Vsebina Stran

H 1 Skice

H 1.1 Skice kompresorja, napeljave cevi in delov obrata

Opis	Št. skice:	Število listov	Pregled
Načrt temeljev	F01/6970 302 003	1	1
Načrt tlorisa	A03/6970 301 965	1	1
Diagram P&I	P01/6970 302 004	6	2
Sklopka	6970 301 458	1	-
Izsek skice kompresorja	1320 102 811	2	-
Montažni razmiki	E02/6970 2242 44	1	-

	Št. skice			
Stopnja	1	2	3	
Rotor	1320 704 610	1320 704 610		
Krilo na vstopnih vodilih	1320 103 439			
Mehanizem sklopa pogonskega kolesa	1320 707 988	1320 707 988	1320 707 988	
Mehanizem rotorskega sklopa	1320 704 610	1320 704 610	1320 704 610	
Vlečni mehanizem pogonskega kolesa	1320 710 361	1320 710 361	1320 710 361	

H 1.2 Skica merilnikov in krmilnih elementov

- **Kompresorja 14 - 2275**

	Št. skice	Število listov	Pregled
List s podatki	S01/6970 307 407	2	A
Stikalna shema	S05/6970 307 408	12	A
Shema kabelske povezave	K03/6970 307 409	6	A
Razdelilna omarica	S08/6970 307 410	4	A
Ploščice z imenom	Z03/6970 307 409	2	-
Seznam merilnikov	G01/6970 307 412	5	A
Nastavitvene točke / seznam alarmov	A07/6970 307 413	5	A
Diagram delovanja	L01/6970 307 414	32	A

- **Kompresorja 14 - 2276**

	Št. skice	Število listov	Pregled
List s podatki	S01/6970 310 533	2	-
Stikalna shema	S05/6970 310 534	12	-
Shema kabelske povezave	K03/6970 310 535	6	-
Razdelilna omarica	S08/6970 310 536	4	-
Ploščice z imenom	Z03/6970 310 537	2	-
Seznam merilnikov	G01/6970 310 538	5	-
Nastavitvene točke / seznam alarmov	A07/6970 310 539	5	-
Diagram delovanja	L01/6970 310 540	32	-

	Št. skice	Število listov	Pregled
Control diagram	6970 312 952	1	0

H 2 Delovni standardi

Priročnik vsebuje le tiste tovarniške standarde, ki so našteti v tabeli v nadaljevanju:

Med pripravo tega priročnika so bile dodatne trenutne različice standardov.

Standardni ne povzročajo sprememb kontrol.

Test tlaka in tesnjenja votlih prostorov, ki so pod tlakom	026.00.1
Čistost površin tlačnih posod in cevovodov	033.21.2 P1
Čistost in čiščenje nameščenih procesnih cevovodov zaradi zagona strojev	033.21.2 P2
Varovanje tlačnih posod, cevovodov in opreme	033.23.5
Naprave za vlečenje sornika	790.21.2
Maziva	903.99.0
Terensko varjenje cevovodov (Dokumenti o zagotavljanju kakovosti)	QSV-WQ-04e
Izvrševanje hidrostatičnih in pnevmatskih testov tlaka in zatesnjenosti. (Dokumenti o zagotavljanju kakovosti)	QSV-QP-07e

Atlas Copco

Pressure and tightness tests of pressurised hollow spaces

(Original version: german-revision C/02.98)

ATLAS COPCO ENERGAS GmbH

Works Standard
ENG 026.00.1 - en

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: (direct probing - tightness test)	The probe of the measuring instrument registers any helium leakages escaping from the pressurised space on the surface of the specimen.
Helium enveloping test: (tightness 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.
Helium vacuum test (tightness test)	The probe of the measuring instrument registers any traces of helium that enter the evacuated space of the test specimen.

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	Habeth	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	Test scope	
Description	Code	Fluids, description	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/N2-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)	A2
	O_2 (oxygen)	
	Refrigerants (R134a, FHC)	B
	CO (carbon monoxide)	
	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 B +(C1)+C2	C1-content ≥5% C2-content <3%	C1
	B +(C1)+C2	C2-content ≥3%	C2
2-	...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: $p_{hydr.}$ (for stability)
$p_{1pneum.}$ (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^{-8} mbar.l/s (detection limit)

Leakage rate: reference values:	normal		10^{-3} to 10^{-4} mbar.l/s
	extreme	reactors	$\approx 10^{-6}$ mbar.l/s
	ACE:	feasible	10^{-4} to 10^{-8} mbar.l/s
	Sniffing sensitivity		10^{-5} to 10^{-8} 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 Energas GmbH	Surface cleanliness of pressure vessels and piping	Works Standard 033.21.2 E part 1

1. Scope of application
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.

2. Execution:
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.

2.1 Blanks
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.

2.2 Finished parts (functional groups)
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:

033.15.0 E for stainless austenitic steels
033.15.1 E " " " "
033.15.2 E for unalloyed and low-alloy steels

3. Drying
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.

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.					

Works Standard 033.21.2 E, 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.

Nur zur Information
For Information only

Continuation page 2

Issued	TNW	Revision No.					Works Standard 033.21.2 E, part 2
Date	90-10-16						
Name							

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 µm 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.

Atlas Copco Energas GmbH	Preservation of pressure vessels, pipes and fittings	Works-Standard 033.23.5E

1. Scope of application:

This Works Standard is applicable for all pressure vessels *1), pipes, and accessories used for operation with technical gases, except for oxygen *2).

2. Surface cleanness:

Execution to Works Standard 033.21.2

3. Execution:

3.1 Cleaned and tested parts will be assembled to the extent permitted by packing and/or transport possibilities.

3.2 Closing and sealing parts:

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 Warning sign:

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 Execution:

4.1 Pressure vessels, pipes, and accessories for operation with gas:

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

Issued	TNW	Revision No.					Works Standard 033.23.5E
Date	89-12-08						
Name	Ant.						

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 lenghts 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 of 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 GmbH

Works 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 homogenously 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	

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 1)	ISO VG 32	ISO VG 46	DIN 51519 ISO 3448
Viscosity at 40 °C (mm^2/s) min	28.8	41.4	DIN 51562 ISO 3104 ASTM D 445
max	35.2	50.6	
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)	≥ 175	≥ 185	DIN ISO 2592
(°F)	≥ 347	≥ 365	ASTM D 92
Pour point (°C)	≤ - 6		DIN ISO 3016
(°F) 2)	≤ 21.2		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 D95
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 (stage) (synthetic sea water)	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.

* * *

Atlas Copco

Atlas Copco Energas GmbH

Tightening torques Mt for screws (For dynamometric keys)

Works Standard 903.99.0E

This Works Standard is an excerpt from VDI guideline 2230 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 σ_{red} 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

Surface Contact of screw head or nut	Lubrication MoS_2 paste	Oil	dry
≤ 16 µm Smooth surfaces, e. g. turned, ground, milled. Spiral-type machining scores such as countersinking of U-type disks and similar.	0.100	0.125	0.160
> 16 to ≤ 100 µm Perceptible cross-type machining scores such as turning scores of milled surfaces (sheet) and similar.	0.125	0.160	-
> 100 µm Rough cross-type machining scores such as rough turning scores or forged surfaces and similar.	0.160	-	-

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 formulas mentioned on page 2 and registered on the drawings.

Screws 8.8 and Cr of DIN flanges must only be tightened with the torque of screw 5.6.

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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

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

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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 (minimum value to DIN 267 page 3)

Tightening torques Mt for screws
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Strength class or material		4,6		5,6		8,8		10,9		KB 12Ni19V		G 24CrMo5V		Cr X20Cr13V		CrNi X10CrNiTi189		5Cr X5CrMnNiN189	
S Kp/mm² N/mm²		24 240		30 300		64 640		90 900		43 430		45 450		50 500		21 210		70 700	
		Tightening torque M_A (Kpm, Nm) of cylindrical screws DIN 931, 933, 912, 7984, 939 and similar																	
Coarse thread	Coeff. of fric.	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm
M 4	0,100	0,10	0,94	0,12	1,17	0,26	2,50	0,36	3,52	0,17	1,68	0,18	1,76	0,20	1,96	0,08	0,82	0,28	2,74
M 4	0,125	0,11	1,08	0,14	1,34	0,29	2,87	0,41	4,03	0,20	1,93	0,21	2,02	0,23	2,24	0,10	0,94	0,32	3,14
M 4	0,160	0,13	1,24	0,16	1,55	0,34	3,30	0,47	4,64	0,23	2,22	0,24	2,32	0,26	2,58	0,11	1,08	0,37	3,61
M 5	0,100	0,19	1,88	0,24	2,35	0,51	5,00	0,72	7,04	0,34	3,36	0,36	3,52	0,40	3,91	0,17	1,64	0,56	5,47
M 5	0,125	0,22	2,16	0,27	2,69	0,59	5,75	0,82	8,08	0,39	3,86	0,41	4,04	0,46	4,49	0,19	1,89	0,64	6,29
M 5	0,160	0,25	2,49	0,32	3,11	0,68	6,63	0,95	9,33	0,45	4,46	0,48	4,66	0,53	5,18	0,22	2,18	0,74	7,25
M 6	0,100	0,32	3,17	0,40	3,97	0,86	8,47	1,21	11,91	0,58	5,69	0,61	5,95	0,67	6,61	0,28	2,78	0,94	9,26
M 6	0,125	0,37	3,64	0,46	4,55	0,99	9,71	1,39	13,65	0,67	6,52	0,70	6,83	0,77	7,58	0,32	3,19	1,08	10,62
M 6	0,160	0,43	4,19	0,53	5,24	1,14	11,18	1,60	15,72	0,77	7,51	0,80	7,86	0,89	8,73	0,37	3,67	1,25	12,23
M 8	0,100	0,78	7,69	0,98	9,61	2,09	20,50	2,94	28,83	1,40	13,77	1,47	14,41	1,63	16,01	0,69	6,73	2,29	22,42
M 8	0,125	0,90	8,84	1,13	11,05	2,40	23,57	3,38	33,14	1,61	15,83	1,69	16,57	1,88	18,41	0,79	7,73	2,63	25,78
M 8	0,160	1,04	10,20	1,30	12,75	2,77	27,20	3,90	38,25	1,86	18,28	1,95	19,13	2,17	21,25	0,91	8,93	3,03	29,75
M 10	0,100	1,54	15,08	1,92	18,85	4,10	40,20	5,77	56,54	2,75	27,01	2,88	28,27	3,20	31,41	1,35	13,19	4,48	43,97
M 10	0,125	1,77	17,38	2,21	21,70	4,72	46,28	6,64	65,09	3,17	31,10	3,32	32,54	3,69	36,16	1,55	15,19	5,16	50,62
M 10	0,160	2,05	20,06	2,56	25,07	5,45	53,49	7,67	75,22	3,66	35,94	3,84	37,61	4,26	41,79	1,79	17,55	5,97	58,50
M 12	0,100	2,66	26,09	3,33	32,61	7,09	69,56	9,98	97,82	4,77	46,74	4,99	48,91	5,54	54,35	2,33	22,83	7,76	76,09
M 12	0,125	3,07	30,06	3,83	37,57	8,17	80,15	11,49	112,72	5,49	53,85	5,75	56,36	6,39	62,62	2,68	26,30	8,94	87,67
M 12	0,160	3,55	34,77	4,43	43,46	9,45	92,72	13,30	130,38	6,35	62,29	6,65	65,19	7,39	72,43	3,10	30,42	10,34	101,41
M 16	0,100	6,53	64,02	8,16	80,03	17,41	170,73	24,48	240,09	11,70	114,71	12,24	120,04	13,60	133,38	5,71	56,02	19,04	186,73
M 16	0,125	7,56	74,18	9,45	92,72	20,17	197,81	28,36	278,17	13,55	132,90	14,18	139,08	15,76	154,54	6,62	64,91	22,06	216,35
M 16	0,160	8,79	86,25	10,99	107,81	23,45	229,99	32,98	323,43	15,76	154,53	16,49	161,71	18,32	179,68	7,70	75,47	25,65	251,55
M 20	0,100	12,69	124,47	15,87	155,59	33,85	331,92	47,60	466,76	22,74	223,01	23,80	233,38	26,44	259,31	11,11	108,91	37,02	363,04
M 20	0,125	14,70	144,19	18,38	180,24	39,21	384,50	55,14	540,71	26,34	258,34	27,57	270,35	30,63	300,39	12,87	126,17	42,88	420,55
M 20	0,160	17,09	167,63	21,37	209,53	45,58	447,00	64,10	628,59	30,62	300,33	32,05	314,30	35,61	349,22	14,96	146,67	49,85	488,91
M 24	0,100	21,86	214,40	27,33	268,00	58,30	571,74	81,99	804,01	39,17	384,14	40,99	402,00	45,55	446,67	19,13	187,60	63,77	625,34
M 24	0,125	25,32	248,35	31,66	310,43	67,53	662,26	94,97	931,30	45,37	444,96	47,48	465,65	52,76	517,39	22,16	217,30	73,86	724,35
M 24	0,160	29,44	288,69	36,80	360,87	78,50	769,85	110,40	1082,61	52,74	517,24	55,20	541,30	61,33	601,45	25,76	252,61	85,86	842,03
M 27	0,100	32,02	314,01	40,02	392,51	85,39	837,35	120,07	1177,52	57,37	562,59	60,04	588,76	66,71	654,18	28,02	274,75	93,39	915,85
M 27	0,125	37,24	365,18	46,55	456,48	99,30	973,82	139,64	1369,44	66,72	654,29	69,82	684,72	77,58	760,80	32,58	319,54	108,61	1065,12
M 27	0,160	43,45	426,12	54,31	532,65	115,87	1136,31	162,94	1597,94	77,85	763,46	81,47	798,97	90,52	887,74	38,02	372,85	126,73	1242,84

