Information to ASB2013/02/18

Containment Risk for NA and NR Turbochargers

MAN Diesel & Turbo SE

Business Unit Turbocharger

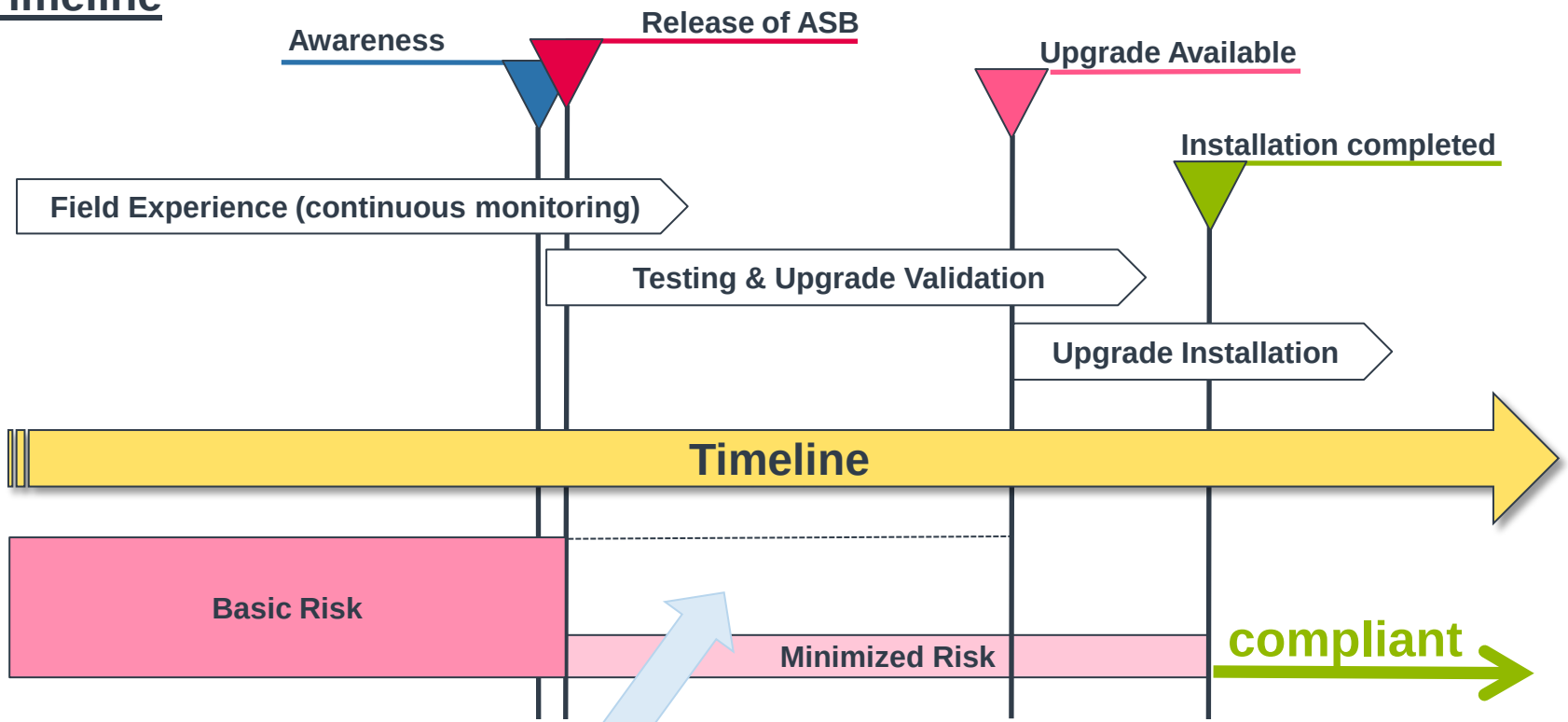
Information to ASB2013/02/18

Agenda

Information to ASB2013/02/18

Why has MAN released ASB2013/02/18 and Supplement Letter?

Timeline



With an early warning MAN wanted to reduce the risk until an upgrade kit is available!

