Technical Documentation
Exhaust Gas Turbocharger
Operating Manual

C1

Exhaust gas turbocharger NR12/RS

D36 6667-1 E

MAN B&W Diesel Aktiengesellschaft • 86224 Augsburg, Germany • Phone +49 821 322 0 • Fax +49 821 322 3382

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Categories of information

- Information
- Description
- Instruction
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Intended for ...

- Experts
- Middle management
- Upper management

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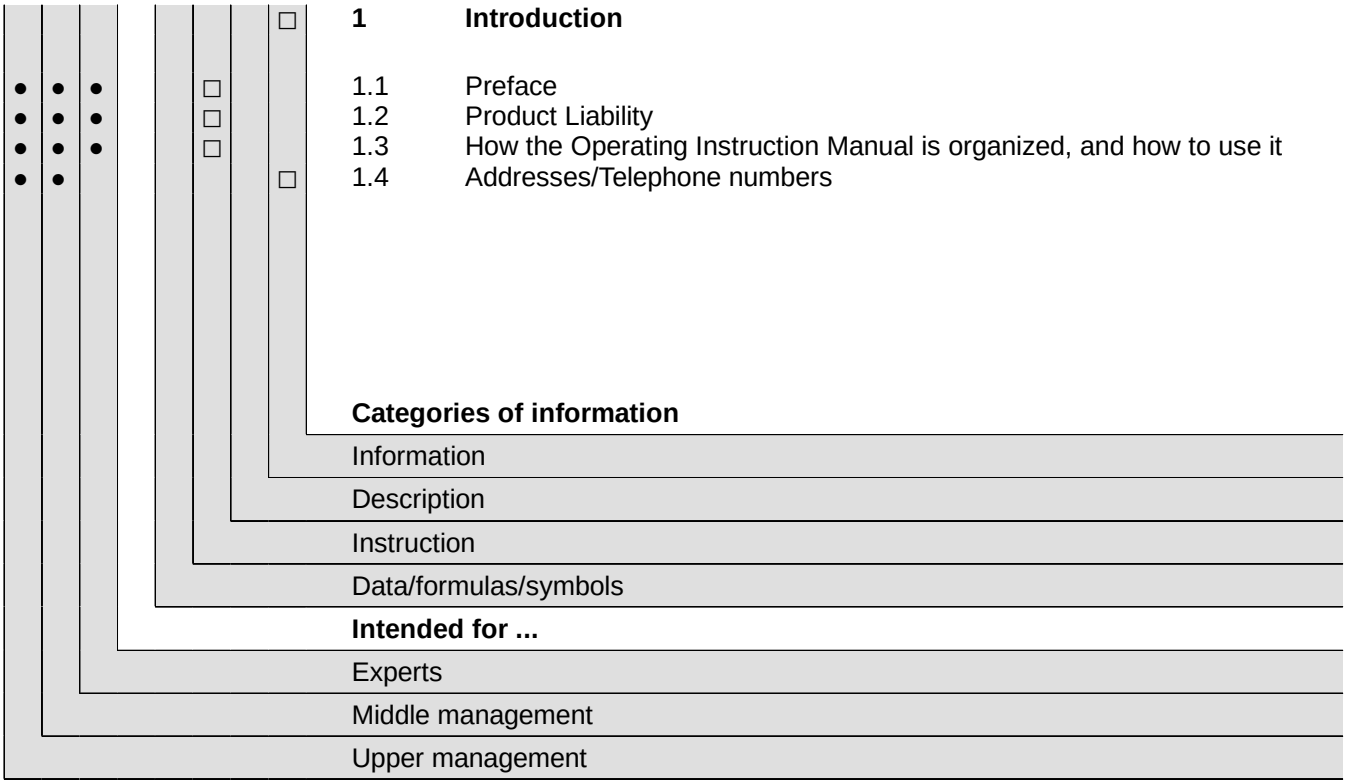

Characteristics of turbochargers, justified expectations, prerequisites

Turbochargers produced by MAN B&W Diesel AG have evolved from periods of continuous, successful research and development work. They satisfy high standards or performance and have ample redundancy of withstanding adverse or detrimental influences. However, to meet all the requirements of practical service, they have to be used to purpose and serviced properly. Only with these prerequisites can unrestricted efficiency and long useful life be expected.

Purpose of the operating manual and work cards

The operating manual as well as the work cards are thought to assist you in becoming familiar with the turbocharger and the equipment. They are also thought to provide answers to questions that may turn up later on, and to serve as a guidance in your activities of engine operation, checking and servicing. Furthermore, we attach importance to familiarising you with the functions, relations, causes and consequences, and to conveying the empirical knowledge we have. Not the least, in providing the technical documentation including the operating manual and work cards, we comply with our legal duty of warning the user of the hazards which can be caused by the turbocharger or its components - in spite of a high level of development and much constructive efforts - or which an inappropriate or wrong use of our products involve.

Condition 1

The technical management and also the persons in charge of servicing works (possibly on order) have to be familiar with the operating manual and work cards. These should all times be available.

▲▲ ***Caution! Missing information and disregard for information can cause injury to persons, damage to property and the environment.***
Please read the operating manual and work cards.

Condition 2

The servicing and overhaul of turbochargers will in each case require previous training of the personnel in charge. The level of knowledge that is acquired during such training is a prerequisite to using the operating manual and work cards. No warranty claims can be derived from the fact that a corresponding note is missing in these.

▲▲ ***Caution! Untrained persons can cause injury to persons, damage to property and the environment.***
Never give orders which may exceed the level of knowledge and experience. Access must be denied to unauthorised personnel.

Condition 3

The technical documentation is valid for one certain order only. There can be considerable differences to other plants. Informations valid in one case can lead to problems in others.

▲ ***Attention! Technical documents are valid for one certain order only. Using information of another order or from foreign sources can lead to disturbances/damages.***
Only use the correct information, never use information from foreign sources.

To be observed as well ...

Please observe also the notes on product liability given in the following section and the introductional passages and safety regulations in Section 3.

Product Liability 1.2

The reliable and economically efficient operation of a propulsion system (inclusive turbocharger) requires that the operator has a comprehensive knowledge. Similarly, proper performance can only then be restored by maintenance or repair work if such work is done by qualified specialists with the adequate expertise and skill. Rules of good workmanship have to be observed, negligence is to be avoided.

This Technical Documentation complements these faculties by specific information, and draws the attention to existing dangers and to the safety regulations in force. MAN B&W Diesel AG asks you to observe the following:

▲▲ ***Caution!*** ***Neglection of the Technical Documentation, and especially of the Operating Instructions, Work Cards and Safety Regulations, the use of the system for a purpose other than intended by the supplier, or any other misuse or negligent application may involve considerable damage to property, pecuniary damage and/or personal injury, for which the supplier rejects any liability whatsoever.***

How the Operating Instruction Manual is organized, and how to use it 1.3

Instructions for use

The operating manual contains written and illustrated information that is both generally useful and specially significant. This information is thought to supplement the knowledge and faculties which the persons have who are entrusted with

- the operation,
- the control and supervision,
- the maintenance and repair

of the engine. The conventional knowledge and practical experience alone will not be adequate.

The operating instructions should be made available to these persons. The people in charge have the task to familiarise themselves with the composition of the operating manual so that they are able to find the necessary information without lengthy searching.

We attempt to render assistance by a clearly organised composition and by a clear diction of the texts.

Structure and special features

The operating instruction manual mainly consists of the sections

1 Introduction
2 Technical details
3 Operation/Operating media,
4 Maintenance/Repair

The operating manual is limited to the vital subjects. It mainly focuses on:

- Understanding the functions/coherences;
- operating it in routine and emergency modes;
- ensuring operational prerequisites on the turbocharger and the peripheral systems, and
- Maintaining the operability of the turbocharger/engine, carrying out preventive or scheduled maintenance work, doing unsophisticated repair work, and contracting and supervising more difficult work.

The manual does not deal with:

- The moving and erection of the turbocharger,
- Steps and checks when putting the engine into operation for the first time,
- Difficult repair work requiring special tools, facilities and experience and the
- Behaviour after fire, inrush of water, severe damage and average.

What is also of importance

The sheet “Scope of supply”

The content of the operating manual and structural details of it can be seen at a glance from the table of contents. We would like to draw your particular attention to the sheet “Scope of supply” in Section 2. The sheet named “Scope of supply” lists and briefly describes all the items that were supplied by MAN B&W Diesel AG. This sheet shows for which components you may expect to receive assistance and spare parts supplies from us. This is the scope to which our information, our maintenance schedules and specifications refer to. Where problems are encountered with systems for which we have supplied but a few items, it will possibly be more helpful to consult the system supplier directly, unless MAN B&W’s scope of supply is mainly concerned, or similar, obvious reasons apply.

Turbocharger design

The operating manual will be continually updated, and matched to the design of the engine as ordered. There may nevertheless be deviations between the sheets of a primiarily describing/illustrating content and the definite design.

Technical details

Technical details of your engine are included in

- the “Technical Data” in Section 2,
- in the work cards in Volume C2, and
- the test run or commissioning certificate included in Volume C5.

Maintenance schedule/ work cards

The maintenance schedule (turbocharger) is closely related to the work cards of Volume C2. The work cards describe how a job is to be done, and which tools and facilities are required for doing it. The maintenance schedule, on the other hand, gives the periodical intervals and the average requirements in personnel and time.

Addresses/Telephone numbers 1.4

Addresses

Table 1 contains the addresses of Works of the MAN B&W Diesel Aktiengesellschaft.

The addresses of MAN B&W service centers, agencies and authorised repair workshops can be looked up in the brochure **“Diesel and Turbocharger Service Worldwide”** from the MAN B&W Diesel Aktiengesellschaft.

MAN B&W Diesel AG

Company	***Address***
Work Augsburg	MAN B&W Diesel Aktiengesellschaft 86224 Augsburg Germany Phone +49 821 322 0 Fax +49 821 322 3382
– Engine Service	MAN B&W Diesel Aktiengesellschaft 86224 Augsburg Germany Phone +49 821 322 3930 Fax +49 821 322 3838
– Turbocharger Service	MAN B&W Diesel Aktiengesellschaft 86224 Augsburg Germany Phone +49 821 322 3994 Fax +49 821 322 3998
Work Hamburg	MAN B&W Diesel Aktiengesellschaft Service Center Werk Hamburg Rossweg 6 20457 Hamburg Germany Phone +49 40 7409 0 Fax +49 40 7409 104
Technical Branch Office Hamburg	MAN B&W Diesel Aktiengesellschaft Vertriebsbüro Hamburg Admiralitätstraße 20459 Hamburg Germany Phone +49 40 378515 0 Fax +49 40 378515 10

Table 1. Companies and addresses of the MAN B&W Diesel Aktiengesellschaft

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MAN B&W Diesel AG's
Scope of Supply/Technical Specification 2.1.1

For all items supplied by us ...	For all questions you have on items supplied by us, please contact ● MAN B&W Diesel AG in Augsburg, and for typical service questions, ● MAN B&W service centers, ● agencies and ● authorised repair workshops all over the world.
For all items not supplied by us ...	For all items not supplied by us, please directly contact the subsuppliers, except the components/systems supplied by MAN B&W Diesel AG are concerned to a major extent or similar, obvious reasons apply.
Technical Specification	The order confirmation, technical specification related to order confirmation and technical specification of the turbocharger contain supplementary information.