Tightening torques Mt for screws (Works Standard 903.99.0e)
(For dynamometric keys)

Tightening torque M_A (Kpm, Nm) of cylindrical screws DIN 931, 933, 912, 7984, 939 and similar

Strength cl[illegible] or material		4,6		5,6		8,8		10,9		KB 12Ni19V		G 24CrMo5V		Cr X20Cr13V		CrNi X10CrNiTi189		5Cr X5CrMnNiN[illegible]	
S Kp/mm² N/mm²		24 240		30 300		64 640		90 900		43 430		45 450		50 500		21 210		70 700	
Coarse thread	Coeff. of fric.	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm
M 30	0,100	43,53	426,86	54,41	533,58	116,07	1138,30	163,23	1600,74	77,99	764,80	81,61	800,37	90,68	889,30	38,09	373,51	126,96	1245,02
M 30	0,125	50,54	495,66	63,18	619,57	134,78	1321,76	189,54	1858,72	90,56	888,06	94,77	929,36	105,30	1032,62	44,23	433,70	147,42	1445,67
M 30	0,160	58,89	577,51	73,61	721,89	157,04	1540,03	220,84	2165,66	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	579,73	73,90	724,67	157,64	1545,95	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	86,07	844,05	183,61	1800,64	258,21	2532,15	123,37	1209,81	129,10	1266,08	143,45	1406,75	60,25	590,84	200,83	1969,45
M 33	0,160	80,46	789,03	100,57	986,28	214,56	2104,07	301,72	2958,85	144,15	1413,67	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	88,08	863,60	110,08	1079,50	234,83	2302,93	330,24	3238,50	157,78	1547,28	165,12	1619,25	183,46	1799,17	77,05	755,65	256,85	2518,83
M 36	0,160	102,75	1007,63	128,44	1259,54	274,00	2687,02	385,31	3778,62	184,09	1805,34	192,66	1889,31	214,06	2099,23	89,91	881,68	299,69	2938,93
M 39	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 39	0,125	114,14	1119,30	142,67	1399,13	304,37	2984,81	428,01	4197,39	204,50	2005,42	214,01	2098,69	237,79	2331,88	99,87	979,39	332,90	3264,63
M 39	0,160	133,49	1309,06	166,86	1636,32	355,96	3490,82	500,58	4908,96	239,16	2345,40	250,29	2454,48	278,10	2727,20	116,80	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	2469,96	105,78	1037,38	352,61	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	2587,92	293,22	2875,47	123,15	1207,70	410,50	4025,66
M 42	0,160	164,39	1612,07	205,48	2015,09	438,36	4298,86	616,45	6045,26	294,52	2888,29	308,22	3022,63	342,47	3358,48	143,84	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	3090,97	329,85	3234,74	366,50	3594,16	153,93	1509,55	513,10	5031,82
M 45	0,160	205,88	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	5608,91
M 48	0,125	229,02	2245,88	286,27	2807,35	610,71	5989,02	858,81	8422,06	410,32	4023,87	429,41	4211,03	477,12	4678,92	200,39	1965,15	667,96	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	4937,66	559,45	5486,29	234,97	2304,24	783,22	7680,81

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or dynamometric keys)

(Works Standard 903.99.0e)
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Tightening torque M_A (Kpm, Nm) of cylindrical screws DIN 931, 933, 912, 7984, 939 and similar

Strength class or material		4,6		5,6		8,8		10,9		KB 12Ni19V		G 24CrMo5V		Cr X20Cr13V		CrNi X10CrNiTi189		5Cr X5CrMnNiN189	
S Kp/mm² N/mm²		24 240		30 300		64 640		90 900		43 430		45 450		50 500		21 210		70 700	
Fine thread	Coeff. of fric.	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm
M 16×1,5	0,100	6,92	67,82	8,64	84,77	18,44	180,85	25,93	254,32	12,39	121,51	12,97	127,16	14,41	141,29	6,05	59,34	20,17	197,80
M 16×1,5	0,125	8,08	79,28	10,11	99,10	21,56	211,42	30,32	297,30	14,48	142,05	15,16	148,65	16,84	165,17	7,07	69,37	23,58	231,24
M 16×1,5	0,160	9,48	92,96	11,85	116,20	25,28	247,89	35,55	348,60	16,98	166,55	17,77	174,30	19,75	193,66	8,29	81,34	27,65	271,13
M 18×1,5	0,100	10,00	98,06	12,50	122,57	26,66	261,48	37,50	367,71	17,81	175,68	18,75	183,86	20,83	204,28	8,75	85,80	29,16	286,00
M 18×1,5	0,125	11,72	114,98	14,66	143,72	31,27	306,61	43,97	431,17	21,01	206,00	21,98	215,58	24,43	239,54	10,26	100,61	34,20	335,35
M 18×1,5	0,160	13,79	135,20	17,23	169,00	36,76	360,53	51,70	507,00	24,70	242,23	25,85	253,50	28,72	281,66	12,06	118,30	40,21	394,33
M 20×1,5	0,100	13,88	136,11	17,35	170,14	37,01	362,96	52,05	510,42	24,87	243,87	26,02	255,21	28,92	283,56	12,14	119,10	40,48	396,99
M 20×1,5	0,125	16,31	160,00	20,39	199,99	43,51	426,65	61,18	599,98	29,23	286,66	30,59	299,99	33,99	333,32	14,28	140,00	47,59	466,65
M 20×1,5	0,160	19,23	188,57	24,04	235,71	51,28	502,85	72,11	707,14	34,45	337,85	36,05	353,57	40,06	392,85	16,83	165,00	56,08	549,99
M 22×1,5	0,100	18,49	181,29	23,11	226,62	49,30	483,45	69,32	679,84	33,12	324,81	34,66	339,92	38,51	377,69	16,18	158,63	53,92	528,77
M 22×1,5	0,125	21,77	213,51	27,22	266,89	58,06	569,36	81,65	800,66	39,01	382,54	40,82	400,33	45,36	444,81	19,05	186,82	63,50	622,74
M 22×1,5	0,160	25,71	252,09	32,13	315,12	68,55	672,25	96,40	945,35	46,06	451,67	48,20	472,67	53,55	525,19	22,49	220,58	74,98	735,27
M 24×1,5	0,100	24,40	239,25	30,50	299,06	65,06	637,99	91,49	897,18	43,71	428,65	45,74	448,59	50,83	498,43	21,35	209,34	71,16	697,80
M 24×1,5	0,125	28,79	282,29	35,98	352,87	76,76	752,79	107,95	1058,60	51,57	505,78	53,97	529,30	59,97	588,11	25,19	247,01	83,96	823,36
M 24×1,5	0,160	34,05	333,89	42,56	417,36	90,79	890,38	127,68	1252,09	61,00	598,22	63,84	626,05	70,93	695,61	29,79	292,15	99,30	973,85
M 20×2	0,100	13,29	130,36	16,62	162,96	35,45	347,64	49,85	488,87	23,82	233,57	24,93	244,43	27,69	271,59	11,63	114,07	38,77	380,23
M 20×2	0,125	15,51	152,10	19,39	190,13	41,36	405,61	58,16	570,39	27,79	272,52	29,08	285,20	32,31	316,88	13,57	133,09	45,24	443,64
M 20×2	0,160	18,15	178,03	22,69	222,53	48,41	474,73	68,08	667,60	32,53	318,96	34,04	333,80	37,82	370,89	15,88	155,77	52,95	519,24
M 24×2	0,100	23,57	231,17	29,47	288,96	62,86	616,44	88,40	866,87	42,23	414,17	44,20	433,44	49,11	481,59	20,63	202,27	68,75	674,23
M 24×2	0,125	27,64	271,03	34,55	338,79	73,70	722,75	103,64	1016,37	49,52	485,60	51,82	508,19	57,58	564,65	24,18	237,15	80,61	790,51
M 24×2	0,160	32,50	318,67	40,62	398,34	86,65	849,79	121,86	1195,02	58,22	570,95	60,93	597,51	67,70	663,90	28,43	278,84	94,78	929,46
M 30×2	0,100	47,48	465,57	59,34	581,96	126,60	1241,52	178,03	1745,89	85,06	834,15	89,02	872,95	98,91	969,94	41,54	407,38	138,47	1357,92
M 30×2	0,125	55,95	548,67	69,94	685,83	149,20	1463,11	209,81	2057,51	100,24	983,03	104,90	1028,75	116,56	1143,06	48,96	480,08	163,18	1600,28
M 30×2	0,160	66,10	648,21	82,62	810,26	176,26	1728,56	247,87	2430,79	118,43	1161,38	123,94	1215,39	137,71	1350,44	57,84	567,18	192,79	1890,61
M 36×3	0,100	79,54	780,05	99,43	975,07	212,12	2080,15	298,29	2925,20	142,52	1397,60	149,14	1462,60	165,72	1625,11	69,60	682,55	232,00	2275,16
M 36×3	0,125	93,26	914,58	116,58	1143,22	248,70	2438,88	349,73	3429,67	167,09	1638,62	174,86	1714,83	194,29	1905,37	81,60	800,26	272,01	2667,52
M 36×3	0,160	109,65	1075,33	137,07	1344,16	292,41	2867,54	411,20	4032,48	196,46	1926,63	205,60	2016,24	228,44	2240,27	95,95	940,91	319,82	3136,37
M 39×3	0,100	102,35	1003,72	127,94	1254,65	272,94	2676,59	383,82	3763,95	183,38	1798,33	191,91	1881,97	213,23	2091,08	89,56	878,25	298,52	2927,51
M 39×3	0,125	120,24	1179,12	150,30	1473,90	320,63	3144,32	450,89	4421,70	215,42	2112,59	225,44	2210,85	250,49	2456,50	105,21	1031,73	350,69	3439,10
M 39×3	0,160	141,63	1388,91	177,04	1736,14	377,68	3703,77	531,11	5208,43	253,75	2488,47	265,56	2604,21	295,06	2893,57	123,93	1215,30	413,09	4051,00

