometimes Denmark and Germany. In case of doubt, contact Quality Control for clarification.

5. **Enclosure:** Certificate on execution and inspection of field welds on pipes
Excerpt from EN25817 „Instructions for visual inspection of welds“

Engl. Rev. 04.03.1997

Enclosure 1 of QSV-WQ-4e dated 04-09-1997

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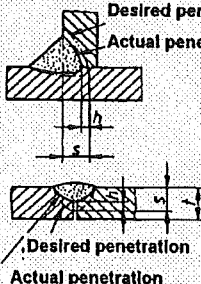
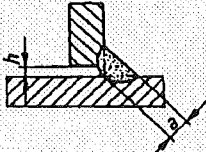
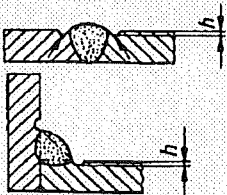
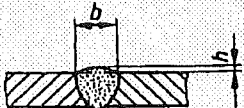
Atlas Copco		Certificate on execution and inspection of field welds on pipes			
ACE order No.:		ACE codeword:			
Piping type/fluid	Water ☐	Oil ☐	Process gas ☐	Gas (seal, leakage) ☐	
Fluid harmless ☐	(Air, nitrogen, water steam or similar)				
Fluid dangerous ☐	(Inflammable, toxic, harmful: CO, NH ₃ , natural gas, ethylene or similar)				
Welding method	GTAW ☐	GTAW/SAW ☐	GMAW ☐	OFW ☐	Other ☐
PQR for application (at least for process gas) carried out/checked by:					
Company in charge			Welding supervisor		
WPS/PQR as per EN288 ☐	WPS/PQR as per ASME section 9 ☐	As per ACE specification (standard welding plan QSV-FBS-1) ☐			
Whenever welds are made on process gas pipes, in particular when these contain dangerous gases, a copy of the WPS/PQR must always be enclosed to this certificate, unless welding is effected as per ACE standard welding plan.					
Employed welding filler metal:					
Name	Manufacturer	Applicable standard	Inspection society		
Welder qualification for the application was verified by:					
Order-specific test weld in the field (only possible for water and oil pipes) ☐	WPQ as per ASME section 9 ☐	WPQ as per EN287 ☐			
Whenever welds are made on process gas pipes, in particular when these contain dangerous gases, welder qualification must be verified by a test as per EN287 or ASME section 9. The WPQ must be enclosed to this certificate.					
The following inspections were carried out:					
Visual inspection as per EN25817 (100 %) ☐					
Hydraulic pressure test ☐ test pressure: _____ bar a duration (≥ 30 min): _____ min					
Pneumatic tightness test ☐ test pressure: _____ bar a duration (≥ 30 min): _____ min					
Air/nitrogen ☐ Nitrogen/helium, helium ☐					
Radiographic inspection ☐ Scope, if < 100%: _____ Films to be enclosed!					
Results of inspections: no complaints ☐ not without complaints ☐					
Notes:					
Checked/released by: Service technician/site supervisor: _____ Date: _____-____-19____				Checked/released by ACE Quality Control:	

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Enclosure 2 of QSV-WQ-4e dated 04-09-1997

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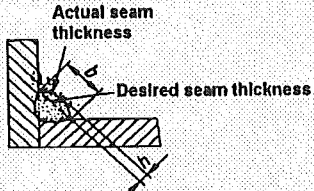
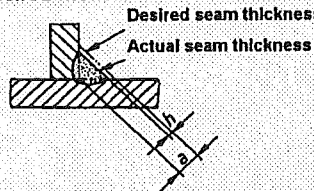
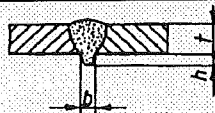
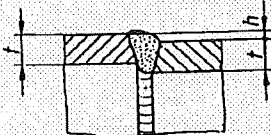
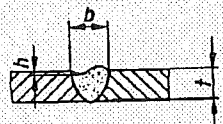
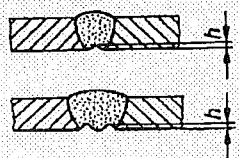
Visual inspection of welds: Irregularities and permissible limit values