Information to ASB2013/02/18

Agenda

Information to ASB2013/02/18

Technical Requirements for Containment Safe Design

Required features for a safe design

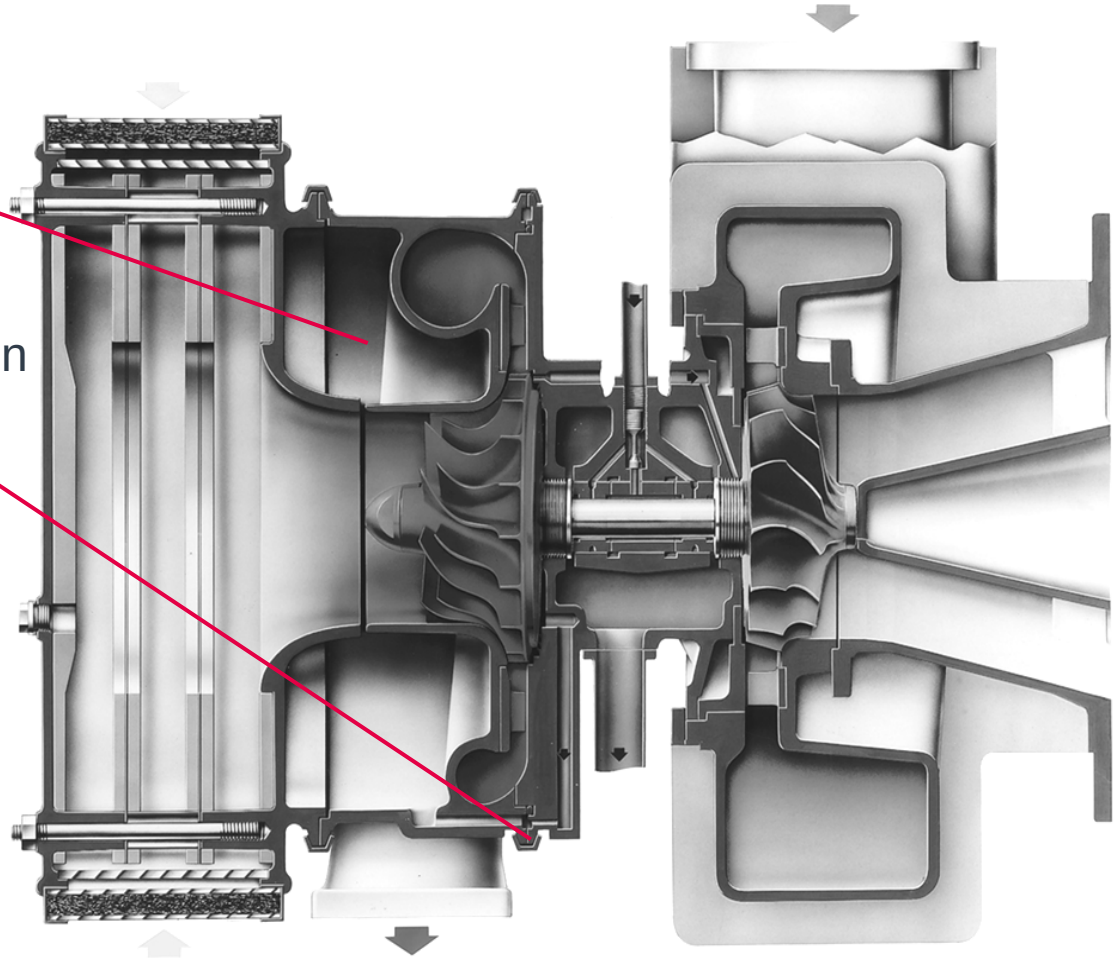
Ductile casings

+

Strengthened flange connection between bearing casing and compressor casing

=

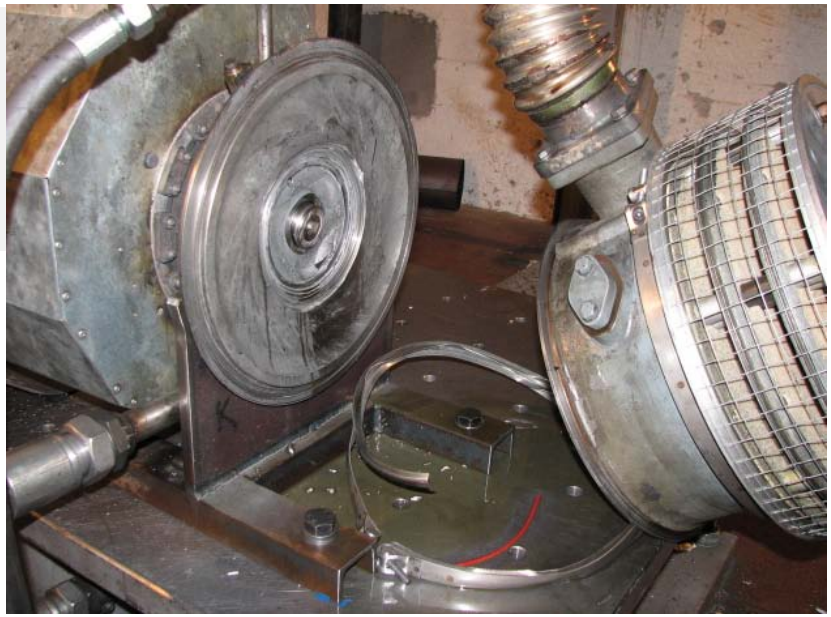
Containment safe design

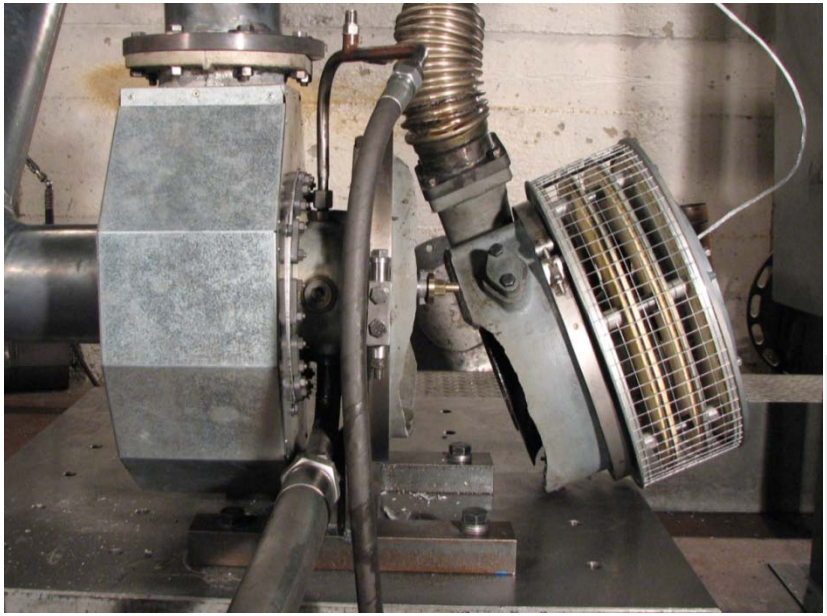


Sample picture only!

Example for test of different versions

v-clamp failed





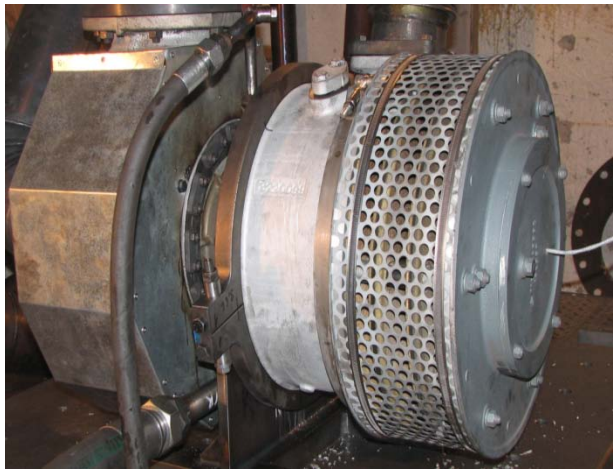
grey cast casing failed

Example for test of different versions

Containment safe design with combination of

- Nodular cast compressor casing **and**
- Improved v-clamp connection between compressor casing and bearing casing

⇨ **Containment safety validated**



!

With nodular cast iron casings and a strong connection of casings, containment safety has been validated for a number of turbochargers.

Information to ASB2013/02/18

Reasons for Rotor Failure

An analysis of damage data has shown that the breakage of a compressor wheel has been at the root of subsequent damage to the turbocharger with a loss of containment. The breakage of a compressor wheel predominantly occurs if there is a pre-damaged compressor wheel wich results in a spontaneous major unbalance of the rotor.

Indigenous reasons:

- Natural aging of the compressor wheel

External reasons

- Impact of debris
- Poor fuel or lube oil quality
- Improper handling

All mentioned pre-damage risks can be reduced by the operator via proper handling and servicing of the turbocharger.

Information to ASB2013/02/18

Agenda

Information to ASB2013/02/18

MAN Risk Evaluation

MAN regularly evaluates the residual risk of products placed onto the market in accordance with ISO standard ISO 12100. These risk parameters are defined as follows:

- Severity of injury
  - In the extreme rare case of rotor breakage and loss of containment fatal injuries are possible
- Possibility of avoidance
  - Not possible to move away from the turbocharger due to the speed at which the hazard occurs (without indications)
- Length of stay in danger zone
  - Several times a day for inspection and maintenance
- Containment incidence rate
  - Statistically one incident within > 3,100 operating years

Information to ASB2013/02/18

Agenda

Information to ASB2013/02/18

MAN Product Safety Policy

Importance of HSSE

Health, Safety, Security, Environment
is an integral part of MAN Diesel & Turbo‘s company policy and corporate governance.

