Document Number	Rev	Page
	FINAL	1(17)

Date	Designer	Checked	Approved
2016-06-22	Tom Mattsson	Ilkka Saisto	Mika Hovilainen
Winmos activity 1: A Case Study On EEDI Effects to Winter Navigation			

Revisions	Alteration or Remark	Date	Changed by	Approved by

A CASE STUDY ON EEDI EFFECTS TO WINTER NAVIGATION

FOR

WINMOS ACTIVITY 1

Co-financed by the European Union
Trans-European Transport Network (TEN-T)

TABLE OF CONTENTS

1 INTRODUCTION

This report is a part of a larger WINMOS project and more specifically Activity 1 that is co-financed by the European Union (EU). The main objective of this report is to present the activity 1 EEDI effects to winter navigation.

2 SCOPE OF WORK

Predicted impact of Energy Efficiency Design Index (EEDI) on the ice going capability for the present and future merchant fleet's compared to current Finnish - Swedish Ice Rules (FSIR) and calculated channel resistance.

The results presents the required minimum power by FSIR and calculated power using AAT standard ice resistance method compared to the allowed maximum power for EEDI Phase 1 and Phase 3. EEDI Phase 1 is at present valid and Phase 3 is valid for new buildings after year 2025.

The study was limited to one ship type and size varying the bow types, the stern arrangements of the vessel was same for all variants.

The chosen ship concept to examine was a LNG carrier with a displacement of about 18500 ton. The required power estimations in open water are based on MCR 85% and a sea margin of 15 % at a service speed of 15 knots. The 15 knots speed requirement was taken as an initial speed to make comparison of the designs in open water, but, because the need to fulfill the EEDI requirements, the real speed has to be less than 15 knots.

3 THE CONCEPTS

The bow types to study were:

- Traditional icebreaking bow
- A bow with vertical stem called “EEDI type of bow form”
- A bow type developed for both performance in open water and ice conditions called “Semi bow”

3.1 TRADITIONAL ICEBREAKING BOW

The traditional ice bow was designed to be close the bows used in the Baltic Sea 20-30 years ago, reminding the bows used in for example product tankers at that period. The bow shape has good ice going capabilities and is even capable to break level Ice. The stem angle is quite moderate being about 30 degrees, which ensures acceptable open water characteristics.

The main dimensions of this concept are the following:

Length, CWL. .... 141.8 m
Breadth, CWL .... 25.0 m
Draft, CWL .... 7.2 m

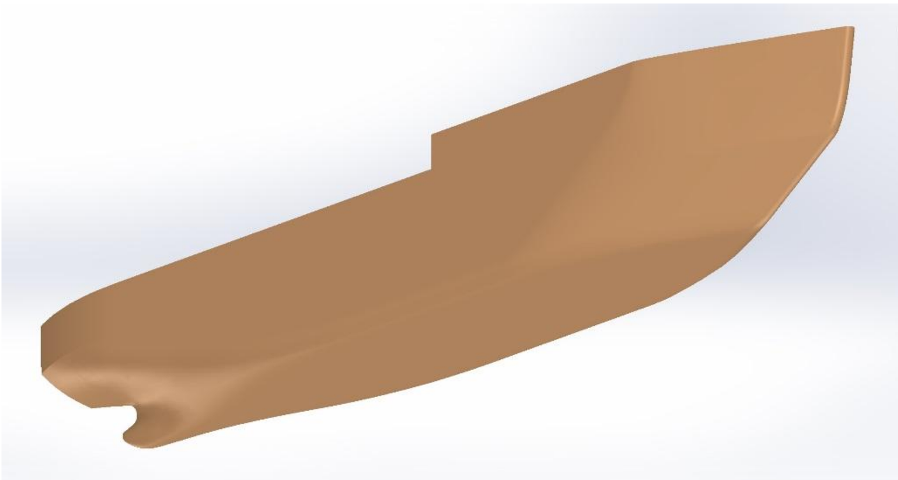


Figure 1 Traditional Icebreaking Bow

The service speed of 15 knots (with 15 % sea margin) is achieved with 5355 kW in propulsion power. The installed diesel power based is 6300 kW.

3.2 SEMI BOW CONCEPT

The new Bow Concept is designed to have excellent open water characteristics and at same time good ice going capabilities. The hull form provides excellent open water performance at the design draught and good ice-going performance at the other," ice draft". In open water conditions the carrier will be operated at loaded water line. In ice conditions the bow can be trimmed down to get a bow shape formed like in ice-going vessels.

The main dimensions of this concept are the following:

