Compliance with EEXI Regulation: Risks associated with Power Limitations

(First edition July 2024)

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The Oil Companies International Marine Forum (OCIMF)
Founded in 1970, the Oil Companies International Marine Forum (OCIMF) is a voluntary association of oil companies having an interest in the shipment and terminalling of crude oil, oil products, petrochemicals and gas, and includes companies engaged in offshore marine operations supporting oil and gas exploration, development and production.

Our vision is a global marine industry that causes no harm to people or the environment.

Our mission is to lead the global marine industry in the promotion of safe and environmentally responsible transportation of crude oil, oil products, petrochemicals and gas, and to drive the same values in the management of related offshore marine operations. We do this by developing best practices in the design, construction and safe operation of tankers, barges and offshore vessels and their interfaces with terminals and considering human factors in everything we do.

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Glossary

Bollard Pull Propeller Curve This curve represents the power required by the propeller at different rotational speeds (rpm) under the bollard pull condition, i.e. when the ship is stationary and generating maximum thrust. The exact value of power required by the propeller in bollard pull conditions is difficult to predict at the ship design stage. In general, a heavy running factor of 15-20% relative to the light propeller curve has been experienced, i.e. an rpm reduction of 15-20% for the same power.

Critical equipment and systems Any ship-based equipment, operating system or alarm that, were it to fail, could lead to an accident or would result in the crew or the ship being placed at risk. Critical equipment or systems should include as a minimum, but not be limited to, fire detection and firefighting systems, ship evacuation systems, crankcase oil mist detectors, steering gear, emergency generator, main engine shutdown alarms, propulsion and positioning systems and ventilation and air conditioning systems. Where redundancy is provided for operational reasons, equipment should still be considered as critical if the outcome of the Failure Mode, Effects and Criticality Analysis (FMECA) advises the equipment is critical, and its failure mode has direct impact on the propulsion capability of the ship.

Deadweight (DWT) The carrying capacity of a ship, including cargo, bunkers and stores, expressed in metric tonnes. It can be given for any draught, but here is used to indicate summer deadweight at summer draught.

Engine's Torque/Speed Limit Curve This curve defines the maximum torque that the engine can develop at a given rotational speed for continuous conditions. It is limited mainly by thermal and bearing loads on the engine.

Failure An occurrence in a component or system that causes one or both of the following effects:

- Loss of component or system function.
- Deterioration of functional capability to such an extent that the safety of the ship, personnel or environment protection is significantly reduced.

Failure Mode, Effects and Criticality Analysis (FMECA) A systematic and comprehensive method for identifying and evaluating potential failure modes in a system, their causes and effects, and the criticality of each failure mode. The goal of FMECA is to identify and prioritise potential failures so that corrective actions can be taken to prevent or mitigate their effects.

International Maritime Organization (IMO) The section of the United Nations with responsibility for coordination of international maritime safety and environmental issues. Conventions and resolutions passed by the IMO are implemented onboard ships by individual Flag States as legislation.

Light Propeller and Engine Layout Curves A light propeller curve is a calculated representation of the power required by the propeller at different rotational speeds (rpm) under ideal conditions, such as a clean hull and calm water. It is based on the ship's design condition, factoring in calm water towing resistance, propulsion coefficients, and propeller characteristics. Real-world operating conditions are accounted for by adding margins, such as sea margin (for wind and waves), engine margin (for power reserve and degradation), and light running margin (for hull fouling and heavy weather). After applying these margins, the light propeller curve transforms into the engine layout curve, which is used for engine selection and determining the specified maximum continuous rating (SMCR).

MAN Engine manufacturer

Safety Critical Equipment An individual piece of equipment, a control system or an individual protection device, which in the event of a single point failure may result in a hazardous situation that could lead to an accident, or directly cause an accident that results in harm to people or the environment.

Ship Any vessel, including barges, that is designed to carry oil, liquefied gases or chemicals in bulk.

SHOPERA-NTUA-NTU-MARIC (SNNM) A semi-empirical method for the prediction of the added resistance of ships in wave.

Under Keel Clearance The vertical distance between the bottom of the ship and the seabed.

Wartsila Engine manufacturer

Wave spectrum A wave spectrum describes the energy distribution among wave components of different frequencies of a sea state. A wave spectrum can be obtained from measured data or by using an established mathematical model (ISSC Wave Spectrum, JONSWAP, Bretschneider Spectrum, etc.).

Abbreviations

ACD	Auxiliary Control Device
ABS	American Bureau of Shipping
BSR	Barred Speed Range
BSR_{PM}	Barred Speed Range Power Margin
CII	Carbon Intensity Indicator
CPP	Controllable Pitch Propeller
DCS	Data Collection System
DLF	Dynamic Limiter Function
DNV	Det Norske Veritas
DWT	Deadweight Tonnage
EEDI	Energy Efficiency Design Index
EEXI	Energy Efficiency Existing Ship Index
EIAPP	Engine International Air Pollution Prevention Certificate
EPL	Engine Power Limitation
ERP	Emergency Response Plan
FMECA	Failure Mode, Effects, and Criticality Analysis
FPP	Fixed Pitch Propellers
GHG	Greenhouse Gas
GT	Gross Tonnage
IACS	International Association of Classification Societies
ICS	International Chamber of Shipping
IMO	International Maritime Organization
ISM Code	International Safety Management Code
ITTC	International Towing Tank Conference
LNG	Liquefied Natural Gas
LRM	Light Running Margin – propeller
MARPOL	The International Convention for the Prevention of Pollution from Ships
MCR	Maximum Continuous Rating
MCR_{lim}	Limited Maximum Continuous Rating Output
MEPC	Marine Environment Protection Committee (IMO)
MPP	Minimum Propulsion Power
MPP_{lim}	Limited Motor Output
MSC	Maritime Safety Committee (IMO)
mt	Metric Tonnes
$NMCR_{lim}$	Limited Engine Speed
NOx	Nitrous Oxide

OICNW	Officer In Charge of Navigational Watch
OPL	Overridable Power Limitation
OEM	Original Equipment Manufacturer
OMM	Onboard Management Manual
PSC	Port State Control
RO	Recognised Organisations (IMO)
RPM	Revolution Per Minute
SEEMP	Ship Energy Efficiency Management Plan
ShaPoLi	Shaft Power Limitation
SCR	Selective Catalytic Reduction
SMCR	Specified Maximum Continuous Rating
SMS	Safety Management System
SNNM	SHOPERA-NTUA-NTU-MARIC

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Ship Inspection Report (SIRE) Programme (OCIMF)

Tanker Management and Self-Assessment (OCIMF)

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1 Purpose and scope

The IMO's greenhouse gas (GHG) levels of ambition are designed to meet specific targets that support the global efforts against climate change and are subject to ongoing reviews. The latest IMO strategy update concluded at MEPC 80 in July 2023.

A range of short-term measures has already come into force and these focus on improving energy efficiency. Short-term measures include the application of technical-efficiency measures for existing ships. This regulation is commonly known as the Energy Efficiency Existing Ship Index (EEXI). Mid-term measures remain under discussion at IMO and, once selected, are expected to come into force in 2027.

When existing designs do not meet the EEXI criteria set by the IMO, shipowners may wish to explore the option of applying an Overridable Power Limit (OPL) to the maximum continuous rating output of the ship's propulsor. This could prove a simple and cost-effective way to meet EEXI regulations. The IMO Marine Environment Protection Committee (MEPC) in its 76th session distinguished between two different OPL methods: Engine Power Limitation (EPL) and Shaft Power Limitation (SHaPoLi).

The purpose of this publication is to provide best practice guidance for managing the risks associated with the implementation and operation of OPL, based on identified gaps in the newly introduced EEXI regulation.

2 Regulatory background

2.1 EEXI Regulation

The International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI amendments, which support the IMO's GHG Strategy to improve the energy efficiency of ships, came into force on 1 November 2022. The requirements for EEXI and Carbon Intensity Indicator (CII) certification which are part of the GHG Strategy's short-term measures, came into effect on 1 January 2023.

To comply with this newly introduced regulatory limit, the technical efficiency of existing (operational) ships will be assessed against the applicable Energy Efficiency Design Index (EEDI) reference line that is dependent on ship type and Deadweight (DWT) segment. A ship's EEXI would be calculated for each individual ship and benchmarked for compliance against the EEDI baseline (Phase 0). A reduction factor (% below that baseline) had initially been set at 20% for commercial tankers of 4,000mt DWT and above. Recognising the challenges that the larger DWT segments of new tanker designs have under the EEDI scope and considering that older hulls would face an even greater challenge, the IMO agreed to adjust the target to 15% for all ships of 200k DWT and above. For LNG carriers the reduction factor is set at 30% below the baseline. For gas carriers, attained EEXI needs to be at or below 30% for DWT segments equal to or greater than 15,000mt, 20% for ships equal to 10,000mt and above but less than 15,000 mt and, 0-20% for ships 2,000mt and above but less than 10,000mt. Table 2.1 summarises the EEXI compliance requirements described.

Ship Type	DWT	Reduction Factor (Below EEDI Phase 0 Baseline)
Tankers	≥ 4,000mt	20%
Tankers	≥ 200,000mt	15%
LNG Carriers	All	30%
Gas Carriers	≥ 15,000mt	30%
Gas Carriers	≥ 10,000mt and < 15,000mt	20%
Gas Carriers	≥ 2,000mt and < 10,000mt	0-20%

Table 2.1: *EEXI Compliance Requirements*

A review will be completed by 1 January 2026 by the IMO to assess the effectiveness of this regulation taking into account any guidelines developed by the IMO. If, based on the review, the amendments to this regulation are adopted, they will be brought into force in accordance with the provisions of article 16 of the MARPOL Convention.

Studies have shown that even newer ship designs would need modifications to meet the EEXI limits. Overridable power limitation (OPL) is one possible pathway to address the requirements of EEXI compliance. Considering that OPL implementation requires less time, effort and cost compared to more complex, innovative solutions, many ships have applied or are planning to install OPL within the timeline for compliance.

2.2 Minimum Propulsion Power

The concept of improving a ship's emissions profile by limiting the propulsion power output is not new. At the early implementation stages of the EEDI regulation, reducing the ship's design speed by selecting a smaller main engine or main propulsion motor was considered one of the most effective ways of reducing a ship's EEDI.

A debate took place at the IMO on how far speed reduction could be used for EEDI reduction. As a result, it was decided that there is a need to limit the use of this method so that it does not lead to unsafe and underpowered ships that may lose manoeuvring capability under adverse weather conditions. To ensure safe manoeuvring in adverse conditions, the Minimum Propulsion Power (MPP) requirement was introduced within the EEDI regulations, defining that "For each ship to which this regulation applies, the installed propulsion power shall not be less than the propulsion power needed to maintain the manoeuvrability of the ship under adverse conditions as defined in the guidelines to be developed by the Organization."