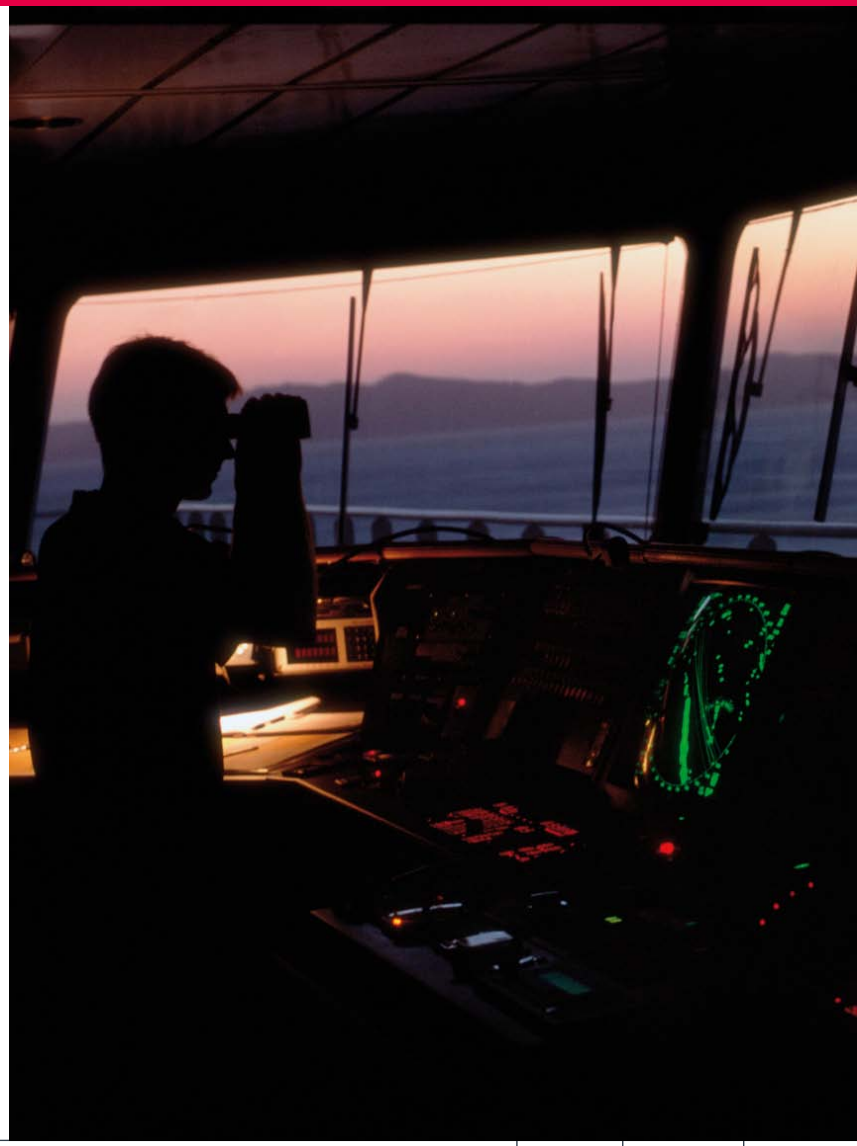
- Environmental impairment
- Safe working places
- Safe products

Safe Processes

Monitoring

Timely Reaction

SAFETY FIRST!



Information to ASB2013/02/18

Agenda

Information to ASB2013/02/18

Affected Products

Turbochargers of type

NR12, NR14, NR15, NR17, NR20, NR24, NR26, NR29, NR34
NA29, NA34, NA40, NA48, NA57, NA70

Owners and operators of concerned Turbochargers are requested to contact MAN Diesel & Turbo and provide:

- turbocharger work number
- name of turbocharger maker
- year of production

of the turbochargers in their fleet.

MAN Diesel & Turbo will check and reply in writing.

Information to ASB2013/02/18

Agenda

Third-Party Risk Analysis

In Cooperation with GL/FutureShip

MAN has asked FutureShip, a subsidiary of Germanic Lloyd, to provide an independent assessment of the individual risk profile of each TC-product in order to support our customers in their efforts to properly gauge and deal with the respective risks.

- Basis: MDT field monitoring data per T/C type
  - Number of T/C in the field
  - Number of accumulated operating hours
  - Number of containment relevant incidents

- Comparison of calculated risk Nos. with other risk Nos. from marine area

Providing our customers the necessary information to act responsibly!

Risk Evaluation of Turbocharger

Methodology and Definitions

Individual risk$_{T/C,\ Appl.}$ = Failure probability$_{T/C,\ Appl.}$ x Individual presence rate in endangered area$_{Appl.}$ x 0.2

Individual risk$_{T/C,\ Appl.}$: The annual fatal risk for an individual engine crew member, caused by one turbocharger of specific type and application.

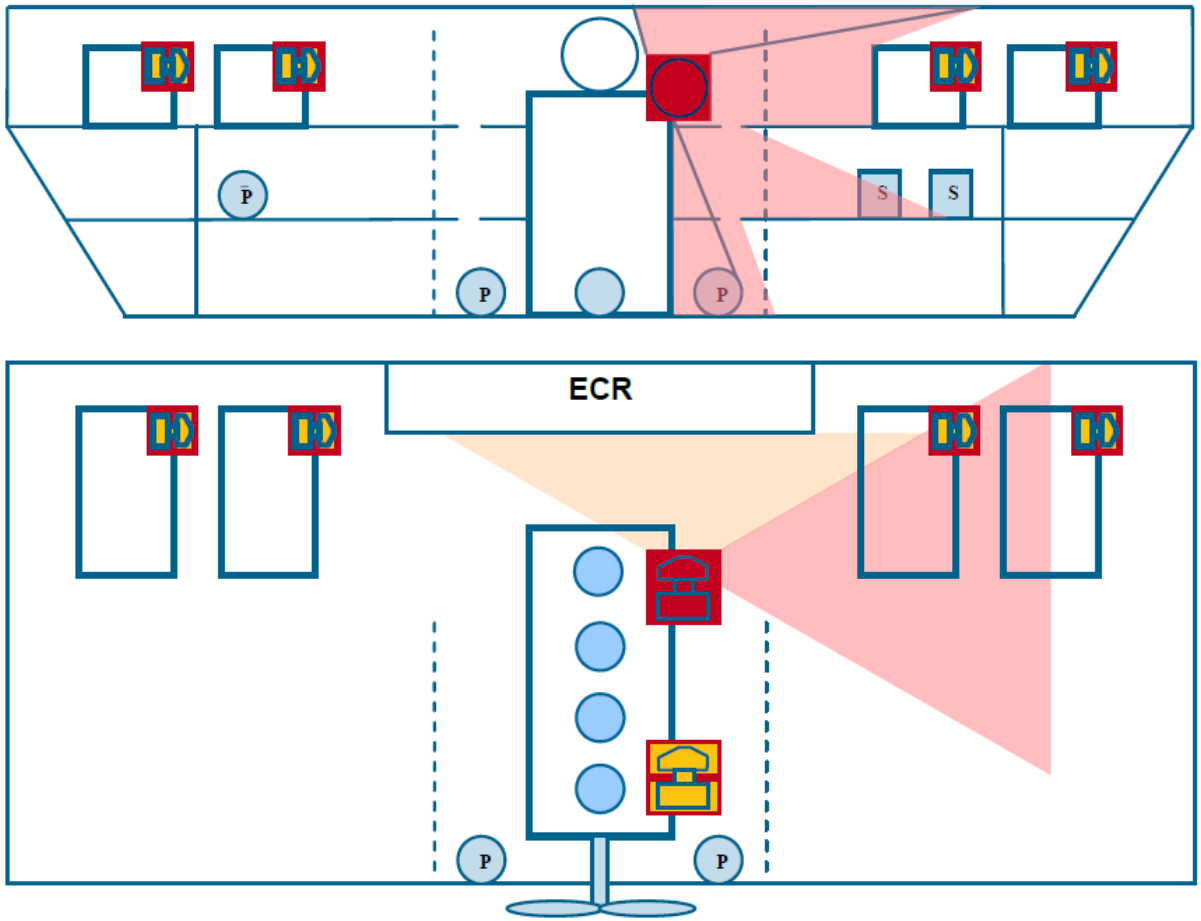
Failure probability$_{T/C,\ Appl.}$: Annual probability of containment failure of one turbocharger of specific type and application. Number of recorded containment incidents observed in the field for this type and application of turbocharger, divided by the cumulated operating years. In case the annual failure probability of a turbocharger type and application is either zero or the population is too small, the value for the corresponding series is used instead.

