

Methodology of MAN NR-/NA-Turbocharger Risk Assessment
Application: 4-stroke Main Engine (multi engine)

FutureShip, a company of the Germanischer Lloyd, is specialised in impartial maritime consultancy and advanced engineering services, with a focus on enhancing ship efficiency and safety both in design and operation. With a fast-growing team of more than 100 experts, FutureShip helps shipowners, shipyards, designers and suppliers in Europe, Asia and around the world to improve fuel efficiency, minimise environmental impacts and increase safety and profitability.

FutureShip was assigned to carry out a risk assessment of NR-/NA-turbochargers of MAN Diesel & Turbo used in maritime applications. The aim of the investigation was to determine the individual risk of a sailor due to a possible containment failure of a single turbocharger and relate it to the acceptance criteria for the professional individual risk for sailors as suggested by the IMO.

The probability of containment failures has been determined based on statistical data of containment failures of MAN Diesel & Turbo. For the turbochargers it turned out reasonable to distinguish between the application in 2-stroke main engine, 4-stroke main engine and auxiliary engines. The work scope contained:

- Verification of assumptions and determination of failure probabilities for the occurrence of a loss of containment for different turbocharger types and applications from MAN damage statistics (see Section 1)
- Sensitivity analysis of the failure probability
- Estimation of the individual risk of an engine crew member in case of containment failure by applying conservative assumptions on engine room arrangements and exposure times of engine crew members to a turbocharger (see Section 1)
- Comparison of resulting individual risk to IMO recommendations (see Section 2 and 3)

1. Results of turbocharger risk assessment

The annual fatal risk of an individual sailor due to a turbocharger containment failure has been estimated. Therefore, the failure probability of the containment is combined by the proportional sailor's exposure time in the endangered area where a sailor is possibly affected (also considering off-times). These values were estimated for each turbocharger type and application within typical engine room arrangements and operational profiles. As each individual containment failure will only affect a part of the endangered area it is assumed that 20% of the sailor's time within this area he is located in a position where scattering debris would have fatal impact.

Formula Determination of Risk:

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

Explanation of factors:

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. The conservative arrangement of the machinery space shown in Figure 1 has been used for determining the presence rate. Additionally, a value for a favourable engine room arrangement has been determined (which is not shown here). These arrangements have been regarded together with standard engine crews (chief, engineers, wiper, oiler, fitter) and by considering the activities of crew members in typical scenarios, i.e. during normal sea going, manoeuvre and harbour. The individual presence rate for 4-stroke main engine (multi engine) is **0.9%** considering the conservative arrangement. Please note that a specific turbocharger application might deviate from these values.

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.

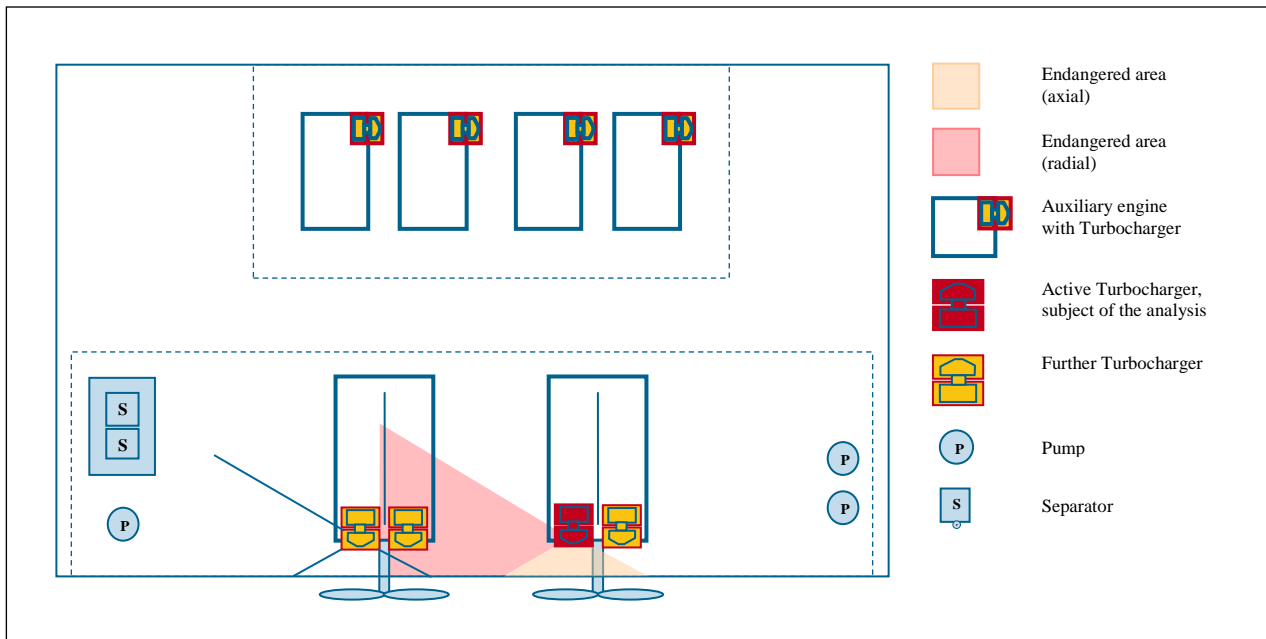


Figure 1: Conservative engine room arrangement for turbocharger application in 4-stroke Main Engine (multi engine)

2. Acceptance of individual risk in shipping

There is no risk acceptance criterion for one specific hazard. Within the maritime environment the International Maritime Organisation IMO released a guideline on formal safety assessments (MSC.83/INF.2). The annex of this guideline provides an example for assigning risk to the categories non-tolerable, tolerable and negligible which is basic prerequisite for verifying if ALARP can be applied. These thresholds are based on the assumption that the risk for crew should be similar to risk of workers in industry. The recommended bounds are determined as a total risk to an individual sailor or group of sailors on board of seagoing vessels and they are mostly approved by flag states, classification societies and the maritime industry, cf. excerpt in Table 1.

Table 1: Cumulative risk acceptance criteria for sailors by IMO (MSC:83/INF.2)

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

ALARP means **As Low As Reasonable Practicable**. The lower bound determines the level of the risk being negligible low, while the upper bound marks the risk being intolerable high. A risk assumed within the ALARP region should be reduced only, when the risk reduction is in proportion to the associated investment. When a risk is evaluated to be intolerable high, then it cannot be justified and has to be reduced irrespective to the costs.

3. Recommendation

The evaluated risk acceptance criteria in Table 1 refer to the total risk, an individual person or a group of people is exposed to. FutureShip recommends that the annual risk of fatal injury of an individual engine crew member caused by turbocharger containment failure should not exceed **10⁻⁸**, i.e. 1% of the lower bound for the cumulative risk.