Exhaust gas turbocharger
Brief description, function 2.2.1

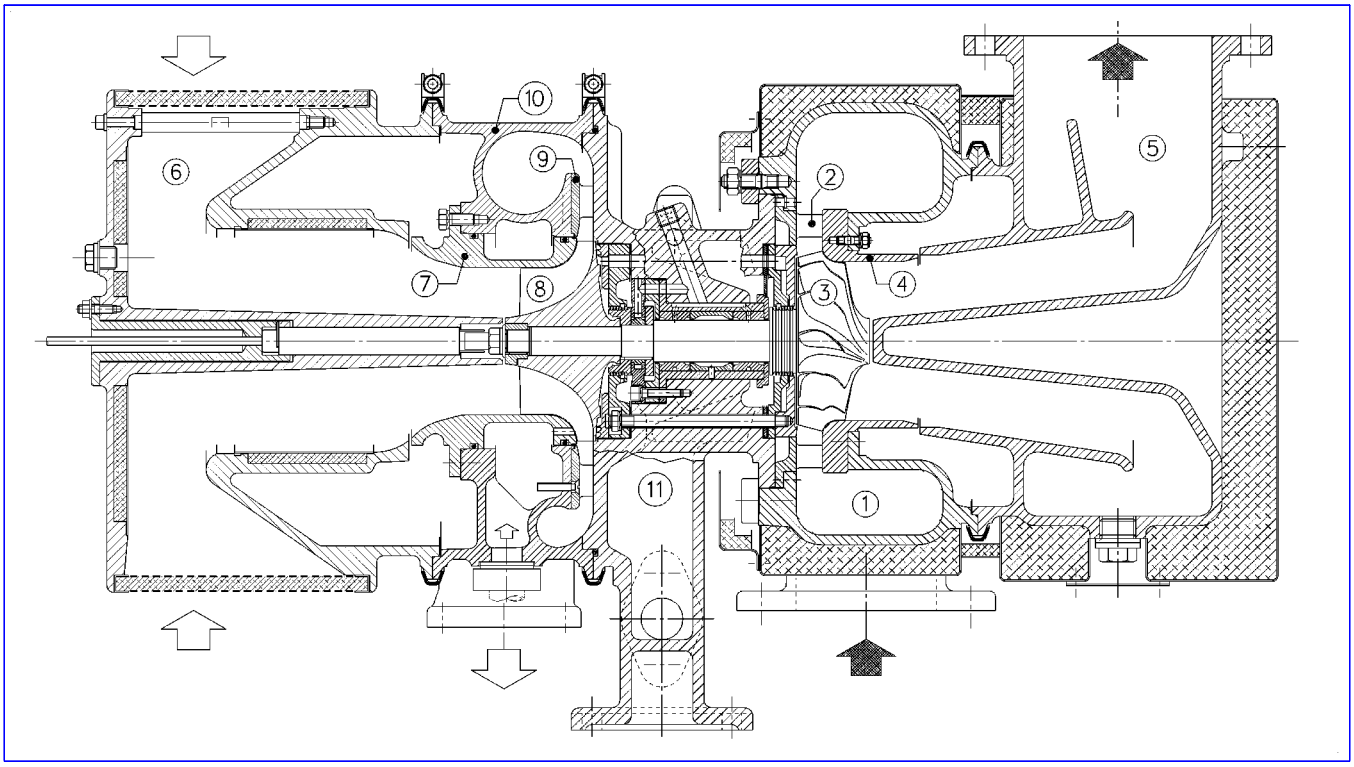


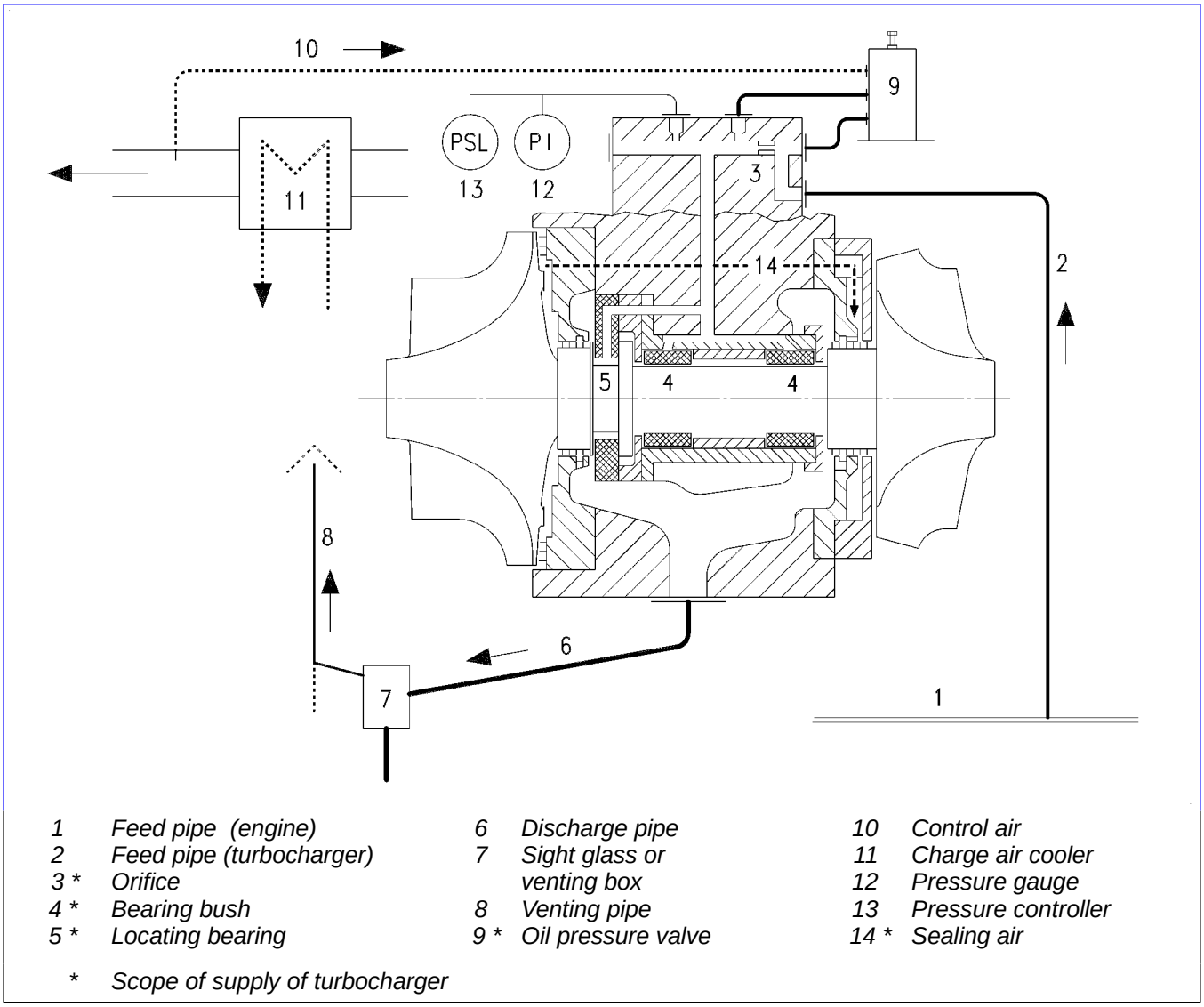
Figure 1. Exhaust gas turbocharger NR12/RS

Brief description

Turbocharger with one radial–flow turbine stage and one radial–flow compressor stage.
Rotor supported on 2 floating bearing bushes and one locating bearing arranged inboard.
Turbine wheel (3) with shaft in one integral piece, compressor wheel (8) mounted on shaft.
Compressor (10) with one outlet socket.
Silencer (6), or air intake casing (if provided).
Bearing lubrication integrated in engine lube oil circuit.
No water cooling. Casings on turbine side with heat insulation.

Function

In operation the engine exhaust gases drive the turbocharger rotor by converting the exhaust gases into energy. The exhaust gases flow from the engine exhaust pipe through the turbocharger via the gas–admission casing (1), turbine nozzle ring (2), turbine wheel (3), insert (4) and gas outlet casing (5) with integrated gas outlet diffuser. Simultaneously, fresh air is drawn in via the silencer (6) or air intake casing and insert (7) and compressed via compressor wheel (8), diffuser (9) and compressor casing (10). Via intercooler and charging air pipe the compressed air is pressed into the engine cylinders.
Generally this process achieves a tremendous increase in the performance of the engine. Flow areas and directions of flow are adjusted to the individual application.
The turbocharger Rotor is guided in radial direction through 2 floating bearing bushes arranged between turbine wheel (3) and compressor wheel (8) in the bearing casing (11). The locating bearing on the compressor side serves both for axial positioning and for taking the axial thrust.
The turbocharger bearings are lubricated by the lube oil circuit of the engine via a common feed pipe. The lube oil serves as well for the cooling of the bearings.



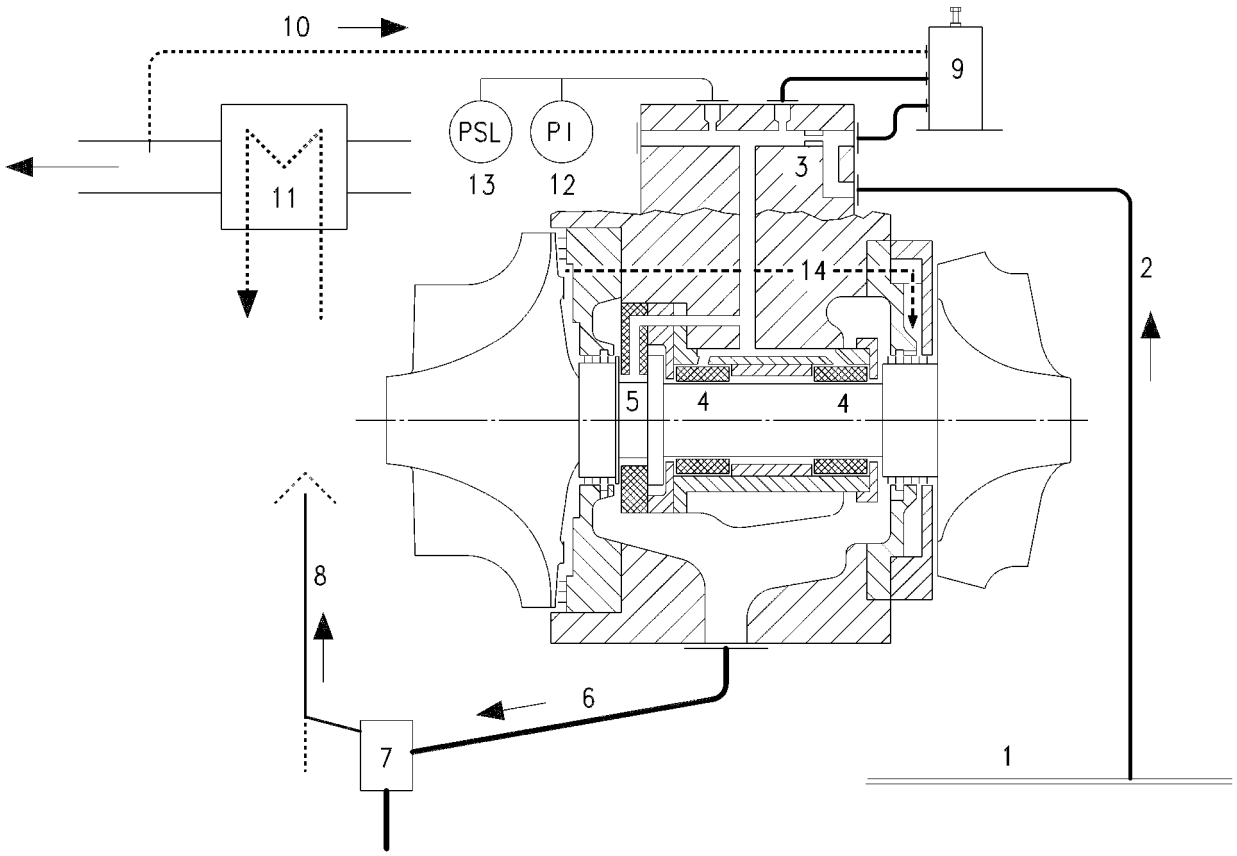
1	*Feed pipe (engine)*	*6*	*Discharge pipe*	*10*	*Control air*
2	*Feed pipe (turbocharger)*	*7*	*Sight glass or venting box*	*11*	*Charge air cooler*
*3 **	*Orifice*			*12*	*Pressure gauge*
*4 **	*Bearing bush*	*8*	*Venting pipe*	*13*	*Pressure controller*
*5 **	*Locating bearing*	*9 **	*Oil pressure valve*	*14 **	*Sealing air*

* *Scope of supply of turbocharger*

Figure 1. Lube oil system NR12/RS

Lube oil system

The turbocharger rotor is guided in radial direction through 2 floating bearing bushes (4) arranged between turbine wheel and compressor wheel in the bearing casing. The locating bearing (5) on the compressor side serves both for axial positioning and for taking the axial thrust.
The turbocharger bearings are lubricated by the lube oil circuit of the engine via a common feed pipe (2). The necessary lube oil pressure is to be adjusted by an installed orifice (3) at the entry of the bearing casing. The lube oil serves as well for the cooling of the bearings.