The 2013 Interim MPP Guidelines were developed by the International Association of Classification Societies (IACS) and applied to tankers, bulk carriers and combination carriers with DWT above 20,000mt. Investigation showed that these ship types are most critical with respect to the sufficiency of power for manoeuvrability in adverse conditions. Views have been expressed at the IMO that further consideration for other ship types/sizes should be given. The MPP Guidelines were recently revised in July 2021 (MEPC.1/circ.850/rev.3).

The current methodologies for estimating the minimum power under Regulation 24, MARPOL Annex VI are based on two assessment levels:

MPP Assessment Level 1:
Minimum Power Lines Assessment. A simple approach that involves calculation of the minimum power from a specific regression as a function of a ship's DWT, based on engine power data from already built ships.

MPP Assessment Level 2:
The MPP Assessment Level 2 aims to confirm that the ship's installed power is enough to achieve the required advance speed. This requires the determination of wind resistance and wave added resistance by model tests or referenced empirical formulas. Recently, the International Towing Tank Conference (ITTC) has accepted the use of the SHOPERA-NTUA-NTU-MARIC (SNNM) semi-empirical method for estimation of wave-added resistance, which has extended the scope of application to waves of arbitrary headings. The SNNM method only needs basic hull form information. It can therefore be used when evaluating the prevailing weather environment for older hulls (with installed power limitation) where detailed hull lines and data are missing.

It should be highlighted here that MPP Assessment applies only to non-overridable limits, for example a permanent engine derating. All ships that have to meet the requirements of Regulation 24, MARPOL Annex VI (Required EEXI) are reviewed for the full installed maximum continuous rating (MCR) output of their propulsion.

However, when a ship has installed an overridable power limitation to comply with the EEXI regulation, the MPP Guidelines serve as the IMO's guidance to justify releasing the limitation in adverse weather without breaching compliance.

2.3 OPL guidelines

As mentioned above, the OPL option, including both engine power limitation (EPL) and shaft power limitation (ShaPoLi), can be implemented for a ship to comply with the EEXI requirement. The IMO MEPC issued accompanying guidelines to the EEXI regulations, including technical and operational conditions that the OPL should satisfy under the EEXI framework (MEPC.335(76) as amended by MEPC.375(80)).

Following the IMO guidelines, ShaPoLi will require sensors for measuring torque and rotational speed delivered to the propeller, a data recording and processing device and a control unit for calculating and limiting the power transmitted by the shaft to the ship's propeller(s).

For EPL, electronically controlled engines can limit the power output (or access the power reserve) using software linked to the fuel index limiter or by directly limiting power in the engine's control system. The power output of a mechanically controlled engine can be restricted using a sealing device that can physically lock the fuel index via a mechanical stop screw sealed by wire or an equivalent device with a governor limit setting.

OPL cannot be overridden without permission from the Master or Officer in Charge of Navigational Watch (OICNW).

Figure 2.1 shows example engine load diagrams where ShaPoLi, electronic EPL and mechanical EPL are applied. The diagrams illustrate how engine power is managed under these limitations, showing the difference between available power during normal operations – limited by either a ShaPoLi or electronic EPL (left) or a mechanical EPL (right) – and the reserved power accessible in both cases. The curves help visualise the relationship between engine power, engine speed, and propeller load under these conditions.

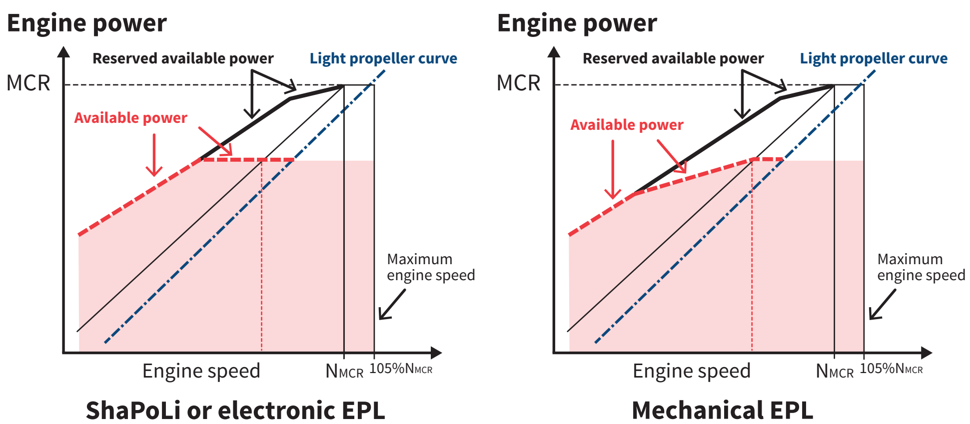

Figure 2.1: *Engine load diagram on Shaft/Engine Power Limitation (Source: IMO MEPC.335(76))*

Furthermore, IACS in REC 172 published in 2022 has clarified that a turbocharger cut-out by butterfly valve is included in the definition of OPL. Solutions such as non-overridable engine derating, turbocharger dismantling, non-overridable adjustment to the fuel index and propeller retrofits restricting shaft power to prevent damage are all non-overridable solutions and subject to relevant statutory reviews (e.g. MPP assessment, Engine International Air Pollution Prevention (EIAPP) certification under MARPOL Annex VI, barred speed range limit). For manoeuvring, a ship fitted with OPL needs to have the manoeuvring booklet and navigational bridge poster updated to indicate that an overridable limitation is in effect. For non-overridable power limitation cases, a more extensive process is required to ensure compliance with SOLAS Reg. II-1/28.3, refer to IACS Rec.172.

The IMO regulation also provides guidance for ship engines fitted with shaft generators and LNG carriers with diesel-electric propulsion where the overridable limitation is applied to the electric power output of the propulsion motor. For planned OPL retrofits, owners should work closely with Original Equipment Manufacturers (OEMs) and Class to ensure that the Failure Mode, Effects and Criticality Analysis (FMECA) of the ship's power management remains within acceptable limits.

2.4 Releasing the OPL

Release of the OPL is only allowed under conditions that would impose a safety risk to the ship, for saving life at sea, to mitigate security risks or to perform necessary maintenance. IMO's MEPC.335(76) cites Regulation 3.1 of MARPOL Annex VI and provides relevant guidance on the acceptable use of power reserve, reinstating the OPL, inspection by authorities and the reporting process to be followed when the need to override arises. A process is also defined for situations where proactive release of the OPL may be considered necessary, but the power reserve is not subsequently used. According to the requirements, the ship's Master and OICNW should have control of the OPL system from the bridge, wherever this setup is technically possible and feasible.

IACS clarifies that retrofitting a new bridge control system is not required for cases where the engine room is manned during critical operating conditions (e.g. adverse weather, piracy, manoeuvring) and that this process is clearly defined in the ship's Safety Management System (SMS). Owners should work closely with OEMs and Class to address requirements for immediate access from the bridge and bridge wing to the power reserve for emergency situations.

OPL reactivation should be physically confirmed by the Flag Administration or the Recognised Organisation (RO) and include supporting evidence (e.g. photos, engine room log) at the earliest opportunity. Confirmation of reactivation may be based on supporting evidence submitted by the owner, if accepted by the Administration or the RO acting on its behalf.

2.5 Onboard Management Manual

When commissioning an OPL system, the ship should be furnished with the accompanying Onboard Management Manual (OMM) which is to be kept permanently onboard and made available for inspection. The OMM is subject to verification by the Flag Administration or RO during the EEXI certification process. The manual should include technical information regarding the OPL system, maintenance and service requirements, descriptions on limiting/unlimiting the power reserve and associated alarms, responsible ship personnel, data capture and recordkeeping, reporting procedures, etc.

A detailed list of the items to be included in the OMM and supporting guidance is provided in MEPC.335(76).

2.6 Survey and certification

Regulation 5.4 of MARPOL Annex VI describes the survey and certification requirements that need to be followed for a ship's EEXI verification. Within this scope, the OPL should be reviewed for compliance with the requirements stipulated in Resolution MEPC.335(76), as amended.

3 Risk mapping overview

3.1 Introduction

This guide has been developed following a risk-based approach to address the challenges associated with the operation of ships fitted with overridable or permanent power limitations to meet the IMO's GHG reduction regulations. The bow tie methodology, a risk assessment tool that is used to identify, analyse and control risks, has been applied to provide a comprehensive understanding of the risks involved and propose practical solutions. See appendix for more on the bow tie methodology and how it was applied in this study.

3.2 Risk assessment result

The application of the bow tie risk assessment methodology identified the following threats under the top event, defined as loss of operational control:

- Adverse/extreme sea and weather conditions (open sea).
- The effect of environmental conditions in restricted waters.

- The lack of familiarity with the impact of limited power.
- The lack of familiarity to unlock reserve power.
- Issues due to continuous operation of equipment outside operational envelope.
- Issues due to continuous operation of equipment at low load.
- The inability to reach adequate speed to respond to emergency scenarios.
- Lack of understanding of overridable power limitation (OPL) requirements.

The following possible consequences were considered:

- Loss of integrity resulting in severe or catastrophic fires or explosions.
- Loss of integrity resulting in severe or catastrophic environmental impact.
- Loss of integrity resulting in severe or catastrophic impact to humans.
- Loss of integrity resulting in reputational damage.

The full bow tie can be found in figure A2 in the appendix. Table 3.1 provides a mapping of the bow tie threats and identified barriers to the corresponding document sections.