Description of irregularity	Remarks	Permissible limit values for irregularities
Cracks, cracks in end-of-weld craters	Any kind of cracks, except for microcracks	Unacceptable
Porosity and pores		Not exceeding ≤ 1 percent of the weld surface Maximum pore diameter $\leq 0.3 * s$ (s =wall thickness) or $0.3 * a$ (for fillet welds)
Pore cluster	The entire pore area within a cluster should be integrated and determined in percentage from the bigger of the two areas: generating curve of an envelope comprising all pores or circle with a diameter that corresponds to weld width. The permissible pore area should be locally limited. The possibility that irregularities might be covered should not be neglected.	Not exceeding 4 percent of the surface Maximum size of any one pore $\leq 0.3 * s$ (s =wall thickness) or $0.3 * a$ (for fillet welds)
Insufficient through-welding		Unacceptable
Poor joint, fillet welds	An excessive or insufficient root opening between parts to be joined.  Root openings in excess of the associated limit values may, in certain cases, be compensated by a corresponding increase in weld thickness.	$h \leq 2 \text{ mm}$
Undercut	Smooth interface is mandatory. 	$h \leq 0.5 \text{ mm}$
Excessive weld reinforcement	Smooth interface is mandatory. 	$h \leq 3 \text{ mm}$

Enclosure 2 of QSV-WQ-4e dated 04-09-1997

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Visual inspection of welds: Irregularities and permissible limit values

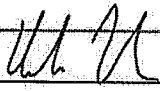
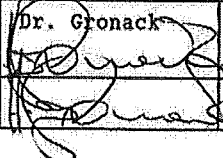
Excessive weld reinforcement		$h \leq 3 \text{ mm}$
Inferior weld thickness (of fillet welds)	Fillet welds with visually smaller weld thickness must not be regarded as fault, when the actual weld thickness is compensated by deeper penetration to comply with the desired measure. 	Unacceptable
Excessive root reinforcement		$h \leq 3 \text{ mm}$
Edge misalignment	The limit values for deviations refer to the optimum position. Unless otherwise specified, the optimum position is the one where the centre lines match (t refers to the lesser thickness). 	$h \leq 2 \text{ mm}$
Inferior reinforcement of cover pass, misplaced weld deposit	Smooth interface is mandatory. 	Max. $h \leq 0.5 \text{ mm}$, long irregularities are unacceptable.
Root-side suckback	Smooth interface is mandatory. 	$h \leq 0.5 \text{ mm}$

Byrd Group Ltd. WARRICK ENGLAND WYDER ENG

QSV-QP-7E	Process specification	Page 1 of 5
	Execution of hydrostatic and pneumatic pressure and tightness tests	09-15-1993

Index

1. Purpose
2. Application
3. Responsibility
4. Description
(General instructions, Hydraulic test, Pneumatic test, Identification, Documentation, Preservation)
5. Enclosures: yes [] no [X]

Rev.	Date	Issued by	Reviewed by	Remarks
0	03-11-91	Dr. Abdellatif	Dr. Gronack	
1	06-14-91	Dr. Abdellatif	Dr. Gronack	
2	07-23-91	Dr. Abdellatif	Dr. Gronack	
3	05-12-93	Dr. Abdellatif	Dr. Gronack	Calibration interval for pressure gauges has been extended
4	09-15-93			

Distribution

QA	MTKD	WK	WQC	W	WFB	WFBA	WQCF					

QSV-QP-7E	Process specification	Page 2 of 5
	Execution of hydrostatic and pneumatic pressure and tightness tests	09-15-1993

1. Purpose

This process specification governs responsibilities for hydrostatic and pneumatic pressure and tightness tests and describes preparative measures and the test cycle itself.

2. Application

This process specification applies to pressure and tightness tests carried out to the following requirements (Works Standard 026.00.1):

- Requirement class A1: hydrostatic test with water,
- Requirement class A2: pneumatic test with air under water,
- Requirement class B1: pneumatic test with helium or He/N2 gas mixture under water

3. Responsibility

3.1 For preparation and execution of tests, identification of released parts, preservation (if required): **Production.**

3.2 For verification, release and documentation: **In-process inspection.**

4. Description

4.1 General instructions

- Information on requirement class and test pressure are always shown on the drawing or in the work instruction.
- The time when the test has to be carried out is scheduled in the Work Plan. Adherence is mandatory.