Length, CWL..144.3 m
Breadth, CWL ....25.0 m
Draft, CWL ....7.2 m

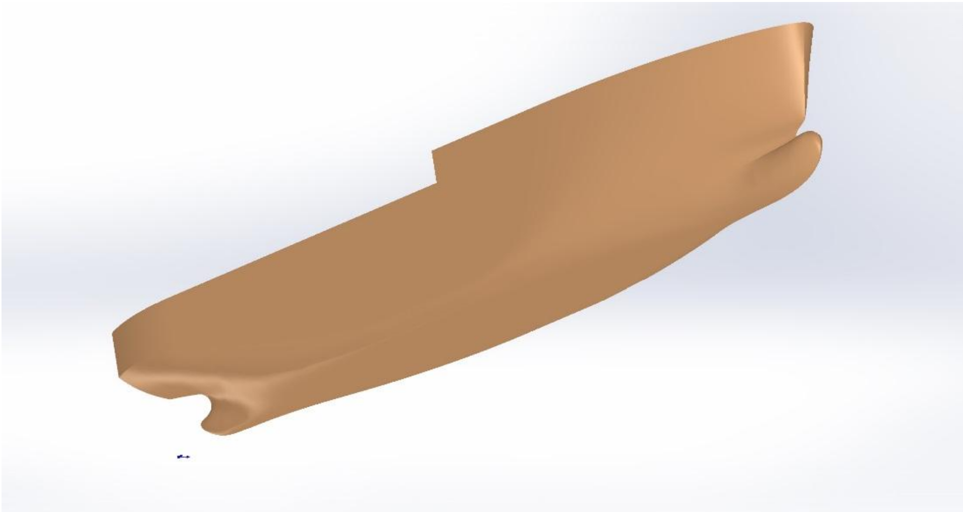


Figure 2 Semi Bow Concept

The service speed of 15 knots (with 15 % sea margin) is achieved with 4675 kW in propulsion power. The installed diesel power is 5500 kW.

3.3 EEDI TYPE OF BOW FORM

The bow shape of the EEDI bow follows the design trends at moment, having a vertical stem. This kind of bow shape is predicted to have almost none capabilities to break level ice and also the capabilities in brash ice channels are predicted to be quit poor, especially if the brash ice is covered with a frozen layer (1A Super requirement). The open water characteristics are designed to be excellent.

The main dimensions of this concept are the following:

Length, CWL..144.3 m
Breadth, CWL ....25.0 m
Draft, CWL ....7.2 m

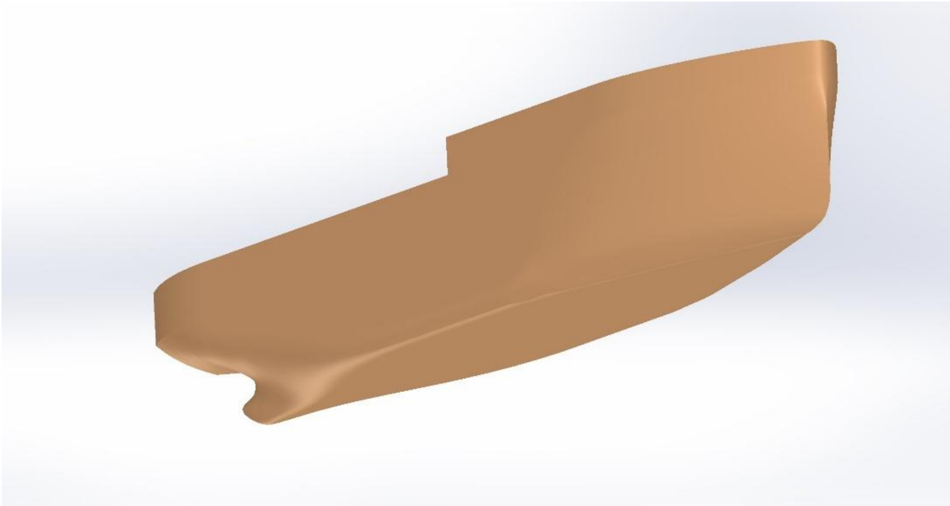


Figure 3 EEDI Type of Bow form

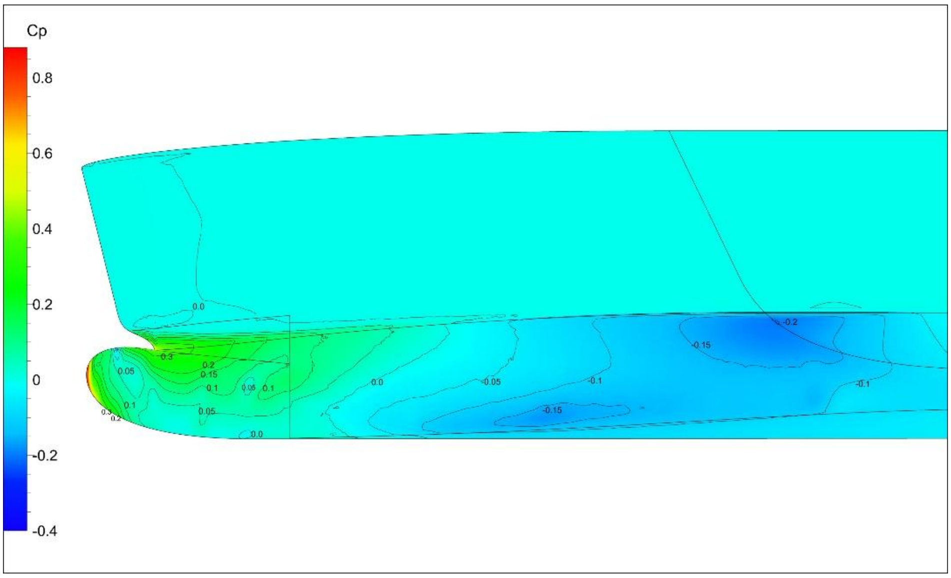
The service speed of 15 knots (with 15 % sea margin) is achieved with 4590 kW in propulsion power. The installed diesel power is 5400 kW.