Threat	Barrier	Document Section
Adverse/extreme sea and weather conditions (open sea)	Ship designed with sufficient power	4.1 4.1.1
	Overridable Power Reserve	4.1 4.1.2
	Well executed berth to berth passage plan and the skills to respond in emergency situations	4.3.1 4.5.1
	Weather routing to avoid adverse weather	4.3.6
	Operators understanding the ship's capability in severe weather conditions	4.5.2
The effects of environmental conditions in restricted waters	Engines designed with sufficient power and torque	4.1.1
	Crew monitoring the situation with the ability to respond to abnormal conditions	4.3.4
	The use of Pilots with extensive local knowledge and ship limitations	4.3.5
	Effective communication with ports, terminals and tugs	4.3.7
	Weather monitoring to identify local threats	4.3.6
	An effective passage plan	4.3.1
	Operators understanding the ship's capability in severe weather conditions	4.5.2
	The use of tugs where required	4.3.7
The lack of familiarity with the impact of limited power	Crew competency	4.5 4.5.3
	Defined authority for OICNW to be able to override or request an override	4.3.2 4.3.3
	Systems designed with Overridable Power Limitation installed	4.1.2
	Updated manoeuvrability posters	4.3.8

Threat	Barrier	Document Section
The lack of familiarity to unlock reserve power	Crew competency	4.5
	Operating procedures to remove and reactivate limitation	4.3.3
	Crew drills	4.5.4
	System designed for ease of operation	4.1.3
	Engine operation in “heavy running”/“overload” area	4.1.1
Issues due to continuous operation of equipment outside operational envelope	Crew competency	4.5
	OPL equipment classed as critical equipment	4.4 4.4.1
	Clear operating instructions	4.3 4.3.9 4.2.2
Issues due to continuous operation of equipment at low load	Clear operating instructions	4.3.7 4.3 4.2.2
	Crew competency	4.5
The inability to reach adequate speed to respond to emergency scenarios	Crew monitoring the situation with the ability to respond to safety-critical conditions	4.3.10
	Crew competency	4.5
	Application of industry best practice, risk assessments and Company Management Systems	3 4.3.11 4.6
	Clear operating instructions	4.3 4.3.9 4.2.2
	Crew drills	4.5.4
	Overridable Power Reserve	4.1.2
	Ship designed with sufficient power	4.1 4.1.1
Lack of understanding of OPL requirements	Clear understanding of regulatory requirements	2 4.2 4.5.5
	Clear operating instructions	4.3 4.3.9 4.2.2
	Crew competency	4.5

Table 3.1: *Map of threats and identified barriers to corresponding document sections*

3.3 Document structure overview

This guide is divided into sections that address the considerations to establish and maintain the preventative barriers identified above.

- **Design:** In this section, we discuss the aspects of the safety barriers related to ships and propulsion systems to accommodate shaft/power limitations without compromising safety. Topics include engines designed with sufficient power and torque, overridable power reserve, simple overridable power limitation.
- **Installation and commissioning:** This section covers best practices for installing and commissioning overridable power limitations. Topics include ensuring compatibility with existing equipment, proper installation procedures, and thorough testing to verify compliance with performance and safety requirements.
- **Operation:** This section provides guidelines for managing ship operations within power limitations while maintaining safety and efficiency. Topics include voyage planning, optimizing speed and power, monitoring and managing equipment load, and understanding OPL requirements.
- **Maintenance:** This section emphasises the importance of a proactive and preventative maintenance program to ensure the reliability and performance of power-limited systems. Recommendations include routine inspections, maintenance scheduling, and identifying and addressing potential issues before they become critical.
- **Competency and training:** In the competency and training section, we discuss the need for comprehensive training and familiarisation with OPL systems. Recommendations include training on understanding and managing power limitations, unlocking reserve power when needed, and emergency response training.
- **Emergency response:** This section covers special considerations related to emergency response procedures when operating ships with OPL. Topics include understanding when and how to unlock reserve power, maintaining communication with relevant authorities, and ensuring crews are well-trained to handle emergency situations.

4 Identified barriers and controls

4.1 Design

4.1.1 Ship designed with sufficient power and torque (non-Overridable Power Reserve). Engine operation in heavy running/overload

For ships intended to comply with the EEXI regulatory limit through a non-overridable engine power limitation, the operating limits within the engine load diagram need to be carefully examined. The MPP Assessment is to be examined and verified according to the latest revision of the IMO's MPP guidelines to ensure that sufficient power and torque are available to allow safe navigation under adverse weather conditions. While sailing in waves, ships can experience dynamic phenomena that can result in extreme motions and momentary reduction in intact stability. These can include parametric rolling and surf riding/broaching. See section 4.5.2 for detailed information.

The effect of limiting the power on a ship's main engine depends on whether the engine is of mechanical or electronic control. For mechanical engines, with camshaft control of the fuel injection a power limitation is attained by limiting the maximum fuel index, which is a de facto limitation of the maximum engine torque. Electronic controlled engines provide the capability to apply direct limitation to the power output by adjusting the fuel index so as not to exceed the desired limitation.

Other means of non-overridable power limitation include potential propeller retrofits, turbocharger dismantling or cut-out by removal of blinding plate and non-overridable engine derating (e.g. cylinder cut-off).

IACS has issued guidelines for implementing the above options of permanent (non-overridable) power limitation to comply with EEXI in its Recommendation 172 (2022).

Before non-overridable limitation installation and commissioning, ship owners and operators are advised to review with engine manufacturers and Class the effect of the limitation to the applicable engine's (mechanical, electronic) load diagram, as well as the ship's compliance with the IMO's minimum propulsion power requirements, manoeuvrability and acceleration capabilities.

Ships undergo tests to check they meet the standards of manoeuvrability in IMO Resolution MSC.137(76) at the design stage via scale model testing and/or at newbuilt stage via full-scale trials. The criteria to be met include initial turning ability, stopping ability, etc. Ship speeds at which these manoeuvring tests are conducted, are required to be at least 90% of the ship's speed corresponding to 85% of the maximum engine output. The initial test speed would likely be altered after implementing EEXI compliance, with engine and propeller RPM limited to lower operating levels. In turn, the manoeuvring characteristics could be altered.

In addition, in operational settings where propeller thrust plays a significant role in changing the ship's heading at slower ship forward speeds (i.e. slow speed manoeuvring), attention may have to be paid to how a power-limited ship copes with such situations especially when the ship is not equipped with supporting propulsion devices, e.g. bow/stern thrusters for direction keeping, or is assisted by tugs.

4.1.1.1 Quick passage through the Barred Speed Range

After the EEDI regulations came into force and ships were required to comply with the strengthened limits of Phases 2 and 3, derated main engines (non-overridable limitation) were installed on several new delivered ships. In some early cases, this measure resulted in reduced power margin around the upper and lower limit of the Barred Speed Range (BSR). The BSR is associated with a large increase in torsional vibration and operation within this range is to be avoided. The BSR is to be passed through as quickly as possible in respect to the torsional vibration limits established by IACS UR M68 and Class rules. This duration has been typically measured in seconds.

Applying a non-overridable limit below a certain level to an engine may result in insufficient torque to pass through the BSR quickly. Concerns were raised on shaft line fatigue life and manoeuvrability in adverse weather due to prolonged stay in the BSR. Engine makers have since investigated mitigation measures and are able to customise solutions to ship propulsion system designs (e.g. the dynamic limiter function shown in figure 4.1, which is applicable only to electronic controlled engines).

Manufacturers' guidance suggests that to avoid slow passage through the barred speed range, a BSR range should not extend higher than 60% engine RPM (see figure 4.1). A more detailed approach is to ensure a BSR power margin BSR_{PM}, of at least 10% in the design:

$$BSR_{PM} = \frac{P_L - P_P \text{ x } 100}{P_P}$$

Where:

- BSR_{PM} is the Barred Speed Range Power Margin.
- P_P is the power required by the bollard pull propeller curve at the upper end of the barred speed range.
- P_L is the engine power limit at the same RPM.

As such, the BSR_{PM} expresses the excess engine power in the upper range of the BSR, and the ship's capability to pass it. [source MAN, *Basic Principles of Ship Propulsion,* 2023].

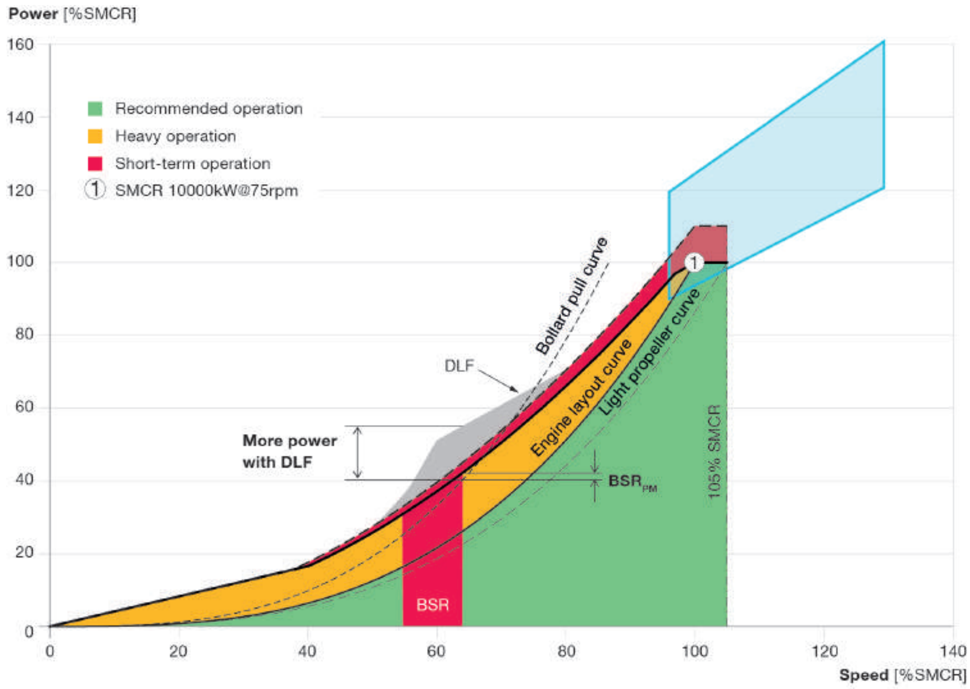

Figure 4.1: *Engine Load Diagram by SMCR within the Engine Layout Diagram [Source MAN]*

4.1.1.2 Propeller Light Running Margin

For cases where a non-overridable limit is considered, one way to increase the power margin at BSR and improve passage speed is to increase the propeller Light Running Margin (LRM). It should be noted that when propeller pitch reduction is applied to increase LRM, a small reduction of propulsive efficiency may be observed.

Higher LRMs are relevant for ships where the expected relative increase in a ship's resistance from fouling, heavy weather, shallow water, ice, etc., is high and may also be relevant if a shaft generator power take-off is applied.

The ship's operational profile, hull form, main engine MCR and propeller/shaft would define the optimum LRM, which should satisfy the following criteria:

- Ship should be able to maintain a certain speed of advance in heavy weather and/or with fouled hull.
- Ship should be able to achieve safe manoeuvring.
- Ship accelerations needed for safe and efficient manoeuvring.
- Quick passage through the BSR at bollard pull.
- For slow speed engines commonly fitted on bulk carriers and tankers, an LRM around 4-7% is typically recommended by engine manufacturers but can increase up to 10% in special cases.

It is the responsibility of the ship designer to select an adequate propeller LRM so that the desired operating points (power and rpm) in all relevant conditions, will not fall inside a BSR, nor outside the engine load diagram.

Example case

For this example ship case, model tests were carried out to compare two propeller designs. The propellers had very similar geometry but the full-scale predictions for the ship fitted with the modified design propeller (1.2% reduced pitch ratio) showed an increased LRM and improvement in terms of % power margin between the bollard pull curve and the engine torque limiting diagram.

Results are shown in the diagrams below for the design loading condition. Calculations are based on self-propulsion test results taken at the lowest tested speeds.