1	*Feed pipe (engine)*	*6*	*Discharge pipe*	*10*	*Control air*
2	*Feed pipe (turbocharger)*	*7*	*Sight glass or venting box*	*11*	*Charge air cooler*
*3 **	*Orifice*			*12*	*Pressure gauge*
*4 **	*Bearing bush*	*8*	*Venting pipe*	*13*	*Pressure controller*
*5 **	*Locating bearing*	*9 **	*Oil pressure valve*	*14 **	*Sealing air*

* *Scope of supply of turbocharger*

Figure 2. Lube oil system NR12/RS (coincident as figure 1)

Lube oil pressure

The measuring connection at the top of the bearing casing is to be used for controlling and monitoring the lube oil pressure.
By adaption of the orifice (3), the lube oil pressure is to be adjusted so that a pressure of 0.6 ± 0.1 bar prevails at this point at a charge air pressure below 1 bar (engine load lower than 25 %) and with the lube oil at service temperature (inlet temperature max. 75 °C).
The oil pressure valve (9) is adjusted to an opening pressure of 1 bar. If the charge air pressure exceeds 1 bar by an increase of the engine load, this valve will be opened through the control air (10).
At full engine load and with the lube oil at service temperature a lube oil pressure of 1.5 ± 0.2 bar must then be available.
On start-up and during heating up of the engine, when the lube oil temperature is relatively low, a lube oil pressure of up to 2.0 bar is admissible for a short period of time.

Control air

The control air should be taken off downstream of the charge air cooler (11). The take-off point must be protected against the ingress of condensate and dirt. Therefore, it should be located in the upper area of the charge air duct. The pipe should extend about 30 mm into the charge air duct in order to avoid the entering of dirt and water which is blown along the wall of the duct.

Differences in height

Differences in height between the indicating instrument and turbocharger centreline must be made allowance for with ± 0.1 bar per 1 m difference.
Example: If the pressure gauge (12) and/or the pressure controller (13) is located 3 metres lower, the pressure gauge must indicate a by 0.3 bar higher pressure

and/or the setting of the pressure controller must by 0.3 bar be higher than the operating pressure specified above.

Alarm, engine shut-down

With charge air pressures higher than 1 bar the alarm point for lube oil pressure is to be adjusted to a value of 1.0 bar. When an alarm is triggered, the engine performance has to be reduced simultaneously (without delay) to half load (engine slow-down). If the oil pressure continues to drop, the engine is to be stopped and the causes are to be remedied.

- Engine shut-down at 0.8 bar oil pressure, if charge air higher than 1 bar
- Engine shut-down at 0.4 bar oil pressure, if charge air below 1 bar

If it is not allowed to stop the engine for an important reason, damages of the turbocharger are to be expected.

Lube oil flow rate

The required lube oil flow rate depends on the viscosity of the lube oil and may differ from that stated in the Operating data (see sheet 2.5.2).

Lube oil quality

The plain bearings are rated for use of standard engine lube oils SAE30 or SAE40 and can therefore be directly connected to the lube oil system of the engine.

Lube oil filtration

The turbocharger does not require its own lube oil filter. The filtration which nowadays is the standard for engines is adequate, provided that the fineness is smaller than/equal to 0.05 mm. A precondition is that the engine lube oil is permanently treated by separation and excessive concentrations of water of more than 0.2 % portion by weight and solid residues larger than 0.02 mm are avoided. Prior to initial operation of the engine or after major servicing work, the pipes between the filter and turbocharger are to be cleaned, pickled and flushed carefully.

Priming

Prior to engine start-up, the bearings of the turbocharger must be primed, which, depending on the lube oil system of the engine system, is done by priming immediately prior to start-up, or by interval or continuous priming.

Post lubrication

For cooling the plain bearings, the turbocharger has to be lubricated after engine stop with a lube oil pressure of min. 0.3 bar. The engine lube oil pumps or the auxiliary pumps must therefore continue running for 10 ... 30 minutes.

Lube oil drain

The discharge pipe (6) should have a gradient as steep as possible, and it should be amply dimensioned and free of resistances and back pressures. On ships, the inclination of the line should be not less than 5° more than the maximum possible inclination of the vessel.
The oil discharge pipe must have a venting facility from a sufficiently large compartment permitting the oil to settle down, e.g. a sight glass/venting box (7). The cross section of the venting pipe (8) should be approximately that of the oil discharge pipe (6).

Shaft sealing

The oil space is sealed on the turbine and compressor sides by labyrinths fitted on the rotor shaft. The radial labyrinth clearance should be such that the rotating labyrinth tips slightly dig into the softer sealing cover layer. At higher speeds, the rotor is slightly lifted corresponding to the lubricating film, so that the labyrinth tips come clear. The rotor will be lowered when the turbocharger stops. The labyrinth tips will then come down into the grooves in the sealing covers, providing better sealing during priming. Local running-in grooves in the bore of the sealing covers are therefore desirable and no reason for replacement of parts.

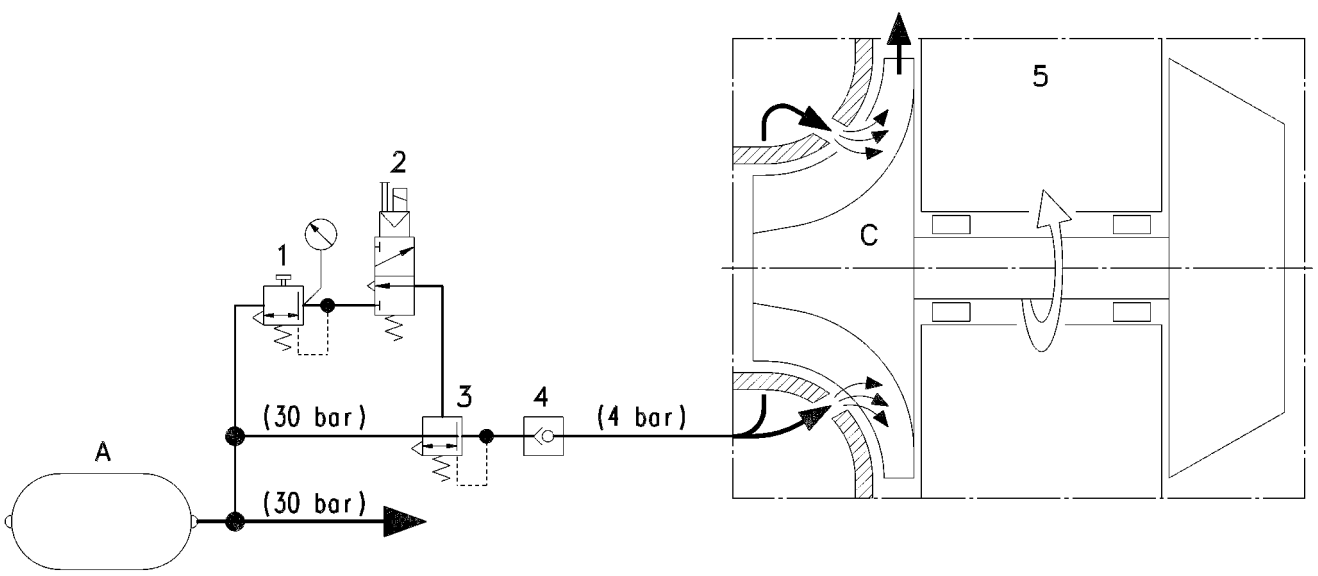
Sealing air

For the shaft sealing on turbine side, sealing air (compressed air) is additionally required:

- against entry of exhaust gas into the oil space,
- against trickle of lube oil into the turbine (oil coke)

During operation, the sealing air (14) is withdrawn downstream of the compressor wheel and led to the labyrinth seal on the turbine side via ducts drilled into the bearing casing.

Acceleration system
”Jet Assist” 2.4.7



1 Pressure reducing valve
2 3/2-way solenoid valve
3 Control valve
4 Non-return valve
5 Turbocharger
A Starting air bottle (30 bar)
C Compressor wheel

Figure 1. System “Jet Assist”

Accelerator “Jet Assist”	The accelerator “Jet Assist” is used where special demands exist regarding fast and virtually soot-free acceleration and/or load application.
System description	In such cases, compressed air is drawn from the starting air bottles (A) and reduced from 30 bar to a maximum pressure (gauge) of 4 bar, and then passed into the compressor casing of the turbocharger (5) to be admitted to the compressor wheel (C) via inclined bored passages of the insert. In that way, additional air is supplied to the compressor which in turn is accelerated, thereby increasing the charge air pressure.
Control	Operation of the accelerator ”Jet Assist” is initiated by a control, and limited to a fixed load range.
System “Jet Assist”	System “Jet Assist”, please refer to the figure 1.

Relation of the Turbocharger/engine

Turbocharger Type	***Engine*** Type	*Rating* [kW]	*Speed* [rpm]
NR12/RS01	5L 16/24	500	1 200
NR12/RS02	6L 16/24	540	1 000
NR12/RS03	6L 16/24	600	1 200
NR12/RS04	7L 16/24	630	1 000

Type plate of the turbocharger

Type: NR12/RS01, NR12/RS02, NR12/RS03, NR12/RS04

Works-No. ..... refer to the type plate (mounted at the pressure socket of the compressor)

Maximum admissible speed (operating limit) n_{max} ..... 75,000 [rpm]

Maximum admissible exhaust gas temperature before turbine (operating limit) t_{max} ..... 650 [°C]

Further data

Display range of the speed transmitter: 0 ... 75,000 [rpm]

Operating speed of the turbocharger: refer to the Acceptance Records of the turbocharger

Further operating data: refer to the Acceptance Records and Operating Manual of the engine

Operating data, temperatures, pressures 2.5.2

Lube oil

Selection of lube oil	SAE-class	SAE 30 or SAE 40	
Filtration of lube oil	grade of filtration smaller than	0.05	mm
Operating temperatures	maximum permissible oil admission temperature		
	at full engine load	75	°C
Operating pressure	using SAE 30 at 60° C or SAE 40 at 65° C		
	(reference measuring point on turbocharger centreline)		
	with charge air pressure up to 1 bar	0.6 ± 0.1	bar
	with charge air pressure higher than 1 bar	1.5 ± 0.2	bar
Flow rate of lube oil	using SAE 30 at 60° C or SAE 40 at 65° C	660	l/h
Further remarks	refer also to the “Lube oil system”, sheet 2.4.1		

Weights

Weights assigned to assemblies/components (approximate values)

500	Exhaust gas turbocharger, complete with silencer	155	kg
501	Gas-admission casing, complete (with covering)	26	kg
506	Gas outlet casing, complete (with covering)	38	kg
513	Turbine nozzle ring	2	kg
517	Bearing casing, complete	31	kg
520	Rotor complete (turbine rotor .... 2.7 kg, compressor wheel ... 1.0 kg)	4	kg
540	Insert, compressor side	6	kg
541	Insert, turbine side	6	kg
542	Diffuser	3	kg
544	Silencer, complete	20	kg
546	Compressor casing, complete	22	kg
599	Cartridge, complete (517 + 520)	35	kg

Pipe connections

Exhaust gas	Entry at the gas-admission casing (501)	mm	105 dia.
	Outlet at the gas outlet casing (506)	mm	290 x 135
	Outlet at the gas outlet casing (506) with counter flange (593)	mm	276 dia.
Charge air	Outlet at the compressor casing (546)	mm	88 dia.
Lube oil	Inlet laterally at the bearing casing (517) flange connection for pipe	mm	15 x 1.5
	Drain laterally at the bearing casing (517) flange connection for pipe	mm	30 x 2.0
Additional lubrication (if provided)	Inlet at the top of the bearing casing (517) for pipe	mm	6.0 x 1.0
Jet assist (if provided)	Connection laterally at the compressor casing (546) flange connection for pipe	mm	25 x 2.0