Tightening torques Mt for screws (Works Standard 903.99.0e)
(For dynamometric keys)

Strength class or material		4,6		5,6		8,8		10,9		KB 12Ni19V		G 24CrMo5V		Cr X20Cr13V		CrNi X10CrNiTi189		5Cr X5CrMnNiN189	
S Kp/mm² N/mm²		24 240		30 300		64 640		90 900		43 430		45 450		50 500		21 210		70 700	
		Tightening torque M_A (Kpm, Nm) of cylindrical screws DIN 931, 933, 912, 7984, 939 and similar																	
Fine thread	Coeff. of fric.	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm
M 42×3	0,100	128,55	1260,63	160,69	1575,79	342,80	3361,69	482,06	4727,38	230,32	2258,64	241,03	2363,69	267,81	2626,32	112,48	1103,05	374,93	3676,85
M 42×3	0,125	151,26	1483,32	189,07	1854,15	403,35	3955,52	587,21	5562,45	271,00	2657,62	283,61	2781,23	315,12	3090,25	132,35	1297,91	441,17	4326,36
M 42×3	0,160	178,44	1749,88	223,05	2187,35	475,83	4666,34	669,14	6562,04	319,70	3135,20	334,57	3281,02	371,75	3645,58	156,13	1531,14	520,44	5103,81
M 45×3	0,100	159,53	1564,44	199,41	1955,55	425,41	4171,85	598,23	5866,66	285,82	2802,96	299,12	2933,33	332,35	3259,26	139,59	1368,89	465,29	4562,96
M 45×3	0,125	187,99	1843,53	234,99	2304,42	501,30	4916,09	704,96	6913,28	336,81	3303,00	352,48	3456,63	391,64	3840,70	164,49	1613,09	548,30	5376,98
M 45×3	0,160	222,08	2177,85	277,60	2722,31	592,21	5807,59	832,79	8166,92	397,89	3901,97	416,40	4083,46	462,66	4537,18	194,32	1905,62	647,73	6352,05
M 48×3	0,100	195,11	1913,40	243,89	2391,75	520,30	5102,40	731,67	7175,25	349,58	3428,18	365,84	3587,63	406,48	3986,25	170,72	1674,23	569,08	5580,75
M 48×3	0,125	230,22	2257,69	287,78	2822,11	613,92	6020,51	863,33	8466,34	412,48	4045,03	431,66	4233,17	479,63	4703,52	201,44	1975,48	671,48	6584,93
M 48×3	0,160	272,30	2670,36	340,38	3337,95	728,14	7120,96	1021,13	10013,86	487,87	4784,40	510,57	5006,93	567,29	5563,25	238,26	2336,57	794,21	7788,56
M 52×3	0,100	249,65	2448,24	312,06	3060,29	665,73	6528,63	936,19	9180,88	447,29	4386,42	468,09	4590,44	520,10	5100,48	218,44	2142,21	728,15	7140,69
M 52×3	0,125	295,01	2893,04	368,76	3616,30	786,69	7714,77	1106,28	10848,89	528,56	5183,36	553,14	5424,45	614,60	6027,16	258,13	2531,41	860,44	8438,03
M 52×3	0,160	349,41	3426,57	436,77	4283,22	931,77	9137,54	1310,30	12849,66	626,03	6139,29	655,15	6424,83	727,94	7138,70	305,74	2998,26	1019,12	9994,18
M 56×4	0,100	318,93	3127,65	398,66	3909,56	850,48	8340,39	1195,99	11728,67	571,42	5603,70	598,00	5864,33	664,44	6515,93	279,06	2736,69	930,22	9122,30
M 56×4	0,125	375,48	3682,23	469,35	4602,79	1001,29	9819,29	1408,06	13808,38	672,74	6597,34	704,03	6904,19	782,26	7671,32	328,55	3221,95	1095,16	10739,85
M 56×4	0,160	443,27	4346,95	554,08	5433,69	1182,04	11591,88	1662,25	16301,09	794,19	7788,30	831,12	8150,54	923,47	9056,15	387,86	3803,59	1292,86	12678,62
M 60×4	0,100	392,44	3848,55	490,55	4810,69	1046,52	10262,82	1471,66	14432,08	703,13	6895,32	735,83	7216,04	817,59	8017,82	343,39	3367,48	1144,63	11224,95
M 60×4	0,125	462,65	4537,07	578,32	5671,34	1233,74	12098,86	1734,95	17014,02	828,92	8128,92	867,47	8507,01	963,86	9452,23	404,82	3969,94	1349,40	13233,13
M 60×4	0,160	546,86	5362,82	683,57	6703,52	1458,28	14300,86	2050,71	20110,58	979,78	9668,38	1025,35	10055,29	1139,28	11172,54	478,50	4692,47	1594,99	15641,55
M 64×4	0,100	476,41	4671,96	595,51	5839,94	1270,42	12458,55	1786,53	17519,85	853,56	8370,59	893,26	8759,92	992,52	9733,25	416,86	4087,96	1389,52	13626,54
M 64×4	0,125	562,31	5514,37	702,89	6892,96	1499,49	14704,98	2108,66	20678,88	1007,47	9879,91	1054,33	10339,44	1171,48	11488,27	492,02	4825,07	1640,07	16083,58
M 64×4	0,160	665,39	6525,21	831,73	8156,51	1774,36	17400,57	2495,20	24469,57	1192,15	11691,00	1247,60	12234,77	1386,22	13594,19	582,21	5709,56	1940,71	19031,88
M 68×4	0,100	571,51	5604,63	714,39	7005,79	1524,04	14945,68	2143,17	21017,36	1023,96	10041,63	1071,59	10508,68	1190,65	11676,30	500,07	4904,05	1666,91	16346,84
M 68×4	0,125	675,28	6622,27	844,10	8277,84	1800,76	17659,40	2532,31	24833,52	1209,88	11864,90	1266,16	12416,75	1406,84	13796,39	590,87	5794,48	1969,58	19314,95
M 68×4	0,160	799,86	7843,98	999,83	9804,96	2132,97	20917,27	2999,49	29414,92	1433,09	14053,80	1499,74	14707,46	1666,38	16341,61	699,88	6863,48	2332,93	22878,27
M 72×4	0,100	678,45	6653,35	848,07	8316,69	1809,21	17742,27	2544,20	24950,07	1215,56	11920,59	1272,10	12475,03	1413,44	13861,14	593,65	5821,68	1978,82	19405,62
M 72×4	0,125	802,41	7868,94	1003,01	9836,18	2139,76	20983,87	3009,04	29508,57	1437,65	14098,54	1504,52	14754,28	1671,69	16393,64	702,11	6885,33	2340,36	22951,11
M 72×4	0,160	951,29	9328,94	1189,11	11661,18	2536,77	24877,20	3567,33	34983,58	1704,39	16714,37	1783,66	17491,77	1981,85	19435,31	832,38	8162,84	2774,59	27209,45
M 80×4	0,100	930,60	9126,04	1163,25	11407,55	2481,59	24336,13	3489,74	34222,68	1667,32	16350,84	1744,87	17111,32	1938,74	19012,59	814,27	7985,29	2714,24	26617,64
M 80×4	0,125	1102,44	10811,28	1378,05	13514,10	2939,85	28830,10	4134,16	40542,29	1975,21	19370,21	2067,08	20271,15	2296,76	22523,50	964,64	9459,87	3215,46	31532,92
M 80×4	0,160	1308,99	12836,83	1636,24	16046,05	3490,65	34231,61	4908,73	48138,20	2345,28	22999,36	2454,37	24069,10	2727,07	26743,45	1145,37	11232,25	3817,90	37440,83

Tightening torques Mt for screws
(For dynamometric keys)

(Works Standard 903.99.0e)
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Tightening torque M_A (Kpm, Nm) of necked-down bolts d_T = 09 · d_K e. g. Works Standard 903.33.0e, DIN 2510 and si