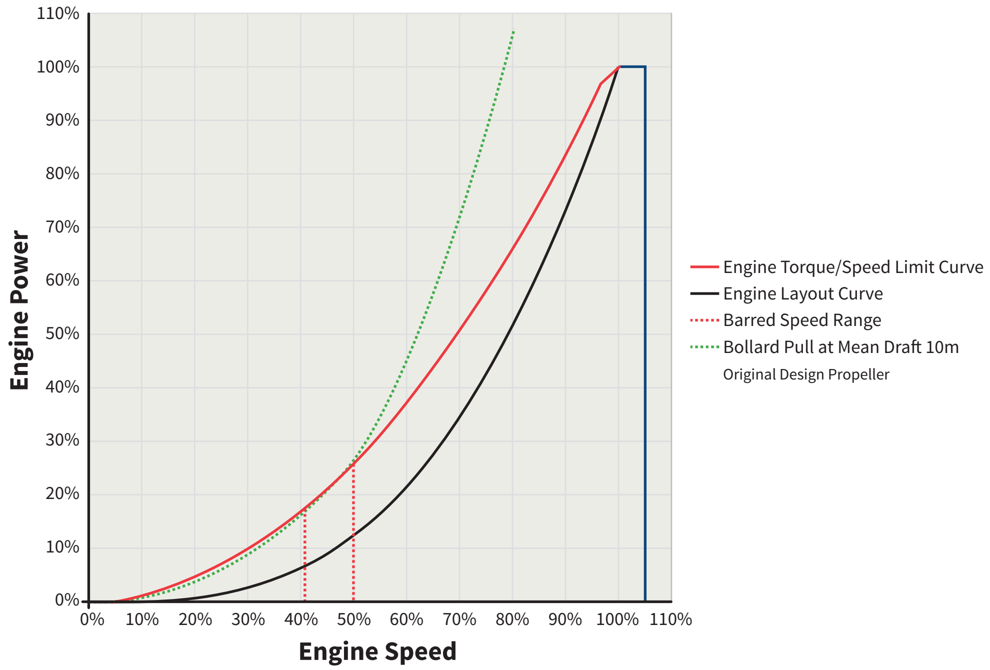

Figure 4.2: *Design Draft with Original Design Propeller*

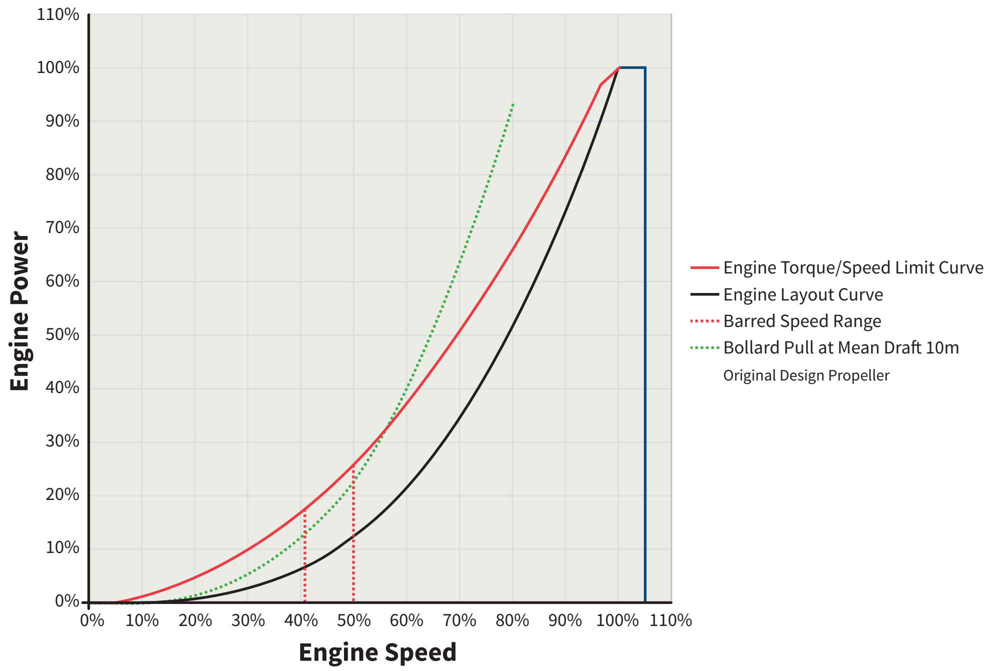

Figure 4.3: *Design draft with modified propeller (reduced pitch ratio at 0.75 R)*

4.1.2 Overridable limitations

As discussed in previous sections of this document, propulsion power limitation systems can be overridable (OPL) or non-overridable depending on projects. Implementation of OPL can be either in the form of engine power limitation (EPL) or shaft power limitation (ShaPoLi). Overriding the OPL allows the operator to deliver power reserve to the propeller when necessary to ensure the safety of the crew and the ship. See also section 4.6 Emergency response.

Table 4.1 provides a summary of the typical overridable power limitation systems.

OPL type	Engine type/ShaPoLi configuration	Component	Means of limitation
EPL	Mechanically controlled engine	Mechanical governor	Mechanical stop screw sealed by wire
EPL	Mechanically controlled engine	Mechanical governor	Mechanical stop screw sealed by wire, with additional setting of maximum limiter at governor to avoid fuel rack touching the mechanical stop
EPL	Electronically controlled engine	Electronic governor	Fuel index limiter which can electronically lock the fuel index, i.e. by setting a second limiter which is lower than the existing one
EPL	Electronically controlled engine	Electronic governor	Direct limitation of the power in the engine's control system
SHaPoLi	Automatic control	Fixed Pitch Propellers (FPP) or Controllable Pitch Propellers (CPP)	ShaPoLi calculates the shaft power using data from a torque meter. The engine control system then uses this information to restrict the engine speed, ensuring the power stays within the established limit
SHaPoLi	Automatic control	CPP	ShaPoLi calculates the shaft power based on measurements from a torque meter. Depending on the engine speed requested by the engine control system, the propeller's pitch may be adjusted accordingly, ensuring the power stays within the established limit
SHaPoLi	Manual control (see IACS REC 172)	FPP or CPP	SHaPoLi calculates the shaft power based on torque-meter and triggers an alarm so that the operator can reduce the engine speed

Table 4.1: *List of typical Overridable Power Limitation systems*

4.1.2.1 System designed to be tamper-proof

MEPC.335(76) specifies that OPL, whether engine power limitation or SHaPoLi, should require the deliberate action of the ship's Master or OICNW to enable the use of power reserve. As such, the limitation method is to be tamper-proof.

Depending on the limitation system being installed, the deliberate action to override the power limitation will be different. A summary of actions is provided here:

- Break the seal of a mechanical limiter when limiting the power by mechanical means in a mechanically controlled engine.
- Use push-button to override an electronic lock or engine control's system limitation.
- Introduce a password to access the limited power override.
- Confirmation of alarm to deliberately use the power reserve.

According to MEPC.335(76) the use of power reserve is only allowed for the purpose of securing the safety of the ship or saving life at sea. Therefore, it is to be ensured that unintentionally overriding the limitation is not possible. In this respect, for the examples given above, the following actions and methods are suggested:

- Update the ship's procedures and training to ensure that all crew members are aware that breaking the seal of a mechanical limiter is only allowed when instructed by the ship's Master or OICNW.
- If feasible, install the override push-button on the bridge. If not feasible, ensure that all crew members working in the vicinity are aware that the use of this push-button is only allowed when instructed by the ship's Master or OICNW. Providing push buttons with cover

guards is seen as an extra protection to ensure that no unintentional activation of the power reserve occurs.

- Password access to be easily available to all authorised personnel on board.
- An additional confirmation before the use of power reserve might support avoiding unintentional use.
- Alarm confirmation to only be available to ship's Master and OICNW.

There should be means to indicate to the Master or OICNW that the OPL is engaged or overridden.

4.1.2.2 Overridable Power Limitation for electronically controlled engines

OPL sets a limit to the allowable engine power in normal operating conditions and in this way, regulates the ship's fuel consumption.

The system uses a fuel index limiter that can electronically lock the fuel index. Alternatively, it calculates the engine power output in real time, then compares the engine power output to the OPL and regulates the fuel index based on actual power. By limiting actual power, the OPL function will not affect the engine's operation under normal conditions, that is, unless the engine power limit is reached, and there is no impact to the engine's heavy running capabilities (see figure 4.4). However, the ship's acceleration may be affected, depending on the extent of the limitation applied.

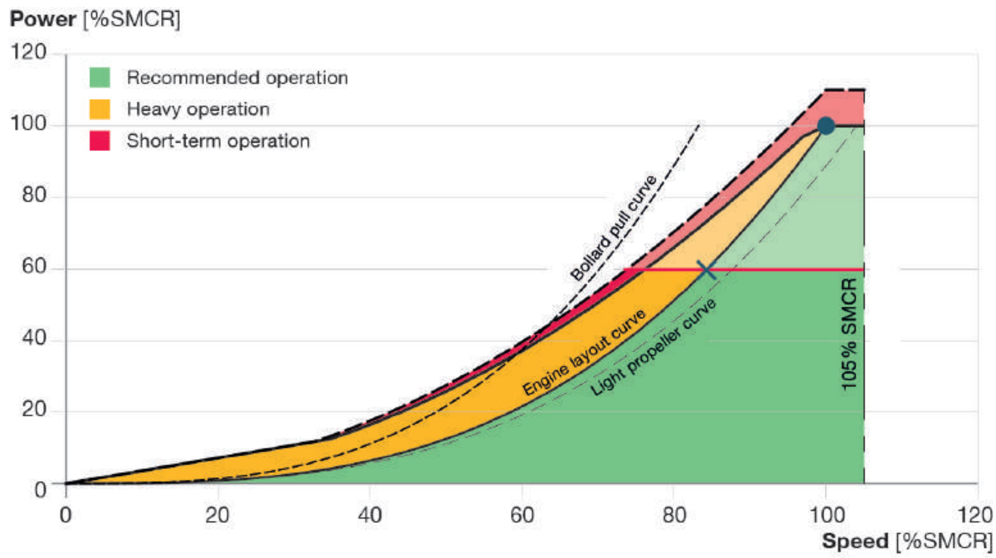

Figure 4.4: *Impact on the engine's load diagram of a 60% OPL for an electronically controlled engine [Source MAN]*

When overriding the engine power limit, the propulsion control system will provide default alarm outputs for logging and reporting of the event.

4.1.2.3 Overridable Power Limitation for mechanically controlled engines

Power limitation for mechanically controlled engines is achieved by limiting the maximum fuel index, i.e. limiting the maximum amount of fuel that can be injected per firing. A fuel index limitation is in practice a limitation of the maximum engine torque. The fuel index is limited so that the power limit is attained along the engine layout curve (see figure 4.5). Limiting the engine power by a torque limitation implies that at engine speeds below the speed corresponding to the OPL on the layout curve, the load diagram of the engine will be restricted as the engine torque is limited. Once the torque limitation reaches the intersection with the original torque limit of the engine, the original torque limitation prevails. The difference between the original and torque/power limited load diagram is indicated in figure 4.5.

