

標題

IACS Recommendation No. 172 の制定について (EEXI 関連)

ClassNK

テクニカル インフォメーション

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各位

2021年6月に開催されたIMO 第76回海洋環境保護委員会 (MEPC 76)において、EEXI 規制を導入するための MARPOL 条約 附属書 VI の改正 (IMO 決議 MEPC.328(76)) が採択され、2022年11月1日に発効いたします。EEXI の計算及び認証等の要件を定めた IMO ガイドライン Res. MEPC.335(76)、MEPC.350(78)並びに MEPC.351(78)が発行されておりますが、上記ガイドラインをサポートするために IACS が EEXI Implementation Guidelines を開発し IACS Recommendation No. 172 として制定しましたのでお知らせいたします。

本テクニカル・インフォメーションに記載の IMO の関連ガイドラインについては、弊会ホームページの下記より入手できます。

ホーム>業務サービス>条約関連>エネルギー効率関連条約(EEXI)

なお、本件に関してご不明な点は、以下の部署にお問い合わせください。

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添付:

1. No. 172 EEXI Implementation Guidelines

NOTES:

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No. EEXI Implementation Guidelines 172

(June 2022) Introduction

These guidelines have been developed by IACS in response to the Resolutions MEPC.333 (76), MEPC.334 (76), and MEPC.335 (76) relating to EEXI. The document may be updated whenever new issues are brought to the attention of IACS.

1 Capacity

- For ships where the capacity refers to deadweight, the deadweight of the ship should be taken as the one in the approved stability information or loading manual.
- For ships where the capacity refers to gross tonnage, the gross tonnage is to be taken from the International Tonnage Certificate.

1.1 Multiple Loadlines

- EEXI calculation using the deadweight at maximum (summer) draught as per IEEC Supplement.
- Flag Administration to advise whether the remaining Load Lines certificates on board are required to be assessed.

2 Ship Type

The ship type should match the ship type mentioned in the IEE Certificate, except for LNG Carriers that were categorised as Gas Carriers under Phase 1 of EEDI. Some ship sizes may have only an *Attained EEXI* without a *Required EEXI*. The reduction factor of *Required EEXI* for Cruise passenger ships with conventional propulsion is not specified in MARPOL Convention at this stage. Cruise passenger ships with conventional propulsion are excluded from *Attained* and *Required EEXI*.

3 EEXI Technical File

3.1 EEDI Technical File vs EEXI Technical File

The EEDI Technical File (EEDI TF) can be submitted for EEXI verification in case the *Attained EEDI*, as documented in the IEE Certificate regardless of the guideline applied at the time of construction, complies with *Required EEXI*. If verification is based on EEDI TF, the supporting documentation should include:

- Cover letter explaining that the ship has not undergone major changes which would affect the final achieved EEDI
- EEDI TF
- IEEC Supplement and/or Review/Approval Letter

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3.2 Dealing with mistakes in EEDI Technical File

In case a mistake is found in a submitted EEDI TF, which was reviewed/approved at ship's delivery, then for cases where a power limitation is implemented to satisfy the *Required EEXI*, the *Attained EEXI* will be calculated based on the correction and an EEXI Technical File to be reviewed/approved.

3.3 Pre-EEDI SOVC Consideration

Irrespective of whether a pre-EEDI ship has a Statement of Voluntary Compliance (SOVC) or a Preliminary Approved EEDI TF, then the ship will still need to prepare an EEXI Technical File and the *Attained EEXI* will be reflected in the IEEC Supplement.

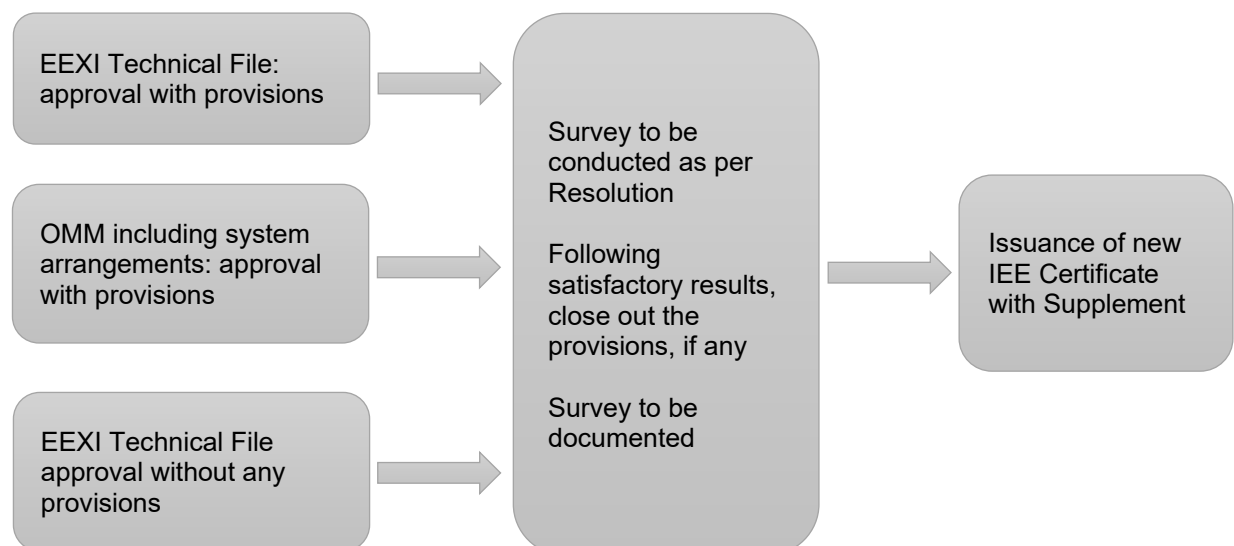
3.4 Approval of EEXI Technical File prior EPL/SHaPoLi on board

In case of EPL/SHaPoLi is intended to be implemented to satisfy the *Required EEXI*, the EEXI Technical File can be approved provided the following supporting documentation is included:

- SFC at new PME to be included. See Section 5 on SFC considerations.
- For ships subject to the NOx Technical Code: In case of change of engine critical settings or components, affecting NOx Technical File, then NOx Technical File to be amended. A statement from engine maker may be considered as acceptable supporting documentation and filed together with NOx Technical File.

3.5 EEXI Technical File & OMM Approval Process

The following flowchart explains the route to the issuance of the new IEE Certificate with supplement:



Note: Provisions refer to the requirement that the power limitation as described in the EEXI Technical File will be installed.

Unless advised otherwise by Flag Administration, the approval of EEXI Technical File & Onboard Management Manual (OMM) will be carried out based on the IMO resolutions and IACS guidelines.

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4 Ship speed V_{ref}

4.1 Transfer from Service/Design draft to EEXI draft

There are three different options to transfer a known speed/power curve from a specific draft to the EEXI draft:

1. Model tests/ CFD calculation: Curves are determined for both drafts, so that the relation is known.
2. Admiralty equation: This well-known, experience-based method is based on the relation of the displacement of both drafts.
3. The formula in MEPC.333(76) para 2.2.3.4: A factor is calculated from the relation of the deadweight of both drafts.

Only model test or CFD calculation can be applied for the transfer from trimmed ballast draft to the EEXI draft. Admiralty equation and the formula in MEPC.333(76) para 2.2.3.4 can only be used for the transfer from design or service draft on even keel to EEXI draft.