Strength class or material			5,6		8,8		10,9		KB 12Ni19V		G 24CrMo5V		Cr X20Cr13V		CrNi X10CrNiTi189		5Cr X5CrMnNiN189	
S Kp/mm² N/mm²			30 300		64 640		90 900		43 430		45 450		50 500		21 210		70 700	
Coarse thread	Coeff. of fric.	Reduced shaft Ø d_T	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm
M 12	0,100	8,8	2,29	22,42	4,88	47,83	6,86	67,26	3,28	32,14	3,43	33,63	3,81	37,37	1,60	15,69	5,33	52,31
M 12	0,125		2,60	25,54	5,56	54,48	7,81	76,61	3,73	36,60	3,91	38,31	4,34	42,56	1,82	17,88	6,08	59,59
M 12	0,160		2,97	29,10	6,33	62,09	8,90	87,31	4,25	41,72	4,45	43,66	4,95	48,51	2,08	20,37	6,93	67,91
M 16	0,100	12,2	5,85	57,34	12,47	122,33	17,54	172,02	8,38	82,19	8,77	86,01	9,75	95,57	4,09	40,14	13,64	133,80
M 16	0,125		6,70	65,75	14,30	140,26	20,11	197,24	9,61	94,24	10,06	98,62	11,17	109,58	4,69	46,02	15,64	153,41
M 16	0,160		7,69	75,41	16,41	160,88	23,07	226,24	11,02	108,09	11,54	113,12	12,82	125,69	5,38	52,79	17,94	175,96
M 20	0,100	15,2	11,28	110,65	24,07	236,06	33,85	331,96	16,17	158,60	16,93	165,98	18,81	184,42	7,90	77,46	26,33	258,19
M 20	0,125		12,93	126,82	27,59	270,55	38,80	380,47	18,54	181,78	19,40	190,23	21,55	211,37	9,05	88,78	30,18	295,92
M 20	0,160		14,83	145,41	31,63	310,20	44,48	436,22	21,25	208,41	22,24	218,11	24,71	242,34	10,38	101,78	34,60	339,28
M 24	0,100	18,3	19,59	192,07	41,78	409,76	58,76	576,23	28,07	275,31	29,38	288,11	32,64	320,13	13,71	134,45	45,70	448,18
M 24	0,125		22,45	220,18	47,90	469,71	67,36	660,53	32,18	315,59	33,68	330,27	37,42	366,96	15,72	154,12	52,39	513,75
M 24	0,160		25,75	252,50	54,93	538,67	77,24	757,51	36,91	361,92	38,62	378,75	42,91	420,84	18,02	176,75	60,08	589,17
M 27	0,100	21,0	29,08	285,15	62,03	608,33	87,23	855,46	41,68	408,72	43,62	427,73	48,46	475,26	20,35	199,61	67,85	665,36
M 27	0,125		33,48	328,30	71,42	700,38	100,43	984,91	47,98	470,57	50,22	492,45	55,80	547,17	23,43	229,81	78,11	766,04
M 27	0,160		38,55	378,05	82,24	806,50	115,65	1134,15	55,26	541,87	57,83	567,07	64,25	630,08	26,99	264,63	89,95	882,11
M 30	0,100	23,1	39,12	383,63	83,46	818,42	117,36	1150,90	56,07	549,87	58,68	575,45	65,20	639,39	27,38	268,54	91,28	895,14
M 30	0,125		44,95	440,86	95,90	940,49	134,86	1322,57	64,44	631,89	67,43	661,28	74,92	734,76	31,47	308,60	104,89	1028,67
M 30	0,160		51,67	506,73	110,23	1081,03	155,02	1520,20	74,06	726,32	77,51	760,10	86,12	844,56	36,17	354,71	120,57	1182,38
M 33	0,100	25,9	54,22	531,69	115,66	1134,28	162,65	1595,09	77,71	762,10	81,33	797,54	90,36	886,16	37,95	372,19	126,51	1240,62
M 33	0,125		62,53	613,26	133,41	1308,29	187,61	1839,78	89,63	879,00	93,80	919,89	104,22	1022,10	43,77	429,28	145,92	1430,94
M 33	0,160		72,14	707,42	153,89	1509,17	216,41	2122,27	103,40	1013,98	108,21	1061,14	120,23	1179,04	50,50	495,20	168,32	1650,66
M 36	0,100	28,0	68,81	674,77	146,79	1439,52	206,42	2024,32	98,62	967,18	103,21	1012,16	114,68	1124,62	48,17	472,34	160,55	1574,47
M 36	0,125		79,22	776,84	168,99	1657,27	237,65	2330,53	113,54	1113,48	118,82	1165,26	132,03	1294,74	55,45	543,79	184,84	1812,64
M 36	0,160		91,22	894,52	194,59	1908,30	273,65	2683,55	130,74	1282,14	136,82	1341,78	152,03	1490,86	63,85	626,16	212,84	2087,21
M 39	0,100	30,7	89,70	879,67	191,36	1876,62	269,10	2639,00	128,57	1260,85	134,55	1319,50	149,50	1466,11	62,79	615,77	209,30	2052,55
M 39	0,125		103,55	1015,50	220,91	2166,40	310,66	3046,50	148,42	1455,55	155,33	1523,25	172,59	1692,50	72,49	710,85	241,62	2369,50
M 39	0,160		119,54	1172,34	255,03	2500,98	358,64	3517,01	171,35	1680,35	179,32	1758,50	199,24	1953,89	83,68	820,63	278,54	2735,45
M 42	0,100	33,0	111,40	1092,47	237,66	2330,61	334,20	3277,42	159,68	1565,88	167,10	1638,71	185,67	1820,79	77,98	764,73	259,94	2549,11
M 42	0,125		128,45	1259,65	274,02	2687,26	385,35	3778,96	184,11	1805,50	192,67	1889,48	214,08	2099,42	89,91	881,76	299,71	2939,19
M 42	0,160		148,14	1452,72	316,02	3099,13	444,41	4358,15	212,83	2082,23	222,20	2179,08	246,89	2421,20	103,70	1016,90	345,65	3389,67

Tightening torques Mt for screws (For dynamometric keys)

(Works Standard 903.99.0e)

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Strength class or material			5,6		8,8		10,9		KB 12Ni19V		G 24CrMo5V		Cr X20Cr13V		CrNi X10CrNiTi189		5Cr X5CrMnNiN189	
S Kp/mm² N/mm²			30 300		64 640		90 900		43 430		45 450		50 500		21 210		70 700	
Coarse thread	Coeff. of fric	Reduced shaft Ø d_T	Tightening torque M_A (Kpm, Nm) of necked-down bolts d_T = 09 · d_K e. g. Works Standard 903.33.0e, DIN 2510 and si																	
			Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm
M 45	0,100	35,6	138,91	1362,23	296,34	2906,10	416,73	4086,70	199,10	1952,53	208,36	2043,35	231,52	2270,39	97,24	953,56	324,12	3178,54
M 45	0,125		160,50	1573,94	342,39	3357,74	481,49	4721,82	230,05	2255,98	240,75	2360,91	267,50	2623,24	112,35	1101,76	374,49	3672,53
M 45	0,160		185,44	1818,56	395,61	3879,60	556,33	5455,69	265,80	2606,61	278,16	2727,85	309,07	3030,94	129,81	1272,99	432,70	4243,31
M 48	0,100	37,7	166,30	1630,84	354,77	3479,12	498,90	4892,51	238,36	2337,54	249,45	2446,26	277,17	2718,06	116,41	1141,59	388,03	3805,29
M 48	0,125		191,87	1881,65	409,33	4014,19	575,62	5644,95	275,02	2697,03	287,81	2822,47	319,79	3136,08	134,31	1317,16	447,71	4390,52
M 48	0,160		221,40	2171,15	472,31	4631,80	664,19	6513,46	317,33	3111,99	332,09	3256,73	368,99	3618,59	154,98	1519,81	516,59	5068,03

Tightening torques Mt for screws (Works Standard 903.99.0e)
(For dynamometric keys)

Strength class or material			5,6		8,8		10,9		KB 12Ni19V		G 24CrMo5V		Cr X20Cr13V		CrNi X10CrNiTi189		5Cr X5CrMnNiN189	
S Kp/mm² N/mm²			30 300		64 640		90 900		43 430		45 450		50 500		21 210		70 700	
Fine thread	Coeff. of fric	Reduced shaft Ø d_T	Tightening torque M_A (Kpm, Nm) of necked-down bolts d_T = 09 · d_K e. g. Works Standard 010.31.0															
			Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm
M 16×1,5	0,100		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 16×1,5	0,125	12,7	7,33	71,85	15,63	153,27	21,98	215,54	10,50	102,98	10,99	107,77	12,21	119,75	5,13	50,29	17,09	167,64
M 16×1,5	0,160		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 18×1,5	0,100		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
M 18×1,5	0,125	14,5	10,74	105,36	22,92	224,77	32,23	316,08	15,40	151,01	16,12	158,04	17,91	175,60	7,52	73,75	25,07	245,84
M 18×1,5	0,160		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 20×1,5	0,100		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 20×1,5	0,125	16,6	15,73	154,26	33,56	329,08	47,19	462,77	22,55	221,10	23,59	231,38	26,22	257,09	11,01	107,98	36,70	359,93
M 20×1,5	0,160		18,34	179,86	39,13	383,70	55,02	539,58	26,29	257,80	27,51	269,79	30,57	299,77	12,84	125,90	42,79	419,67
M 22×1,5	0,100		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 22×1,5	0,125	18,2	20,52	201,25	43,78	429,32	61,56	603,74	29,41	288,45	30,78	301,87	34,20	335,41	14,36	140,87	47,88	469,57
M 22×1,5	0,160		23,95	234,83	51,08	500,96	71,84	704,48	34,32	336,58	35,92	352,24	39,91	391,38	16,76	164,38	55,87	547,93
M 24×1,5	0,100		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 24×1,5	0,125	20,0	27,25	267,26	58,14	570,16	81,76	801,79	39,06	383,08	40,88	400,89	45,42	445,44	19,08	187,08	63,59	623,61
M 24×1,5	0,160		31,86	312,45	67,97	666,56	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 20×2	0,100		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
M 20×2	0,125	15,8	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 20×2	0,160		16,29	159,79	34,76	340,89	48,88	479,38	23,36	229,04	24,44	239,69	27,16	266,32	11,41	111,85	38,02	372,85
M 24×2	0,100		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 24×2	0,125	19,3	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
M 24×2	0,160		29,28	287,14	62,46	612,56	87,84	861,42	41,97	411,57	43,92	430,71	48,80	478,56	20,50	201,00	68,32	669,99
M 30×2	0,100		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 30×2	0,125	24,8	52,48	514,64	111,96	1097,91	157,44	1543,93	75,22	737,66	78,72	771,96	87,46	857,74	36,74	360,25	122,45	1200,83
M 30×2	0,160		61,26	600,75	130,69	1281,60	183,78	1802,25	87,81	861,07	91,89	901,12	102,10	1001,25	42,88	420,52	142,94	1401,75
M 36×3	0,100		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 36×3	0,125	29,0	85,49	838,36	182,38	1788,50	256,47	2515,08	122,53	1201,65	128,23	1257,54	142,48	1397,27	59,84	586,85	199,47	1956,17
M 36×3	0,160		99,24	973,18	211,70	2076,08	297,71	2919,49	142,24	1394,87	148,85	1459,75	165,39	1621,94	69,46	681,22	231,55	2270,72
M 39×3	0,100		96,01	941,54	204,82	2008,61	288,03	2824,61	137,61	1349,54	144,02	1412,30	160,02	1569,23	67,21	659,08	224,02	2196,92
M 39×3	0,125	31,8	111,76	1096,01	238,43	2338,15	335,29	3288,03	160,19	1570,95	167,64	1644,01	186,27	1826,68	78,23	767,21	260,78	2557,36
M 39×3	0,160		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

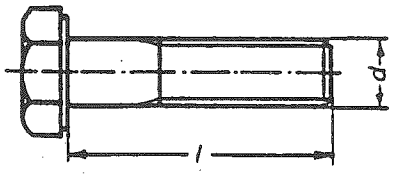
Tightening torques Mt for screws (Works Standard 903.99.0e)
(For dynamometric keys)