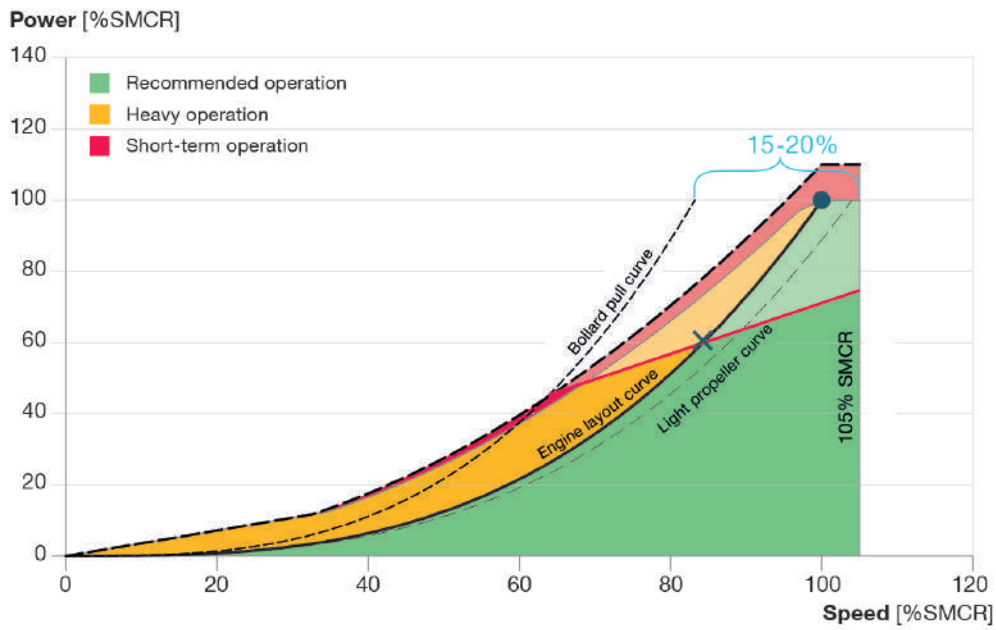

Figure 4.5: *Impact to the engine load diagram of a fuel index limitation for a mechanically controlled engine to attain 60% power limitation [Source: MAN]*

The narrower load diagram resulting of an index limitation implies that acceleration capabilities of the ship could be reduced, depending on the extent of heavy running of the bollard pull curve and its intersection with the new load limitations. This is important to consider with respect to the passage of a BSR.

For mechanically controlled engines, the OPL is a sealing device to physically lock the fuel index to a precalculated set value by using a mechanical stop screw sealed by wire or an equivalent device with governor limit setting so that the ship's crew cannot release the OPL without permission from the ship's Master or OICNW.

Release and reinstatement of the OPL should be recorded and reported according to the IMO Guidelines. See section 4.3.3 Operating procedures to remove and reactivate limitation.

4.1.2.4 Overridable Power Limitation ShaPoLi

ShaPoLi is a technical measure developed to reduce ship fuel consumption and emissions profile by restricting the output power of the propeller shaft(s). Before the introduction of EEXI regulation, ShaPoLi was a proven permanent energy efficiency option for ships that have excess installed propulsion power, following the re-design of a propeller aimed at new operational requirements. After the adoption of EEXI, the ShaPoLi function was agreed to be a practical and low-cost statutory compliance method.

A ShaPoLi system consists of sensors to measure torque and rotational speed delivered to the propeller(s) of the ship, a data recording and processing device and a control unit for calculation and limitation of the power transmitted by the shaft to the propeller(s). ShaPoLi limits the shaft power output by altering the RPM setpoint for electronically controlled engines driving Fixed Pitch Propellers or the pitch setpoint for Controllable Pitch Propellers.

For systems with shaft generators, separate signals will ensure that the ShaPoLi level is not affected by power take-off.

In the event of ShaPoLi override, the event signal, timestamp and required background information will be sent to and logged by a recording system for documentation and reporting purposes.

Before OPL installation and commissioning, ship owners and operators are advised to review with engine manufacturers the effect of the applicable OPL type, mechanical or electronic, on the engine load diagram and the ship's acceleration capabilities. This will ensure procedures for timely override are included within the ship's OMM and SMS.

4.1.3 System designed for ease of operation

Simplicity should be considered when evaluating the suitability of an OPL system, not only at the installation and commissioning stage but in terms of usage and interface with the crew while the ship is in operation. In general terms, simplicity will provide benefits such as:

- Ease of operation for crew onboard.
- Decreased chance of malfunction.
- Reduced possibility of human error in operating the OPL system.
- Faster overriding or setting up the system.
- Assurance that, if the system needs to be overridden, it can be reactivated quickly and correctly to the original limitation setting by the crew members.

4.1.4 Ship's optimum operating condition

Issues associated with non-overridable power limitation

Reducing the maximum available propulsion power may reduce the ship's manoeuvring capability under adverse weather conditions. This can be made worse by increased hull roughness and/or degradation of the main engine performance.

To help mitigate these effects, the hull and the main engine should be regularly monitored. This can be achieved through vessel performance monitoring and hull condition monitoring. In addition, hull cleaning and engine maintenance are particularly important to ensure there is no further reduction of the performance envelope.

Issues associated with overridable power limitation

Whereas a ship fitted with an overridable limitation may suffer from the same issues as with non-overridable, the option to revert to full power would mitigate these effects in emergency situations.

To address potential uncertainty regarding the timing and process of overriding the OPL, it is recommended that the Master and crew familiarise themselves with the OMM procedures and conduct regular simulation training and/or drills. See section 4.5 for more on competency and training.

4.1.5 Engines designed to meet MARPOL emission limits

Many existing ships are expected to apply power limitation measures in order to comply with the IMO's GHG reduction strategy and specific regulations on carbon intensity or energy efficiency.

When limiting the propulsion power of an existing ship, consideration will need to be given to the effects these modifications may have on the engine's emissions certification. IMO's MARPOL Annex VI regulation 13 NOx emissions regulations are based on all engines being certified to the applicable limit. That limit is based on the rated engine speed and verified by undertaking testbed emissions measurements under steady state conditions to the applicable duty cycle at set points of the engine's rating based on the engine nameplate MCR.

Engines are required to be operated within the bounds of the approved NOx Technical File throughout the lifetime of the engine. Any changes to engine ratings, NOx critical components, settings or performance need to be considered with regard to the implications on the NOx certification. For some engine types, regular performance checks are required to verify the engine is operating within the performance bounds of the NOx Technical File. This is detailed in the On-Board NOx Verification Procedure and an OPL may prevent operators undertaking this required check. Consideration will also need to be given to any potential impacts on emission control measures or equipment fitted to engines such as Selective Catalytic Reduction (SCR) systems or any Auxiliary Control Device (ACD) identified in the approved NOx Technical File. There is guidance on this in MEPC.335(76), the IMO's guidelines on shaft or engine power limitations, which indicates that such power limitations are permitted where there is no change to the NOx critical settings and/or components outside those that are permitted by the approved NOx Technical File, otherwise such power limitations will require the engine NOx emissions to be re-certified.

The IMO's guidelines on shaft or engine power limitations in MEPC.335(76) indicate that such power limitations are permitted when there is no change to the NOx critical settings and/or components, outside those that are permitted by the approved NOx Technical File. If the settings/components do change, then such power limtations will require the recertification of the NOx emissions. There is also guidance on this in IACS Recommendation 172.

The power limitation method may also affect the Ship Energy Efficiency Management Plan (SEEMP) implementation and CII Rating. Amendments or updates to the procedures under the ship's SEEMP might need to be considered. This should be reviewed by owners and operators and updates reviewed on a case-by-case basis.

4.2 Installation and commissioning

4.2.1 Installation by OEM authorised technicians

The best practice is for the EPL to be installed by the engine OEM authorised technicians, specific to the make and model of the engine.

The best practice for ShaPoLi is to use authorised technicians duly qualified by the propulsion control system manufacturer for automatically controlled systems. For manually controlled systems, the technicians should be qualified by the monitoring system manufacturer.

A comprehensive management of change process considering the impact of the OPL is recommended. See OCIMF publications *Tanker Management Self Assessment (TMSA)* and *International Safety Guide for Oil Tankers and Terminals (ISGOTT)* for process guidance.

The OPL functionality and operation are subject to Port State Control inspection. The commissioning of the installation should be witnessed by the relevant crew onboard. The location of the sealing device, the fuel index sealing system, and the alert-monitoring system, if applicable, should be clearly marked.

It is recommended that the power limitation override is tested at least once at sea at the earliest opportunity after installation.

Upon installation and verification of the OPL, the IEE Certificate should be re-issued by the RO. This certificate should be retained on board the ship after approval of the EEXI Technical File and OMM by the Administration or RO.

4.2.2 Key verification activities by Recognised Organisation

In relation to propulsion power limitation, the RO's key verification activities are outlined below:

- EEDI/EEXI Technical File review and approval by RO's engineering department. If in future a ship undergoes major conversion, then the process is to be repeated.
- In case of overridable power limitation, OMM review and approval by RO's engineering department.
- During the first IAPP after 1 January 2023, the RO's surveyor is to confirm the approved arrangements and then issue a new IEEC with supplement.
- During the next IAPP annual, intermediate or renewal surveys, the RO's surveyor is to review the OMM with its records, as well as the bridge and engine room logbooks.
- During the periodical surveys, RO's surveyor is to verify records to confirm that the operator has notified Flag Administration/RO when required.
- In case of reactivation or replacement of the overridable power limitation, the operator is to provide relevant evidence and the RO will then need to confirm acceptance by physical or remote survey.

4.3 Operation

4.3.1 An effective well executed passage plan

Safe operation requires a well-developed and executed berth-to-berth passage plan and the skills to respond to emerging situations.

The ship's final berth-to-berth passage plan should be developed in such a way that there is no need to normally override the OPL. While developing the passage plan the ship's Master and Navigation officers should study the impact of the OPL on each leg to determine alternatives in cases where an override of OPL is identified.

If changes to the route are not possible due to navigation constraints, the passage plan review should highlight areas and times when a limitation will be relevant, and include the necessary actions required. One such action could be an override of the OPL as permitted under regulation 3.1.1 of MARPOL Annex VI, this should however be done in a timely manner taking into consideration the safety criteria stated in the OMM.

Weather and tidal conditions should be reviewed considering the ship's OPL and the effect of vibration on the ship at certain engine RPM. Consideration might be needed with regards to increased propeller cavitation and the resulting underwater noise, especially when transiting environmentally sensitive areas.