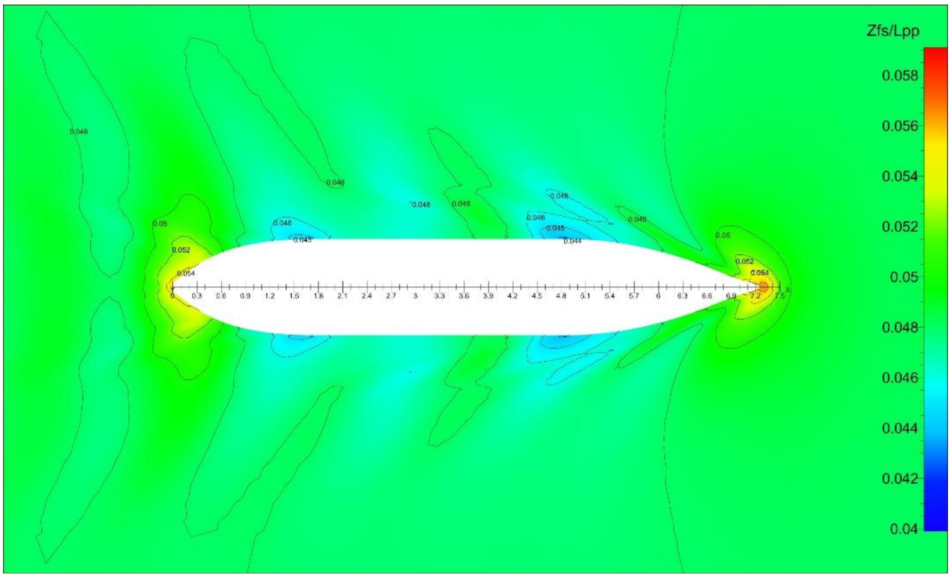
4 OPEN WATER PERFORMANCE

CFD calculations were made for all concepts to verify that the open water performances are decent and represent typical performance of the bow type. The analyzed performances were also used in determination of the net thrust curves for ice performance analysis.

The CFD calculations were conducted with the finite volume element RANS code ISIS-CFD, which is a core part of the FINE/Marine ver.4.2 ship flow computational software. The final power prediction was made using a combination of the CFD results and statistical prediction method of *Holtrop 84*.

Two examples of the CFD results for the Semi Bow concept are presented in the pictures below.





5 ICE PERFORMANCE

According the Finnish Swedish Ice Class Rules the ice resistance of the vessel in a brash ice channel can be determined either using the ice class equations or by model testing in an ice model tank.

In this study the ice performance in different FSICR class ice channels for each concept was determined using two different methods, the Aker Arctic standard calculation method and the required minimum power calculated with FSICR equations. With Aker Arctic method the ice performance in level ice was also determined. The required minimum power calculated with FSICR equations as the estimated minimum power need with AAT standard method were compared to the allowed maximum power for the corresponding ice class vessels in the EEDI Phase 1 and Phase 3.

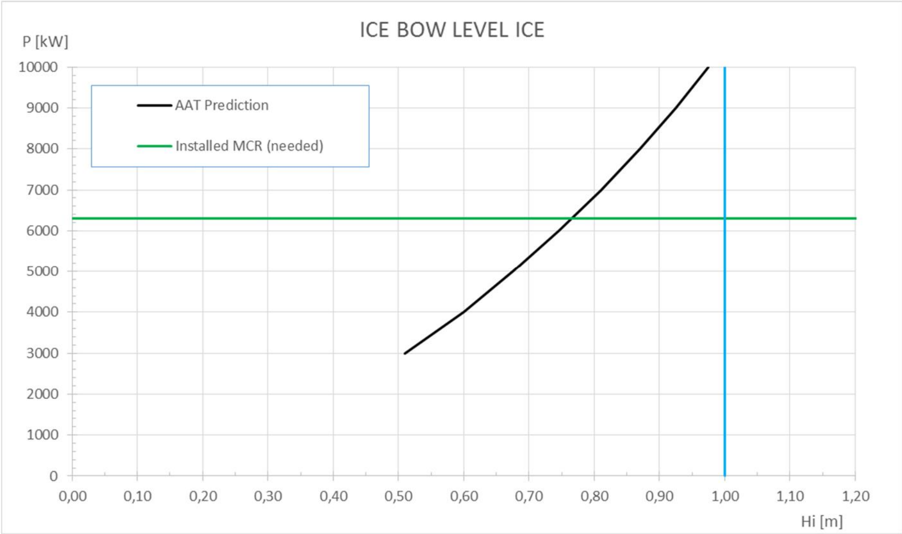
The Aker Arctic standard calculation method, which is a modified Lindqvist method for ship ice performance (POAC 1989, G. Lindqvist), is calibrated with AAT's database of model and full scale tests. As a result the method gives a power ice thickness curve for various ice conditions. The method gives a good estimate of the ship's performance in ice class model tests.