Page 10

Strength class or material			5,6		8,8		10,9		KB 12Ni19V		G 24CrMo5V		Cr X20Cr13V		CrNi X10CrNiTi189		5Cr X5CrMnNiN189	
S Kp/mm² / N/mm²			30 / 300		64 / 640		90 / 900		43 / 430		45 / 450		50 / 500		21 / 210		70 / 700	
Fine thread	Coeff. of fric	Reduced shaft $\varnothing$ d_T	Tightening torque M_A (Kpm, Nm) of necked-down bolts d_T = 09 · d_K e. g. Works Standard 010.31.0															
			Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm	Kpm	Nm
M 42×3	0,100		121,17	1188,25	258,49	2534,93	363,50	3564,74	173,67	1703,15	181,75	1782,37	201,95	1980,41	84,82	831,77	282,72	2772,57
M 42×3	0,125	34,5	141,30	1385,64	301,43	2956,02	423,89	4156,91	202,52	1986,08	211,94	2078,45	235,49	2309,39	98,91	969,94	329,69	3233,15
M 42×3	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	3768,12
M 45×3	0,100		151,89	1489,58	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
M 45×3	0,125	37,3	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	1218,13	414,05	4060,44
M 45×3	0,160		207,18	2031,76	441,99	4334,43	621,55	6095,28	296,96	2912,19	310,77	3047,64	345,30	3386,27	145,03	1422,23	483,43	4740,78
M 48×3	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
M 48×3	0,125	40,0	218,02	2138,02	465,10	4561,11	654,05	6414,07	312,49	3064,50	327,03	3207,03	363,36	3563,37	152,61	1496,62	508,71	4988,72
M 48×3	0,160		254,88	2499,55	543,75	5332,38	764,65	7498,66	365,33	3582,69	382,32	3749,33	424,81	4165,92	178,42	1749,69	594,73	5832,29
M 52×3	0,100		240,52	2358,69	513,11	5031,88	721,56	7076,08	344,75	3380,79	360,78	3538,04	400,87	3931,15	168,36	1651,08	561,21	5503,62
M 52×3	0,125	43,7	281,88	2764,28	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
M 52×3	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
M 56×4	0,100		291,79	2861,49	622,49	6104,51	875,37	8584,47	418,23	4101,46	437,69	4292,23	486,32	4769,14	204,25	2003,04	680,84	6676,80
M 56×4	0,125	46,2	340,13	3335,53	725,61	7115,81	1020,39	10006,61	487,52	4780,94	510,20	5003,30	566,88	5559,23	238,09	2334,88	793,64	7782,91
M 56×4	0,160		396,17	3885,10	845,16	8288,22	1188,51	11655,30	567,84	5568,65	594,26	5827,66	660,28	6475,17	277,32	2719,57	924,40	9065,24
M 60×4	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
M 60×4	0,125	49,8	421,80	4136,46	899,84	8824,45	1265,41	12409,39	604,58	5928,93	632,70	6204,69	703,00	6894,10	295,26	2895,52	984,20	9651,75
M 60×4	0,160		492,02	4825,10	1049,65	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
M 64×4	0,100		440,97	4324,41	940,73	9225,42	1322,90	12973,25	632,05	6198,33	661,45	6486,62	734,95	7207,36	308,68	3027,09	1028,93	10090,31
M 64×4	0,125	53,4	515,52	5055,55	1099,78	10785,16	1546,57	15166,65	738,92	7246,29	773,28	7583,32	859,20	8425,91	360,87	3538,89	1202,89	11796,28
M 64×4	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
M 68×4	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
M 68×4	0,125	57,5	634,74	6224,63	1354,10	13279,21	1904,21	18673,89	909,79	8921,97	952,10	9336,95	1057,89	10374,38	444,32	4357,24	1481,05	14524,14
M 68×4	0,160		742,89	7285,22	1584,82	15541,80	2228,66	21855,67	1064,80	10442,14	1114,33	10927,82	1238,14	12142,03	520,02	5099,66	1733,40	16998,85
M 72×4	0,100		635,89	6235,96	1356,57	13303,40	1907,68	18707,91	911,45	8938,23	953,84	9353,95	1059,82	10393,28	445,12	4365,18	1483,75	14550,60
M 72×4	0,125	60,7	745,22	7308,10	1589,80	15590,63	2235,66	21924,33	1068,15	10474,95	1117,83	10962,16	1242,03	12180,17	521,65	5115,68	1738,85	17052,25
M 72×4	0,160		872,49	8556,18	1861,31	18253,19	2617,46	25668,55	1250,57	12263,86	1308,73	12834,27	1454,15	14260,30	610,74	5989,33	2035,81	19964,43
M 80×4	0,100		880,82	8637,93	1879,09	18427,60	2642,48	25913,83	1262,52	12381,05	1321,24	12956,90	1468,04	14396,56	616,58	6046,55	2055,26	20155,19
M 80×4	0,125	68,0	1034,31	10143,13	2206,53	21638,68	3102,94	30429,41	1482,51	14538,49	1551,47	15214,70	1723,85	16905,23	724,02	7100,20	2413,39	23667,31
M 80×4	0,160		1213,29	11898,27	2588,34	25382,99	3639,86	35694,84	1739,04	17054,19	1819,93	17847,40	2022,14	19830,45	849,30	8328,80	2831,00	27762,65

Tightening torques Mt for screws (For dynamometric keys) (Works Standard 903.99.0e)

DIN 931



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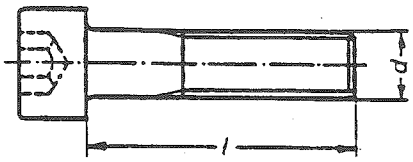

Subsequently indicated values of tightening torques Mt for screws of

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 $R_{p\ 0.2}$ 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 ($R_{p\ 0.2}$ = 210 N/mm^2) apply for thread diameters exceeding 30 mm.

Tightening torques for cylindrical screws

	Kgm
	Nm

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

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

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.

Rev.	Date	Issued by	Checked by	Note
0	04-03-97	Udo Junk		First edition

Distribution:

MTD	QA	WK	WQ	WP	WPA	WFS	AS	ASI	

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

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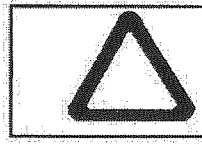

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0	04-03-97	Udo Junk		First edition

Distribution:

MTD	QA	WK	WQ	WP	WPA	WFS	AS	ASI	

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 ≤ 10 bar, t ≤ 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. 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/SMAW (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.

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

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"

Enclosure 1 of QSV-WQ-4e dated 04-09-1997 Sheet 5 of 7

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/SMAW .....[ ]	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!

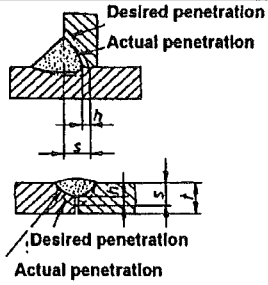
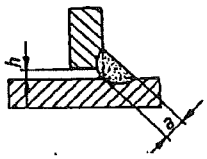
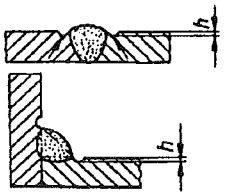
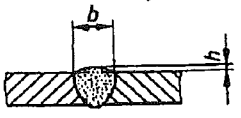
Results of inspections: no complaints [ ] not without complaints [ ]

Notes:

Checked/released by: Service technician/site supervisor: _____ Date: ___-___-19___	Checked/released by ACE Quality Control:

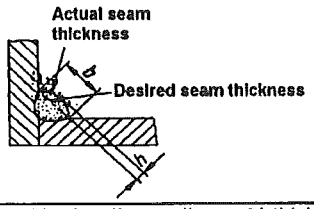
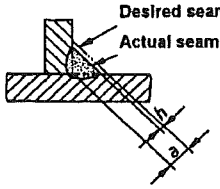
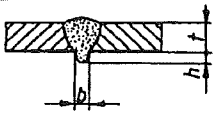
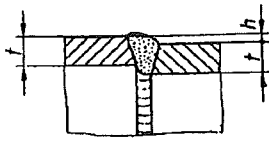
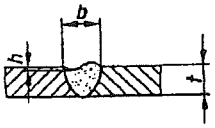
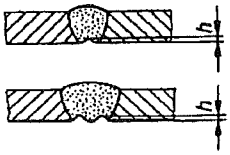
Enclosure 2 of QSV-WQ-4e dated 04-09-1997 Sheet 6 of 7

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 ≤ 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 ≤ 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 ≤ 2 mm
Undercut	Smooth interface is mandatory. 	h ≤ 0.5 mm
Excessive weld reinforcement	Smooth interface is mandatory. 	h ≤ 3 mm

Enclosure 2 of QSV-WQ-4e dated 04-09-1997 Sheet 7 of 7

Visual inspection of welds: Irregularities and permissible limit values

Excessive weld reinforcement		h ≤ 3 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 ≤ 3 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 ≤ 2 mm
Inferior reinforcement of cover pass, misplaced weld deposit	Smooth interface is mandatory. 	Max. h ≤ 0.5 mm, long irregularities are unacceptable.
Root-side suckback	Smooth interface is mandatory. 	h ≤ 0.5 mm

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	Execution of hydrostatic and pneumatic pressure and tightness tests	09-15-1993

Index

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					

	Process specification	Page 2 of 5
QSV-QP-7E	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

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- 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.

.../4

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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).

.../5

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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

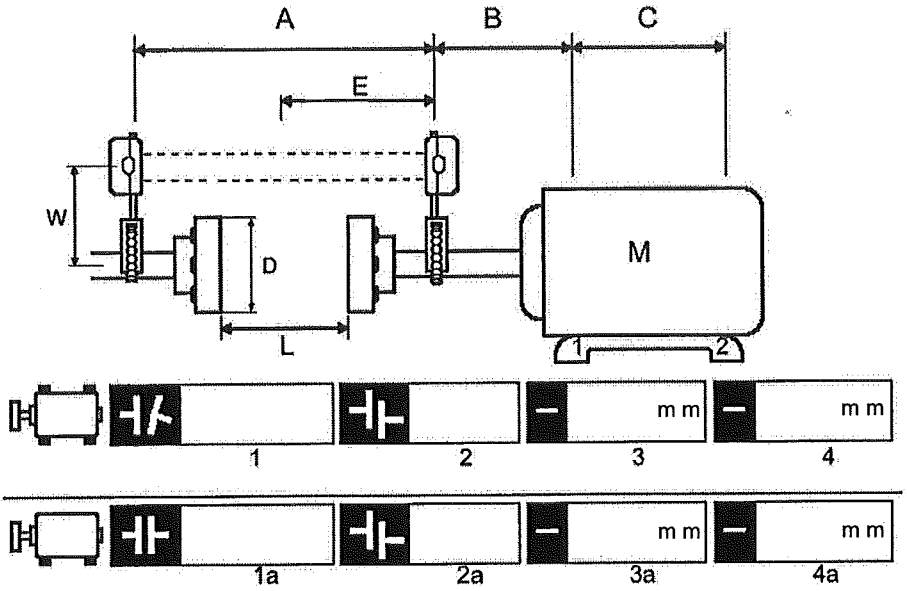
Casing parts made of cast iron and non-alloyed steels must be treated with preservative suited for long-term storage of the part after termination of the test to protect surfaces against rust.