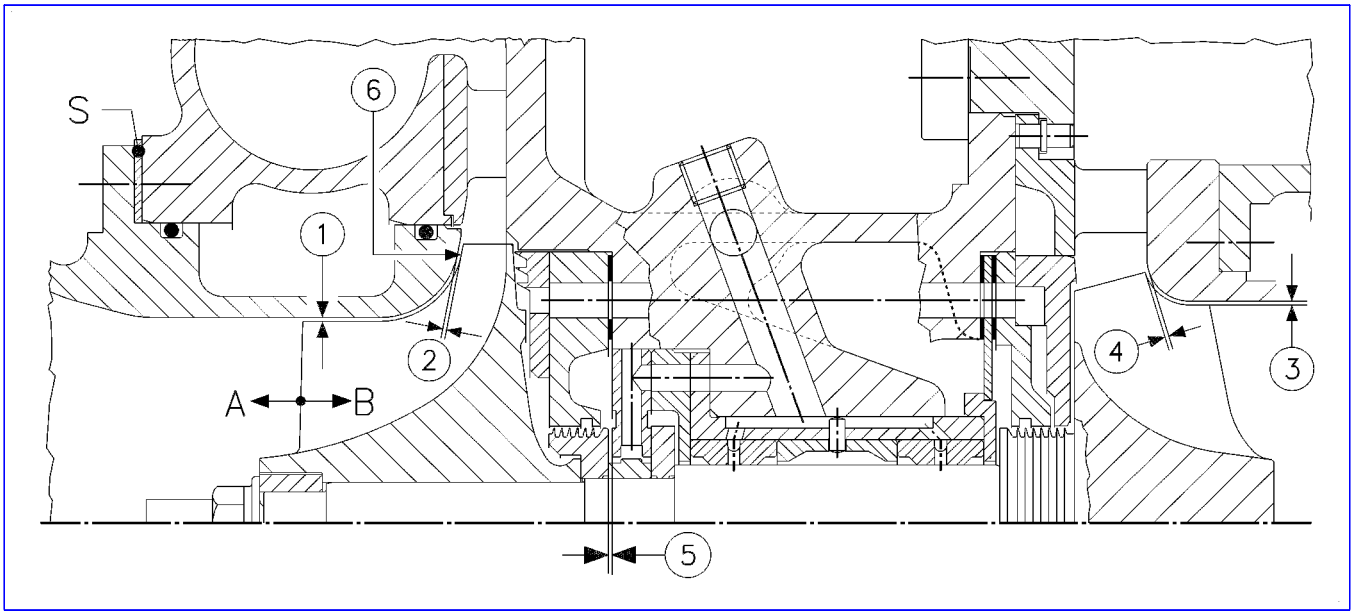


Figure 1. Gaps and clearances

Item No.		Designations of parts	Order No.		When new		Replace or remachine parts	
					min [mm]	max [mm]	min [mm]	max [mm]
1	a)	Compressor wheel Insert	(520.005) (540.001)	Radial gap	0.30	0.40	0.20	0.50
2	b) c)	Compressor wheel Insert	(520.005) (540.001)	Axials gap	0.15	0.30	0.10	0.40
3	a)	Turbine rotor Insert	(520.001) (541.001)	Radial gap	0.30	0.40	0.20	0.50
4	d)	Turbine rotor Insert	(520.001) (541.001)	Axials gap	0.05	0.60	---	0.70
5	e)	Locating bearing Labyrinth ring	(517.002) (520.006)	Axial clearance	0.19	0.21	---	0.28
6		Compressor wheel	(520.005)		admissible aberration from the plane of rotation (face runout) ..... 0.06 mm			

a) Using feeler gauge, measure at 4 points on the circumference and calculate mean value.

b) Measure by means of soft metal imprint (lead wire) at 3 points on the circumference and calculate the mean value. Deduct the measured axial clearance (5) from calculated mean value with the rotor pushed up in direction (B).

c) Adjustable by remachining or by shim at balance ring (S).

d) Measure by means of soft metal imprint (lead wire) at 3 points on the circumference and calculate the mean value. Deduct the measured axial clearance (5) from calculated mean value with the rotor pushed up in direction (B).

e) Using the dial gauge, measure while vigorously moving the rotor in the directions (A) and (B). In case of labyrinth seals already run in it might be possible that the measured value is smaller.

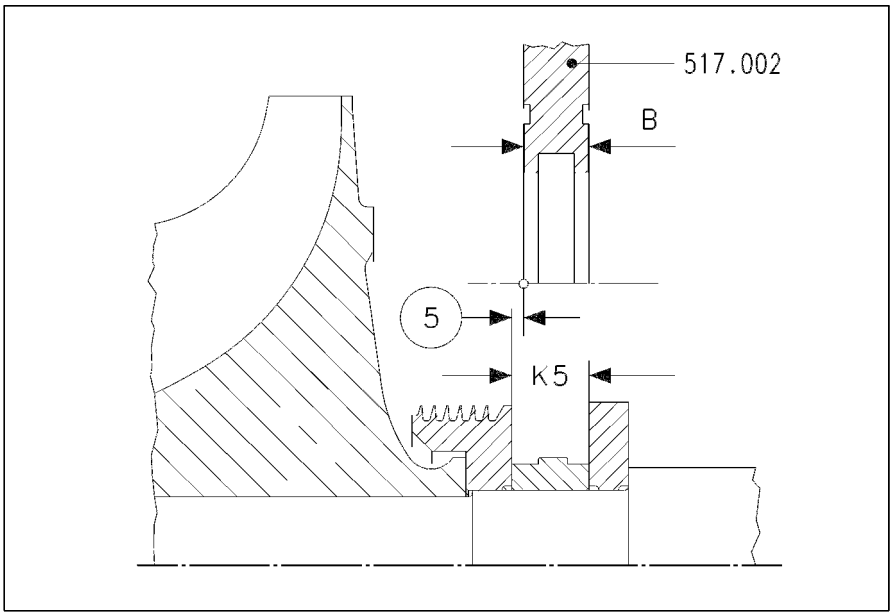


Figure 2. Exact measurement of the axial clearance (5)

Exact mesurement of the axial clearance (5)

1. Measure the distance (K5) and note down.
2. Measure the width (B) of the locating bearing (517.002) and note down.
3. Axial clearance (5): actual value = (K5) – (B).

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Data/formulas/symbols

Intended for ...

Experts

Middle management

Upper management

Prerequisites dating back into the past

Some of the prerequisites for successful operation of the engine/engine plant are already dating back into the past when the phase of day-to-day operation commences. Other prerequisites can, or have to be directly influenced.

The factors that are no longer accessible to direct influence, are

- the source of the engine,
- qualified manufacture including careful controlling under the eyes of control boards/classification societies,
- reliable assembly of the engine and its exact tuning during the trials.

The factors dating back into the past and having effects on future performance also include

- the care invested in the planning, layout and construction of the system,
- the level of cooperation of the buyer with the projecting firm and the supplier, and
- the consistent, purpose activities during the commissioning, testing and breaking-in phases.

Day-to-day prerequisites

The prerequisites directly required for day-to-day operation and to be provided for again and again are, for example

- the selection of appropriate personnel and its instruction and training,
- the availability of technical documentation for the system, and of operating instructions and safety regulation in particular,
- ensuring operational availability and reliability, in due consideration of operational purposes and results,
- the organisation of controlling, servicing and repair work,
- the putting into operation of systems, ancillaries and engines in accordance with a chronologically organised checklist, and
- definition of the operating purposes, compromising between expense and benefit.

Detailed information on the above items is given in the following.

Preliminary remarks

Personell	The engine and the systems required for its operation may only be started, operated and stopped by authorised personell. The personell has to be trained for this purpose, possess complete understanding of the plant and should be aware of the existing potential risks.
Technical documentation	The personnel must be familiar with the technical documentation of the plant, in particular the operating manual of the engine, the turbocharger and the accessories requiered for engine operation, particularly the safety regulations contained therein.
Service log book	It is advisable to keep a service log book into which all the essential jobs and deadlines for their performance, the operating results and special events can be entered. The purpose of this log book is that in the event of a change in personnel the successors are in a position to duly continue operation using this data log. Moreover, the log book permits to derive a certain trend analysis and to trace back faults in operation.
Accident prevention regulations	The accident prevention regulations applicable for the plant should be observed during engine operation as well as during maintenance operations and overhauls. It is advisable to post those regulations conspicously in the engine room and to stress the danger of accidents over and over again.
Warranty claims	The given advices does not claim to be complete. Safety requirements mentioned in other passages of the technical documentation are supplementarily valid and are to be observed in the same way. Please also note that incorrect behaviour might result in the loss of warranty claims.

Containment safety

Extraordinary influences	The turbocharger is one of the highest loaded components in modern diesel engines. The high rotor speeds of a turbocharger result in high centrifugal force stresses at simultaneous high component temperatures. A consequence of additional extraordinary influences might be – in extremlely rare cases – a failure of the components.
Precautions	MAN B&W turbochargers correspond to the required containment safety according to the rules stipulated by the classification societies so that the state of the art prevents fragments from escaping. In extrem cases, particularly if the turbocharger has not been sufficiently or properly maintained, there may be the risk of damages to persons or property in vicinity of the turbocharger. To eliminate residual risks we kindly ask you to observe following rules: ● Persons are by no means allowed to stay without any reason near the operating turbocharger. ● Turbine and compressor are to be cleaned at regular intervals as specified in the operating manual.

- The maintenance of the turbocharger must be carried out by trained personnel as well as in the maintenance intervals as stipulated in the operating manuals.
- Inadmissible operating conditions, such as frequent load releases, compressor surging, excessive turbocharger speeds, must be avoided.
- Corrosive and erosive media in the intake air are to be avoided.

Precautions

Opening of pipes/pressure vessels	Before opening pipes, flanges, screwed connections or fittings, check if the system is depressurised respectively emptied. ▲ ***Attention! Disregarding this means: risk of burns when hot fluids are involved, fire hazard in case of fuel, injuries caused by flung-out screw plugs or similar objects when loosening same under pressure.***
Disassembling/assembling pipelines	In case of disassembly, all pipes to be reinstalled, especially those for fuel oil, lube oil and air, should be carefully locked. New pipes to be fitted should be checked whether clean, and flushed if necessary. It should in each case be avoided that any foreign matter gets into the system. All parts involved have to be subjected to preservation treatment for prolonged storage.
Removing/refitting of heavy engine components	When removing or detaching heavy engine components it is imperative to ensure that the transportation equipment is in perfect condition and has the adequate capacity of carrying the load. The place selected for depositing must also have the appropriate carrying capacity. This is not always the case with platforms, staircase landings or gratings.
Coverings	Following assembly work, check whether all the coverings over moving parts and laggings over hot parts have been mounted in place again. Engine operation with coverings removed is only permissible in special cases, e.g. if the valve rotator is to be checked for proper performance. ▲ ***Attention! Loose clothing and long hair might get entangled. Spontaneous supporting against moving parts when loosing ones balance may result in serious injury. In addition, there is the risk of burning and/or fire.***
Use of cleaning agents	When using cleaning agents, observe the suppliers instructions with respect to use, potential risks and disposal. ▲ ***Attention! Disreagarding this means: danger of caustic skin and eye injury, and also of the respiratory tract if vapours are produced.*** ▲ ***Attention! Using Diesel fuel for cleaning purposes involves the risk of fire or even explosion. Otto fuel (petrol) or chlorinated hydrocarbons must not be used for cleaning purposes.***
Use of high-pressure cleaning equipment	When using high-pressure cleaning equipment, be careful to apply this properly. Air filters, shaft ends including ones with lip seal rings, controllers, splash water protected monitoring equipment, cable entries and sound/heat insulating parts covered by water-permeable materials have to be appropriately coverd or excluded from high-pressure cleaning.
Fire hazard	The use of fuel and lube oils involves an inherent fire hazard in the engine room. Fuel and lube oil pipes must not be installed in the vicinity of unlagged, hot engine components (exhaust pipe, turbocharger). After carrying out overhaul work on exhaust gas pipes and turbochargers, all insulations and coverings must be carefully refitted completely. The

tightness of all fuel oil and oil pipes should be checked regularly. Leaks are to be repaired immediately.