Individual presence rate in endangered area$_{Appl.}$: Average time of an individual engine crew member in the endangered area, i.e. where fatal injury is possible in case of a containment incident. Off times are considered within the individual presence rate.

0.2: This factor is the fatality rate, i.e. the probability that a person is affected by actual turbocharger destruction scenario, when such failure occurs and when the person is located in the endangered area.

Risk Evaluation of Turbocharger

Endangered Area 2-Stroke Main Engine



Endangered area (axial)

Endangered area (radial)

Auxiliary engine with Turbocharger

Active Turbocharger, subject of the analysis

Further Turbocharger

P Pump

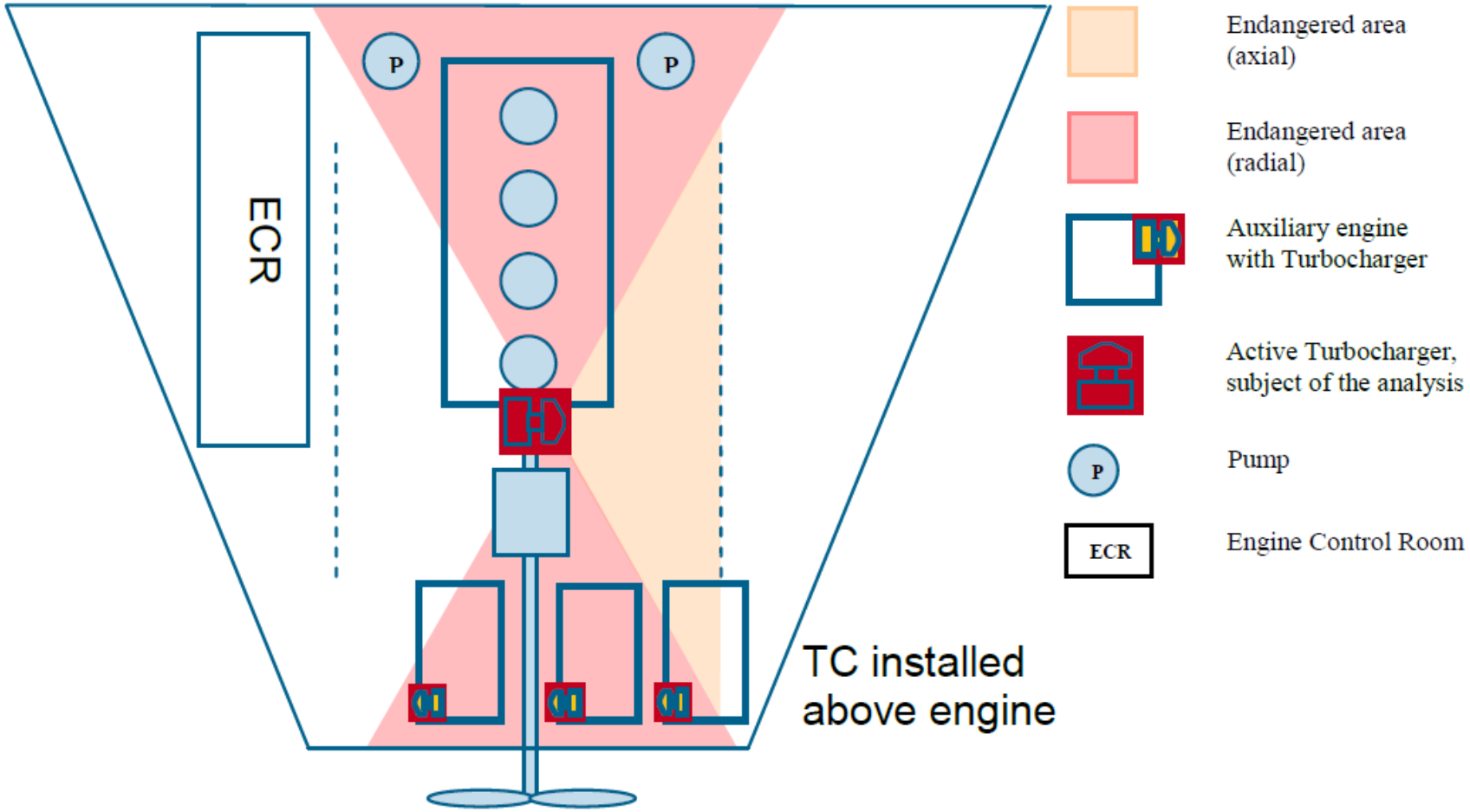
S Separator

ECR Engine Control Room

Conservative engine room arrangement

Risk Evaluation of Turbocharger

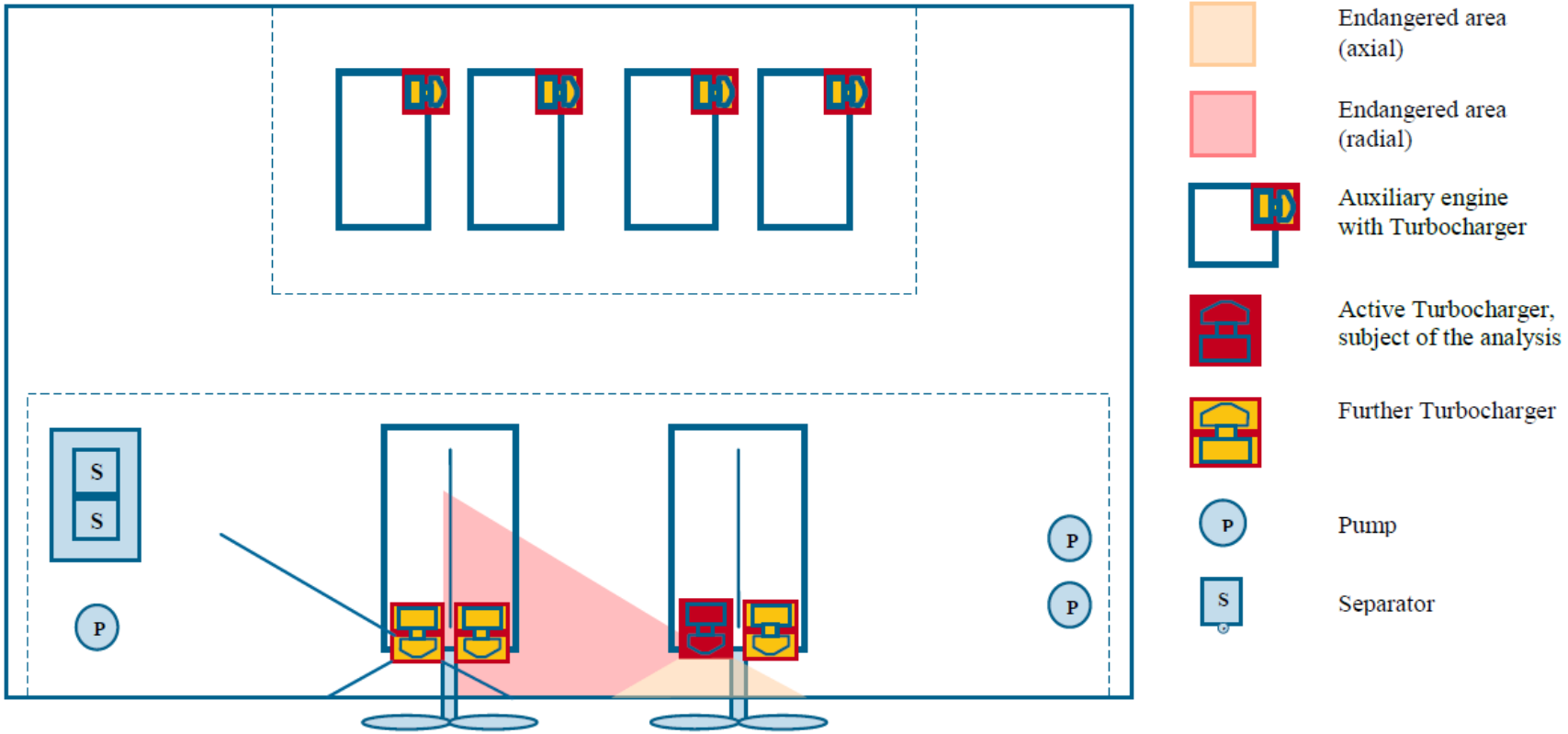
Endangered Area 4-Stroke Main Engine (Single Engine)



Conservative engine room arrangement