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

H 3 Zapisi, obrazci in potrditveni seznami

H 3.1 Zapis o uskladitvi sklopke

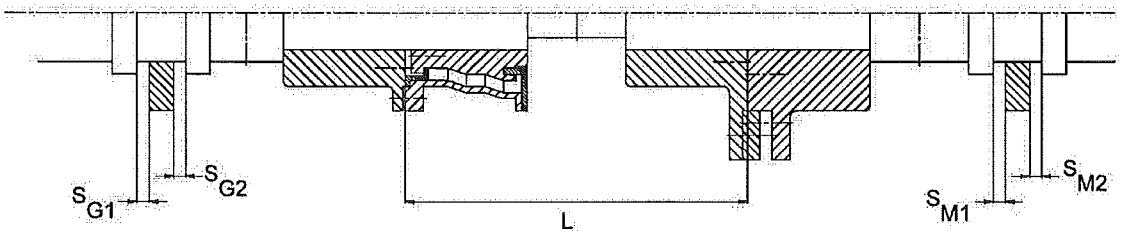
Nameščen model laserja	
Vgrajen tip sklopke	Zobati sklop, Posiflex ZEAKF-151 E 520
Δh = Zamik pogonskega stroja po višini pri temperaturi okolja	**+ 0.15 $^{+0.05}$mm** / 20 °C + gonilni stroj nameščen višje
Serijska št.:	14 - 2275 14 - 2276



		mm		
A	Razdalja med optičnimi elementi opreme poravnalnega laserja		**1**	Kotni zamik pogonskega stroja, gledano od zgoraj
B	Razdalja med optičnimi elementi in središčem podnožja 1 pogonskega stroja		**1a**	Kotni zamik pogonskega stroja, gledano s strani
C	Razdalja med podnožjem 1 in 2 pogonskega stroja		**2**	Vzporedni zamik pogonskega stroja gledano od zgoraj
D	Zunanji diameter sklopnega elementa		**2a**	Kotni zamik pogonskega stroja, gledano s strani (ustreza **Δh**)
E	Razdalja med elementi laserja in centrom sklopnega distančnika		**3**	Horizontalni zamik s specificirano mero
M	pogonski stroji (premični element)		**3a**	Razlika v višini podnožja 1 pogonskega stroja
L	Dolžina sklopnega distančnika (glejte načrt ureditve)	**520**	**4**	Horizontalni zamik s specificirano mero
W	Meritec središča radija kroga gredi proti centru laserskega elementa		**4a**	Razlika v višini podnožja 2 pogonskega stroja
	Temperatura okolja med poravnavo		**°C**	
	Temperatura stroja med poravnavo		**°C**	

H 3.2 Nastavitev osne zračnosti

L = dolžina sklopnega distančnika **520 mm**



POZOR

Pogonski stroj mora biti poravnan tako, da bo možno določiti popolno osno zračnost v sklopljenem in nesklopljenem stanju. Obvezno je potrebno upoštevati dovoljeno minimalno zračnost.

	Dim.	Določena vrednost	Izmerjena vrednost		
Menjalnik					
S_{G1}	mm				
S_{G2}	mm				
Pogonski stroj			Motor		Turbina
Z osnim ležajem					
S_{M1}	mm				
S_{M2}	mm				
Brez osnegam ležaja					

Pri poravnavi generatorja opazujte oznake in izdelovalčeve podatke o mehaničnem in magnetnem središču.

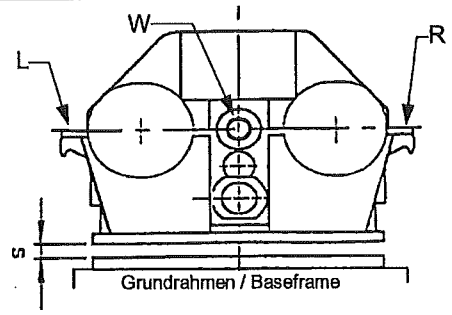
Stranka			Datum	Mesto
Atlas Copco				
Izdelovalec generatorja				

H 3.3 Zapis o uskladitvi (predloga)

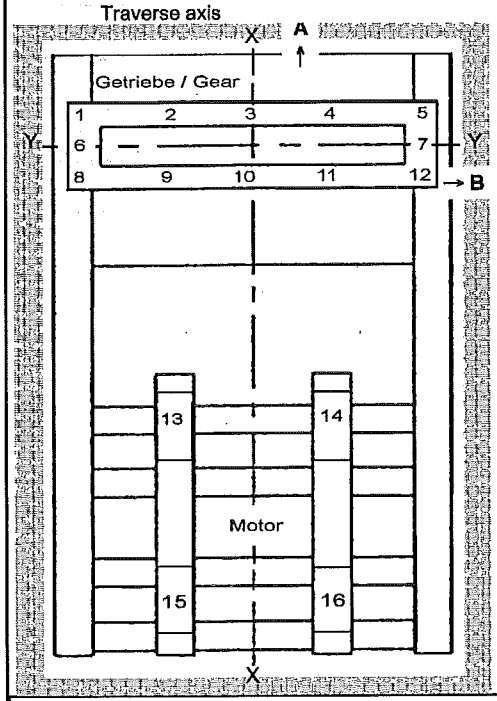
Atlas Copco Ausrichtprotokoll / Alignment protocol
Getriebe - Grundrahmen / Gear - baseframe

Auftr.-Nr.: Order no.:	
Masch.-Nr.: Serial. no.:	
Kennwort: Plant code:	

Messungen mit Wellenwasserwaage, Genauigkeit: ein Teilstrich = 0,1 mm /m
Measurement with spirit level, precesion: one graduation mark = 0,1mm/m



W = Welle / Shaft
L / R = Ausrichtleiste Links / Rechts
Alignment board left / right
S = Spaltprüfung Getriebe zum Grundrahmen
Check gap gear to baseframe
X = Kompressorachse
Compressor center line
Y = Querachse
Traverse axis



Montagephase / steps of erection	Werksmontage in workshop	1. Aufbau first erection	Endausrichtung final alignment

	→ A	→ A	→ A
S1			
S3			
S5			
S8			
S10			
S12			
W			
L			
R			
X6			
X7			
X3			
X10			
X13			
X14			
X15			
X16			

	→ B	→ B	→ B
Y6			
Y7			
Y3			
Y10			
Y13			
Y14			
Y15			
Y16			

Bemerkungen / Notes

Abnahme / Approved:	Kunde / Client	Atlas Copco
Datum / Date:		
Name / Unterschrift / Sign.:		

H 3.4 Potrditveni seznam za instalacijo

- ☐ Potrdite pregled obsega pošiljke v skladu s tovornim seznamom.
- ☐ Sestavni deli so: nepoškodovani - poškodovani
- ☐ Potrdite, da so temelji pripravljeni za namestitev pošiljke in da so dimenzije, raven in ravnost pravilne ter da so luknje v temelju za sornike in njihov položaj v skladu z načrtom temelja.
- ☐ Prevrite pravilno sestavitev hladilnika in temeljnega okvirja.
- ☐ Namestite priložena vijačna vretena v luknje za sornike na obeh straneh temeljev kot je prikazano na načrtu temlejev. Spustite kompresorski okvir temeljev s sidrnimi sorniki privitimi v okvir na vijačna vretena.
- ☐ ravnajte temeljni okvir preko temeljeve.
- ☐ Sestavljanje kompresorske enote (centralna enota)
- ☐ Spustite glavni pogonski motor (če ga imate) v njegov podporni okvir, ga na grobo poravnajte s turbino in ga pritrdite v pozicijo. Namestite nastavljalna vretena.
- ☐ Pripravite podatke o legi za usmerjanje proti severu in vzhodu. Ponovno preverite poravnanost in jo nastavite kot je potrebno in naravnajte poravnanost vreten, da bi dobili pravilno višinsko referenco o višini datuma lege.
- ☐ Preverite poravnanost gredi motor – kompresor in pričvrstite pritrjevalne sornike generatorja. Ne nameščajte še spojnega vretena.
- ☐ Z malto zalijte sidrne sornike v temeljni okvir stroja do do vrha temelja (poglejte v načrt temeljev).
- ☐ Ko je malta zalila matice temeljnmih sornikov, preverite poravnanost.
- ☐ Preverite poravnanost gredi motor – kompresor in pričvrstite pritrjevalne sornike generatorja. Ne nameščajte še spojnega vretena.
- ☐ Pred povezovanjem kompresorskih sesalnih cevi preverite delovanje sistema vodil kompresorskih lopatic.
- ☐ Pritrdite notranje procesne cevi v skladu z diagramom P&I.
- ☐ Vzpostavite in pritrdite spoje cevi s podporniki.
- ☐ Ponovno preverite poravnanost kompresorja in gredi in potrdite, da se od prejšnjega koraka ni spremenila poravnanost.
- ☐ Povežite cevi za hladilno vodo in olje. Povežite še vse druge različne cevi.

- ☐ Povežite vse zaključne cevne točke s cevovodi porabnikov (glejte risbo cevnih povezav porabnikov).
- ☐ Ponovno preverite poravnanost kompresorja in gredi in potrdite, da se od prejšnjega koraka ni spremenila poravnanost.
- ☐ Preverite in končajte vsa električna ožičenja do priključnih doz motorja, grelcev in instrumentov itd. s pomočjo strokovnjaka za elektriko, po naročilu stranke

Če so bila dela, našteta v tem odseku, zadovoljivo končana je turbomehanizem pripravljen za predhodno obratovanje.

H 3.5 Potrditveni seznam za obratovanje

Cilj tega postopka je, da se zagotovijo popolne in pravilne predobratovalne dejavnosti in se tudi izvedejo ter zabeležijo kot sestavnegi del samega obratovanje, zaradi predaje kompleta v obratovanje.

Namen je, da se na koncu teh testov izvrši še test neskloplјenega vrtenja motorja.

- ☐ Preverite integralnost/varnost pritrjevalnih sornikov v temeljih.
- ☐ Izvršite popolno preverjeanje po postopkovnem seznamu, da bi zagotovili, da so mehanični, električni in instrumentalni ustroji in sklopi kompletni.
- ☐ Preverite vrtenje in delovanje pomožne mazalne oljne črpalke in motor razprševalca oljne megle.
- ☐ Zagotovite, da razprševalec oljne megle deluje pravilno in preverite pravilen vakuum.
- ☐ Posodo napolnite z določenim oljem. Zaženite pomožno oljno črpalko in se prepričajte, da je črpalka pripravljena za delo. Splakujte oljni vod pri maks. temperaturi (za segrevanje olja uporabite oljni grelec) 6 ur, dokler ni čist, očistite tudi filtre, kot je zahtevano. Ustavite črpalko.
- ☐ Preglejte in zamenjajte elemente oljnega filtra ob koncu splakovanja, razen če diferencialni tlak olja nakazuje problem že prej.
- ☐ Funkcionalno preverjanje alarma in sistema za izklop za ‚dopusten zagon" in ‚ustavitev"
- ☐ Simulirajte delovanje motorja in preverite zaščitne tokokroge. V testnem položaju je potrebno izvesti najmanj eno preverjanje prekinitve s stikalom menjalnika.
- ☐ Preverite, da so obsegi vseh tlakov in diferencialnih tlakov pravilni in delujoči.
- ☐ Preverite, da so vsi prenosniki tlakov in diferencialnih tlakov pravilni in delujoči.
- ☐ Preverite, da so vsi indikatorji temperature pravilni in delujoči.
- ☐ Preverite, da so vsi temperaturni elementi (TE) in stikala (TS) pravilni in delujoči. Zabeležite nastavitve vseh temperaturnih stikal,
- ☐ Preverite delovanje vseh grelcev oljnih maziv. Preverite delovanje kontrolnikov gretja (TC) in zabeležite natavitvene točke temperaturnih stikal grelcev (TS).
- ☐ Preverite delovanje stikal na vseh ravneh.
- ☐ Preverite napetostno razpoko vseh vibracijskih tipal in preverite vse vibracijske monitorje za sprejemljive odčitanje in delovanje.