Although MEPC.333(76) para 2.2.3.4 refers to the service power point only, the speed/power curve in design load draft should be considered for the transfer to the EEXI draft following the formula in MEPC.333(76) para 2.2.3.4.

Applying the actual speed/power curve from model tests or sea trials gives more accurate results than applying the cubic law as included in Admiralty equation and in the formula in MEPC.333(76) para 2.2.3.4 for the transfer from service speed power to P_{ME} .

The whole speed/power curve is shifted along the x-axis (speed) by multiplying each speed point with the constant factor calculated from Admiralty equation or the formula in MEPC.333(76) para 2.2.3.4 as given in the next paragraphs.

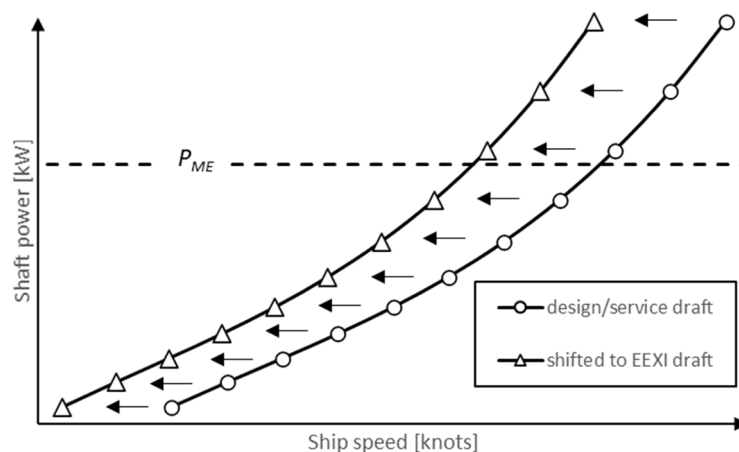


Figure 4.1 Shift of design/service draft model test curve to EEXI draft

Only if no curve is given in the report, then a cubic curve is drawn through the given point, transferred to EEXI draft and then the speed for the EEXI relevant power can be taken from this curve.

4.1.1 Ships other than bulk carriers, tankers and containerships

The Admiralty equation is a well-known formula for estimation of required power P depending on displacement Δ and ship speed V :

$$P = const \cdot \Delta^{\frac{2}{3}} \cdot V^3$$

This relation can be applied to calculate the influence of different draft on power and ship speed.

Case A

The curve at design load draft (service) is available. At this draft the speed V_d is derived at the P_{ME} . Subsequently, the V_{ref} at EEXI draft is calculated based on the formula below:

$$V_{ref} = \left(\frac{\Delta_{S,service}}{\Delta_{EEXI}} \right)^{\frac{2}{9}} * V_d$$

Case B

The curve at design load draft (service) is not available and only one service point is available ($P_{s,service}$, $V_{s,service}$). The V_{ref} at EEXI draft is calculated based on the formula below:

$$V_{ref} = \left(\frac{\Delta_{S,service}}{\Delta_{EEXI}} \right)^{\frac{2}{9}} * V_{s,service} * \left(\frac{P_{ME}}{P_{s,service}} \right)^{\frac{1}{3}}$$

Applicability criteria

Case	The following criteria to be assessed at the P_{ME} in the original unlimited power case.
For case A	<p>V_{ref} to be within the performance margin m_V of V_d, which should be 5% of V_d or one knot, whichever is lower.</p> <p>In case $(V_d - V_{ref}) > m_V$, then the Admiralty equation is not to be applied, instead $V_{ref,app}$ to be used.</p>
For case B	<p>V_{ref} to be within the performance margin m_V of $V_{s,service} * \left(\frac{P_{ME}}{P_{s,service}} \right)^{\frac{1}{3}}$ which should be 5% of the above or one knot, whichever is lower.</p> <p>When $(V_{s,service} * \left(\frac{P_{ME}}{P_{s,service}} \right)^{\frac{1}{3}} - V_{ref}) > m_V$, then the Admiralty equation is not to be applied, instead $V_{ref,app}$ to be used.</p>

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4.1.2 Bulk carriers and tankers

Admiralty equation not to be applied for bulk carriers and tankers. For bulk carriers and tankers, the formula in MEPC.333(76) para 2.2.3.4 with scale coefficient k as defined in MEPC.333(76) can be applied to transfer the speed-power curve from a draft that is below the maximum summer load draft. The term DWT for k factor definition refers to the DWT at the summer load draft (and not the $DWT_{s,service}$).

In case the curve at design load draft (service) is available, the speed V_d is derived at the P_{ME} . Subsequently, the V_{ref} at EEXI draft is calculated based on the formula below:

$$V_{ref} = k^{\frac{1}{3}} * \left(\frac{DWT_{s,service}}{Capacity} \right)^{\frac{2}{9}} * V_d$$

In case the curve at design load draft (service) is not available and only one service point is available ($P_{s,service}$, $V_{s,service}$), then the V_{ref} at EEXI draft is calculated based on the formula below:

$$V_{ref} = k^{\frac{1}{3}} * \left(\frac{DWT_{s,service}}{Capacity} \right)^{\frac{2}{9}} * V_{s,service} * \left(\frac{P_{ME}}{P_{s,service}} \right)^{\frac{1}{3}}$$

In MEPC.333(76) there is no limit for the DWT relation given when applying the formula in MEPC.333(76) para 2.2.3.4. The service draft to be on even keel, a trimmed draft cannot be applied for the formula in MEPC.333(76) para 2.2.3.4.

If more than one speed-power curve is available for a loaded draft on even keel (e.g. design draft and scantling draft before DWT increase), the curve of the draft that is closer to EEXI draft is to be applied for the transfer to EEXI draft. The even keel definition to be taken as the one described at the sea trial analysis ISO standard applicable at the time.

4.1.3 Containerships

Admiralty equation not to be applied for containerships. For containerships, the formula in MEPC.333(76) para 2.2.3.4 with scale coefficient k as defined in MEPC.333(76) can be applied to transfer the speed-power curve from a draft that is different from the EEXI draft. For containerships this different draft might be larger or smaller than the EEXI draft which is defined by 70% DWT.

Service draft to be on even keel. There is no limitation for the relation of the DWT for both drafts, but trimmed conditions cannot be accepted.

If more than one speed-power curve is available for a loaded draft on even keel (e.g. design and scantling draft), the curve of the draft that is closer to EEXI draft is to be applied for the transfer to EEXI draft.

The V_{ref} at EEXI draft is calculated based on the containership size as per table below.

In the table below the term DWT refers to the DWT at the summer load draft (and not the $DWT_{s,service}$) and the term $Capacity$ refers to MEPC.308(73) chapter 2.2.3.