Risk Evaluation of Turbocharger

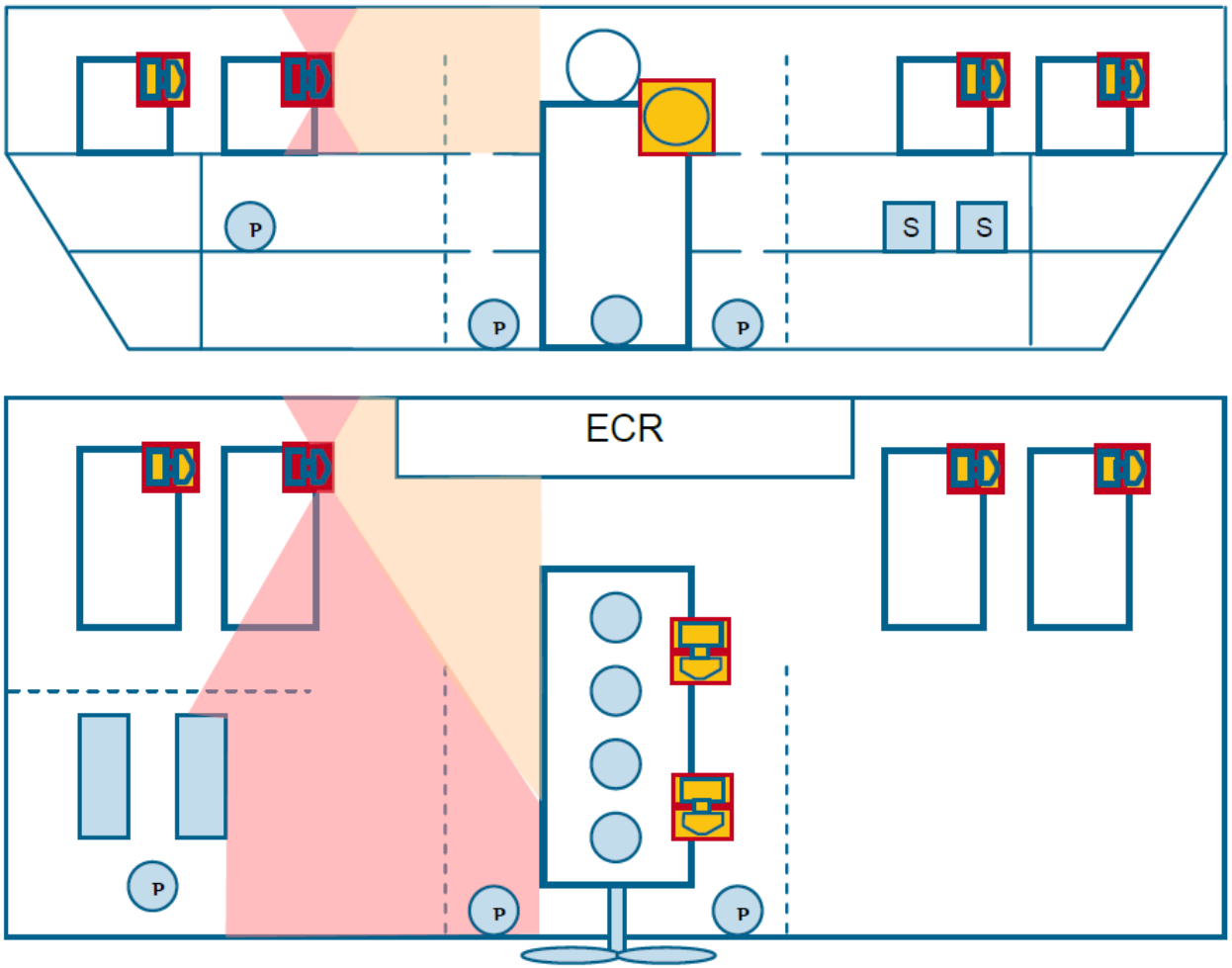
Endangered Area 4-Stroke Main Engine (Multi Engines)

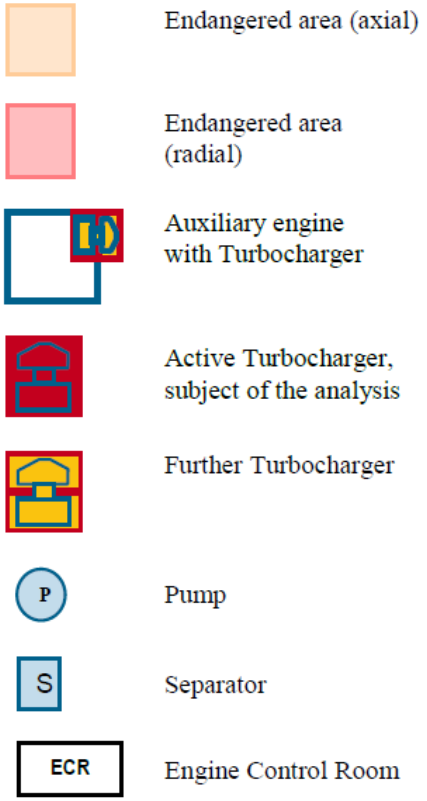


Conservative engine room arrangement

Risk Evaluation of Turbocharger

Endangered Area 4-Stroke Auxiliary Engine





Conservative engine room arrangement

Risk Evaluation of Turbocharger

Individual Presence Rate in Endangered Area

FutureShip has defined the presence rate of the individual crew member in the endangered area for each application whereas for 2- and 4-stroke main engines a conservative and a favorable engine arrangement were considered:

- 2-stroke propulsion: 0.9% (favorable), 3.5% (conservative)
- 4-stroke propulsion (single engine): 0.5% (favorable), 2.3% (conservative)
- 4-stroke propulsion (multi engine): 0.9%
- 4-stroke auxiliary: 2.3 %

For turbochargers without any containment incident in the field, the average risk value of the corresponding series is used instead. This figure is provided in brackets.