- ☐ Preverite in zabeležite nastavitev vseh vibracijskih alarmov in izklopov.
- ☐ Preverite delovanje IGV-jev. Udarite ob popolnoma odprtem in popolnoma zaprtem ter preverite delovanje mejnega stikala ter po potrebi nastavite ustavitev vodila lopatic.
- ☐ Preverite delovanje ob udaru in napaki premostitvenega ventila . Preverite in zabeležite čas udara ob popolnoma odprtem in popolnoma zaprtem.
- ☐ Preverite delovanje in zabeležite nastavitev vseh kontrolnih ventilov.
- ☐ Pripravite stroj za posnemovalni zagon, da bi se prepričali, če so IGV-ji zaprti in če je izpušni ventil odprt ter pripravljen za zagon, lučka je prižgana z znakom, da so vse prekinitve pojasnjene.
- ☐ Odklopite sesalni vod do kompresorja in izpihnite sesanje s stisnjenim zrakom. Preglejte sesalno lužino in impulz ter očistite, če je potrebno . Ponovno namestite sesalno linijo.
- ☐ Zagotovite, da vodni hladilni sistem na zunanji strani stroja deluje pravilno.
- ☐ Pokličite servisnega elektrikarja in pripravite motor za neskloplјen tek. Zagotovite vzdrževanje pravilne oskrbe s hladilno vodo in mazivnim oljem.
- ☐ Zaženite motor. Opravite neskloplјen tek in preverite pravilno vrtenje na startu in čas ustavljanja. Ustavite motor.
- ☐ Ponovno preverite poravnanost in instalirajte vezni distančnik ter vodila in preverite ter zabeležite osni zamik sklopljene enote, da bi zagotovili, če je osno nihanje znotraj varnih obratovalnih meja ležaja motorja. Zagotovite, da vodni hladilni sistem na zunanji strani stroja deluje pravilno.

☐

Turbomehanizem je sedaj pripravljen za predavjo v proces obratovanja.

H 4 Informacije o nadomestnih delih in zapiski o poizvedbah

H 4.1 Struktura centrifugalnih kompresorskih obratov

Naši izdelki so strukturirani po sklopih, prikazanih v strukturi centrifugalnega kompresorja v nadaljevanju (tukaj so prikazani le dobavljeni deli).

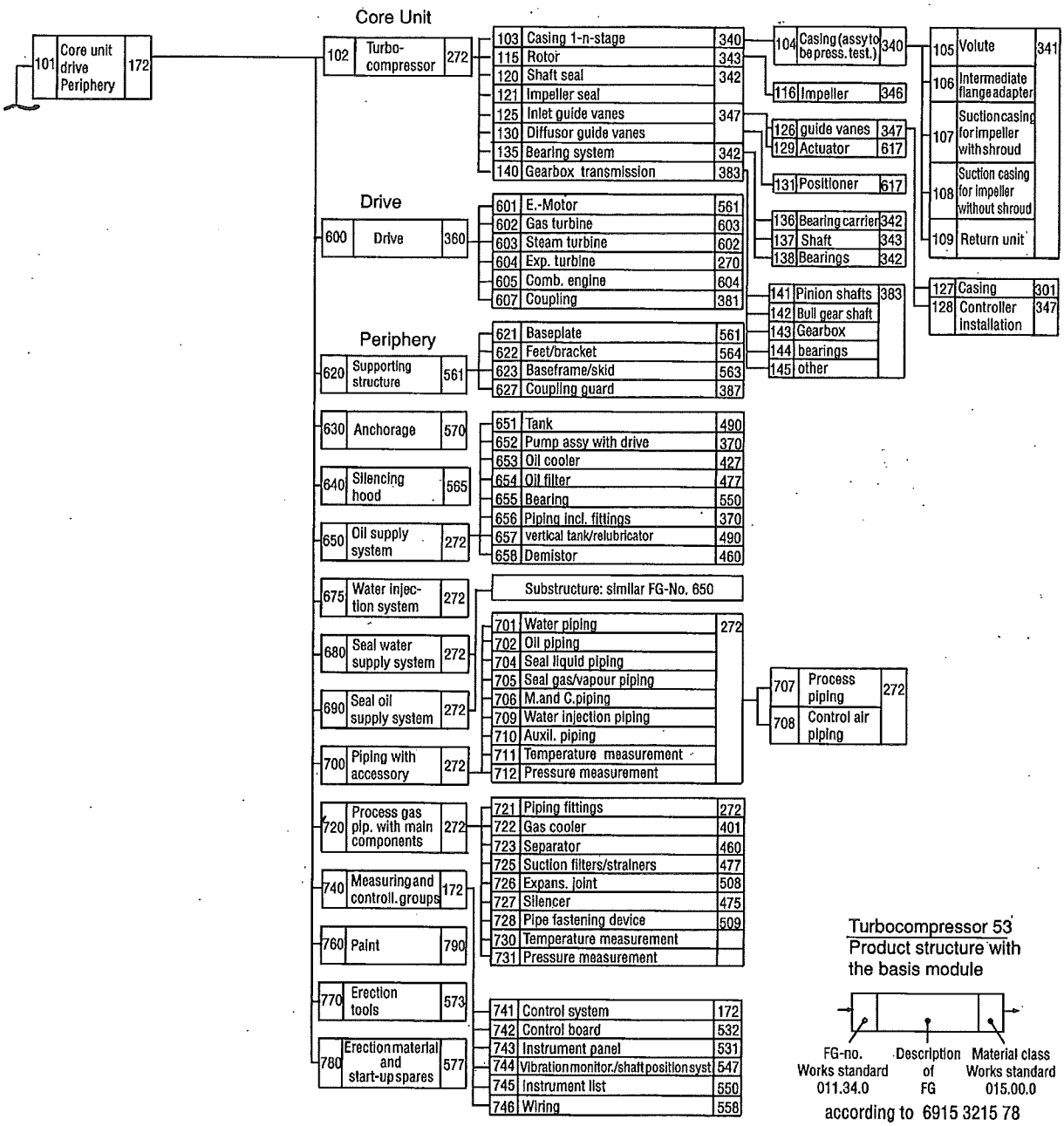
Posamezni sektorji kažejo dominacijo sklopov in njihove številke sklopov. Struktura je prikazana na naslednji strani.

Obratovalni sklop 101 centrifugalnega kompresorja se sestoji iz naslednjih sklopov: osrednja enota 102, gonilo 600 in periferija z vsemi sestavnimi deli sklopa štev. 620 ali višje.

Sklop centrifugalnega kompresorja 102 se sestoji iz ohišja 103, rotorja 115, tesnila gredi 120 itd. do menjalnika 140, prenosa.

Menjalnik 140 v prodajni različici se sestoji iz gredi s pastorkom 141, gredi centralnega kolesa 142 itd. V tem primeru ni dodatnih pododdelkov. Za druge sklope je to vendarle možno.

Na primer, 125 dovodno vodilo lopatic lahko nadalje strukturirate v 126 vodilo lopatic in 129 sprožilo z podstrukturiranim 126 v namestitev 127 ohišja in 128 kontrolnika.


Core Unit
101 Core unit drive Periphery 172
102 Turbo-compressor 272
103 Casing 1-n-stage 340
115 Rotor 343
120 Shaft seal 342
121 Impeller seal
125 Inlet guide vanes 347
130 Diffusor guide vanes
135 Bearing system 342
140 Gearbox transmission 383
104 Casing (assy to be press. test.) 340
116 Impeller 346
126 guide vanes 347
129 Actuator 617
131 Positioner 617
105 Volute 341
106 Intermediate flange adapter
107 Suction casing for impeller with shroud
108 Suction casing for impeller without shroud
109 Return unit
Drive
600 Drive 360
601 E.-Motor 561
602 Gas turbine 603
603 Steam turbine 602
604 Exp. turbine 270
605 Comb. engine 604
607 Coupling 381
136 Bearing carrier 342
137 Shaft 343
138 Bearings 342
141 Pinion shafts 383
142 Bull gear shaft
143 Gearbox
144 bearings
145 other
127 Casing 301
128 Controller installation 347
Periphery
620 Supporting structure 561
621 Baseplate 561
622 Feet/bracket 564
623 Baseframe/skid 563
627 Coupling guard 387
630 Anchorage 570
640 Silencing hood 565
650 Oil supply system 272
651 Tank 490
652 Pump assy with drive 370
653 Oil cooler 427
654 Oil filter 477
655 Bearing 550
656 Piping incl. fittings 370
657 vertical tank/relubricator 490
658 Demistor 460
675 Water injection system 272
Substructure: similar FG-No. 650
680 Seal water supply system 272
690 Seal oil supply system 272
700 Piping with accessory 272
701 Water piping 272
702 Oil piping
704 Seal liquid piping
705 Seal gas/vapour piping
706 M.and C.piping
709 Water injection piping
710 Auxil. piping
711 Temperature measurement
712 Pressure measurement
707 Process piping 272
708 Control air piping
720 Process gas plp. with main components 272
740 Measuring and controll. groups 172
760 Paint 790
770 Erection tools 573
780 Erection material and start-up spares 577
721 Piping fittings 272
722 Gas cooler 401
723 Separator 460
725 Suction filters/strainers 477
726 Expans. joint 508
727 Silencer 475
728 Pipe fastening device 509
730 Temperature measurement
731 Pressure measurement
741 Control system 172
742 Control board 532
743 Instrument panel 531
744 Vibration monitor./shaft position syst 547
745 Instrument list 550
746 Wiring 558
Turbocompressor 53
Product structure with the basis module
FG-no. Works standard 011.34.0
Description of FG
Material class Works standard 015.00.0
according to 6915 3215 78

H 4.2 Struktura seznama nadomestnih delov

Naš seznam nadomestnih delov vključuje ces obratovalne sklope, celoten enote in posameznih nadomestnih delov, ki jih vsak posamezen sklop potrebuje:

- Vzdrževanje,
- Pregled
- Revizija ali kot zaloga za preprečevanje kakršnega koli tveganja (gre za zalogo pripravljenih nadomestnih delov, ki omogočajo hitro popravilo kompresorja v nujnih primerih brez povzročanja daljših časov mirovanja stroja zaradi dolgih časov dobave).

Za seznam nadomestnih delov stroja glejte naslednje strani.

Prva tabela nadomestnih delov vsebuje seznam številk delov sklopa skupine z ustrezno risbo.

Naslednja tabela vsebuje originalno številko za naročilo dela, opis, štev. sklopa in ustrezno risbo sklopa, če obstaja. Za vsak del, tudi njegovo risbo je prikazana številka.