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Ship size applicability	Derivation of Vref
Where: $(DWT_{s,service} / Capacity) < 1.0$ or where: $DWT \leq 120,000$ tonnes and $(DWT_{s,service} / Capacity) > 1.08$ or where: $DWT > 120,000$ tonnes and $(DWT_{s,service} / Capacity) > 1.12$	In case the curve at service draft is available, the speed V_d is derived at the P_{ME} . Subsequently, the V_{ref} at EEXI draft is calculated based on the formula below: $V_{ref} = k^{\frac{1}{3}} * \left(\frac{DWT_{s,service}}{Capacity} \right)^{\frac{2}{9}} * V_d$ In case the curve at service draft is not available and only one service point is available ($P_{s,service}$, $V_{s,service}$), then the V_{ref} at EEXI draft is calculated based on the formula below: $V_{ref} = k^{\frac{1}{3}} * \left(\frac{DWT_{s,service}}{Capacity} \right)^{\frac{2}{9}} * V_{s,service} * \left(\frac{P_{ME}}{P_{s,service}} \right)^{\frac{1}{3}}$
Where: $DWT > 120,000$ tonnes and $1.0 < (DWT_{s,service} / Capacity) \leq 1.12$	V_{ref} to be derived from the available curve at P_{ME} .
Where: $DWT \leq 120000$ tonnes and $1.0 < (DWT_{s,service} / Capacity) \leq 1.08$	V_{ref} to be derived from the available curve at P_{ME} .

4.2 Change of EEXI draft

In case of change of EEXI draft:

- The new speed may be derived following the application of Admiralty equations as described earlier, or
- $V_{ref,app}$, or
- V_{ref} as per the formula in MEPC.333(76) para 2.2.3.4, extrapolating from design draft to new EEXI draft or from the old EEXI draft to new EEXI draft.

The maximum summer load draft deadweight is to be used, according to paragraph 2.2.4 of MEPC.308(73). In absence of the speed power curve at summer load draft, reference can be made to the so-called "scantling draft" speed power curve, which is to be adjusted as per above.

In case the final V_{ref} is below or above the range of speeds from the sea trials and/or model tests and/or numerical analysis, an extrapolation of the speed power curve can be used based on power law (power exponent) *e.g.* $P = a * V^b$.

4.3 Service Speed & Power Definition

As per discussions at the Correspondence Group before the MEPC76, based on submissions ISWG-GHG 7/2/31, the service speed and service power are defined as follows:

- Service Power = $\frac{NCR}{1+SM}$ or $\frac{CSR}{1+SM}$
- with $NCR = CSR$, as shown in the sea trial and/or model test report and/or ship's technical specification
- and SM stands for Sea Margin as per the sea trial and/or model test and/or ship's technical specification
- Service speed is the speed corresponding to the service power.

4.4 Sister ship V_{ref}

A sister ship is one built in a series by same shipyard with identical main dimensions, body lines, appendages, and propulsion system.

For pre-EEDI ships it was common practice to perform detailed sea trials for the lead ship of a series whilst for the rest of sister ships a reduced scope was applied, i.e. one double run. In such case, results from model tests or numerical calculation can be considered for the whole series. Whilst for the lead ship the model test curve can be calibrated by the sea trial results if adequately documented, for the sister ship the calibration of the model test curve to the sea trial result should not be carried out in case only a single double run was performed as in such case the tidal current was ignored.

In a case of identical Propulsion Improvement Device retrofitted on sister ships, the percentage of power savings verified (*by either sea trials, or model tests, or numerical analysis, as applicable*) for one ship of the series can be applied to the sisters with means of deriving a new speed-power curve.

4.5 Pre-EEDI ship with Sea Trial Report

MEPC.334(76) states that sea trial results are acceptable when in accordance with "ISO 15016:2002 or equivalent". Equivalence is difficult to define, especially in regard of the fact that the 2015 version of the guideline follows a different approach than the 2002 version. For example, the BSRA method is similar with ISO 15016:2015 but different from ISO 15016:2002. The minimum requirement to a pre-EEDI sea trial report is that double runs were performed, and the results of the single runs can be identified.

For Pre-EEDI ships, the sea trial analysis report at the time, can be considered as valid supporting documentation for the EEXI calculation, even if the speed-power curve is uncorrected at a weather condition. In such case, a re-evaluation of sea trial report with regard to weather conditions is not acceptable. If the sea trial analysis report contains the speed-power curve from model tests, the V_{ref} derived from this curve would be acceptable.

4.6 Pre-EEDI ship with Sea Trial Report and Model Tests Report

In case the ship has a model tests report and a sea trials report based on ISO 15016:2002 or equivalent, then the EEXI calculation can be based on a speed-power curve from either the model tests report or the sea trial report.

4.7 Performance of new Sea Trial based on ISO 15016:2015

For both pre-EEDI and EEDI certified ships, in case of new sea trial, the analysis is to be based on ISO 15016:2015:

- Prior the sea trials, the sea trial plan to be submitted to Class for confirmation that it is according to ISO 15016:2015. Power settings may be selected with the view to potential power limitation.
- Sea trials to be witnessed by Class Surveyor and a witnessing statement to be issued.
- Sea trial analysis can be carried out only if relevant data at EEXI draft and sea trial draft are available from model tests and/or numerical calculations.
- The sea trial analysis software program utilized must be acceptable to Class.
- The EEXI Technical File will include the sea trial analysis and the Surveyor's statement are to be submitted as supporting documentation along with the EEXI Technical file.

4.8 PID retrofit with comparative model tests

In case of retrofitted propulsion improvement device (PID) where comparative model tests have been carried out, the V_{ref} derived from the following recommended processes will be acceptable. Other processes where the propulsion power savings from comparative model tests are applied for the derivation of V_{ref} , may be acceptable to Verifier's consideration. For instance, when the original speed-power curve is available, then that can be applied instead of a cubic curve approach.

Case No	Available information	Recommended process where applicable (see note)
1a	<ul style="list-style-type: none"> - Original sea trial design draft without PID - Comparative model tests EEXI draft with and without PID 	<ul style="list-style-type: none"> - Apply the formula in MEPC.333(76) para 2.2.3.4 including the k scale factor to original sea trial design draft without PID → speed-power curve at EEXI draft without PID - Comparative model tests EEXI draft with and without PID → power savings percentages at different speeds - At these speeds, the estimated power curve at EEXI draft with PID is calibrated
1b	<ul style="list-style-type: none"> - Original sea trial design draft without PID - Comparative model tests EEXI draft with and without PID 	<ul style="list-style-type: none"> - Comparative model tests EEXI draft with and without PID → power savings percentages at different speeds - At these speeds, the original sea trial at design draft is calibrated - Apply the formula in MEPC.333(76) para 2.2.3.4 including the k scale factor
2a	<ul style="list-style-type: none"> - Original sea trial design draft without PID - Comparative model tests design draft with and without PID 	<ul style="list-style-type: none"> - Apply the formula in MEPC.333(76) para 2.2.3.4 including the k scale factor to original sea trial design draft without PID → speed-power curve at EEXI draft without PID - Comparative model tests design draft with and without PID → power savings percentages at different speeds - At these speeds, the estimated power curve at EEXI draft with PID is calibrated