IMO Guideline for Acceptance of Risk

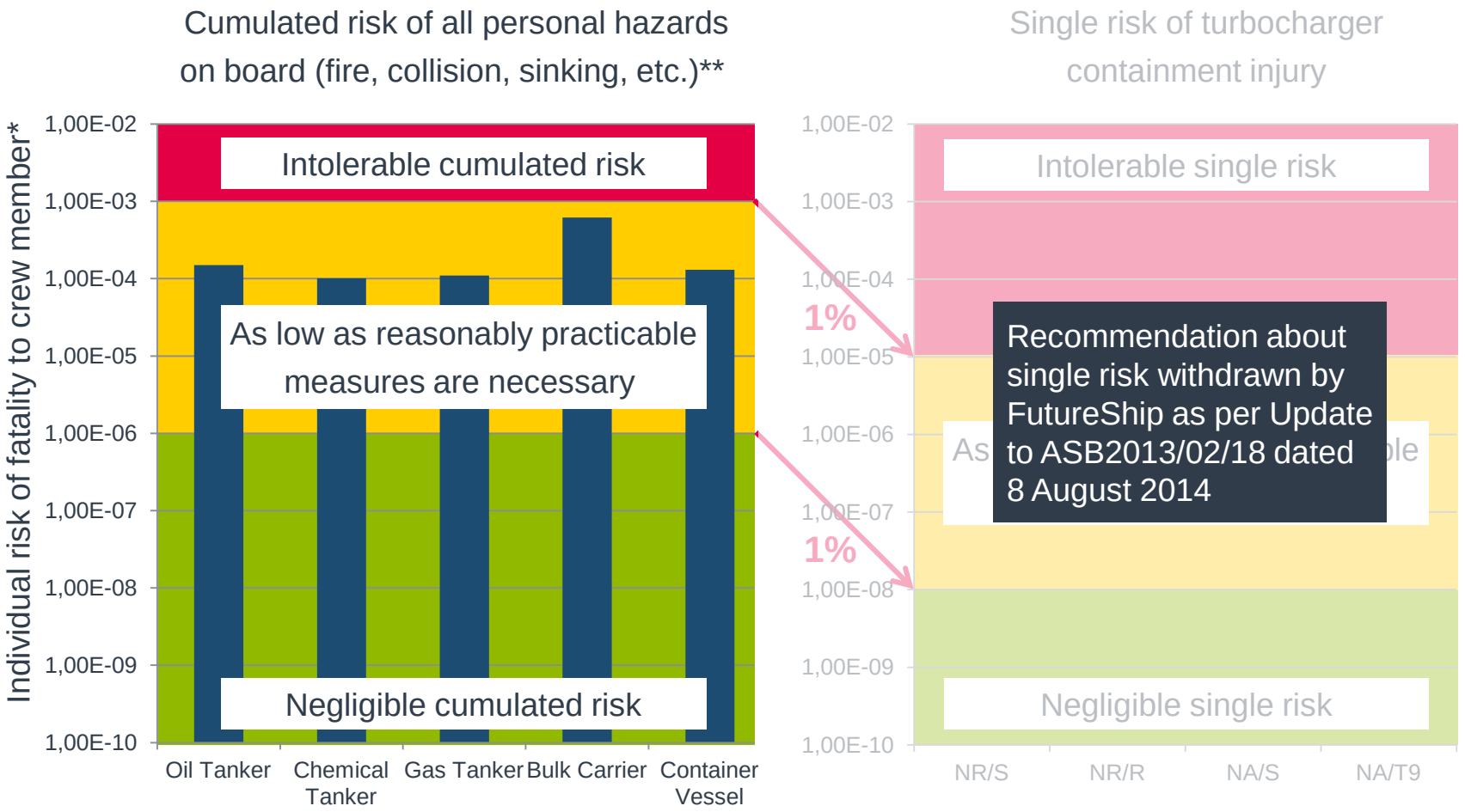
(MSC 83 INF 2; 2007)

Decision Parameter		Acceptance Criteria	
		Lower bound for ALARP region	Upper bound for ALARP region
		Negligible (broadly acceptable) fatality risk per year	Maximum tolerable fatality risk per year
Individual Risk	to crew member	10^{-6}	10^{-3}
	to passenger	10^{-6}	10^{-4}
	to third parties, member of public ashore	10^{-6}	10^{-4}
	target values for new ships *)	10^{-6}	Above values to be reduced by one order of magnitude
Societal Risk	to groups of above persons	To be derived by using economic parameters as per MSC 72/16	