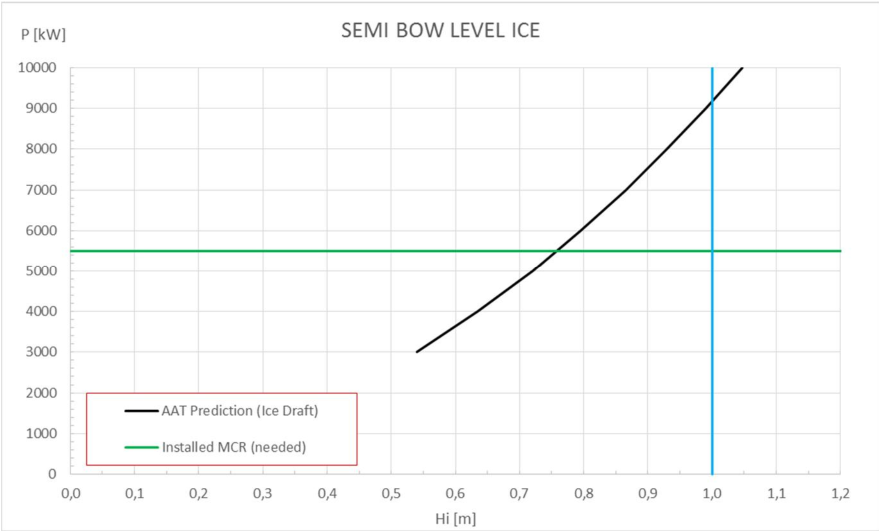
The equations for minimum power for each ice class according FSICR are presented in: *Guidelines for the application of the Finnish-Swedish Ice Class Rule (Trafi/21816/03.04.01.01/2011 Helsinki, 20 December 2011)*

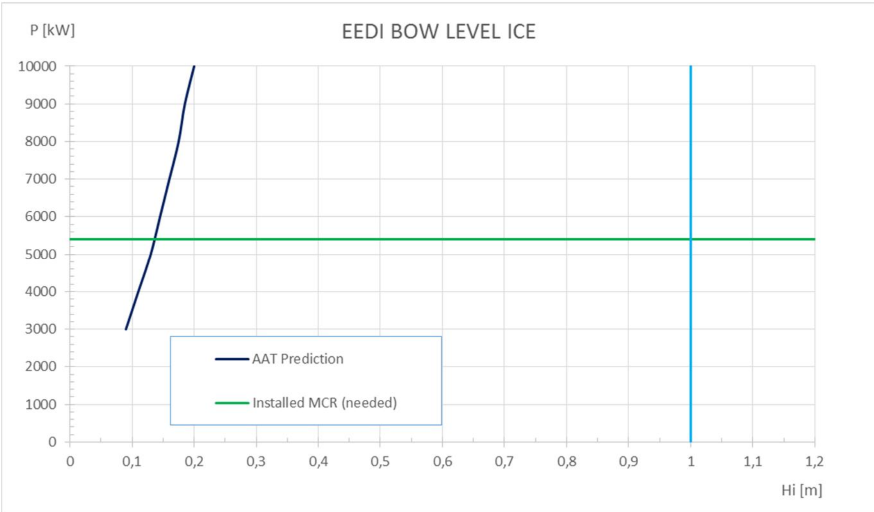
The Energy Efficiency Design Index (EEDI) has been estimated by using the *BIMCO EEDI calculator*. The ice class corrections for each ice class were used in the calculations. The formulas and principles of EEDI calculations are presented closer in: *Guidelines on the method of calculations of attained Energy Efficiency Design Index (EEDI) for new ships.*

5.1 PERFORMANCE IN LEVEL ICE

The required power to maintain 2 knots speed in level ice has been estimated using AAT standard method (see figures below). The green line represents power requirement from open water performance. Note that icebreaking capability of more than 1 m has not to complain with the EEDI requirements.







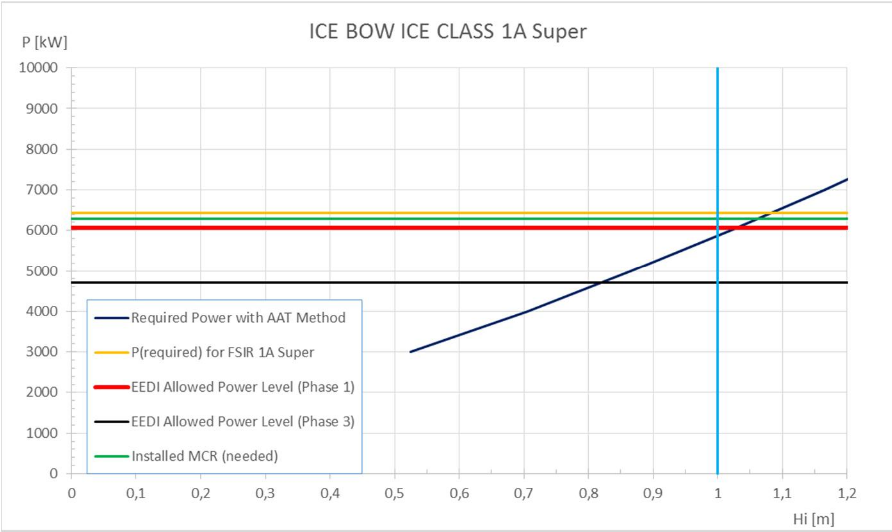
The Ice bow and Semi bow concepts require around 10 MW to achieve the 2 knots speed in 1 m thick level ice. This is about 2 times the installed power to fulfill the open water requirements, but might still be reasonable to install in some special cases. The