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2b	<ul style="list-style-type: none"> - Original sea trial design draft without PID - Comparative model tests design draft with and without PID 	<ul style="list-style-type: none"> - Comparative model tests design draft with and without PID → power savings percentages at different speeds - At these speeds, the original sea trial at design draft is calibrated - Apply the formula in MEPC.333(76) para 2.2.3.4 including the <i>k</i> scale factor
3	<ul style="list-style-type: none"> - Original sea trial with design draft without PID - Comparative model tests with design and EEXI drafts, with and without PID 	<ul style="list-style-type: none"> - Derive deviation between the original sea trial design draft and the comparative model tests design draft WITHOUT PID → power deviation percentage at different speeds - The power deviation percentage is applied to the EEXI draft WITH PID from the comparative model tests
4	<ul style="list-style-type: none"> - Original sea trial with ballast draft without PID - Comparative model tests with ballast and design drafts, with and without PID 	<ul style="list-style-type: none"> - Derive deviation between the original sea trial ballast draft and the comparative model tests ballast draft WITHOUT PID → power deviation percentage at different speeds - The power deviation percentage is applied to the design draft WITH PID from the comparative model tests - Apply the formula in MEPC.333(76) para 2.2.3.4 including the <i>k</i> scale factor
5	<ul style="list-style-type: none"> - Original sea trial with ballast draft without PID - Comparative model tests with ballast and EEXI drafts, with and without PID 	<ul style="list-style-type: none"> - Derive deviation between the original sea trial ballast draft and the comparative model tests ballast draft WITHOUT PID → power deviation percentage at different speeds - The power deviation percentage is applied to the EEXI draft WITH PID from the comparative model tests
6	<ul style="list-style-type: none"> - No sea trials are available - Comparative model tests at design draft with and without PID 	<ul style="list-style-type: none"> - Apply the model tests results at design draft with PID - Apply the formula in MEPC.333(76) para 2.2.3.4 including the <i>k</i> scale factor
7	<ul style="list-style-type: none"> - No sea trials are available - Comparative model tests at EEXI draft, with and without PID 	<ul style="list-style-type: none"> - Apply the model tests results at EEXI draft

Note: for ship types other than bulk carriers, tankers and containerships where the formula in MEPC.333(76) para 2.2.3.4 including the *k* scale factor approach is not applicable, the formula per para 4.1.1 should be applied

4.9 Propeller trimmed cases

Not all propeller trimmed cases are the same. Some cases are cropping off blades for balancing purposes (*usually after a damage of one or more blades*), whilst other cases may be pitch reduction to ease off the ship from a heavy operating range, i.e. to bring operation from the left of the propeller curve onto or to the right of the propeller curve. From an EEXI perspective:

- Trailing edge pitch reduction will not be considered as affecting the ship's performance. In other words, the original sea trials will be considered valid for EEXI calculations and supporting documentation.
- Cropping off blades remaining in the cropped condition, will be treated as "new propeller". In such case the original sea trials are no longer valid for EEXI calculation. This infers that as in the case of "new propeller" the Owner will need to consider submitting supporting documentation, which may be new model tank tests and/or comparative numerical analysis. Alternatively, the V_{ref} will be based on the $V_{ref,app}$ formula which in most cases results to a lower conservative value.

4.10 Lower Friction Hull Coatings

In case of lower friction hull coatings, which are considered an EET (Energy Efficiency Technology) in Category A as per IMO MEPC.1/Circ 896, the V_{ref} can only be derived by sea trials.

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5 SFC considerations

In case of new type of fuel nozzles or optimization of injection:

- the new SFC specified by the main engine designer is acceptable, provided the approved NOx Technical File of the engine is amended accordingly.

In case of power limitation:

- In case where the main engine designer is involved, the main engine designer to provide SFC at new P_{ME} , based on interpolation from test bed measurements ISO corrected and this is to be shown in the main engine designer's power limitation report. The SFC value at P_{ME} to be used in the EEXI calculation is to be to the satisfaction of the Verifier.
- In case the main engine designer is not involved, the SFC value at P_{ME} to be used in the EEXI calculation to be confirmed by the Verifier.

The EEXI calculation should be based on the SFC value based on the following options:

Options	1	2	3	4
	Parent Engine ISO corrected is available	Member engine ISO corrected is available	Parent Engine not ISO corrected is available but corrected as best as possible based on available data (e.g. LCV)	Member engine not ISO corrected is available but corrected as best as possible based on available data (e.g. LCV)
Pre-EEDI with power limitation	Acceptable	Acceptable	Acceptable	Acceptable
Pre-EEDI without power limitation	To be used	Acceptable only in case of 1 is not available	Acceptable only in case of 1 is not available	Acceptable only in case of 1 is not available
EEDI with power limitation	Acceptable	Acceptable	Acceptable	Acceptable
EEDI without power limitation	Value used in EEDI TF to be used			

Notes:

- If fuel flow (e.g. gr/h) is only available (instead of SFC) this can be converted to SFC. This is equivalent to measured SFC.
- If two or more sets of measurements at the same rating are submitted for the various loads of the same engine, then the average to be used.
- If shop test results and/or NOx Technical file for ME or AE of individual ship and parent engine are not available, those of a sister ship can be used.
- Scrubber retrofits are not considered to affect EEXI calculation in terms of SFC.

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6 Power Limitation

In MEPC.335(76) IMO defines measures to limit the propulsion power to be considered in the EEXI calculation. It is distinguished between two different power limitation methods: EPL and SHaPoLi. EPL limits the engine power by restricting the fuel rack (mechanically controlled engines) or the fuel index (electronically controlled engines). Besides, EPL might directly limit the power in electronically controlled engines. SHaPoLi measures the shaft power with an independent torque meter and the limitation is based on this value. The power limitation as described in MEPC.335(76) is defined as overridable.

IACS agrees to consider all power limitation measures that are equivalent to power limitation as described in MEPC.335(76) regarding limitation method, meaning that P_{ME} is 83% of MCR_{lim} .

This means in detail that all limitation of the fuel rack is considered in this way, independent from whether the crew can easily remove the blockage by breaking a seal or a tool is needed to remove the mechanical blockage.

A different method of power limitation is the derating, e.g. deactivating of cylinders or reduction of stroke length. This limitation is considered in the EEXI calculation following MEPC.308(73) by replacing MCR with MCR_{lim} , meaning that P_{ME} is 75% of MCR_{lim} . In the same way a turbocharger cut-out is considered. If the turbocharger is dismantled or blocked with a bolted or welded plate, the limited power is used for determination of *Attained EEXI*. However, if the turbocharger is locked with a butterfly valve, even if sealed, then the P_{ME} is 83% of MCR_{lim} .

When there is no modification on engine side, but the propulsion system is limited to a certain power, e.g. by propeller retrofit, P_{ME} is calculated according MEPC.308(73) chapter 2.2.5.2, option 2, meaning that P_{ME} is 75% of the power the propulsion system is limited to. Whilst this option was limited to propulsion arrangements with a PTO in the EEDI regime, IACS agrees that the option is applicable to all propulsion arrangements regarding EEXI.

The term “propeller retrofit” infers the case where shaft power limitation has or will be applied to avoid damage. The new maximum power after the propeller retrofit is documented in the propeller description or certificate. If for EEXI purposes, the power needs to be reduced below the new maximum power, then the case will be considered as overridable.