Table 1: Quantitative risk evaluation upper and lower bounds

Risk Levels on Board of Ships

Cumulated Risk and Single Risk

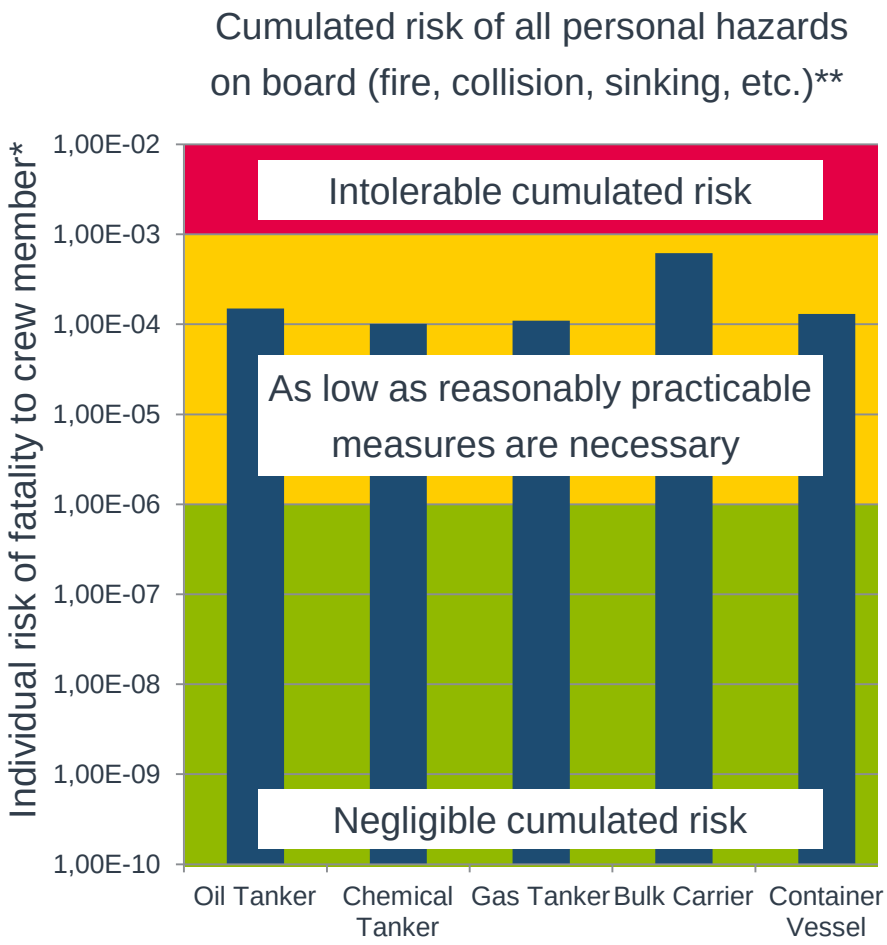


* IMO Regulation for Execution of Formal Safety Analysis (FSA), MSC.83 INF 2, 2007

** Data from 1978 – 1998 LMIS /Ship accidents; Rolf Skjong, surface transport technologies for sustainable developments, Valencia, Spain 4-6 June 2002

Risk Levels on Board of Ships

Cumulated Risk



* IMO Regulation for Execution of Formal Safety Analysis (FSA), MSC.83 INF 2, 2007

** Data from 1978 – 1998 LMIS /Ship accidents; Rolf Skjong, surface transport technologies for sustainable developments, Valencia, Spain 4-6 June 2002

Risk Evaluation of Turbocharger

Individual Risk Values NR Turbochargers (Excerpt)

Turbocharger type	Individual fatal risk of life of engine crew member per turbocharger [1/a]					
	2-Stroke Propulsion		4-Stroke Propulsion (single)		4-Stroke Propulsion (multi)	4-Stroke Auxiliary
	favorable	conservative	favorable	conservative		
NR29/S	$(4.03 \cdot 10^{-7})$	$(1.57 \cdot 10^{-6})$	$1.21 \cdot 10^{-6}$	$5.57 \cdot 10^{-6}$	$2.18 \cdot 10^{-6}$	$(1.03 \cdot 10^{-6})$
NR34/S	no application	no application	$2.82 \cdot 10^{-7}$	$1.30 \cdot 10^{-6}$	$5.08 \cdot 10^{-7}$	$(1.03 \cdot 10^{-6})$

Risk information for all T/C types has been distributed on 28 August 2013.

**The Risk Value indicates the risk of bodily injury of a crew member/maintenance personnel following a containment loss. It takes into account the statistic probability of loss of containment and length of stay within in the hazardous area of the turbocharger. Maintenance of the turbocharger in accordance with the instruction manual of the turbocharger will decrease the probability of a critical rotor failure. All risk values are based upon our best knowledge and currently available data.*

Information to ASB2013/02/18

Agenda

Information to ASB2013/02/18

ASB Handling Process

MAN	▪ Release/Supplement of ASB2013/02/18
Customer	▪ Information about turbocharger work number, name of turbocharger maker and year of production
MAN	▪ Identification of affected turbochargers and return information
Customer	▪ Implementation of short term measures for risk minimization according to ASB2013/02/18
MAN	▪ Information upon availability of an upgrade kit ▪ Coordination of delivery of kits and modification of TC

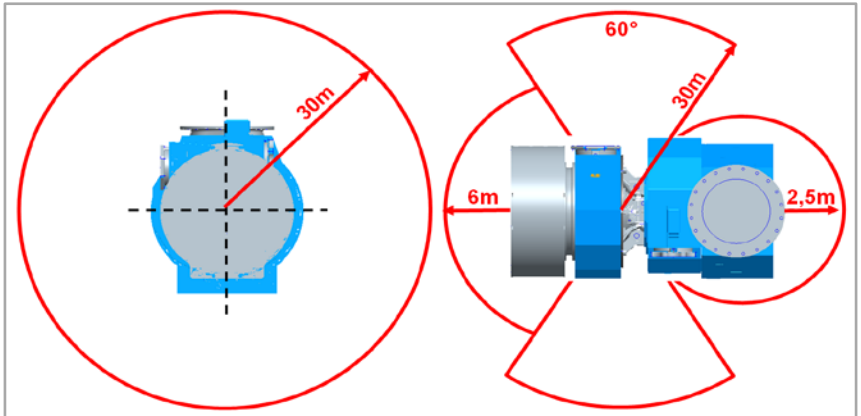
MAN is developing upgrade kits and retrofit solutions for affected NA and NR types

Containment proven turbocharger

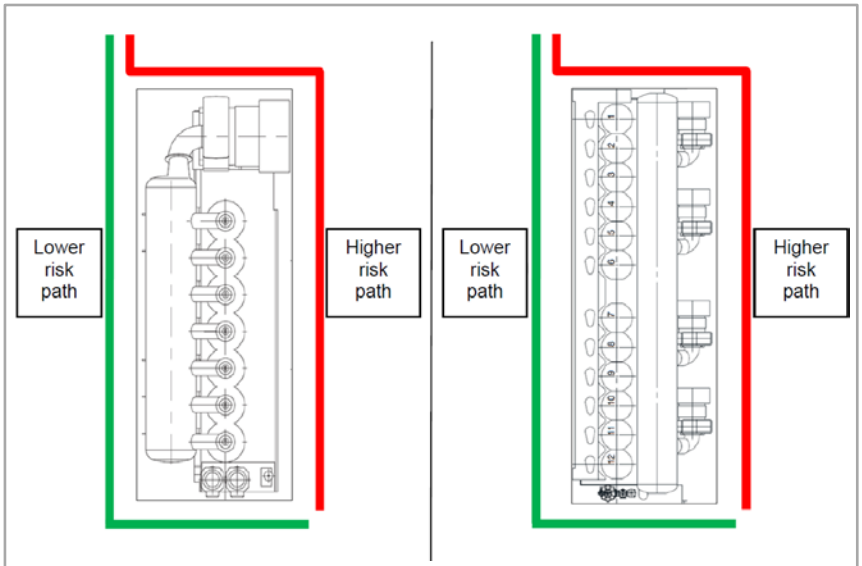
Information to ASB2013/02/18

Short Term Measures for Risk Minimization

- Never enter the turbocharger hazardous area as long as the engine is in operation, unless unavoidable.
- Minimize your stay in the engine room and
  operate your engine exclusively from the engine control room.
- Do not use the operating panel which is attached to the engine close to the turbocharger.
- Wear appropriate protective clothing, protective goggles, safety boots, hard helmet etc. as recommended in the Instruction Manual of your turbocharger.
- In any case please optimise your path through the engine room in order to minimize your stay in the hazardous area.



Turbocharger hazardous area



Optimized path around the engine

Information to ASB2013/02/18

Short Term Measures for Risk Minimization (Page 1)

MAN Diesel & Turbo recommends to change the maintenance work as follows.