Za informacije o poddobaviteljih sklopov poglejte ustrezno poglavje v razdelku H5.

Naš oddelek z nadomestnimi dekli vas bo na zahtevo opremil s celotno količino nadomestnih delov.

Na splošnno je priporočljivo, da imate v zalogi in za minimalno razpoložljivost za turbomehanitezem naslednje nadomestne dele:

- **Za zagon**
- 1 komplet tesnil
- 1 komplet temperaturnih tipal
- 1 komplet oljnih filtrnih vstavkov
- 1 dušilnik vibracij

- **Za dveletno delovanje**
- 1 kompleten roto
- 1 komplet grednih tesnil
- 1 komplet oljnih filtrnih vstavkov
- 1 komplet ležajev

- **Za nekajletno obratovanje**
- 1 komplet ležajev
- 1 komplet grednih tesnil
- 1 kompleten roto
- 1 komplet oljnih filtrnih vstavkov

H 4.3 Navodila za naročanje nadomestnih delov z zgledom

Če želite spraševati za naročilo nadomestnih delov, vas prosimo, da kontaktirate izključno servisni oddelek AC

Zahteve ali naročila morajo vedno imeni naslednje informacije:

- Originalno število za naročilo AC dela, številko AC navedka
- Tip stroja in serijsko štev.
- Številko risbe in pojma, številko materiala. in opis zahtevanega nadomestnega dela
- Količino zahtevanih delov

Primer:

Na osnovi vaše navedbe naročamo naslednje dele:

Vaša štev. naročila:	XE 8812
Vašpa številka navedbe:	140-88-4711
Tip stroja	HL8-4-75
Originalna številka naročenega dela.	572 37 318
Serijska štev:	14-2275 14-2276

4 kompleti tesnil, štev. materiala: 69XXXXXXXX, pojem X iz risbe štev.: 69XXXXXXXX.

Če se izjemoma zgodi, da zahtevanega sestavnega dela, ki ga želite, ni v našem seznamu nadomestnih delov, vas bomo zaprosili, da opišete sestavni del, njegovo funkcijo, glavne mere, domnevne materiale itd. Vedno je obvezno da nas seznanite s podobno originalno AC številko za naročilo dela.

Bodite prepričani, da vam bomo pomagali.

Na naslednjih straneh so našteti nadomestni deli, ki so dobavljeni skupaj s strojem.

H 4.4 Nadomestni deli, ki jih prejmete skupaj s strojem

Part no.: Oil demister
Pos.: 6970268299

6970276976	Filter element	7

H 4.5 Seznam nadomestnih delov

Ersatzteile Core Unit
Spare Parts Core Unit

Part no.:	Core Unit	Drawing
Pos.:	6970 3014 69	1320 1028 11
1420 1126 22 77	Schwingungsmeßsonde Vibration probe	4
1420 1126 23 77	Verlängerungskabel Extension cable	4
1420 1126 25 77	Proximitor Proximitor	4
1320 7022 18 27	Wellenabdichtung 1.Stufe Buffer seal 1st. stage	1
1320 7022 13 28	Wellenabdichtung 1.Stufe Buffer seal 1st.stage	1
1320 7022 74 29	Wellenabdichtung 2.Stufe Buffer seal 2nd. stage	1
1320 7022 73 30	Wellenabdichtung 2.Stufe Buffer seal 2nd. stage	1
1320 7015 18 31	Wellenabdichtung 3.Stufe Buffer seal 3rd. stage	1
1320 7015 17 32	Wellenabdichtung 3.Stufe Buffer seal 3rd. stage	1
1320 7022 08 33	Öldichtung 1.Stufe Oil seal 1st. stage	1
1320 7015 21 48	Öldichtung 2.Stufe Oil seal 2nd. stage	1
1320 7015 22 34	Öldichtung 3.Stufe Oil seal 3rd. stage	1
1320 7023 31 19	Öldichtung Antriebswelle Oil seal drive gear	1
1320 7041 56 113	Öldichtung Antriebswelle Oil seal drive gear	1

1320 7022 41 14	Antriebsrad Drive gear	1
1320 7025 00 15	Radiallager L.S. Journal bearing L.S.	1
1320 7025 25 16	Radial/Axiallager L.S. Journal/thrust bearing	1
1320 7110 00 20	Lager 1. Stufe Bearing 1st. stage	1
1320 7110 22 21	Lager 2. Stufe Bearing 2nd. stage	1
1320 7111 60 22	Lager 3. Stufe Bearing 3rd. stage	1
1320 7111 80 23	Lager gegenüber 3. Stufe Bearing opposite 3rd. stage	1
1320 7016 10 24	Ausgleichsbleche für Lager Shim pack for bearings	4
1320 7016 09 25	Ausgleichsbleche für Lager Shim pack for bearing	4
1420 1104 80	PT 100 im Lager Bearing RTD	16
0800 0012 38 01	O-Ring O-ring	2,5 m
0800 0000 43 18	O-Ring O-ring	1
1420 0500 90 36	O-Ring O-ring	1
1420 0501 64 42	O-Ring O-ring	2
0800 0013 13 43	O-Ring O-ring	3
1320 7077 52 44	O-Ring O-ring	1

1320 7077 53 45	O-Ring O-ring	1	
1320 7077 54 46	O-Ring O-ring	1	
0663 3127 00 68	O-Ring O-ring	2	
1420 0501 65 72	O-Ring O-ring	1	
1420 0510 53	O-Ring IGV O-ring IGV	7	
1420 0507 02	O-Ring IGV O-ring IGV	7	
1420 1201 34 13	Hauptölpumpe Main oil pump	1	
1320 7082 10 13	Kupplung Hauptölpumpe Main oil pump coupling	1	
1320 7064 30 13	Vorgelege Hauptölpumpe Spur gear pump	1	
0502 1090 32 13	Wälzlager Ball bearings	2	
0502 1090 32 59	Wälzlager Ball bearings	2	
1320 1021 49 11	Rotor Stufe 1/2 Rotor stage 1/2	1	
1320 7070 70 12	Rotor Stufe 3 Rotor stage 3	1	
1420 1126 22	Schwingungsmeßsonde Vibration probe	1	Key phasor pinion 1
1420 1126 22	Schwingungsmeßsonde Vibration probe	1	Key phasor pinion 2
1420 1126 21	Schwingungsmeßsonde Vibration probe	1	Axial pinion 1

1420 1126 22	Schwingungsmeßsonde Vibration probe	1	Axial pinion 2
1420 1126 23	Verlängerungskabel Extension cable	4	
1420 1126 26	Proximitor Proximitor	2	Axial
1420 1126 25	Proximitor Proximitor	2	Key Phasor
1320 7078 48 88	Öldruckregelventil Oil pressure relieve valve	1	
1420 1501 01	Sperrgasdruckregelventil Sealgas pressure relieve valve	1	
1420 1301 00	Rückschlagventil Sperrgassytem Check valve sealgas system	1	
1420 1505 24 102	Rückschlagventil Sperrgassytem Check valve sealgas system	1	
1420 1201 64	Dichtungssatz Hauptölpumpe Seal main oil pump		

H 5 Tehnična dokumentacija in navodila za uporabo poddobaviteljev podjetja AC


Glejte angleško različico

Poglavje H 5 glejte angleška razlicica.

Št.	Ime	Tip	Št. dela	Dobavitelj
	Osrednja enota			
1	Sklopka	ZEAKF	6970 3014 58	Tschan
2	Sprožilo za IGV	C-2250SR3	1420 1529 78	Bettis
	Kontrolnik položaja in prenosnik z stikalom mejnega položaja	760E 15BAAG12B7	1420 1521 29	Moore
	Postaja za oskrbo z zrakom	FRS923-3SK	6915 2629 88	Eckardt
	Periferija			
3	Hladilna enota ZK1, ZK2	EKE77	6970 3014 57	Oeltechnik
	Naknadni hladilnik ZK3	EKE66	6970 3014 63	
4	Obvodni ventil	DN 150 PN 16	6970 3014 64	Arca
	Ventil	101-L1 (LS)		
	Sprožilo	812		
	Pričvrščevalna priprava	827A		
	Magnetni ventil	8020766.0240		Herion
	Ventil za hitri izpuh	EAQ 5000-F04L		
	Ventil za dušenje	T1100C 2800		Herion
	Filtrirna in zmanjševalna postaja	961 DS961		Arca
	Omejitvena stikala	GC UV1Z AH		
5	Spojka cevovoda	Mod.77, DN 150	6341 00005	Victaulic
		Mod.77, DN 250	6341 00007	
		Mod.77, DN 300	6341 00008	

Št.	Ime	Tip	Št. dela	Dobavitelj
6	Regulacijski ventil	BB14G/24G DN 200 PN 16	6970 2411 50	Gestra
7	Varnostni ventil	4335.8752 H2	6970 1170 47	Leser
8	Regulator tlaka	Mod.42H-30	6915 2940 99	Mobrey
9	Termometer s prikazovalnikom	TMVT	6915 2585 06	Rueger
	Mazanje			
10	Glavna oljna črpalka	Trilub 80R36	6970 2267 40	Allweiler
11	Hladilnik za olje	OK13 H140	6970 3014 49	Oeltechnik
12	Oljni filter	DU 251.10VG DN 50 PN 32	6970 2758 86	Internormen
13	Grelec	HF-4,5	6970 2897 85	Elmess
14	Lovilnik megle iz posode za olje	FF2-066	6970 2682 99	Franke
15	Diferencialni manometer	702.02-E-BBG	6970 2578 37	Wika
16	Regulator temperature	M40D8A110-52 DN 40 PN 16	6970 2125 06	MVA
17	Nadtlačni ventil	RSN 1,6-5	6970 2102 37	Rickmeier
18	Regulacijski ventil	RK41 DN 40 PN 16	6970 0802 62	Gestra
		RK41 DN 50 PN 16	6970 0802 63	
	Level switch	SNK 3	6970 2493 38	Stauff

Št.	Ime	Tip	Št. dela	Dobavitelj
	MCR			
19	Uporovni termometer	2PT100	6915 2910 88	AC
20	Proksimitor	3300 RAM	1420 1126 25	Comptec
	Tipalo položaja	330905-00-13	1420 1126 21	Bentley Nevada
	Tipalo vibracij	330905-00-25	1420 1126 22	
		330930-065-00	1420 1126 23	
	Oddajni za položaj	991-25-70-02-01	1420 1126 26	
	Oddajnik vibracij	990-05-70-02-01	1420 1126 25	
21	Tlačno stikalo	PA36K	6970 1036 75	Georgin
22	Spreminjevalec tlaka	PMP71	6970 3086 51	Endress+Hauser
		PMP71	6970 3086 69	
		PMP71	6970 3086 70	
		PMP71	6970 3086 71	
		PMP71	6970 3086 72	
		PMP71	6970 3086 73	
		PMD75	6970 3086 74	
		PMD75	6970 3086 86	
23	Postaja za oskrbo z zrakom	42H-30	6915 2940 99	Mobrey
24	Controller	Protronic 550	6970 3129 24	ABB

*) za kalibracijo poglejte seznam nastavitvenih točk