Overridable	Non-overridable (permanent during ship operation)
EPL or SHaPoLi (see Note 1)	Propeller retrofit with shaft power limitation to prevent damage on the propeller or shaft (see Note 2)
Turbocharger cut-out by butterfly valve (see Note 1)	Turbocharger dismantling (see Note 2)
	Turbocharger cut-out by removable blinding plate, e.g. bolted, or permanent blinding plate, e.g. welded (see Notes 2 and 3)
	Permanent adjustment of fuel index (see Notes 2 and 3)
	Permanent Engine derating, i.e. cylinder cut-off, reduction of combustion volume (see Note 2)

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Notes:

1. The 83% approach is applicable to overridable power limitation cases. Password protected systems are to be considered as overridable.
2. The 75% approach is applicable.
3. All the following provisions to be satisfied:
 - a. Permanent physical sealing subject to annual survey.
 - b. Description of the power limitation to be included in the EEXI Technical File.
 - c. The limited power value is to be stated in the EEXI Technical File and if applicable, in the reissued EIAPP.

Depending on the power limitation method, different *MCR* values are to be considered in the EEXI formula according to the following table:

Parameter	Source		Variable	Overridable ¹	Non-overridable other than propeller retrofit ²	Non-overridable propeller retrofit ³
	Reference	Chapter		function of	function of	function of
P_{ME}	MEPC.333(76)	2.2.1	MCR_{lim}	83% MCR_{lim}	75% MCR_{lim}	75% MCR_{lim}
	MEPC.308(73)	2.2.5.1				
	MEPC.308(73)	2.2.5.2				
P_{AE}	MEPC.308(73)	2.2.5.6	MCR	MCR	MCR_{lim}	MCR
$f_{j,ICE}$	MEPC.308(73)	2.2.8.1	MCR	MCR	MCR_{lim}	MCR
$f_{j,RoRo}$	MEPC.333(76)	2.2.6	$V_{ref,F}$	75% MCR	$P_{ME} = f(MCR_{lim})$	$P_{ME} = f(MCR_{lim})$
	MEPC.308(73)	2.2.8.3	V_{ref}			
$f_{j,GeneralCargo}$	MEPC.308(73)	2.2.8.4	V_{ref}	$P_{ME} = f(MCR_{lim})$	$P_{ME} = f(MCR_{lim})$	$P_{ME} = f(MCR_{lim})$

Notes:

1. calculation following MEPC.333(76)
2. calculation following MEPC.308(73) by replacing MCR with MCR_{lim}
3. calculation following MEPC.308(73) chapter 2.2.5.2 option 2

6.1 PTO

For cases with shaft generator PTO and overridable power limitation, the formula for P_{ME} is as follows, unless it is decided otherwise at IMO.

$$P_{ME} = 0.75 * (MCR_{lim} - P_{PTO}) \text{ with } P_{PTO} \leq \frac{P_{AE}}{0.75}$$

6.2 Cruise ships with diesel electric propulsion

For cruise ships with diesel electric propulsion, the propulsion power of the electric engines MPP is the relevant power for the EEXI calculation. A limitation of this electric power by technical means (e.g. restriction of current) is an EPL with relevant power MPP_{lim} . Alternatively, the propulsion power can be limited by measuring the shaft power with a SHaPoLi system.

The rated output of the electric propulsion motors MPP can be identified with the quantity noted $P_{PTI,Shaft}$ in MEPC.308(73) for the calculation of the EEXI value:

$$\sum P_{PTI(i)} = \frac{\sum(0.75 \cdot MPP(i))}{\eta_{PTI} \cdot \eta_{Gen}}$$

In case of power limitation, P_{PTI} is calculated as follows:

$$\sum P_{PTI(i)} = \frac{\sum(0.75 \cdot MPP_{lim}(i))}{\eta_{PTI} \cdot \eta_{Gen}}$$

V_{ref} is obtained at 75% of MPP or 75% of MPP_{lim} , respectively.

The diesel engines of the cruise ship are considered as auxiliary engines. The SFC is taken at 75% of MCR power of the diesel engines as the P_{AE} value is significantly different from total power used at normal seagoing (MEPC.308(73), chapter 2.2.7.1). The SFC is independent from potential limitation of the electric engines.

6.3 LNG carriers with diesel electric propulsion

For LNG carriers with diesel electric propulsion, the propulsion power of the electric engines $MPP_{Motor(i)}$ is the relevant power for the EEXI calculation. A limitation of this electric power by technical means (e.g. restriction of current) is an EPL with relevant power MPP_{lim} . Alternatively, the propulsion power can be limited by measuring the shaft power with a SHaPoLi system.

P_{ME} is calculated as follows:

$$P_{ME(i)} = 0.83 \cdot \frac{MPP_{Motor(i)}}{\eta(i)}$$

And in case of power limitation:

$$P_{ME(i)} = 0.83 \cdot \frac{MPP_{lim}}{\eta(i)}$$

V_{ref} is obtained at 83% of MPP or 83% of MPP_{lim} , respectively.

The diesel engines of the LNG carrier are called main engines. The SFC_{ME} is taken at 75% of MCR power of the diesel engines. The SFC_{ME} is independent from potential limitation of the electric engines.

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The same diesel engines of the LNG carrier are considered as auxiliary engines at the same time. The SFC_{AE} is taken at 75% of MCR power of the diesel engines.

In case of overridable power limitation, P_{AE} is to be kept constant as in the original unlimited power case.

6.4 Minimum Propulsion Power

For overridable cases:

- For pre-EEDI bulk carriers, tankers, and combination carriers of 20,000 tonnes deadweight and above, there is no requirement for Minimum Propulsion Power Assessment as per Circular 850, unless the ship has undergone a major modification which is so extensive that the ship is regarded by the Administration as a newly constructed ship. In the latter case, the Minimum Propulsion Power Assessment to be verified according to Circ 850 latest revision at the time of modification.
- For EEDI bulk carriers, tankers, and combination carriers of 20,000 tonnes deadweight and above, there is no need to reassess the Minimum Propulsion Power Assessment as per Circ 850.

For non-overridable (permanent during ship operation) cases:

- For both EEDI and pre-EEDI bulk carriers, tankers, and combination carriers of 20,000 tonnes deadweight and above, the Minimum Propulsion Power Assessment is to be verified according to Circ 850 latest revision at the time of modification.

6.5 Maneuvering

For overridable cases:

- The existing maneuvering booklet, if available, and the maneuvering information displayed on the navigating bridge to include that the ship's power has been limited and state the limiting power for the attention of the Master to account for the ship's performance so caused in case no corresponding trials are carried out.

For non-overridable (permanent during ship operation) cases:

- The stopping times and distances, and the data of the turning circles as per SOLAS Reg. II-1/28.3 and Res.MSC.137(76) respectively, to be recorded on new trials where applicable. Also, the existing maneuvering booklet, if available, and the maneuvering information displayed on the navigating bridge (pilot card and wheelhouse poster) to be updated.

6.6 Onboard Management Manual (OMM)

- Regarding Resolution MEPC.335(76), section 2.1.1.3 “*a control unit for calculation and limitation of the power transmitted by the shaft to the propeller(s)*”: If this control is independent from the engine automation the following shall be satisfied:
 - Override of limitation is indicated by giving an alarm on the bridge, clearly informing the ship’s master or OICNW:
 - In case of exceedance, the ship’s master or OICNW to manually reduce the power within the limit;
 - In case of deliberate use of power reserve, data recording to commence automatically;
 - Data recording device as defined in section 2.1.1.2.

The OMM should clearly define this confirmation of the alarm as the deliberate action in agreement with requirement in chapter 2.2.1.