Fire extinguishing equipment must be available and is to be inspected periodically.

In case of fire, the supply of fuel and lube oil must be stopped immediately (stop the engine, stop the supply pumps, shut the valves), and the fire must be attempted to be extinguished using the portable fire-fighting equipment. Should these attempts be without success, or if the engine room is no longer accessible, all openings are to be locked, thus cutting off the admission of air to quench the fire. It is a prerequisite for success that all openings are efficiently sealed (doors, skylights, ventilators, chimney as far as possible). Fuel oil rquires much oxygen for combustion, and the isolation from air is one of the most effective measures of fighting the fire.

▲▲▲ ***Danger!*** ***Carbon dioxide fire extinguishing equipment must not be used until it has been definitely ensured that no one is in the engine room. Ignoring this means danger of life!***

Destination/suitability of the turbocharger

Use in accordance with the destination

The delivered turbocharger is destined for (firstly) operation under the marginal conditions stipulated

- under Technical Data, Section 2.5,
- in the scope of supply/technical specification and
- in the order confirmation.

Furthermore destined for (secondly)

- operation using the specified operating media,
- taking into consideration the design/layout of the supply, measuring, control and regulating systems as well as laying down of the marginal conditions (e.g. removal space/crane capacities) in accordance with the recommendations of MAN B &W Diesel AG or according to the state of the art.

Furthermore destined for (thirdly)

- start, operation and stopping of the engine in accordance with the usual organisational rules, exclusively by authorised, qualified, trained persons who are familiar with the plant.

With restrictions destined/suitable for

The turbocharger is with restrictions destined/suitable for:

- operation at operating values resulting in an alarm situation,
- operation in case of failure of supply equipments,
- operation at reduced maintenance expenditures,
- speeded-up acceleration/abrupt loading/unloading to a moderate extent,

Not destined/suitable for

The Turbocharger is not destined/suitable for:

- operation at operating values due to which engine stop or load reduction was effected,
- operation in case of failure of supply equipments,
- operation within barred speed ranges,
- operation without appropriate surveillance/supervision,
- operation without maintenance expenditures or if they have been reduced to a great extent,
- unauthorised modifications,
- use of other than original spare parts,
- long-term shut-down without taking preservation measures.

Dangers due to deficiencies concerning personnel/level of training

Expectations in case of vessel plants	*Propeller operation/generator operation (normal operation/operation in road stead):* Chief engineer on board. Operational control by technical officer. Maintenance work/repair work in the port: To be carried out by engine operator, technical assistants or technicians and helpers. For instructions and in difficult cases: technical officer or chief engineer. *Generator operation (in port):* *Operational control* by technical officer. Maintenance work/repair work in port: As mentioned above.
Supplementary, the following applies	Persons responsible for the operational control must be in possession of a qualification certificate/patent which is in accordance with the national requirements and international agreements (STCW). The number of required persons and their minimum qualification are, as a rule, specified by national requirements, otherwise by international agreements (STCW).
Expectations in case of stationary plants (power plants)	During operation*:* Plant manager (engineer) available. Operational control/supervision of the engine and the belonging supply systems by trained and specially instructed engine operator or technical assistant. Maintenance work/repair work: Execution by engine operator, technical assistants or technicians and helpers. For instructions and in difficult cases: engineer or chief engineer.
Supplementary, the following applies	For persons responsible for the operational control and for persons carrying out/supervising maintenance and repair work, proof must be furnished in Germany in accordance with the power economy law (Energiewirtschaftsgesetz = EnWG) that, among other things, the technical operation is ensured by a sufficient number of qualified personnel. In other countries, comparable laws/guidelines are to be observed. Deficiencies regarding personnel/level of training cannot be compensated by other efforts.

Dangers due to components/systems

Certain dangers do of course originate from technical products and from certain operating conditions or actions taken. This also applies to engines and turbochargers in spite of all efforts in development, design and manufacturing. They can be safely operated in normal operation and also under some unfavourable conditions. Nevertheless, some dangers remain, which cannot be avoided completely. Some of them are only potential risks and some do only occur under certain conditions or in case of unforeseen actions. Others do absolutely exist.

Dangers due to emissions

Emission	*Danger*	*Preventive/protective measure*
Treated cooling water, lube oil, hydraulic oil, fuel	Harmful to skin and noxious, polluts water	Use/dispose in accordance with the instructions of the manufacturers/suppliers
Cleaning agents and aids	According to the manufacturers' specification	Use/dispose in accordance with the instructions of the manufacturers/suppliers
Exhaust gas with the dangerous constituents NO_x, SO_2, CO, HC, soot	Noxious, has a negative effect on the the environment in case the limit values are exceeded	Carry out maintenance work according to the maintenance schedule, maintain danger–oriented operational control, critically observe operating results
Sound	Noxious, has a negative effect on the environment in case the limit values are exceeded	Wear ear protection, restrict exposure to the necessary minimum

Planned working places

Engines are usually operated under remote control. Regular rounds according to the rules of "observation–free operation" are required. In this connection, measurement, control and regulating devices as well as other areas of the plant, which require special attention, are preferably checked. A continuous stay in the immediate vicinity of the running engine/ turbocharger is not planned.

Personal protective measures

The regulations for prevention of accidents (Unfallverhütungsvorschriften = UVV) and other regulations of the proper trade association or other comparable institutions are to be observed without restriction.

This includes wearing of protective working clothing and safety shoes, the use of a safety helmet, safety goggles, ear protection and gloves.

The relevant sections of the technical documentation must be read and comprehended.

Characterisation/danger scale

Characterisation

According to the relevant laws, guidelines and standards, attention must be drawn to dangers by means of safety instructions. This applies to the marking used on the product and in the technical documentation. In this connection, the following information is to be provided:

- type and source of danger,
- imminence/extent of danger,
- possible consequences,
- preventive measures.

The statements in Section 3.2.3 follow this regulation, just as the other safety instructions in the technical documentation do.

Danger scale

The imminence/extent of danger is characterised by a five-step scale as follows:

▲▲▲ ***Danger!*** ***Imminent danger***
Possible consequences:
Death or most severe injuries,
total damage to property

▲▲ ***Caution!*** ***Potentially dangerous situation***
Possible consequences: Severe injuries

▲ ***Attention!*** ***Possibly dangerous situation***
Possible consequences: Slight injuries,
possible damage to property

△△ *Important!* *For calling attention to error sources/handling errors*

△ *Tip!* *For tips regarding use and supplementary information*

Preparations for start, Starting, Stopping

Preparations for start

Turbocharger	Prior to engine start-up, the bearings of the turbocharger must be primed, which, depending on the lube oil system of the engine system, is done by priming immediately prior to start-up, or by interval or continuous priming.
Engine/Turbocharger	Ensure that the shut-off elements of the systems have been set to in-sevice position. Check the lube oil pressure upstream of the turbocharger.

Starting

Turbocharger	The turbocharger is driven by the exhaust gases and starts automatically on engine start.

Stopping

Turbocharger	The rotor of the turbocharger continues rotating for some more time on engine shut-down, due to the flywheel effect. The run-down time of the rotor is indicative of the mechanical condition of the turbocharger. An early stop suggests mechanical damage to the bearings, a touching of the compressor or turbine wheel, a solid object that has got caught somewhere or the like.
Post lubrication	Refer to the lube oil system 2.4.1 of the turbocharger.

Monitoring the turbocharger/routine checks

General

State-of-the-art engine systems are operated automatically as a rule, using intelligent control and regulation systems. Dangers and damage are precluded to a large extent by internal testing routines and monitoring equipment. Regular checks are necessary nevertheless so as to recognise the cause of potential problems as early as possible, and to take remedial action in due time. Moreover, the necessary maintenance work should be done as and when required.

It is the operator's duty to carry out the checks listed below, at least during the warranty period. However, they should be continued on expiry of the warranty term. The expense in time and costs is low as compared to that for remedying faults or damage not recognised in time. Results, observations and actions taken in connection with such checks should be entered in an engine log book. Reference values should be defined so as to make an objective assessment of findings possible.

Regular checks on the turbocharger

The regular checks should include the following measures:

- Turbine speed
- Lube oil pressure upstream of turbocharger
- Lube oil temperature upstream of turbocharger
- Lube oil temperature downstream of turbocharger
- Exhaust gas pressure upstream of turbine
- Exhaust gas temperature upstream of turbine
- Charge air pressure downstream of compressor
- Charge air temperature downstream of compressor
- Exhaust gas, charge–air and oil–carrying pipes and conduits for tightness
- Air filter mat on the silencer for dirt accumulation / saturation
- Turbocharger for quiet running
- Rotor for unimpeded running

Quiet running

Damage to the rotor and bearings is in most cases announced by irregular running due to imbalance or contact of rotating parts. Listening to the running noise of the turbocharger in many cases permits to recognise irregular running at an early time.

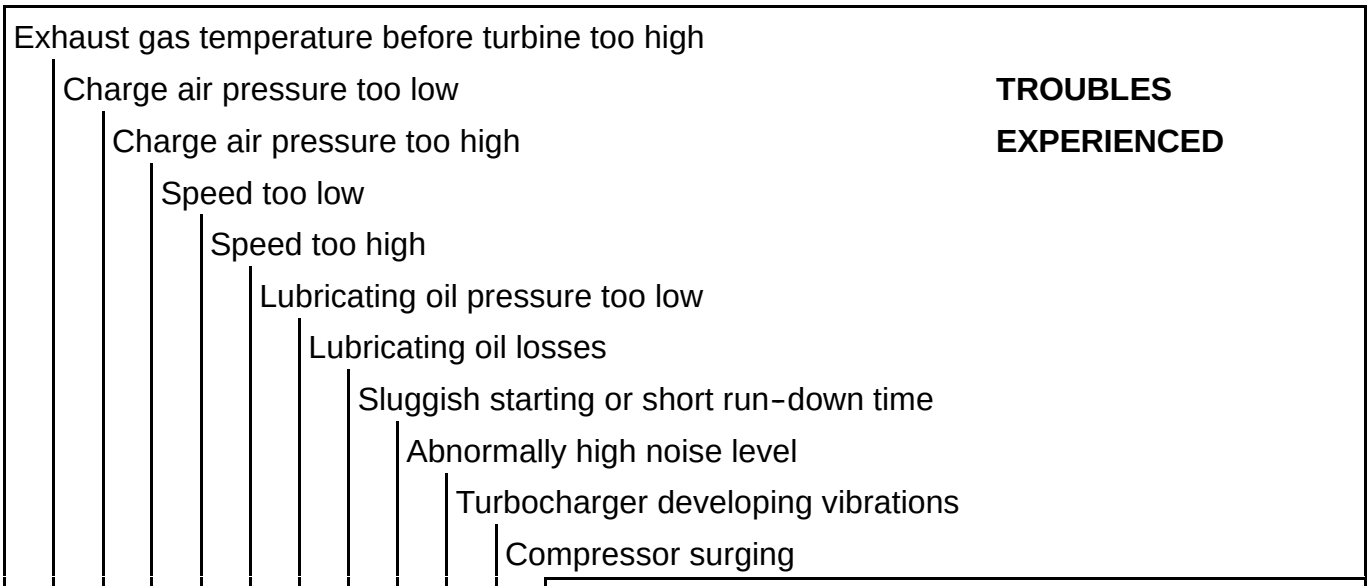
Speed

Provided the air ducts of the compressor are properly clean, a specific charge–air pressure is related to every turbine rotor speed. Therefore it is possible to conclude the rotor speed from the charge–air pressure as a rough method of speed control.

Faults/Deficiencies and their causes (Trouble Shooting) 3.6.1

Preliminary conditions

Operating faults	Operating faults normally manifests itself by abnormal readings (exhaust gas temperature, charge–air pressure and speed), by distinct running noice or by leaks in the oil pipes.
Possible consequential damage	Should anomalies turn up on the turbocharger on starting or during engine operation, the cause is to be traced immediately, if possible, and the fault is to be eliminated. Otherwise, there will be risk of minor initial faults causing consequential damage to the turbocharger, and also to the engine.
First preparations	In case of faults, the engine load should be reduced, if possible, or the engine should be shut down completely and not be restarted before the cause of faults has been eliminated. △ △ *Important! Unsystematic trying out should be avoided because it will lead to success in rare cases only.*
Fault–finding chart	The fault–finding chart (refer to page 2) is thought to contribute to reliably recognising trouble that turns up and finding the cause it is due to, and to taking prompt remedial action.