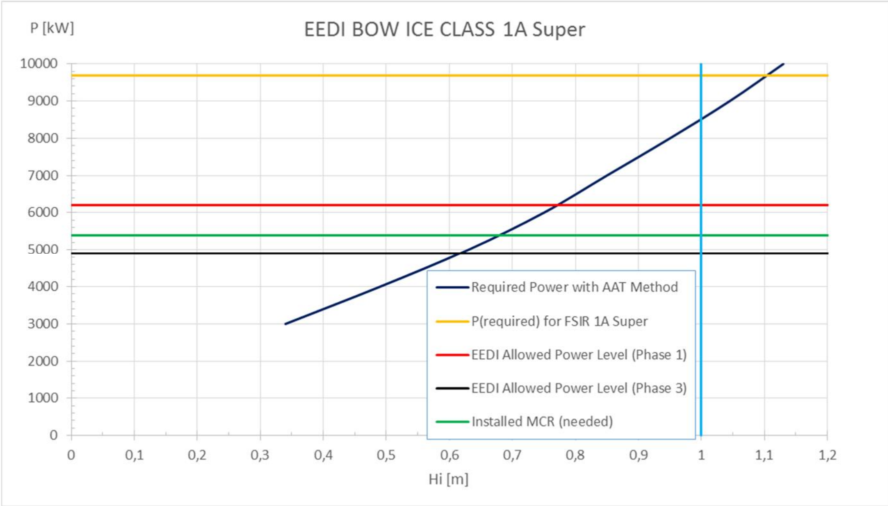
EEDI bow will need so high power outputs to move in level ice that it will not be realistic in economical way.

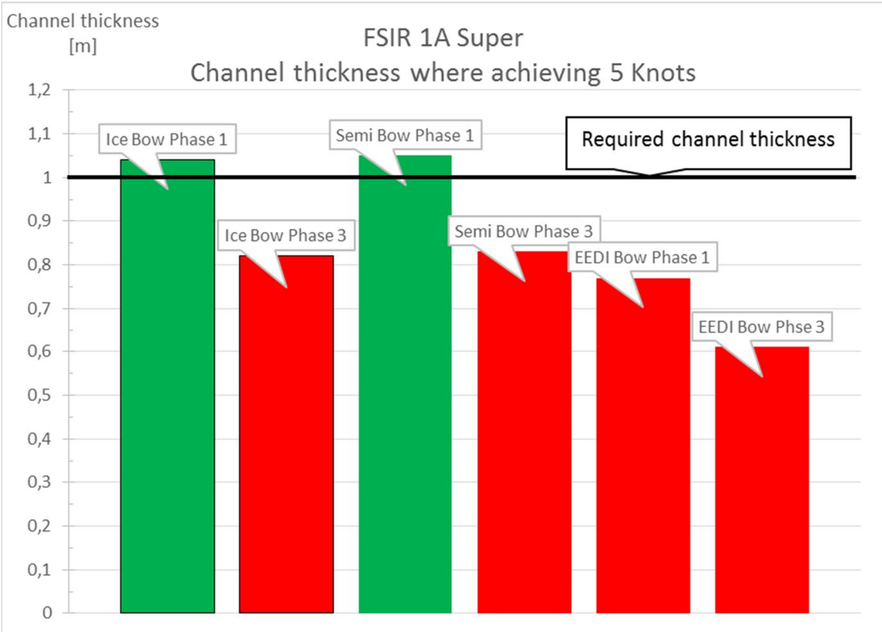
5.2 FINNISH-SWEDISH ICE CLASS 1 A SUPER

The power need for each vessel concept has been estimated for the channel defined by FSIR for 1A Super ice class (1 m thick with a 10 cm thick consolidated layer) at a speed of 5 knots. The required power has been calculated in two ways by the FSIR equation (market with orange line in figures) and by AAT method (dark blue line). AAT method is based on performed ice class model tests. The AAT required power can be seen as the lowest achievable power need to fulfill the ice class requirements.

The figures also presents the allowed maximum power to meet the Phase 1 and Phase 3 of EEDI.