- Regarding Resolution MEPC.335(76), section 2.1.3 “*where technically possible and feasible, the SHaPoLi/EPL system should be controlled from the ships’ bridge and not require attendance in the machinery space by ship’s personnel*”: It is clarified that strictly speaking there is no mandatory requirement to retrofit a new control system from bridge provided in any critical operating condition (*such as adverse weather, piracy, traffic separated zone, maneuvering*), other than normal seagoing, the engine control room will be manned as per ship’s safety management system procedures. If applicable, this needs to be covered in the OMM.
- A SHaPoLi / EPL system (or each sub system) in the context of section 2.2 of MEPC.335(76), is considered tamper-proof if it prevents the following actions:
 - Overriding the limitation without authorization, from any operating or control position;
 - If applicable, intentionally disabling the alerting-monitoring system;
 - In case of SHaPoLi, intentionally disabling sensors, control unit, data recording and processing devices.
- Regarding Resolution MEPC.335(76), section 2.2.5.2 “*for EPL, a fuel index sealing system or power limitation system which can indicate and record the use of unlimited mode.*”: It is clarified that the indication and recording can be addressed via fuel index alarm set up and recording as per ship’s existing systems, if suitable, provided these are stated in the OMM.
- Regarding Resolution MEPC.335(76), section 3.5 “*The reactivation or replacement of the SHaPoLi / EPL system should be confirmed (e.g. validation of mechanical sealing) with supporting evidence (e.g. engine power log, photo taken at the occasion of resetting the mechanical sealing) by the Administration or the RO at the earliest opportunity.*”: In respect of the above requirement, confirmation may be based on supporting evidence submitted by the owner, if accepted by the Administration or the RO acting on its behalf.
- The surveyor may issue the IEEC after the EPL/OMM survey where the Surveyor verifies that the arrangements indicated in the OMM are in place.

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6.7 NOx

	Amendment to NOx TF	Change engine name plate	EIAPP certificate to be reissued	OMM	MPP (see note 2)
Overridable					
EPL or SHaPoLi	No (see note 1)	No	No	Yes	No
Turbocharger cut-out by butterfly valve	Yes	No	No	Yes	No
Non-overridable (permanent during ship operation)					
Propeller retrofit with restricted shaft power to prevent damage	No	No	No	No	Yes (Level 2 assessment is required)
Turbocharger dismantling	Yes	Yes	Yes	No	Yes
Turbocharger cut-out by removable blinding plate, e.g. bolted, or permanent blinding plate, welded					
Permanent adjustment of fuel index	No	No	No	No	Yes (Level 2 assessment is required)
Permanent Engine derating, i.e. cylinder cut-off, reduction of combustion volume	New NOx Technical File	Yes	Yes	No	Yes

Notes:

1. For EPL or SHaPoLi, in case of change of engine critical settings or components, affecting NOx Technical File (NTF), then NTF to be amended. A statement from engine maker may be considered as acceptable supporting documentation and filed together with NTF.
2. Minimum Propulsion Power Assessment as per Circular 850 is applicable only to bulk carriers, tankers, and combination carriers of 20,000 tonnes deadweight and above.
3. In general, other class requirements remain as applicable.

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6.8 Barred Speed Range

The following shall apply to the satisfaction of ship's classification society.

Overridable	EPL or SHaPoLi	<ul style="list-style-type: none"> - The RPM corresponding to New MCR Power after the power limitation is to be outside the Barred Speed Range limit (RPM) with an operational margin of 25%, based on IACS UR M68. - The Barred Speed Range as indicated in the Torsional Vibration Calculation document needs to be made available during the review of EEXI Technical File.
Non-overridable	Permanent adjustment of fuel index	
Overridable	Turbocharger cut-out by butterfly valve	<ul style="list-style-type: none"> - New Torsional Vibration Calculations to be carried out and reviewed/approved. - The new Barred Speed Range as indicated in the newly Torsional Vibration Calculation document needs to be made available during the review of EEXI Technical File. - The RPM corresponding to new MCR Power after the power limitation is to be outside the new Barred Speed Range limit (RPM) with an operational margin of 25%, based on IACS UR M68.
Non-overridable	Turbocharger dismantling Turbocharger cut-out by removable blinding plate, i.e., bolted, or permanent blinding plate, e.g. welded	
Non-overridable	Propeller retrofit with restricted shaft power to prevent damage	<ul style="list-style-type: none"> - The RPM corresponding to new MCR Power after the power limitation is to be outside the new Barred Speed Range limit (RPM) with an operational margin of 25%, based on IACS UR M68.
Non-overridable	Permanent Engine derating, e.g., cylinder cut-off, reduction of combustion volume	

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7 LNG Carriers

7.1 Treatment of LNG Carriers

EEXI requirement is applied based on the definitions in Regulation 2 of MARPOL Annex VI as they will stand when EEXI enters into force, i.e. separate definitions and ship categories for gas carriers (regulation 2.26) and LNG carriers (regulation 2.38).

For the purposes of compliance with EEXI, an LNG carrier will be an LNG carrier regardless of when ship has been delivered and the ship type applied when her *Attained EEDI* was verified.

It is recognized that there may be confusion in case ship was delivered before 1 September 2019 with an IEEC stating Gas Carrier as ship type. For all other cases the ship is anyway considered as LNG Carrier.

Therefore, to clarify the case when an LNG Carrier delivered before 1 September 2019 with an IEEC stating Gas Carrier as ship type, the requirements are shown in the table below as applicable.

IEEC Gas Carrier delivered before 1 Sept 2019		
If there is EEDI TF and the <i>Attained EEDI</i> (as Gas Carrier in the original EEDI TF) is below the <i>Required EEXI</i> as LNG Carrier, then this is acceptable.	If there is EEDI TF and the <i>Attained EEDI</i> (as Gas Carrier in the original EEDI TF) is above the <i>Required EEXI</i> as LNG Carrier, then <i>Attained</i> and <i>Required EEXI</i> to be calculated as per LNG Carrier.	If there is no EEDI TF, then the <i>Attained</i> and <i>Required EEXI</i> to be calculated as per LNG Carrier.
When the new IEEC is issued during 1 st survey in 2023, the IEEC ship type will be changed to LNG Carrier		

7.2 Calculation of Attained EEXI for steam-turbine LNG Carriers

According to MEPC.333 (76) par. 2.2.1, the power from combustion of excessive natural boil-off gas in the engines or boilers to avoid releasing to the atmosphere or unnecessary thermal oxidation, should be deducted from $P_{ME(i)}$ with the approval of the verifier.

The formula for the *Attained EEXI* for steam turbine LNG carriers becomes straightforward as according to MEPC.308(73) no separate term for the auxiliary power is needed:

$$Attained\ EEXI = \frac{P_{ME} \cdot SGC \cdot C_{F,LNG}}{DWT \cdot V_{ref}}$$

In case of power limitation and after deduction of the power from combustion of excessive natural boil-off gas, the formula changes as follows:

$$Attained\ EEXI = \frac{P_{ME_revised} \cdot SGC(P_{ME_lim}) \cdot C_{F,LNG}}{DWT \cdot V_{ref}(P_{ME_lim})}$$

The methodology cannot be applied prior to power limitation.