Vulnerable parts of the passage legs, where tidal currents and strong winds work against the ship in restricted sea room, should be planned or timed so that the tidal current and/or the winds are favourable.

In all cases, where it has been determined that the override of the OPL is unavoidable then such an override should be performed before getting into the deemed critical situation. In the case where this occurs inside the port limits then the override should be performed well before making a port entry.

A tabletop exercise and risk assessment may need to be performed if the passage plan determines that an OPL override is anticipated.

4.3.2 Defined authority for OICNW to be able to override or request an override

The operator should clearly define the authority of the OICNW to override the OPL either directly from the bridge or through coordination with the engine officer in the engine room. The use of power reserve by overriding the OPL should only be permitted for the purpose of securing the safety of a ship or saving life at sea as permitted by regulation 3.1.1 of MARPOL Annex VI.

Should the circumstances of the case allow the Master should first be informed. In any case this event should be recorded in the bridge and engine logbooks and the full details to be recorded in the OMM per MEPC 335(76) 3.2.

A copy of this authority delegation should be posted on the bridge and detailed instruction available in the bridge and engine procedures guide with easy access to the user at the respective positions.

4.3.3 Operating procedures to remove and reactivate limitation

The engine manufacturer's instructions should be strictly followed for both activating and deactivating OPL. These instructions should be posted in the working language of the ship in the wheelhouse, engine control room and at all local engine control stations. The Master and all OICNW should also be aware of the safe activation and deactivation procedures for the OPL, including any need for reducing engine power for the purpose of removal/reactivation of OPL.

For mechanical limitations, the required tools to carry out the removal and reactivation of OPL should be readily available at all times at a location as close as possible to the limitation mechanism. These tools should be dedicated for limitation/reactivation procedures, clearly marked and not be removed from their dedicated location for any other purpose.

The bridge and engine logbook recording requirements and the reporting requirements are provided in para.3.3 and para.3.4 of MEPC.335(76) respectively.

Regular drills should be conducted on removing and reactivating OPL. Crew should be able to demonstrate that they are able to reset the limitation to the original conditions, bearing in mind that the initial installation should be by OEM authorised technicians but the reactivation should be carried out by crew on board.

4.3.4 Crew monitoring the situation with the ability to respond to abnormal conditions

The bridge officer and the lookout should be aware of the power restrictions imposed by the OPL installation. They should also consider the time needed to bypass such a system. Navigation decisions should account for these factors and the current weather and traffic conditions the ship is facing.

Ship owners and ship managers should ensure that the ship staff are properly trained in the OPL operations, and its override as contained in the OMM.

4.3.5 Safe navigation of ships in mandatory or recommended pilotage areas

In mandatory pilotage waters, or areas where the IMO recommends that ships take a maritime pilot, the services of a Pilot with extensive local knowledge and ship-handling experience are critical to the safe navigation of the ship, prevention of pollution and the efficiency of shipping operations.

Whether non-overridable or overridable, power limitation introduces a new constraint on the ship-handling options available to a Pilot.

This section addresses the use of the power reserve in response to control orders from a Pilot. It focuses on the appropriate characteristics of OPL arrangements and the policies and procedures contained in the OMM when required.

Any guidance should be consistent with IMO Resolution MEPC.335(76).

4.3.5.1 Threats and main events in pilotage waters

From a pilotage perspective, the main event is any instance in which the Pilot does not have the full range of main engine power required to deliver:

- The additional water flow over the rudder to increase its efficacy.
- Additional and sufficient speed.
- The astern thrust required to reduce the ship's speed or to take all way off.

In pilotage waters (including port approaches, ports, terminals, canals and rivers), the threats to the safety of the ship using OPL include, but are not limited to:

- **Loss of directional stability**. In a restricted waterway, a ship may encounter shoaling and experience shallow water effects or another type of unexpected force that causes the ship to lose directional stability and veer towards a bank, structure, or other navigational hazard or ships in the vicinity.
- **Volatile environmental conditions.** Due to seabed or other topographical features, a ship may encounter volatile environmental conditions (e.g. tidal currents, wind speed and direction or a combination of both). This volatility will need to be countered to avoid the ship being set down on a navigational hazard or being unable to manoeuvre clear of ships in the vicinity.
- **Unexpected change in other ship traffic speed**. When operating in a restricted waterway, a ship may need to reduce speed or take all way off in response to a situation onboard a ship ahead (e.g. due to a propulsion or steering malfunction that requires them to slow down). In the absence of sufficient power, the Pilot may be unable to slow the ship down fast enough, and the range of emergency manoeuvring options may be limited, risking an allision, collision or grounding.
- **Unexpected traffic management demands**. When operating in a restricted waterway, a ship may need additional speed to react to an unforeseen risk of meeting another ship in an area where the risk posed by interaction between ships is considered unacceptable (e.g. a narrower channel or higher traffic density).

4.3.5.2 Barriers and escalation factors in pilotage waters

The principal barrier to averting allisions, collisions and groundings in pilotage waters on a ship using OPL is the ability to use the full range of installed main engine power where required by a Pilot.

The most effective way to achieve this capability is by ensuring that the ship's designated crew is properly trained to safely override the OPL during pilotage if required in an emergency. The crew should understand the reactivation procedures, and know what actions to take whether the power reserve is used or not.

The ability to disengage/disarm the OPL is degraded by any policies, procedures or technical arrangements that prevent or otherwise delay OPL override. Escalation factors include:

- For any reason, the Master or bridge team are unwilling to override the OPL. This includes the actual or perceived risk of adverse impacts on propellors, shafts and related machinery and systems.
- The Master or bridge team being unfamiliar with the procedures for overriding an OPL.
- Complex override procedures or systems that delay access to the power reserve, including the involvement of personnel ashore.

Consequently, policies and procedures relating to power limitation, including the OMM, should:

- Explain the impact of power limitation on the efficacy of the rudder and ship manoeuvring characteristics in pilotage waters, and emphasise the authority of the Master and bridge team to override the OPL when a Pilot gives control orders requiring the use of the power reserve.
- Avoid policies and procedures that result in the Master and bridge team being unwilling to override the OPL when a Pilot gives control orders requiring the use of the power reserve.
- Recognise that the Master and bridge team should be aware of and comply with national and local regulations about the readiness to override the OPL in pilotage waters.
- Provide for pre-arrival drills that may be required by national or port regulations, in addition to those provided for in IMO guidelines (refer to section 4.5.3.2). Ships' crews should note that harbour authorities may require that drills are carried out to test the override procedures.
- In addition to policies and procedures, the Master and bridge team should be provided with the following:
  - Training and familiarisation so that they are confident with the procedure for overriding the OPL.
  - Information about the ship's handling characteristics, both with and without OPL. This information should also be displayed on the bridge for reference by the bridge team and the Pilot.
  - The bridge Pilot card and Master-Pilot Exchange (MPX) should be updated to clearly highlight the restriction imposed by the power limitation resulting from the SHaPoli/EPL installation as well as the time required to override such a system. This has become a requirement by regional authorities such as the United States Coast Guard Commercial Vessel Compliance (CG-CVC). Where the ship's Manoeuvring Characteristics have been amended, then this should be brought to the attention of the Pilot. From the perspective of safety in pilotage waters, OPL arrangements which cannot be operated from the bridge or which require the intervention of personnel other than the Master or bridge team may result in a ship being subject to additional operational risk management measures, including but not limited to the use of escort tugs (refer to section 4.3.5).

Reference: CG-CVC, Pilot Cards, July 28, 2023.

4.3.6 Weather routing with OPL installations

Weather routing is an integral part of executing a safe passage plan, which becomes even more important when considering ships' power limitation resulting from the SHaPoLi/EPL installations and the need to reduce environmental footprint. Once a route is planned it is necessary for the ship's staff to monitor the weather conditions so that the route can be adapted to the current and future weather situations.

On a ship with OPL installed, the Master should bear in mind the power limitation imposed on the ship when planning a transit through a region that is expected to experience heavy weather. If in the Master's experience the situation cannot be managed using existing engine power, then the Master should consider an OPL override well in advance of getting into a critical situation should other alternatives become unreasonable. Certain weather conditions can result in bow slamming, heavy pitching, synchronous rolling, excessive hull vibration and increased hull stress, which could result in damage to the hull and engine if proper control measures are not adopted. Early action is necessary to resolve a critical situation such as contact with another ship. Conditions such as proximity to navigation hazards, traffic density, effects of interaction and reduced under keel clearance due to swell build up will also play a role in such decision making.

As a ship would be expected to use reduced power while negotiating heavy weather to avoid damage to the propulsion machinery, the need to use reserve power by overriding the OPL is not normally envisioned.

4.3.7 The use of tugs where required

This section is related to circumstances requiring tug use beyond the normal/mandatory port requirement for the size of the ship and prevailing weather e.g. to address any situation in which the ship OPL is unable to be overridden in a timely manner. In such circumstances, an additional tug(s) may be needed for escort purposes or to be engaged in pushing and pulling operations. The option to use a tug to transit a specific restricted zone in such a condition should not be overlooked.

Where it has been determined that the OPL override is necessary to ensure safe operation in port, this should as far as possible, be completed before arrival in port.

An OPL system is fitted on board to restrict power at the higher ranges of engine power, usually used in a sea passage outside confined waters, so the engagement of tugs to complement reserve power in this power range is not normally envisioned.

Where non-overridable power limitation substantially affects the range of main engine power available to the Pilot and exposes the ship to the threats highlighted above, the use of escort tugs should be considered by the Master and may be advised by the port, terminal, canal or river authorities.

4.3.8 Updated manoeuvrability posters

Detailed guidance on the display of a ship's manoeuvring characteristics, e.g. turning circle, stopping distance, etc., is contained within IMO Resolution A601(15), and this information would normally be included within:

- A wheelhouse mounted poster.
- The Pilot Card.
- The manoeuvring booklet.

The manoeuvring characteristics may be affected by the installation of overridable power. Although it is not an IMO requirement, ideally the above listed documentation should include the characteristics for the ship at speeds commensurate with both full and limited power applied. Master and officers should be made aware of which levels of power are commensurate with the displayed information, i.e. with or without the power limitation.

Where the current power limitaton does not match the ship's manoeuvring characteristics displayed in the wheelhouse mounted poster, there should be a note that this is the case.

4.3.9 Clear operating instructions

The ship operating procedures for the bridge and engine room should provide detailed guidance on the operation and/or restriction imposed by the power limitation resulting from the OPL installations as well as the time duration required to by-pass such a system with specific references to the OMM.

4.3.10 Crew ability to respond

Watchkeepers should bear in mind the additional responsibility that comes with a ship fitted with an OPL, especially in restricted waters or when in a close quarter situation. Having an OPL may cause an increased response time and may impact course keeping capability of the ship.