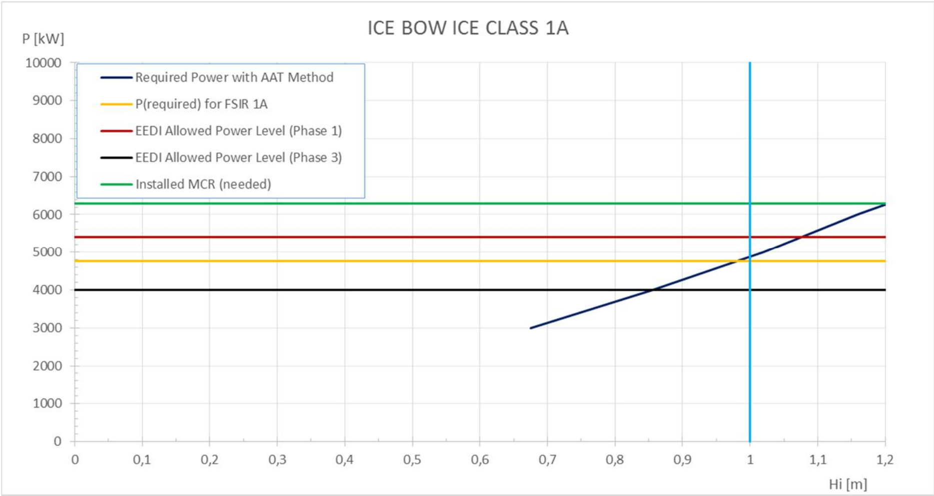


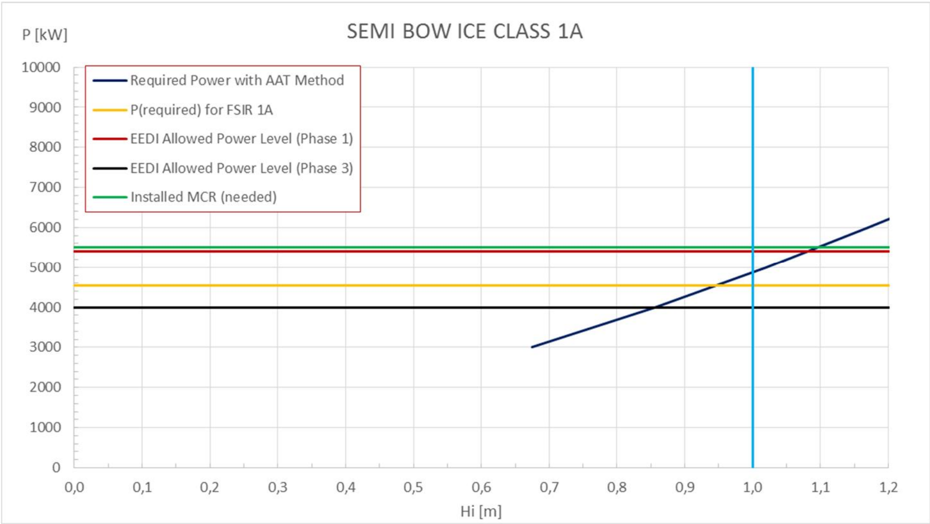
The maximum power allowed by EEDI Phase 1 for ice class 1A Super is 6100-6200 kW. The Ice bow and Semi bow concepts fulfills the EEDI requirements for Phase 1 (green pillars). The estimated power need of the EEDI bow concept is about 8500 kW in power, which is much more than the EEDI allowed power. The allowed power of Phase 3 is 4700-4900 kW, which means that none of the studied concepts will not correspond to the EEDI or Ice Class requirements at the same time.

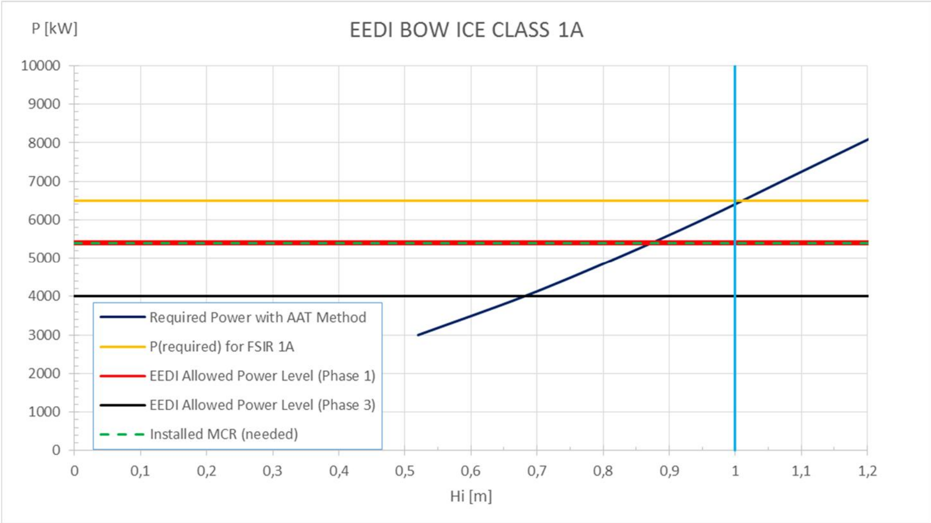
5.3 FINNISH-SWEDISH ICE CLASS 1 A

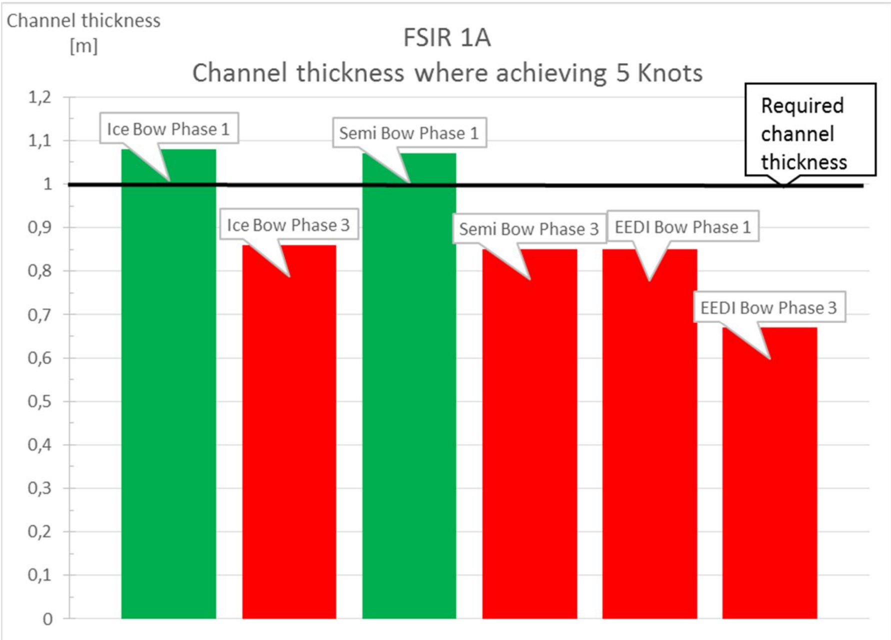
The power need for each bow type has been estimated for the channel defined by FSIR for 1A ice class (1 m thick brash ice channel) at a speed of 5 knots. The required power has been calculated in two ways by the FSIR equation (market with orange line in figures) and by AAT method. AAT method is based on performed ice class model tests. The AAT required power can be seen as the lowest power value to fulfill the ice class requirements.