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Nomenclature

MCR	Maximum Continuous Rating (Value of MCR specified on the Steam Heat Balance and Flow Diagram as Maximum Propulsion Power)
P_{ME}	0.83 MCR
V_{ref}	Reference Speed
SFC	Certified specific fuel consumption, given in g/kWh, of the steam turbines, usually related to HFO with lower calorific value of 40,200 kJ/kg
SGC	Specific gas consumption, the result of SFC's correction to the value of LNG using the standard lower calorific value of the LNG (48,000 kJ/kg) at SNAME Condition (condition standard; air temperature 24°C, inlet temperature of fan 38°C, sea water temperature 24°C)
C_F	Conversion factor between fuel consumption and CO2 emission, for LNG, $C_F=2.750$ t-CO2/t-Fuel
MCR_{lim}	The new MCR to which the propulsion system must be limited to comply with the <i>Required EEXI</i>
$P_{ME_{lim}}$	$0.83 MCR_{lim}$
R_f	Reduction factor R_f ($R_f < 1$) with $MCR_{lim} = R_f \cdot MCR$
P_{BOG}	Is the nominal power generated by consuming all boil-off gas from the cargo tanks
$P_{Excessive}$	The excessive power from combustion of excessive natural boil-off gas is defined as the difference between nominal power generated by consuming all boil-off gas from the cargo tanks and MCR_{lim} , $P_{Excessive} = P_{BOG} - MCR_{lim}$
$P_{ME_{revised}}$	The relevant power value after deduction of $P_{Excessive}$. This value will be used in the calculation of the <i>Attained EEXI</i> , $P_{ME_{revised}} = 0.83 MCR_{lim} - P_{Excessive}$
BOR_{LNG}	Daily boil-off rate, in t/day, $BOR_{LNG} = 0.000864 \cdot V_{Cargo}$
V_{Cargo}	Cargo Tank Volume to be taken as the 100% net volume, as per capacity plan, in m ³

Based on the daily boil-off rate BOR_{LNG} and inputs from the ship's Steam Heat Balance and Flow Diagram, P_{BOG} can be determined.

Steam Heat Balance and Flow Diagram provides the Fuel Oil Consumption at Different Power Levels in kg/h (minimum 4 points) or the corresponding fuel oil rate in g/kWh. The Fuel

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Oil Consumption is converted to Daily LNG Consumption using the ratio of the Lower Calorific values as stated by IMO in MEPC.308 (73).

Daily LNG consumption (tons LNG/day) is calculated at the different power levels as follows:

$$LNG\ Consumption = \frac{Fuel\ Oil\ Consumption\ (\frac{kg}{h}) \cdot 24}{1000} \cdot \frac{LCV_{FO}}{LCV_{LNG}}\ (\frac{tons}{day})$$

P_{BOG} can be read from the relation between the calculated Daily LNG consumption and the corresponding power. Typical curves given as example in following figure.

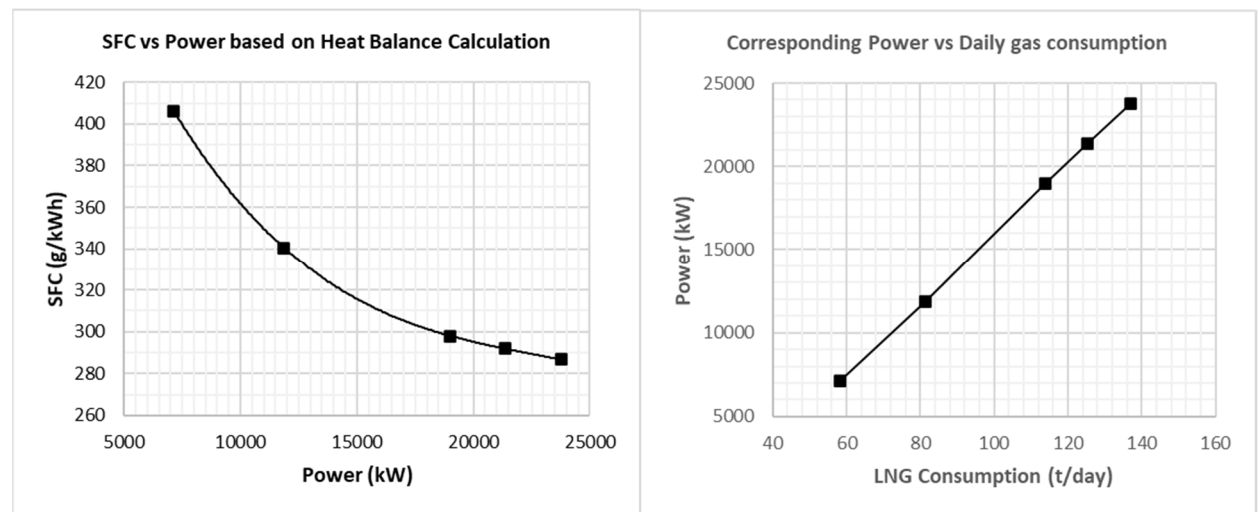


Figure 7.2.1 Example of SFC vs Power from heat balance and Corresponding Power vs Daily Gas Consumption curves for a typical steam ship.

Once the power of the ship's engine is limited, this results in a limited power, namely MCR_{lim} . The calculation of the MCR_{lim} is an iterative process as a reduction factor R_f ($R_f < 1$) shall be applied to the documented MCR until the *Attained EEXI* is less than or equal to the *Required EEXI*.

7.3 SGC for steam-turbine LNG Carriers

Regarding the Specific Gas Consumption (SGC) calculation for the steam-turbine LNGs, in most cases the specific gas consumption at varying loads is not available in the Steam Heat Balance & Flow Diagram drawing. In case the gas consumption is available at the Steam Heat Balance & Flow Diagram drawing (3 or more load points), then these values are to be used.

The Fuel Oil Consumption (FOC) to be corrected to the value of LNG as per MEPC.308 (73) para 2.2.7.2.2. The FOC should be multiplied with the ratio of the lower calorific values (LCV) of the respective Fuel oil and LNG. Conversion of SFOC to SGC, is taken as follows:

$$SFOC \cdot \left(\frac{LCV_{(Fuel\ Oil)}}{LCV_{(LNG)}} \right)$$

7.4 $V_{ref,app}$ for steam-turbine LNG Carriers

The formula for steam-turbine LNG carriers is to be as follows:

$$V_{ref,app} = (V_{ref,avg} - m_V) \cdot \left[\frac{\sum MCR_{SteamTurbine}}{MCR_{avg}} \right]^{\frac{1}{3}}$$

and in case of power limitation:

$$V_{ref,app} = (V_{ref,avg} - m_V) \cdot \left[\frac{\sum MCR_{lim}}{MCR_{avg}} \right]^{\frac{1}{3}}$$

7.5 Calculation of Attained EEXI for Diesel Electric LNG Carriers

According to MEPC.333 (76) par. 2.2.1, the power from combustion of excessive natural boil-off gas in the engines or boilers to avoid releasing to the atmosphere or unnecessary thermal oxidation, should be deducted from $P_{ME(i)}$ with the approval of the verifier. This deduction is only acceptable if no reliquefaction plant is installed. In case a reliquefaction plant is installed then the additional auxiliary power to be used.