Depending on the OPL type, the time to override the limitation may vary significantly, and will be referenced in the OMM. For a specific ship, key crew members should be aware of the time to override the power limitation considering the type of OPL, location onboard, necessary tools, etc.

Should the watchkeepers observe there to be a significant difference between the operation of the OPL as mentioned in the OMM versus actual installation onboard, then such situation should be brought to the attention of the ship's management without delay so the OMM can be updated accordingly.

In certain circumstances, the crew may need to prepare in advance to avoid any delays in the release of the limitation. That may require a staffed engine room, ready to respond, in case of a mechanically controlled EPL.

4.3.11 Application of industry best practice, risk assessments, and company management system

It is recommended that the ship operator risk assess the specific installation and operation of the OPL with the intent to comply with the EEXI regulations. The ship's SMS should be updated accordingly. Ship operators should refer to industry's best practices guides with respect to the risk assessment process.

See OCIMF publications *TMSA* and *ISGOTT* for Management of Change process guidance.

At the time of publishing there is a lack of statistical data reflecting the performance of OPL systems, so risk assessments are likely to take a qualitative approach. As statistical data based on experience becomes available, a quantitative approach could be taken.

4.4 Maintenance

4.4.1 OPL equipment considered critical equipment

Critical equipment usually refers to the equipment critical for the ship's safety. In this regard, safety-critical equipment is those elements whose failure would cause or contribute substantially to an accident or whose purpose is to prevent or limit the effects of such. Safety-critical equipment should be determined by putting all the equipment supporting the reliable propulsion through a structured FMECA executed by a competent authority and the right team in participation. Situations such as loss of power or propulsion at any moment in time are to be considered accidents in this context.

Integration of OPLs with existing systems on board is key to ensure safety of the ship. The effect of the power limitation on the ship critical equipment should be investigated fully to understand any new interactions. Any failure of an OPL system should not adversely affect the continuous operation of the engine or propulsion system. Considering that OPLs are an add-on to the existing system, it would generally be expected that their failure would render the power limitation inoperative, hence, potentially losing the ability to limit the existing power. This would not mean that the power reserve will be used but, in any case, the notification actions highlighted under MEPC.335(76) Annex 3 should be followed until the OPL's ability to limit the power is restored. The overriding function of OPLs is to ensure the ship's reserve of engine power is available when the situation calls for it.

The OPL's maintenance instructions and spare parts (if applicable) should be added to the ship's Maintenance Plan as with other equipment on board. Electronic systems would need minimal maintenance and inspections, and these will be dictated by the manufacturers. Mechanical systems might need increased routine inspections and spare parts, such as locking seals. Mechanical systems designed and installed by OEMs will be provided with documentation that can be used to add the OPL to the Maintenance Plan. Other mechanical systems might need a case-by-case evaluation to consider necessary maintenance tasks.

4.5 Competency and training

4.5.1 Passage planning

Effective training in developing and executing a berth to berth passage plan that includes a study of the impact of the OPL on each leg to determine alternatives in cases where an override of OPL is identified and the skills to respond to emerging situations is required for Masters and officers.

References: *Bridge Procedures Guide* (ICS) and *SIRE VIQ* (OCIMF).

4.5.2 Understanding ships' capabilities and the potential impact of OPL on excessive ship motions

While sailing in waves, ships can experience dynamic phenomena that can result in extreme motions and momentary reduction in intact stability. These can include parametric rolling and surf riding/broaching, as described in detail in this section.

Such phenomena are partly determined by the speed of a ship relative to the waves, and hence the installation of OPL may increase the risk of encountering these phenomena.

Ships operating in a particular region with a characteristic wave spectrum may not have previously experienced such phenomena, but with the adoption of OPL, ship speeds will reduce. This will affect the wave encounter frequency and could increase a ship's susceptibility. When implementing OPL, it is important for crews to be aware of these risks, and of the necessary mitigations to minimise any excessive motions.

Ship's crew should be made aware of these phenomena, and of the recommended actions to mitigate against these risks in their normal training procedures.

4.5.2.1 Parametric rolling

Parametric rolling is a resonant effect where a ship's length approximately matches the wave length and the time it takes for each wave to pass the ship is about half the natural roll period of the ship. The phenomena may be best explained by considering the passage of a ship through two consecutive wave crests as a series of steps.

With the wave crest amidships the ship's waterplane reduces, and the stability may reduce to the point where a roll is initiated (say, for example, to port).

1. If the relative speed of wave encounter is such that the ship reaches its maximum roll angle at the same time as the wave trough is amidships, then due to the increased waterplane area, the ship's stability increases, and the increased righting moment accelerates the roll to starboard.
2. As the ship rolls past the upright position, the next wave crest is amidships, and again the reduced waterplane area destabilises the ship and encourages the roll to starboard.
3. As the ship reaches its maximum roll angle to starboard the next wave trough aligns with midships, and the larger waterplane increases the ship's stability. The increased righting moment then encourages the roll to port.

In this way, quite large roll angles can build up, generating excessive accelerations that may affect crew performance and lead to the movement of cargo, etc.

4.5.2.2 Surf riding and broaching

Broaching can occur when operating in following seas and when the speed of the waves is the same or faster than the ship's speed. It occurs when the ship accelerates down the steep face of a wave and begins to surf-ride. This can result in the ship losing steerage and uncontrollably turning across the wave. The risk of occurrence is greater for smaller ships. The potential consequences for smaller ships are also greater, with an associated risk of capsize.

4.5.2.3 Mitigations

If the ship's crew start to experience parametric rolling or reduced steerage due to surf riding/broaching, it is important to take early action to change the relative encounter frequency of the ship relative to the waves. This may be done by altering ship speed, the course relative to the waves, or both.

In extreme circumstances, if the above measures do not work, the crew should consider overriding the power limitation in a timely manner to safeguard the ship and cargo.

More detailed guidance on how to mitigate against such dynamic phenomena may be found in IMO's circular MSC.1/Circ. 1228.

Analytical methods to assess the vulnerability of a ship design or an existing ship to these and other dynamic phenomena can be found in MSC.1/Circ.1627 Interim Guidelines on the Second Generation Intact Stability Criteria.

4.5.3 Crew competency

4.5.3.1 Crew's awareness of the potential impact of OPL on course keeping and manoeuvrability

Detailed guidance on the display of a ship's manoeuvring characteristics, e.g. turning circle, stopping distance, etc., is contained within IMO Resolution A601(15), and this information would normally be included within the wheelhouse mounted poster, the Pilot Card and the Manoeuvring booklet.

Masters and officers should be aware of the information available including changes due to any power limitation.

Wind and wave action can have an appreciable effect on course keeping and manoeuvrability. For large wave heights a ship may behave erratically, and in certain situations lose course stability. These effects are expected to become more pronounced at the reduced power associated with the installation of an OPL. Hence within their normal training procedures, Masters and officers should be made aware of these effects and trained in their obligation in an emergency situation to override the power limitation, e.g. when there is a collision risk or a risk of being driven onto a lee shore.

4.5.3.2 Provision of OPL operating procedures and crew training

Under Chapter IX of SOLAS, compliance with the International Safety Management (ISM) Code is mandatory for ships above 500 gross tonnage that undertake international voyages. Chapter 6 of the ISM Code requires the company to:

- Establish and maintain procedures for identifying any training which may be required in support of the SMS.
- Establish procedures by which the ship's personnel receive relevant information on the SMS.

Hence ship owners and ship managers must ensure that the on-board operational procedures are extended to include detailed guidance on any OPL system fitted to a ship. In accordance with resolution MEPC.335(76), this guidance should be held within the OMM, which must as a minimum include:

SHaPoLi:

- A technical description of the main system as specified in section 2 of MEPC.335(76) as well as relevant auxiliary systems.
- Identification of key components of the system by manufacturer, model/type, serial number and other details as necessary.
- The identification of responsibilities.
- Description of a verification procedure demonstrating that the system complies with the technical description in accordance with items 1 and 2.
- The maximum shaft power for which the unit is designed.
- Service, maintenance and calibration requirements of sensors according to sensor manufacturer and a description of how to monitor the appropriateness of the calibration intervals, if applicable.
- The SHaPoLi record book for the recording of service, maintenance and calibration of the system.
- The description of how the shaft power can be limited and unlimited and how this is displayed by the control unit as required by paragraph 2.2.5 of MEPC.335(76).

- The description of how the controller limits the power delivered to the propeller shaft.
- Procedures for notification of the use of power reserve and the detections of malfunctions of the system in accordance with paragraphs 3.4 and 3.5 of MEPC.335(76).
- Time required for unlimiting the SHaPoLi.
- Procedures for survey of the SHaPoLi system by the Administration/RO.

EPL:

- Rated installed power (MCR) or motor output (MPP) and engine speed (NMCR).
- Limited installed power (MCR_{lim}) or motor output (MPP_{lim}) and engine speed ($NMCR_{lim}$).
- Technical description of the EPL system.
- The identification of responsibilities.
- Method for sealing the EPL (mechanically controlled engine).
- Method for locking and monitoring the EPL (electronically controlled engine).
- Procedures and methods for releasing the EPL.
- Time required for unlimiting the EPL.
- Procedures for survey of the EPL system by the Administration/RO.
- Procedure for the report on release of the EPL.
- Administrator of the EPL system.

Appropriate training should also be provided to those crew members responsible for overriding the power limitation to ensure that it is clear who has the authority to do this and how the override can be achieved.

Relevant guidance may be found in *IACS Recommendation 172.*

See also OCIMF publications *TMSA* and *ISGOTT* for Management of Change process guidance.

4.5.4 Crew drills

It is recommended that OPL override drills are conducted every 3 months. If there has been a crew change of key members such as navigation or engine room officers, the drill should be carried out immediately after sailing. Drills should be as realistic as possible without compromising regulatory compliance.

Such a drill should include:

- An explanation of the purpose, effects and limitation of the OPL.
- Examples of circumstances when the OPL may need to be overridden.
- An on-site demonstration to the extent possible so that the relevant crew can sight the location of the OPL and become familiar with its parts and tools required to override it.
- Awareness of the time required to override the power limitation considering the type and location of the OPL.
- Crew should be able to demonstrate that they are able to reset the limitation to the original conditions.

Such drills should be conducted by personnel previously trained in the ship's OPL taking guidance from the OMM. A record of such drills should be maintained in the ship's drill register and logbooks.

If a drill is not possible without a regulatory breach, it should be performed in an alternative way, for example, by video demonstration of how the ship's OPL can be overridden.

4.5.5 Clear understanding of regulatory requirements

Use of power reserve by unlimiting the engine or shaft power limitation is only allowed if the purpose is to secure the safety of the ship or to save life at sea, consistent with Regulation 3.1 of MARPOL Annex VI.