The figures also presents the allowed maximum power to meet with Phase 1 and Phase 3 of EEDI for required FSIR Ice Class 1A.









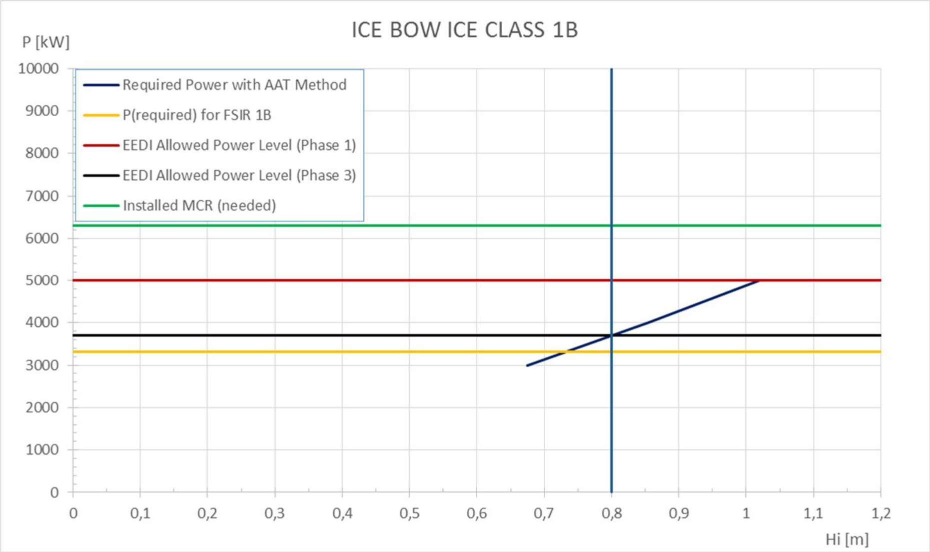
The maximum power allowed by EEDI Phase 1 for ice class 1A is 5400 kW. The Ice bow and Semi bow concepts are in compliance with EEDI requirements for Phase 1 (green pillars) and fulfills the 5 knot speed requirement for FSIR Ice Class 1A at allowed EEDI power. The estimated power need to achieve the ice class for the EEDI bow concept is more than allowed by EEDI.

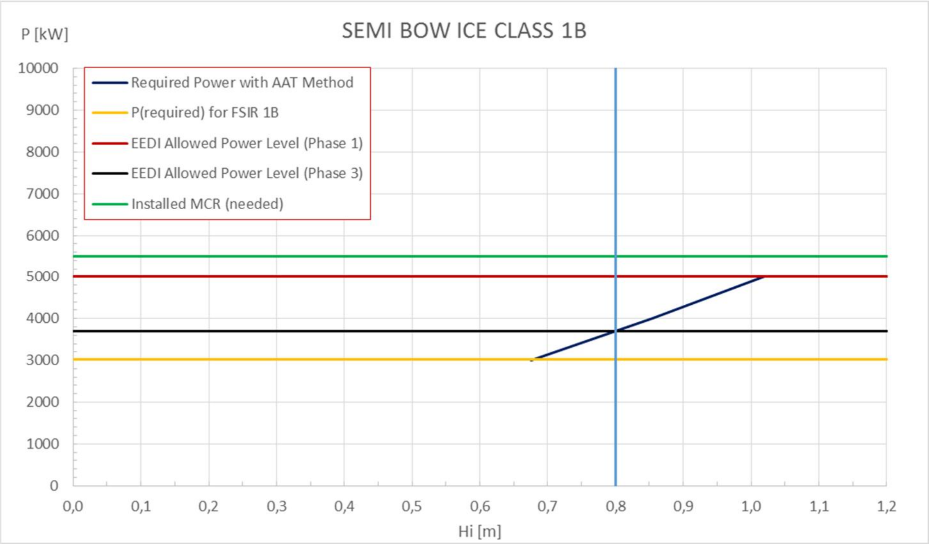
The allowed power of Phase 3 is 4000 kW, which means that none of the studied concepts will not fulfill the EEDI and Ice Class requirements at the same time (red pillars).