TROUBLES EXPERIENCED

POSSIBLE CAUSES
Silencer or air filter fouled
Compressor fouled
Turbine wheel heavily fouled
Turbine nozzle ring slightly fouled / narrowed
Turbine nozzle ring heavily fouled / narrowed
Trust ring, labyrinth ring or locating ring damaged
Labyrinth seals defective
Seals damaged, leaking connections
Defective bearings, imbalance of the rotor
Rotor rubbing
Foreign bodies before or in turbine
Foreign bodies before or in compressor
Turbine or compressor wheel damaged
Sealing air ineffective, oil coke behind turbine wheel
Large erosion on turbine wheel/shroud ring, nozzle ring
High air inlet temperature
Low air inlet temperature
Intercooler fouled
Leaking charge air pipe
Charge air temperature too high
Lubricating oil inlet temperature too high
Lubricating oil pressure too high
Dirty lubricating oil filter
Lubricating oil pressure gauge disturbed
Excessive pressure in oil discharge or crankcase
Deposits on inlet or exhaust valves / slots of engine
Leaking exhaust gas pipe
Exhaust gas backpressure after turbine too high
Fuel injection system on engine disturbed

Emergency operation on failure of one turbocharger 3.6.3

Preliminary remarks

Turbochargers are turbo machines subjected to high stresses which must reliably ensure the entire gas renewal performance of the engine at very high speeds and relatively high temperatures and pressures. Like the engine, the turbocharger can also suffer disturbances, despite careful system operation, and emergency operation is also possible in most cases unless the damage can be repaired immediately.

Means available

The following means are availabe for emergency operation of the engine with the turbochargers defective:

NR turbochargers: refer to work card 500.05 in Volume C2

- End cover to close the turbine rear side with the rotor and bearing housing removed (cartidge)

NA turbochargers: refer to work cards 500.05 in Volume C2

- Arresting key to block the rotor from the compressor side (the suction cross-sectional opening remains unclosed) – such a key is also available for NR 34/S,
- end cover to close the compressor and turbine rear side with the rotor dismantled.

All of these elements are so designed that the flow is not obstructed on the air side and exhaust side of the turbocharger.

Means for use on the engine:

- Cover piece (protection grid) for the far end of the turbocharger charge-air pipe (remove the charge-air bypass pipe before if required). This cover piece serves to facilitate suction.
- Blind flange for the exhaust gas pipe at the end opposite the turbocharger (if there is a charge-air bypass). The blind flange serves to lock the exhaust pipe during suction, with the bypass removed.
- In the case of V-type engines, depending on the layout of charge-air and exhaust pipes on the engine, blind flanges for the charge-air pipe socket and exhaust pipe socket (charge air side: downstream of the compressor, exhaust gas side: upstream of the turbine). These blind flanges serve to prevent wrong switching/backflow/leakage in emergency operation.

Emergency operation with one or both turbochargers failing

The following possibilities exist if the rotor of the turbocharger can no longer rotate freely, or must be prevented from rotating. Please refer to Table 1.

Emergency measures	***Supplementary measures/ provisiones*** ***Code number***
Engine stop not permitted for compulsory reasons	
Nothing is changed on the turbocharger	1-3
Engine may be stopped (temporarily)	
NR turbocharger ● Dismantle the rotor and bearing housing (cartridge), mount the end cover on the rear of the turbine (see turbocharger operating manual and relevant work cards). Gas renewal of the engine is through the partly stripped turbocharger on the air side and exhaust side. This possibility exists in case of failure of 1 turbocharger In-line engine V-type engine 2 turbochargers V-type engine	1-7
NA turbocharger ● Measure A Block the rotor from the compressor side using the arresting key (suction opening remains open). Subsequently re-assemble intake air silencer or intake casing. Please refer to turbocharger operating manual and work card 500.05. Take measure A only if measure B cannot be taken for reasons of time. Consequential damage possible. ● Measure B Dismantle the rotor with bearings, block the bearing casing by mounting end covers on the compressor and turbine sides. Reassemble the silencer/intake casing and the turbine inlet casing, if applicable. Please refer to the turbocharger operating manual and work card 500.05. Possibilities in case of failure of 1 turbocharger In-line engine V-type engine 2 turbochargers V-type engine	1-4, 7 (5-7 depending on situation and required) 1-7

Table 1. Emergency operation with one or both turbochargers failing (continued from preceding page)

Explanations

Code number	***Supplementary measures/provisions***
1	Reduce the engine output. The maximum exhaust gas temperatures downstream of the cylinders and upstream of the turbocharger and (on engines equipped with two turbochargers) the maximum admissible turbocharger speed must not be exceeded. Observe the exhaust gas for discolouration.
2	Use all the endeavours that appear appropriate to reduce consequential damage.
3	With the rotor arrested or dismantled, cut off the lube oil supply to avoid fouling and fire hazards.
4	The engine has to be operated in the naturally aspirated mode, (if equipped with two turbochargers) with reduced super-charging.

Code number	*Supplementary measures/provisions*
5	In-line engines: Cover pieces (protection girds) have to be mounted on the charge-air pipe. On engines equipped with a charge-air bypass, it is also necessary to mount the blind flange at the exhaust gas side connection.
6	V-type engines On V-type engines having a common charge-air pipe, a blind flange is to be mounted on the compressor outlet of the defective turbocharger so as to avoid air losses.
7	V-type engines Separate the exhaust gas inlet side of the defective turbocharger from the gas flow of the second turbocharger by fitting a blind flange.

1 turbocharger failing	*In-line engine*	*V-type engine*
Fixed-pitch propeller	15% of the rated output at the corresponding speed	up to 50%
Controllable-pitch propeller/generator service	20% of the rated output at the rated speed	up to 50%

Table 2. Output/speed that can be reached

Behaviour in case operating values are exceeded/ alarms are released 3.6.7

General remarks

Operating values/limit values	Operating values, e.g. temperatures, pressures, flow resistances and all other safety-relevant values/characteristics, must be kept within the range of nominal values. Limit values must not be exceeded.
Alarms, reduction and stop signals	Depending on the extent to which values are exceeded and on the potential risks, alarms, reduction or stop signals are released for the more important operating values. This is effected by means of the alarm system and the safety controls. Reduction signals cause a reduction of the engine output on vessel plants. This is effected by reducing the pitch of controllable-pitch propeller plants. Stop signals cause an engine stop.
Behaviour in emergency cases - technical possibilities	Acoustic or visual warnings can be acknowledged. The displays remain active until the malfunction is eliminated. Reduction or stop signals can in the case of vessel plants be suppressed by means of the override function of the valuation "ship takes precedence over engine". For stationary plants, this possibility is not provided. For these, there is also no reducing function.
Fixing alarm and limit values	For fixing the alarm and the safety-relevant limit values, the requirements of the classification societies and the own assessment are decisive.

Legal situation

Alarm, reduction and safety signals serve the purpose of warning against dangers or of avoiding them. Their causes are to be traced with the necessary care. The sources of malfunctions are to be eliminated consistently. They must not be ignored or suppressed, except on instructions from the management or in cases of a more severe danger.

▲▲ *Caution!* ***Ignoring or suppressing of alarms, the cancellation of reduction and stop signals is highly dangerous, both for persons and for the technical equipment.***

Liability claims for damages due to exceeded nominal values and supressed or ignored alarm and safety signals respectively, can in no case be accepted.

Shut down/preserve the turbocharger 3.7.1

The instructions given for the Diesel engine (refer to the Diesel engine operating manual) also apply correspondingly to a preservation and prolonged storage of the turbocharger.

Table of contents

Categories of information

Information

Description

Instruction

Data/formulas/symbols

Intended for ...

Experts

Middle management

Upper management

General remarks 4.1

Purpose of maintenance work/ prerequisites

Similarly to regular checks, maintenance work belongs to the user's duties. Both serve the purpose of maintaining the reliable and safe serviceability of the system. Maintenance work should be done by qualified personnel and at the times defined by the maintenance schedule.

Maintenance work is of support to the engine operators in their endeavours to recognise future failures at an early stage. It provides useful notes on overhaul or repair becoming due, and is of influence on the planning of downtimes.

Maintenance and repair work can only be carried out properly if the necessary spare parts are available. It is advisable besides these spare parts to keep an inventory of parts in reserve for unforeseen failures. Please request MAN B&W Diesel AG to submit a quotation whenever required.

Maintenance schedule/ maintenance intervals/ personnel and time required

The jobs to be done are shown in the maintenance schedule (Turbocharger) 4.7.3,
which contains

- a brief description of the job,
- the intervals of repetition,
- the personnel and time required, and it makes reference to
- the corresponding work cards/instructions.

Work cards in Volume C2 respectively

The work cards, comprised in Part C2 of the technical documentation, contain brief descriptions of

- the purpose of jobs to be done.

They contain

- information on the tools/appliances required, and
- detailed descriptions and drawings of the operating sequences and steps required.

Maintenance schedule (explanations) 4.2

Preliminary remarks

General

The maintenance schedule of the turbocharger comprises works to be done on components/subassemblies of the turbocharger (see 4.7 and 4.7.3).

Binding character and adaptabilities

Validity of the maintenance schedule

The maintenance schedule (turbocharger) 4.7.3 is a summary of all the maintenance and inspektion works up to a major overhaul of the turbocharger after an operating period of

- 12,000 –18,000 hours for NR–turbochargers,
- 12,000 –18,000 hours for NA–turbochargers at four–stroke engines,
- 24,000 – 30,000 hours for NA–turbochargers at two–stroke engines.

Whenever major overhaul of the turbocharger has been carried out, for practical considerations in common with an engine maintenance being doe, the maintenance schedule is to be started anew.

A major overhaul comprises the disassembly of the complete turbocharger for the inspection of the actual condition, careful cleaning and checking of all parts.

▲ ***Attention! In consideration of the operational safety of the turbocharger and engine, the maintenance works should be carried out as timely as possible and not later than scheduled.***

Adaption of the maintenance schedule

The maintenance schedule has been drawn up for standard operating conditions and an operation of 6,000 hours per year. After a critical evaluation of the operating values and conditions shorter intervals may become necessary provided external operating conditions as timetable/ timetable of ships/inspection time for plants allow it.

Favourable operating conditions are:

- constant load within the range of 60% to 90% nominal load,
- observing the specified temperature and pressure of the operating media,
- using the specified lube oil and fuel quality,
- as well as a proper separation of the fuel and lube oil.

Adverse operating conditions are:

- long-term operation at maximum or minimum load; prolonged idling times; frequent, drastic load changes,
- frequent engine starting and repeated warming-up phases without adequate preheating,
- higher loading of the engine before the specified cooling water and lube oil temperatures are reached,
- lube oil, cooling water and charge air temperatures that are too low,
- using inappropriate fuel qualities and insufficient separation,
- inadequate combustion air filtering (e.g. on stationary engines).

Tools for turbochargers

Inventory tools	Commercial tools are not included in the delivery scope of the turbocharger. It is expected that these tools are contained in the inventory of the plant.
Standard tools	If included in the delivery scope, the turbochargers are equipped with a set of standard tools. For a plant with several turbochargers, 1 set of standard tools is generally sufficient. These standard tools and the inventory tools permit the usual maintenance work to be carried out. The tools set intended for the turbocharger(s) is contained in one box (or in several boxes), and a table of contents is also included. A list specifying the extent and designations of these tools is also contained in Volume C6 of the Technical Documentation.
Tools on customer's request	In particular case, such tools/devices are supplied on request. MAN B&W Diesel AG will gladly submit an offer, if desired.
Special tools	Certain jobs, which are rather repair jobs than maintenance jobs, require special expert knowledge, experience and supplementary equipment/auxiliary means. Further special tools are made available to our service bases, and possibly also our authorised workshops, for such purposes. We therefore recommend that you consult these partners, or entrust them to do jobs for you whenever the own capacities in terms of time, qualification or personnel are inadequate.