Override is subject to the judgment of the Master or the OICNW.

Action to override the OPL should be recorded in the record page of the OMM. Below is the complete list of items to be recorded in the OMM record:

- Ship type.
- IMO number.
- Ship size in DWT and/or GT, as applicable.
- Ship's limited shaft/engine power and ship's maximum unlimited shaft/engine power.
- Position of the ship and time stamp when power reserve was used.
- Reason for using power reserve.
- Beaufort number and wave height or ice condition in case of using power reserve under adverse weather conditions.
- Supporting evidence (e.g. expected weather condition) in case of using power reserve for avoidance action.
- Records from the OPL system for the electronically controlled engine during the use of power reserve.
- Position of the ship and time stamp when the power limit was reactivated or replaced.

Information on the use of the power reserve should then be reported without delay to the Flag Administration/RO and the port of destination. The Flag Administration will report all cases of use of power reserve to the IMO by 30 June every year. Reporting should include uses of a power reserve over a 12-month period from 1 January to 31 December for the preceding calendar year using the IMO defined reporting format. (Reference: MEPC 335(76) and MEPC 375(80)).

In case the engine/shaft power limitation override is activated but the power reserve is not subsequently used, it is sufficient to record the event in the bridge and engine room logbooks without reporting the event to the Flag Administration/RO. The engine room logbook should then record the power used during the period when the override was activated, together with details on the reactivation of power limitation.

Immediately after the risk has been mitigated, power limitation should be reactivated, and the ship operated within the limited power again as per the OMM. The reactivation should then be confirmed with supporting evidence by the Flag Administration/RO based on the OMM procedure.

The following table summarises the cases explained above, on logging, reporting and reactivation.

OPL Override Case	ER/ Bridge logbook record	OMM record	Notify Flag State/ RO	Notify PSC	Flag State/ RO to confirm reactivation
Power reserve USED		✓	✓	✓	✓
Power reserve NOT USED	✓				✓

Table 4.2: *OPL override: actions on logging, reporting and reactivation*

Failure to report emergency cases where the power reserve has been used may result in findings during Port State Controls.

Procedures included in the OMM should be written in a clear and concise manner to ensure that the necessary steps are well understood and that they can be followed correctly and efficiently. Shipboard manuals are typically written in English. However, consideration should be given to seafarers of foreign nationality to reduce the possibility of miscommunication and errors.

There might be transitory periods and isolated spikes in the recorded output (e.g. fluctuation of load due to weather and sea conditions). This short transitory exceedance of the power limit should not be considered as a “reserve power used” to be reported to the Flag Administration and subsequently to the IMO. Operators should confirm the allowable exceedance period with their respective Flag Administrations.

4.6 Emergency response

4.6.1 Emergency response plan

The ISM Code defines a ship operating company and requires it to establish procedures to identify, describe and respond to potential shipboard emergencies. This includes adequate manning to respond to emergencies while at sea or in port. In developing emergency response plans, operators are encouraged to refer to applicable industry publications and guidelines, such as *ISGOTT.*

The IMO guidelines state that the use of reserve power is only allowed for the purpose of securing the safety of a ship or saving life at sea. For example:

- Operating in adverse weather.
- Operating in ice-infested waters.
- Participation in search and rescue operations.
- Avoidance of pirates.
- Engine maintenance.

Any potential implications to the ship's Emergency Response Plan (ERP), as a result of power limitation measures, should be reviewed and appropriately addressed.

Appendix: Understanding the bow tie methodology

The bow tie methodology is a risk assessment tool that is used to identify, analyse, and control risks. It is a visual tool that helps to communicate risk information to a wide audience. Bow Ties are divided into three main parts:

- The top event.
- The left side, which represents the initiating events, also known as threats, and preventative barriers.
- The right side, which represents the mitigative barriers and possible consequences of the top event.

The top event is the undesirable event that could occur if the risk is not controlled. It is the central element of a bow tie diagram and is represented by a circle in the middle of the diagram. The top event is typically described in terms of the potential consequences of the risk, such as injury, damage to property, or environmental impact.

A threat is an event that could lead to the top event. It is represented by a blue box at the extreme left side of the bow tie diagram. Initiating events can be either internal or external to the system. Internal initiating events are events that occur within the system, such as an equipment failure or human error. External initiating events are events that occur outside the system, such as a natural disaster or an intentional assault.

Preventative barriers are controls that are in place to prevent the top event from occurring. They are represented by boxes in-between the threat and the top event.

The possible consequences of the top event are the negative effects that could occur if the top event happens and the mitigative barriers fail. They are displayed on the extreme right-hand side of the bow tie.

A mitigative barrier is a control that is in place to mitigate the consequences of the top event if it does occur.

Figure A1 shows an example of a simple bow tie associated with the top event "slip and fall". Threats and preventative barriers are on the left-hand side. Mitigative barriers and consequences are on the right-hand side.

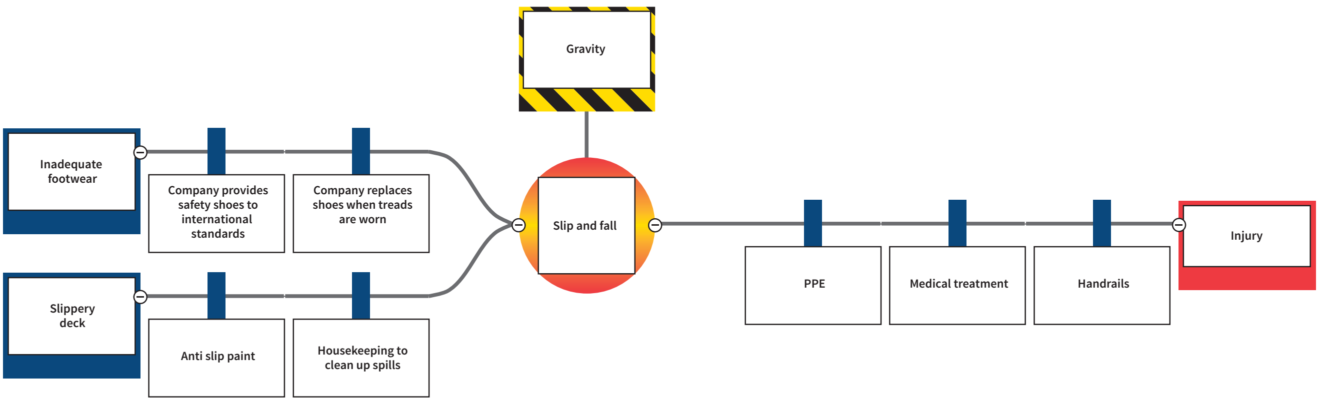

Figure A1: *Example of a simple bow tie*

The application of this methodology in the context of this paper resulted in the following bow tie, with the top threat identified as loss of operational control (enlarge to read):

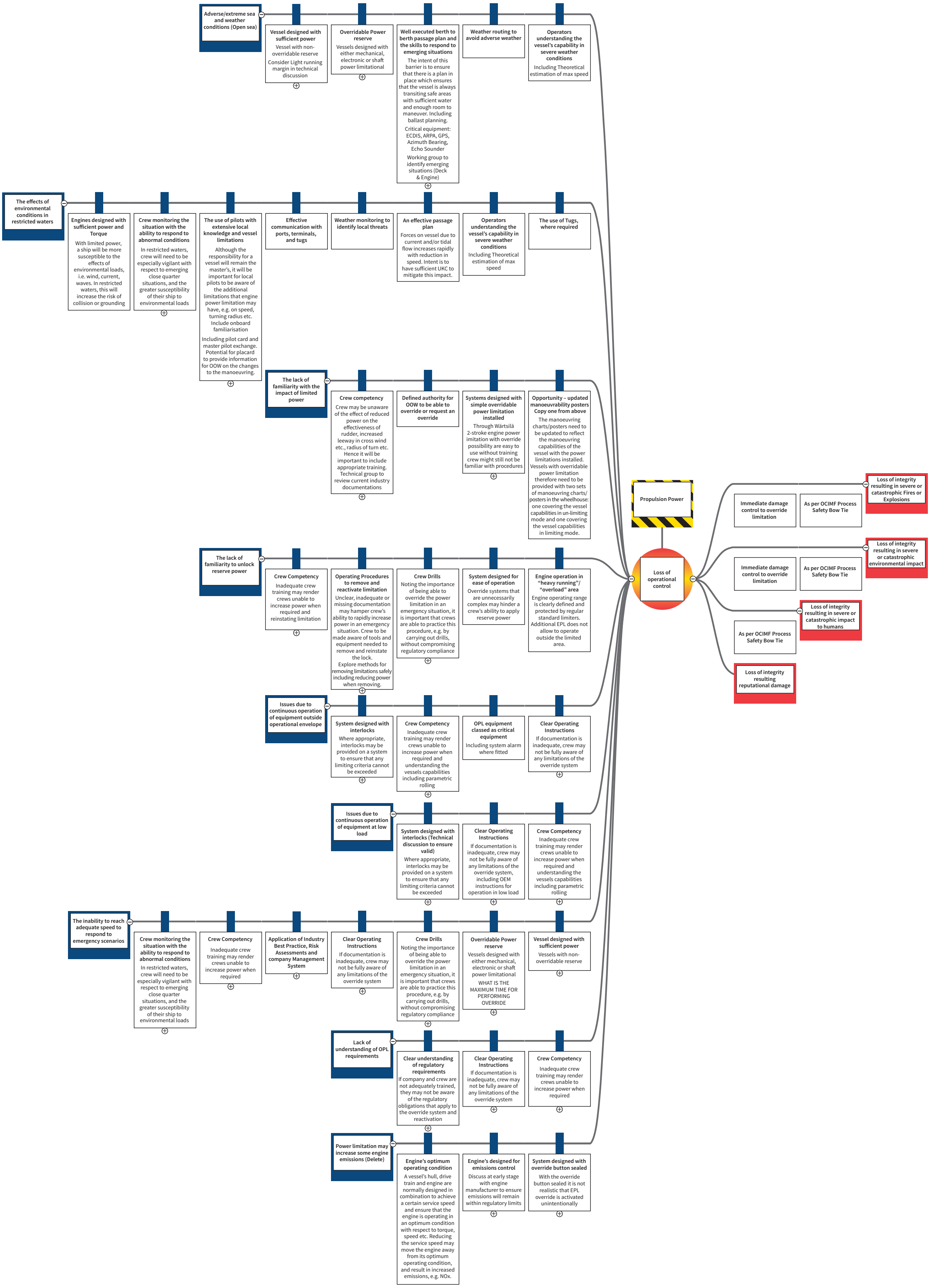

Figure A2: *Bow tie associated with the application with shaft/engine power limitations to meet EEXI and EEDI regulations*

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