.../3

QSV-QP-7E	Process specification	Page 3 of 5
	Execution of hydrostatic and pneumatic pressure and tightness tests	09-15-1993

- Pneumatic tests must only be carried out after the part has passed the hydrostatic pressure test without any objections. Also, they must only be carried out in the safety tank, otherwise adequate safety measures have to be taken (e.g. erect protective walls, put up signs that tell that this is a danger zone).
- Pressure must only be measured by means of calibrated pressure gauges of precision class 1.0 (to DIN 16005) which must be checked for correct operation and indication every 12 months.
- Nominal pressures of flanges and fittings used to close nozzles and openings must at least be equal to the hydrostatic test pressure.
- The use of the original bolts and gaskets ordered for the group to be pressure-tested is mandatory for tests of casing parts and bearing carriers. The use of original bolts and gaskets of pipes and other parts should be considered to the extent possible.
- Execution of the test and release of the part are verified by a stamp which is applied on the part by the in-process inspector.

4.2 Hydrostatic test

4.2.1 Preparation

- Clean outer and inner surfaces of the part to be tested by mechanical means such as blasting and honing or by chemical means, i.e. using solvents, then wipe and blow dry.
- Visually check parts to be tested for any outer and inner cracks or transport damage. If there are indications of faults, further tests must be triggered (dye penetrant test or radiographic inspection).
- Fill hollow spaces completely with water. Air enclosed in hollow spaces must be vented via openings located at the highest places of the parts to be tested.
- After openings are closed, the part to be tested must be wiped or blown dry.

4.2.2 Test fluid

Water with a chloride content < 150 ppm (refer to QSV-FVT-06). In special cases (customer's specifications) the chloride content can be reduced to < 50 ppm by means of an ion exchanger.

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4.2.3 Test cycle

- Admit test pressure, close water valve, maintain pressure for at least one hour, then relieve pressure.
- Repeat previous step maintaining pressure for 10 minutes.
- Visually check pressure-tested part thoroughly during and at the end of the period during which it was pressurized.
- If there are no objections (no moist spots or emerging water), mark tested part (refer to 4.4) and release.
- After disassembly the parts must be dried (by compressed air or hot-air blower).

4.3 Pneumatic test

4.3.1 Preparation

- On termination of the hydrostatic pressure test, drain all water from the part to be tested, blow dry and check inner and outer surfaces for cracks.
- Cast parts made of aluminium alloys must be subjected to dye penetrant inspections for cracks, then cleaned with water and blown dry.
- If requirement class is B1, either dry part to be tested in the oven (at 80° C for at least one hour) or expose it to a hot-air blower for at least 3 hours.

4.3.2 Test fluid

- Air for requirement class A2.
- Pure helium (for maximum test pressures of 40 bar) or a gas mixture with a helium content of at least 10 percent and a nitrogen content of 90 % (for test pressures > 40 bar) for requirement class B1.

To encourage the formation of bubbles, a wetting agent is added to the water contained in the safety tank to reduce surface tension (refer to QSV-FVT-06).

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4.3.3 Test cycle

- Close safety tank, admit pre-test pressure, maintain for at least 2 minutes, reduce to test pressure and open cover of the safety tank.
- Leave part in water for 30 minutes (requirement class A2) or 60 minutes (requirement class B1) maintaining test pressure.
- Carefully check the pressure-tested part during and at the end of the period during which it was pressurized.
- If there are no signs of gas bubbles in the water, end test and identify and release part.
- Afterwards the parts must be dried (use compressed air or hot-air blower).

4.4 Identification

Released parts must be identified as follows using marking punches:

- Part No.,
- Order No.,
- Test pressure in bar,
- Requirement class: A1, A2 or B1,
- Test date: day, month, year,
- Inspector's stamp.

4.5 Documentation

A test certificate according to EN 10204 is issued by in-process inspection and signed by the third-party inspector (if present). The certificate becomes part of the quality documentation.

4.6 Preservation

Casing parts made of cast iron and non-alloyed steels must be treated with preservative suited for long-term storage of the part after termination of the test to protect surfaces against rust.

Preservatives should be applied immediately after the parts have been blown dry.