The below methodology considers LNG as the primary fuel. DFDEs are fitted with dual fuel auxiliary engines with no dedicated LNG fuel tanks.

The formula for the *Attained EEXI* for Diesel Electric LNG carriers is the below:

Attained EEXI

$$= \frac{P_{ME} \cdot (C_{FMEGas} \cdot SFC_{MEGas} + C_{FMEPilotfuel} \cdot SFC_{MEPilotfuel}) + P_{AE} \cdot (C_{FAEGas} \cdot SFC_{AEGas} + C_{FAEPilotfuel} \cdot SFC_{AEPilotfuel})}{Capacity \cdot V_{ref}}$$

Simplified:

$$Attained EEXI = \frac{(P_{ME} + P_{AE}) \cdot (C_{FMEGas} \cdot SFC_{MEGas} + C_{FMEPilotfuel} \cdot SFC_{MEPilotfuel})}{Capacity \cdot V_{ref}}$$

This simplification is justified since DFDEs – do not have separate MEs & AEs but have a number of 4-stroke Dual Fuel Gensets all acting as MEs. Thus,

$$(C_{FMEGas} \cdot SFC_{MEGas} + C_{FMEPilotfuel} \cdot SFC_{MEPilotfuel}) \text{ and } (C_{FAEGas} \cdot SFC_{AEGas} + C_{FAEPilotfuel} \cdot SFC_{AEPilotfuel})$$

are exactly the same.

In case of shaft power limitation (motor power limitation) and after deduction of the power from combustion of excessive natural boil-off gas, the formula changes as follows:

$$Attained EEXI = \frac{(P_{ME, revised} + P_{AE}) \cdot (C_{FMEGas} \cdot SFC_{MEGas} + C_{FMEPilotfuel} \cdot SFC_{MEPilotfuel})}{Capacity \cdot V_{ref} (P_{MElim})}$$

The methodology cannot be applied prior to power limitation.

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Nomenclature

MCR	Maximum Continuous Rating
MPP	Rated output of motor (kW)
P_{ME}	$0.83 MPP / \eta_{electrical}$
V_{ref}	Reference Speed
$\eta_{electrical}$	0.913
$SFC_{ME(i)_{electric, gas mode at 75\% of MCR}}$	Certified specific fuel consumption, given in g/kWh, of the 4-stroke dual fuel gensets (considered as ME in this case), on gas mode
$SFC_{ME(i)_{Pilotfuel}}$	Specific fuel consumption of pilot fuel for dual fuel ME at 75% MCR according to testbed result
C_F	Conversion factor between fuel consumption and CO2 emission, for LNG, $C_F=2.750$ t-CO2/t-Fuel
MPP_{lim}	The new MPP to which the motor must be limited to comply with the <i>Required EEXI</i>
$P_{ME_{lim}}$	$0.83 MPP_{lim} / \eta_{electrical}$
R_f	Reduction factor R_f ($R_f < 1$) with $MCR_{lim} = R_f \cdot MCR$
P_{BOG}	Is the nominal power generated by consuming all boil-off gas from the cargo tanks
$P_{Excessive}$	The excessive power from combustion of excessive natural boil-off gas is defined as the difference between nominal power generated by consuming all boil-off gas from the cargo tanks and ($MPP_{lim} / \eta_{electrical} + P_{AE}$), $P_{Excessive} = P_{BOG} - (MPP_{lim} / \eta_{electrical} + P_{AE})$
$P_{ME_{revised}}$	The relevant power value after deduction of $P_{Excessive}$, This value will be used in the calculation of the <i>Attained EEXI</i> , $P_{ME_{revised}} = 0.83 MPP_{lim} / \eta_{electrical} - P_{Excessive}$
BOR_{LNG}	Daily boil-off rate, in t/day, $BOR_{LNG} = 0.000864 \cdot V_{Cargo}$
V_{Cargo}	Cargo Tank Volume as per capacity plan, in m ³

Based on the daily boil-off rate BOR_{LNG} and inputs from the Gensets NOx Technical File (Parent Engine), P_{BOG} can be determined. The SFC_{MEgas} to be used is the weighted average corresponding to the 75% of the engines' MCR values.

$$P_{BOG} = \frac{BOR_{LNG} \cdot 1000000}{SFC_{MEgas} \cdot 24} \text{ [kW]}$$

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Typical curve given as example in following figure.

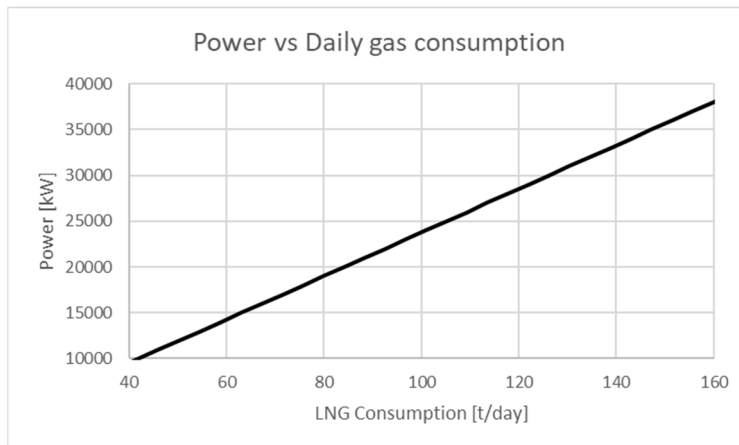


Figure 7.5.1 Example of daily LNG consumption vs Power for a typical DFDE ship.

Once the power of the ship's engine is limited, this results in a limited power, namely MPP_{lim} . The calculation of the MPP_{lim} is an iterative process as a reduction factor R_f ($R_f < 1$) shall be applied to the documented MPP until the *Attained EEXI* is less than or equal to the *Required EEXI*.

7.6 Primary Fuel

According to MEPC.308(73), in cases where the cruising time is defined, the primary fuel can be decided based on the corresponding gas volume and cruising time. However, in case where the cruising time is not defined, for LNG carriers with dual fuel engines (e.g. all the diesel-electric ships) LNG can be considered as primary fuel provided cargo tanks and engines/boilers are connected.

7.7 Reliquefaction Plants Considerations

All kind of reliquefaction plants to be considered according to MEPC.308(73) chapter 2.2.5.6.3 only in case that BOG cannot be used for propulsion or auxiliary engines. The following parameters can be sourced from the respective documents:

Parameter	Sourcing document
COP_{cooling} is the coefficient of design performance of reliquefaction	Typically, 0.166 for $COP_{cooling}$ is used according to 2.2.5.6.3.1 of MEPC.308(73). Alternatively, a value calculated by the manufacturer and verified by the administration or RO according to the regulation 2.2.5.6.3.1 of MEPC.308(73).
R_{reliquefy} is the ratio of boil-off gas (BOG) to be re-liquefied to entire BOG R_{reliquefy} = BOG_{reliquefy} / BOG_{total}	BOG _{reliquefy} and density of BOG are derived from the ship's technical specification.
COP_{comp} is the design power performance of compressor	Typically, 0.33 is used according to the regulation 2.2.5.6.3.2 of MEPC.308(73). Alternatively, a value calculated by the manufacturer and verified by the administration or RO according to the regulation 2.2.5.6.3.2 of MEPC.308(73).

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