Since it is so important, we are repeating below a sentence which we have used already:

△ *Tip Maintenance and repair work can only be carried out properly if the necessary spare parts are available.*

The information given below is thought to assist you in quickly and reliably finding the correct information source in case of need.

Spare parts for turbocharger

Spare parts for the turbocharger can be identified by means of the spare parts catalogue contained in Volume C3 of the technical documentation. For this purpose, illustration and text sheets with order numbers are available. An order number consists of a three-digit subassembly number and a three-digit item number, which are separated by a dot. The spare parts catalogue is arranged in the order of the subassemblies.
The order numbers, however, can also be looked up in the respective work cards contained in Volume C2.

Spare parts for tools/ordering of tools (turbocharger)

Complete or individual tools for turbochargers can be ordered with the aid of the list of contents for tools, stating the respective order numbers. This list of contents is included in the tool box for the turbocharger. An order number is composed of a three-digit subassembly number 596 (= subassembly for tools) and a three-digit item number, which are separated by a dot.
The order numbers, however, can also be looked up in the respective work cards contained in Volume C2.

Special services/Repair work 4.6

No matter whether routine cases or really intricate problems are concerned,

- MAN B&W Diesel AG, Augsburg works,
- MAN B&W Diesel AG, Service Center Hamburg,
- MAN B&W Diesel Pte. Ltd., Service Center Singapore,
- service bases and authorised repair workshops

are readily available to offer you a wide spectrum of services and expert advice, ranging from spare parts supplies, consultation and assistance in operating, maintenance and repair questions, ascertaining and settling cases of damage through to the assignment of fitters and engineers all over the world. Some of these services are doubtless the standard offered by suppliers, shipyards, repair workshops or specialist firms. Some of this whole range of services, however, can only be rendered by someone who can rely on decades of experience in Diesel engine systems. The latter are considered as a part of the expert commitment towards the users of our engines and for our products.

Please note the supplementary information contained in the printed publications of Volume A1 of the Technical Documentation. In these, you will also find the addresses and telephone numbers of the nearest service bases which you can approach whenever required.

Information on turbochargers, see also Volume C1 of the Technical Documentation, Page 1.4.

Maintenance schedule (signs/symbols) 4.7

Explanation of signs and symbols

The heading of the maintenance schedule shows symbols instead of entries in two languages. They have the following meaning:

1, 2, 3	Serial number of the maintenance work. The series shows gaps for changes/up-dates which could become necessary.
	Brief description of the job
	Related work cards. The work cards listed contain detailed information on the work steps required. A No Work card required/available
x **y**	Relation between working cards. These notes are of particular significance within the maintenance system CoCoS. They give you information on the jobs with a temporal connection to the work in question.
	Required personnel
	Time required in hours per person
per	Relational term to indicate the time required
24 ... 18,000 **24 ... 30,000**	Repetition intervals given in operating hours 24 ... 18,000 (NR) 24 ... 18,000 (NA, at the four-stroke engine) 24 ... 30,000 (NA, at the two-stroke engine)
X, 1, 2	Signs used in the columns of intervals. Their meaning is repeated in each sheet. We assume that the signs and symbols used in the head are sufficiently pictorial and that it is not necessary to repeat them constantly.

Table 1. Explanation of signs and symbols of the maintenance schedule

1, 2, 3				x y			per	24	50	150	250	1500	3000	6000	12000	18000		
Inspektion (während des Betriebes) • Inspection (during operation)																		
901	Turbolader auf abnormale Geräusche und Vibrationen kontrollieren	*Check turbocharger for unusual noise and vibrations*	A		1	0.1	Turbo-lader *Turbo-charger*	X										
903	Turbolader und Systemleitungen auf Leckagen kontrollieren (Sperrluft, Ladeluft, Abgas, Schmieröl)	*Check turbocharger and system pipes for leakages (sealing air, charge air, exhaust gas, lube oil)*	A		1	0.2	Turbo-lader *Turbo-charger*	X										
905	Alle Befestigungsschrauben, Gehäuseschrauben und Rohrleitungsanschlüsse auf festen Sitz prüfen	*Check all the fixing screws, casing screws and pipe connections for tight fit*	500.10		1	1	Turbo-lader *Turbo-charger*				2		X					
Wartung (während des Betriebes) • Maintenance (during operation)																		
911	Turbine reinigen (im Schwerölbetrieb) – Trockenreinigung, falls vorhanden	*Clean the turbine (in HFO operation) – Dry cleaning, if provided*	500.07		1	0.3	Turbo-lader *Turbo-charger*	1										
913	Turbine reinigen (im Schwerölbetrieb) – Naßreinigung, falls vorhanden	*Clean the turbine (in HFO operation) – Wet cleaning, if provided*	500.07		1	0.6	Turbo-lader *Turbo-charger*			1								

X Wartungsarbeit fällig
1 Nach Bedarf/Zustand
2 Kontrolle neuer oder überholter Teile erforderlich (einmal nach der angegebenen Zeit)

X Maintenance work is necessary
1 As required/depending on condition
2 Check new or overhauled parts once after the time given in the column

1, 2, 3				x ⟷ y			per	24	50	150	250	1500	3000	6000	12000	18000		
915	Verdichter reinigen (im Betrieb)	*Clean the compressor (in operation)*	500.08		1	0.3	Turbo-lader *Turbo-charger*			1								
917	Luftfilter reinigen (falls vorhanden)	*Clean the air filter (if provided)*	500.11		1	0.4	Turbo-lader *Turbo-charger*				1							
Wartung (gemeinsam mit einer Motorwartung) • Maintenance (in common with an engine maintenance)																		
931	Verdichtergehäuse, Einsatzstück, Nachleitapparat und Verdichterrad reinigen und kontrollieren (Sichtkontrolle). Betriebsbereitschaft des Turboladers wieder herstellen	*Clean and check (visually check) the compressor casing, insert, diffuser and compressor wheel. Restore the turbocharger for operation*	500.10 500.14		2	4	Turbo-lader *Turbo-charger*							X				
951	Grundüberholung 12 000 ...18 000 Betriebsstunden: Alle Komponenten des Turboladers abbauen, reinigen und kontrollieren. Spalte und Spiele beim Zusammenbau kontrollieren	*Major overhaul 12,000 ... 18,000 operating hours: Remove, clean and check all components of the turbocharger. Check gaps and clearances on reassembly*	000.31 500.06 500.10 500.16 500.24 500.27	931	2	20	Turbo-lader *Turbo-charger*								X			

X Wartungsarbeit fällig
1 Nach Bedarf/Zustand
2 Kontrolle neuer oder überholter Teile erforderlich (einmal nach der angegebenen Zeit)

X Maintenance work is necessary
1 As required/depending on condition
2 Check new or overhauled parts once after the time given in the column

General

To keep the exhaust gas turbocharger in a good, reliable condition, it is to be subjected to inspection and checking at various points and at specific intervals as specified in the maintenance schedule.

Depending on the special conditions in the engine room, the best way of disassembly has to be chosen. To perform maintenance and control jobs, it will in most cases be sufficient to strip subassemblies of the turbocharger. Dismounting the complete turbocharger from the engine normally will only be required for basic overhaul.

For basic overhaul of the turbocharger, or for repair work involving essential components, it is recommended to note down the condition of the individual subassemblies and to include this information in the engine operating records. A form sheet ”Check list” (4.8.7 for NR–Turbochargers or 4.8.8 for NA–Turbochargers) has been enclosed herein as a sample.

Spare parts

Wear and damage suffered, specifically if affecting the strength or balance precision and hence the running smoothness of rotating parts, require replacement by original spare parts or repair in an authorised repair shop or at the works. Rotor components sent out for repair have to be appropriately packed and protected against corrosion to prevent further damage in transit.

For ordering original spare parts, please refer Volume C3 (Technical Documentation - Exhaust Gas Turbocharger - Spare Parts Catalogue).

Screwed connections

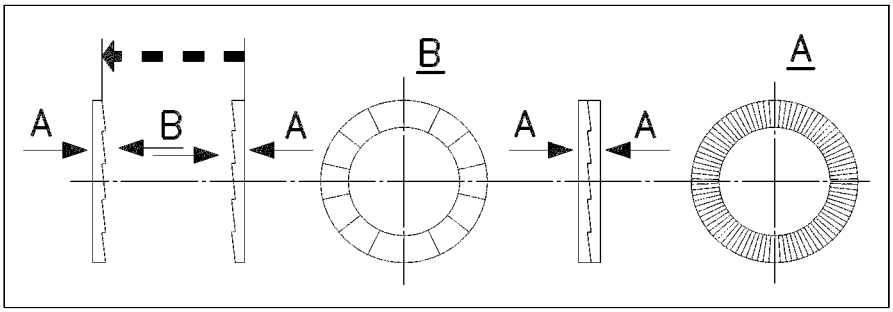
Where screws and nuts cannot be loosened straight away because they have seized, avoid applying excessive force because the components might be destroyed in this way and would have to be replaced. It may also become necessary to bore broken bolts out of casings and to retap the bored–out threads. Seizures can in most cases be slackened by lubricating the threads with Diesel fuel oil or low-viscosity special lubricants (such as Caramba or Omnigliss) and by slightly tapping the bolt head with a hammer. Such solvents should be applied liberally and allowed to act upon the bolted or screwed joint for some time (1/2 hour or longer) so that they will be able to penetrate right down into the threads. The recommendations issued by the suppliers of such solvents should be observed.

Screws, nuts and lockwashers used in joints on the turbine side and exposed to elevated temperatures are made of non-scaling materials. In order to prevent such non-scaling screws and nuts from being mixed up with normal ones, they are identified by markings on their face (SM, VM or 4923, Z1 or 4828). During disassembly, such elements should therefore be put down somewhere separately until being reassembled.
All the lockwasher pairs used on the turbocharger are of non-scaling material but not marked.

To prevent screws and nuts from sticking, thereby facilitating later disassembly, screwed connections and seats should be made sure to be treated with a high-temperature lubricant (such as Molykote HSC) prior to every reassembly. Before applying this lubricant, clean the threads carefully. Threads of stud screws remain untreated.

All the bolted and screwed connections of the turbocharger must be in an unobjectionable condition on assembly, or replacement is necessary. Inappropriately tightened and secured screws and nuts may come loose by vibratory effects and be drawn into the turbocharger by the air or gas flow, causing severe damage.

When assembling the lockwasher pairs (one pair consisting of 2 identical washers), make sure that the long wedged surfaces (B) contact each other (on the inside), otherwise the securing effect will be lost.



Air filter

Air filter mat	The air intake opening of the silencer is covered by a air filter mat of high filtering effect. The silencer, compressor and charge-air cooler are therefore effectively protected against fouling. To maintain this efficiency, timely cleaning or replacement of the air filter mat is necessary and is definitely due when the inside of the air filter mat starts getting dark, a reliable sign that the absorbing capacity of the air filter mat is exhausted and dirt begins to appear at the filter. Taking the pressure differential as an indicator is not reliable because it depends on the rate of air flow as prevailing, which is to say on the service point and the position in the map.
Cleaning intervals	For recommended cleaning intervals, please refer to the maintenance schedule (4.7.3) and work card (500.11).

Compressor

Cleaning during operation by injecting water	In the case of NR turbochargers, dirt depositing on the blades of the compressor wheel and on the nozzle ring vanes may cause a measurable loss in efficiency, because of the relatively small dimensions. We therefore recommend a compressor washing device, especially in cases of extremely dirt-laden intake air. Freshwater is to be used exclusively. Sea water and chemical additives and cleansers are not permitted. Cleaning agents for the charge-air cooler have to be introduced downstream of the compressor. Cleaning should be carried out with the engine being at operating temperature and under full load.
Cleaning intervals	For recommended cleaning intervals, please refer to the maintenance schedule (4.7.3) and work cards (500.08).
Versions available	A portable water container with accumulator to be connected to the cleaning opening on the compressor casing, silencer or air intake casing. A syringe is provided for small frame sizes such as NR12. As an alternative, a water tank can be installed at a fixed, easily accessible point. The tank is to be located not less than 600 mm lower than the point of injection to avoid that the water is prematurely extracted by a vacuum in the compressor as the tank is topped up with water. The air required to draw the water out of the tank should be withdrawn downstream of the charge-air cooler.
Mechanical cleaning	Dirt that has deposited on the compressor wheel, the air diffuser and compressor volute can be removed during maintenance periods by means of the steam jet. A further possibility is the soaking in Diesel fuel or other liquid cleansers and the subsequent brushing off of the dirt deposits. Chlorous cleaning agents may attack the aluminium alloy (of the compressor wheel) and must therefore not be used.