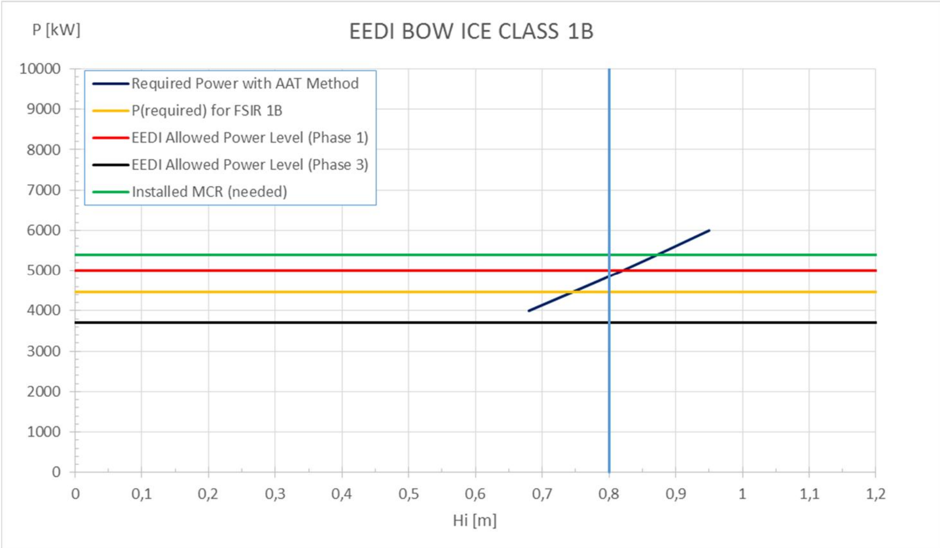
5.4 FINNISH-SWEDISH ICE CLASS 1 B

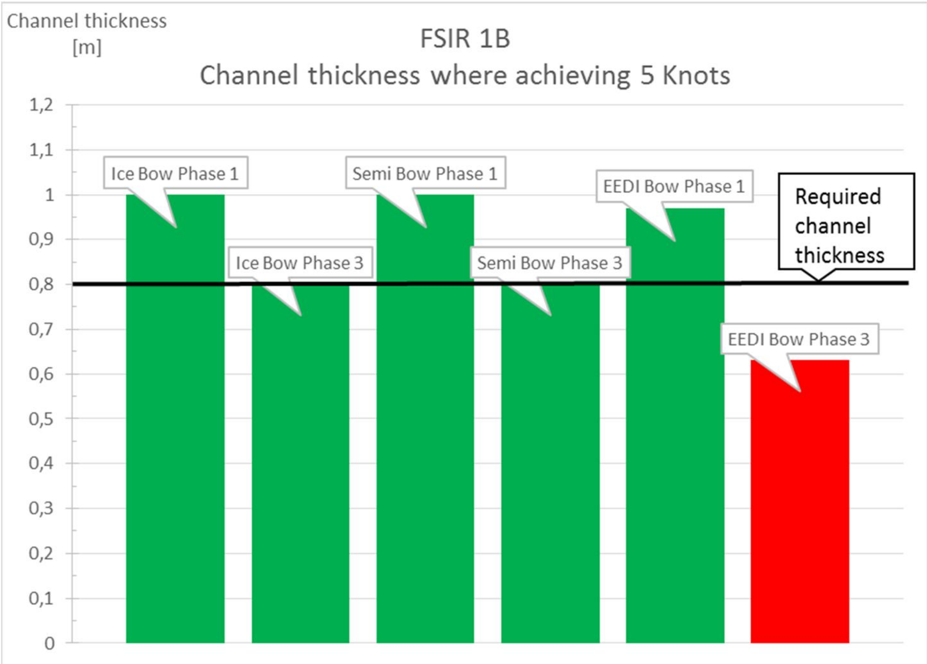
The power need for each bow type has been estimated for the channel defined by FSIR for Ice Class 1B (0.8 m thick brash ice channel) at a speed of 5 knots. The required power has been calculated in two ways by the FSIR equation (market with orange line in figures) and by AAT method. AAT method is based on performed ice class model tests. The AAT required power can be seen as the lowest power value to fulfill the ice class requirements.

The figures also presents the allowed maximum power to meet with Phase 1 and Phase 3 of EEDI and for required for FSIR Ice Class 1 B.









The maximum power allowed by EEDI Phase 1 for ice class 1B is 5000 kW. All three concepts are compliance with EEDI requirements for Phase 1 (green pillars) and fulfills the 5 knots speed requirement for FSIR Ice Class 1B.

The Ice bow and Semi bow concepts are even in compliance with EEDI requirements for Phase 3, (green pillars) and fulfills the 5 knots speed requirement for FSIR Ice Class 1B with allowed power output (3700 kW).

The needed power for the EEDI bow concept will not fulfill EEDI Phase 3 (red pillar) and the needed power will be higher than allowed by EEDI.

6 SUMMARY

The results indicates quite clearly that achieving higher ice class (1A and 1A Super) might be very difficult to achieve with EEDI allowed power at Phase 3. Depending on bow type EEDI phase 1 is possible to be compliance with both ice class and EEDI requirements. The lower ice class 1 B is will most probably been achievable even at EEDI Phase 3.

The Tables below shows the possibility achieve different ice classes with EEDI restricted power output, (Green numbers shows the compliance with the EEDI and Red none compliance). The installed power is determined from the open water performance requirements.

Phase 1	EEDI allowed power			Required power						Installed
				1A Super		1A		1B		
	1A Super	1A	1B	FSIR equation	AAT calculations	FSIR equation	AAT calculations	FSIR equation	AAT calculations	
Ice bow	6100	5400	5000	6434	5900	4768	4800	3311	3700	6300
Semi bow	6200	5400	5000	7264	5700	4537	4800	3029	3700	5500
EEDI bow	6200	5400	5000	9685	8800	8605	8400	4461	4900	5400

Phase 3	EEDI allowed power			Required power						Installed
				1A Super		1A		1B		
	1A Super	1A	1B	FSIR equation	AAT calculations	FSIR equation	AAT calculations	FSIR equation	AAT calculations	
Ice bow	4700	4000	3700	6434	5900	4768	4800	3311	3700	6300
Semi bow	4900	4000	3700	7264	5700	4537	4800	3029	3700	5500
EEDI bow	4900	4000	3700	9685	8800	8605	8400	4461	4900	5400

It can be noticed that for higher ice classes (1AS and 1A) the power demand is on average higher when using FSICR equations than AAT method (comparable to model tests) but for ice class 1B the FSICR equations gives smaller power demand than AAT method.