Work item	Description in the manual	Recommendation
901 / 501	Inspection for abnormal noise and vibrations	Stay out of the hazardous area for this inspection. In case of an abnormal noise stay away from the turbocharger, stop the engine immediately, identify and eliminate the source of the noise before re-starting the engine.
903	Check turbocharger and system pipes for leaks	If possible carry out this work ideally when the engine is stopped. Oil leaks as well as gas leaks can normally be identified by residues even when the engine is stopped.
905 / 508	Check all the fixing screws, casing screws and pipe connections for tight fit	Carry out this inspection only when the engine is stopped.
911 / 504	Turbine dry cleaning	Use it regularly at reduced engine load of 15% or below. Operating experience has shown that for turbochargers that are equipped with a turbine dry cleaning device only, the dry cleaning of the turbine below 15% engine load (as recommended) may not provide the desired result. In case no wet cleaning device is installed, we recommend to retrofit it for a proper cleaning effect below 15% load.
913 / 503	Turbine wet cleaning	Use it regularly at reduced engine load according to the manual.

Information to ASB2013/02/18

Short Term Measures for Risk Minimization (Page 2)

MAN Diesel & Turbo recommends to change the maintenance work as follows.

Work item	Description in the manual	Recommendation
915 / 502	Compressor wet cleaning	Stop using the cleaning device. Consider mechanical cleaning during inspections, if necessary.
917 / 505	Cleaning of air filter	Carry out this work only when engine is stopped. Make sure that the filter mat is always installed properly and undamaged. In case a U-pipe manometer is installed on your turbocharger stop using it; it does not provide value during operation..
931	Compressor wheel inspection	Carry out visual compressor wheel inspection every 3,000 h (instead of an interval of 6,000 h).
506	Inspection of sealing air valve	Carry out this work only when engine is stopped.
	Jet Assist	Ensure that jet-assist pressure does not exceed 4 bar (as per operating manual).

Information to ASB2013/02/18

Medium Term Measures for Risk Minimization

Upgrade Kit

MAN Diesel & Turbo is developing upgrade solutions with highest priority. The upgrade kits will be released step by step as soon as they are available.

Once MAN Diesel & Turbo has received the customer's fleet information, MAN Diesel & Turbo will inform the customer specifically about following details (as applicable) on their affected turbocharger population via a dedicated MAN Diesel & Turbo SE internet page:

- A risk evaluation based upon our actual field experience
- Recommendations on a turbocharger specific rotating speed, for which the turbocharger can be considered containment safe without any further restrictions or modifications
- A date when an upgrade kit may be made available
- A date when an intermediate, temporary measure may be made available (e.g. a validated protection around the turbocharger)
- Information about retrofitting possibilities for increased charging efficiency

Information to ASB2013/02/18

Agenda

NR/NA Containment Improvement

Concept of Upgrade Solution

Problem

With NR and NA turbochargers, the casings and/or the flange connections are not sufficiently strong to withstand extreme load situations which may for example occur in the very rare case of a rotor failure.

Solution concept

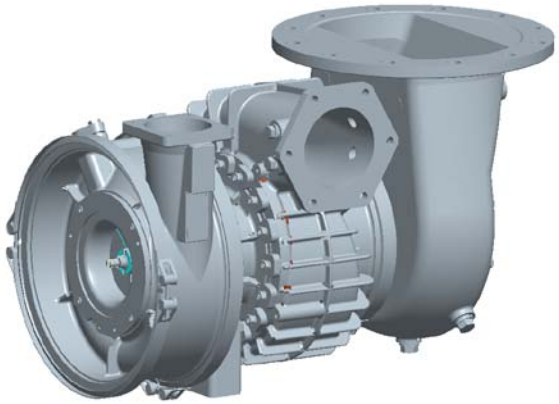
- Modification of the casing design (compressor casing, insert piece)
- Modification of connection of compressor and bearing casing
- Scope (number of components) varies per turbocharger type

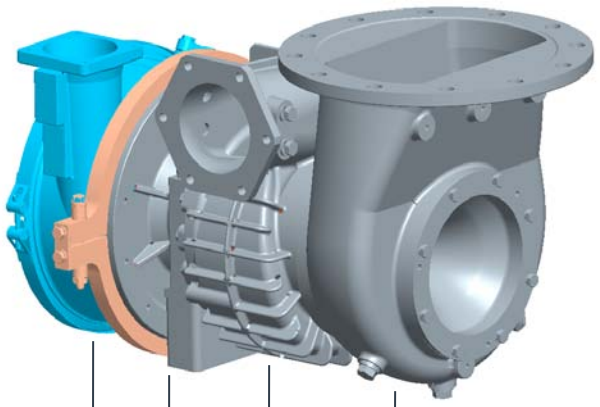
NR/NA Containment Improvement

Concept of Upgrade Solution

Example of modification (NR turbocharger)

previous





new

compressor casing

bearing casing

turbine intake casing

turbine outlet casing

Remarks

- The upgrade kit comprises all required parts to perform the upgrade (including sealing rings etc)
- In some cases the turbocharger has to be lifted from the engine to install the kit
- In some cases a rib of the foot holding the turbocharger must be grinded
- Assembly time depends on scope (4 - 24 h)

Containment Safety Certificate

After installation of the Upgrade Kits a Containment Safety Certificate will be issued.

As a result the restriction of use and operation, contained in the ASB2013/02/18 are no longer applicable and none of the engine performance limitations mentioned in that ASB have to be respected any more.

MAN | PrimeServ

CONTAINMENT SAFETY CERTIFICATE

Turbocharger-Type _____

Turbocharger-ID _____

Engine-Type _____

Power Plant / Vessel Name _____

IMO _____

Modification of Turbocharger based on MAN Diesel & Turbo ASB2013/02/18

All containment modifications for the above mentioned turbocharger have been successfully completed. The restriction of use and operation, contained in the ASB2013/02/18 are no longer applicable and none of the engine performance limitations mentioned in that ASB have to be respected any more.

Engraved Containment Code Yes No No. _____

Chief Representative

MAN Diesel & Turbo Engineer

This certificate does not any way alter, change or expand the responsibilities of MAN Diesel & Turbo or the limitations of liability stated in the original sales contract or subsequent service contracts.

Information to ASB2013/02/18

Medium Term Measures for Risk Minimization

Retrofit

In most cases a turbocharger retrofit with a new TCR or TCA turbocharger is a viable option with the additional benefit of improved engine performance.

Please contact MAN Diesel & Turbo for detailed information.

Retrofit Example:

MAN Diesel & Turbo engine 25/30

Before Retrofit: NR26/R

After Retrofit: TCR20-4

Information to ASB2013/02/18

Agenda

Information to ASB2013/02/18

Contact

Our Service Department is always at your disposal:

MAN Diesel & Turbo SE
86224 Augsburg
Germany

Hotline: +49 821 322 4402
Fax: +49 821 322 49 2830
e-mail: TC-ASB-Feedback@mandieselturbo.com

Thank you for your attention.

All data provided in this document is non-binding.

This data serves informational purposes only and is especially not guaranteed in any way. Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.