It should in each case be avoided that some of the cleaning agent or dissolved dirt gets into the lube oil system. It is not allowed to use high-pressure cleaners.

Turbine

Cleaning during operation

Depending on the fuel oil grade and the engine operating mode, residues from combustion may accumulate on the vanes / blades of the nozzle ring and turbine. The progressing build-up of dirt deposits and the considerable deterioration of operating performance involved may lead to compressor surging or to the excitation of dangerous vibrations of the turbine wheel blades due to uneven fouling of the nozzle ring. Incipient fouling is indicated by a rising charge-air pressure as a result of the narrower nozzle ring cross section. The charge-air pressure will drop as fouling proceeds, and the exhaust gas temperature will rise as a result.
Contrary to the HFO-operated engines, gas engines or engines using gas oil do not need a cleaning device.

Turbochargers of HFO-operated engines require cleaning at regular intervals from initial operation onwards.

Cleaning intervals

For recommended intervals of cleaning, please refer to the maintenance schedule (4.7.3) and work card (500.07). Depending on the fuel oil grade and engine operating mode, other intervals may be appropriate.

Two methods are available for cleaning the turbine during operation:

Wet cleaning

The engine has to be brought down to approx. 10 ... 15% output for this purpose so as to avoid an overloading of the turbine blades (thermo shock). The medium used for cleaning is freshwater introduced without any chemical additives upstream of the turbine.

Dry cleaning

Granulates of nut shells or activated charcoal (soft) of a grain size of 1 ... 1.5 mm are introduced upstream of the turbine, under normal engine service load and using compressed air from the board mains.
The engine loading need not be reduced for this purpose.
The cleaning device is designed to introduce the necessary amount of granulate over a period of 20 to 30 seconds rather than at a time. This will prevent a sudden speed drop and surging of the compressor, especially where several turbochargers are operated in parallel.

The required granulate can be ordered by:

MAN B&W Diesel Aktiengesellschaft
Turbocharger Service Dept.
86224 Augsburg, Germany

Mechanical cleaning

During maintenance work, severe fouling (such as heavy fuel oil deposits or oil coke) accumulated on the nozzle ring and turbine wheel can be soaked in water treated with standard domestic detergents and subsequently brushed off. If necessary, the process has to be repeated several times. Soaking can be done in an appropriate vessel over several hours.

It must be made absolutely sure that the water and dissolved dirt cannot get into the lube oil system.

The following notes and questions are intended for guidance, e.g. for

- judging the condition of the turbocharger
- recording engine operating data and preparing checklists
- checking, reusing, repairing and replacing components

Oil coke downstream of the turbine wheel	Sealing air bore in the bearing casing clogged Shaft seal on turbine side damaged Priming pressure too high
Touching marks over the entire circumference (turbine rotor, compressor wheel, inserts)	Check of the bearings (refer to work card 500.06) Check of gaps and clearances (refer to sheet 2.5.5)
Touching marks in sections of circumference (turbine rotor, compressor wheel, inserts)	Signs of imbalance
Crack detection tests on the blades (turbine rotor, compressor wheel)	By acoustic testing or fluorescent dye penetration method
Gaps and clearances	For admissible limits, refer to sheet 2.5.5
Erosion in HFO operation	Where heavy fuel oil is used, the exhaust gas contains solids of small size (e.g. ”Cat fines”) which have an erosive effect especially at the outlet of the turbine nozzle ring, where gas velocities and concentrations of these particles are high. Moreover, there is a very pronounced deflection of the flow in circumferential direction, and the particles are furthermore subject to the centrifugal effect.
“Cat Fines”	Where do these erosive solid particles come from? As a result of the refining process, and depending on the quality, heavy fuel oil contains ”Cat fines”, fine-grained and very hard powdered solids (indicators are the Al and Si concentrations), and other impurities of abrasive effect. Amply dimensioned, heated settling tanks and adequate separation are means to reduce their concentration.
Admixtures	Of a particularly negative effect is the admixing of used engine lube oil, characterised by more-than-normal Ca and Fe concentrations. Used engine lube oil not only contains wear residues but specifically ”detergent dispersant additives”. Fine-grained solids are bound by these additives so that ”Cat fines” and other impurities cannot be extracted by separating. Much more severe erosion damage is the result of blending the fuel with ”Waste oil”. Residues from incomplete combustion may also have an erosive effect. Clean combustion should therefore be ensured.

Casings	Which casings are heavily fouled by soot, oil or oil coke? Were the casings tight, especially at the joints and connecting flanges? Did the casings have cracks? Had bolts broken off? Had all the bolts and nuts been firmly tightened and secured? Were any sealing air or oil ducts in the bearing casing clogged? Are the seals in order?
Silencer, if provided	What is the condition of the air filter mat? What is the condition of the felt linings? Have cracks formed on components?
Electronic speed measuring device	Was the speed transmitter or the speed indicator defective? Were the two pole plates on the speed transmitter deformed?
Compressor wheel	Are blades affected by cracks or pronounced wear? Do the blades show impact marks at the leading edge, caused by solid objects drawn in? Are traces of touching found? What is the seat of the compressor wheel? Is the seating surface bright, or does it show fretting corrosion?
Turbine rotor	Have blades been damaged or are blades affected by pronounced wear or erosion on the edges? Are blades affected by cracks? Are any traces of touching found on blades, on the wheel or shaft? Concentricity of the shaft? Condition of the bearing points? Have the labyrinth tips of the locating ring been severly worn? Are the seating faces bright or do they show fretting corrosion?
Inserts	Are there any signs of touching?
Thrust ring, labyrinth ring	Are there traces of fretting or pronounced wear? Are the seating faces bright or do they show fretting corrosion?
Bearings	Check the bearings (refer to work card 500.06) Wear diagonally across on both bearings suggests rotor imbalance.
Sealing cover	Does the pattern of labyrinth tip running-in appear normal?
Turbine nozzle ring	Are there vanes that have been bent? Have vanes suffered serious erosive wear? Have foreign objects got jammed in the ducts? Are there traces that are indicative of foreign objects? Are cracks found on the vanes?

Check list 4.8.7

Relating to service report of . . . . . Date . . . . . .

Name of customer . . . . . Turbocharger . . . . . .

Address . . . . . Works No. . . . . .

Site . . . . . Engine type . . . . . .

Ship's name . . . . . Works No.. . . . . .

Turbocharger inspected / overhauled on . . . . . by . . . . . .

Reason . . . . . .

Last inspection / overhaul on . . . . . by . . . . . .

No. of operating hours since last inspection / overhaul . . . . . h

No. of operating hours since commissioning . . . . . h

Air intake casing, if provided

☐ fouled

by . . . . . .

Silencer, if provided

air filter mat

☐ replaced

reason: . . . . . .

felt linings

☐ fouled
☐ wavy
☐ separated

Speed transmitter, if provided

☐ defective
☐ pole plates deformed

Speed indicator, if provided

☐ defective

Insert on compressor side

☐ used ☐ replaced
☐ fouled

by . . . . . .

signs of touching

☐ radial
☐ over the entire circumference
☐ in sections of the circumference

Compressor casing

☐ fouled

by . . . . . .

☐ cracks
☐ damage by foreign object

Diffuser

☐ used ☐ replaced
☐ fouled

by . . . . . .

☐ vanes bent
☐ vanes with incipient cracks
☐ damage by foreign object

Compressor wheel

☐ fouled

by . . . . . .

signs of touching

☐ axial
☐ radial
☐ over the entire circumference
☐ in sections of circumference

blades

☐ bent
☐ with cracks
☐ damage by foreign object

bore

☐ fretting corrosion

Turbine rotor

☐ fouled

by . . . . . .

signs of touching

☐ radial
☐ over the entire circumference
☐ in sections of circumference

blades

☐ bent
☐ with cracks
☐ erosion
☐ damage by foreign objects

bearing points

☐ fretting marks
☐ wear

seating faces

☐ fretting corrosion

labyrinth tips

☐ oil coke
☐ wear

Labyrinth ring

☐ used ☐ replaced

☐ fretting marks
☐ wear
☐ fretting corrosion

Thrust ring

☐ used ☐ replaced

☐ fretting marks
☐ wear
☐ fretting corrosion

Bearing casing

☐ fouled

by . . . . . .

☐ cracks

sealing air bores
☐ clogged ☐ cleaned

oil bore
☐ clogged ☐ cleaned

seals
☐ replaced

Locating bearing

☐ used ☐ replaced

☐ fretting marks
☐ wear
☐ axial face, compressor side
☐ axial face, turbine side
☐ inside diameter

Bearing bush compressor side

☐ used ☐ replaced

☐ fretting marks
☐ wear
☐ outside diameter
☐ inside diameter

Bearing bush turbine side

☐ used ☐ replaced

☐ fretting marks
☐ wear
☐ outside diameter
☐ inside diameter

Sealing cover compressor side

☐ used ☐ replaced

☐ abnormal running-in pattern
☐ wear
☐ signs of touching

Sealing cover turbine side

☐ used ☐ replaced

☐ abnormal running-in pattern
☐ wear
☐ oil coke ☐ cleaned

Cover disc

☐ used ☐ replaced

☐ wear
☐ oil coke ☐ cleaned

Turbine nozzle ring

☐ used ☐ replaced

☐ vanes bent
☐ vanes with incipient cracks
☐ damage by foreign object
☐ erosion

Insert turbine side

☐ used ☐ replaced

☐ fouled
☐ erosion

signs of touching
☐ over the entire circumference
☐ in section of the circumference

Gas-admission casing

☐ fouled

by . . . . . .

☐ cracks
☐ erosion
☐ damage by foreign object

screwed connections

☐ slack
☐ torn off
☐ replaced

Gas outlet casing

☐ fouled

by . . . . . .

☐ cracks
☐ damage by foreign object

screwed connections
☐ slack
☐ torn off
☐ replaced

☒ please tick the appropriate box

Gaps and clearances, (for admissible values refer to sheet 2.5.5)

Item 1	Compressor wheel / insert	(radial gap)	mm
Item 2	Compressor wheel / insert	(axial gap)	mm
Item 3	Turbine rotor / insert	(radial gap)	mm
Item 4	Turbine rotor / insert	(axial gap)	mm
Item 5	Locating bearing / labyrinth ring	(axial clearance)	mm
Item 6	Face runout, compressor wheel	. . . . .	mm

Remarks: . . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .
. . . . . .

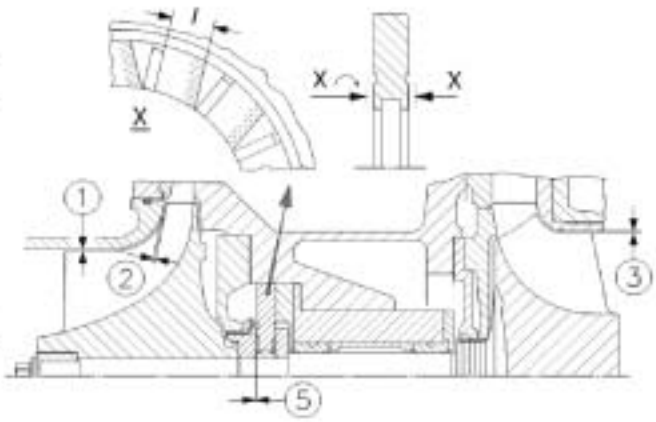
Service Report
Turbocharger NR/S

Author:			
Customer:			
Plant/vessel:			
Turbocharger type:		Engine type:	
Turbocharger work No.:		Engine work No.:	

Compressor wheel, gap (1)

before maintenance

after maintenance



Turbine rotor, gap (3)

before maintenance

after maintenance

maintenance	2	5	I		Turbine rotor COC-No.	Compressor wheel COC-No.
before	---					
after						

Remarks:

Date Chief Inspector Service Engineer