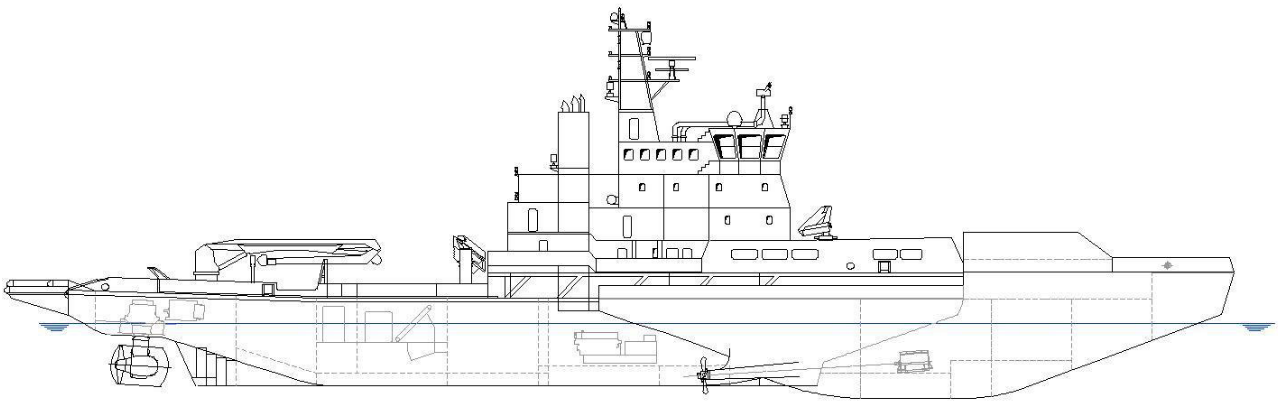
P-899 WINMOS SUB-ACTIVITY 2.3

REMOVABLE ICEBREAKER BOW CONCEPT COMPARISON TO ATLE/URHO CLASS



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Trans-European Transport Network (TEN-T)

ILS OY
Puutarhakatu 45, 20100 Turku, Finland
Telephone +358 2 417 22 00
Telefax +358 2 417 22 10
ils@ils.fi
www.ils.fi

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REMOVABLE ICEBREAKER BOW CONCEPT COMPARISON TO ATLE /URHO CLASS

1. General description of removable icebreaker design

1. General

The idea of removable bow icebreaker is based on the use of pusher vessel of smaller size and lower power than a conventional icebreaker and connect it to a removable bow with propulsion.

The pusher can be e.g. existing vessel or a newbuilding optimized for its primary tasks and it would thus work most of the time efficiently in other tasks than icebreaking. In this way the investment cost to build an icebreaker is limited to the construction of wider removable bow with propulsion.

As starting point for removable bow icebreaker design following requirements were selected, see also Report ILS 899-010-001-4 A, "Preliminary Description of Removable Bow Icebreaker Design Alternatives".

- Speed in 0,8 m level ice ahead min about 6 knots to guarantee high enough escort speed
- Total propulsion power about 11 MW (Pusher+ removable bow)
- Waterline breadth of removable bow abt. 24 m
- Fixed coupling of the pusher and removable bow
- The ice strengthening of removable bow and its propulsion to correspond present Baltic ice breakers
- The pusher ice class to be min 1A Super

I.e. removable bow icebreaker is designed for Baltic ice conditions excluding hard Gulf of Bothnia operations.

The selected requirements give also a good basis for the comparison of the performance and economy of the concept with existing icebreakers, e.g. Botnica and Tor Viking classes, and also the reference vessel Atle/Urho class which was model tested in Winmos project.

1.2 Selected pusher vessel for the design

To give realistic basis for the design M/S Louhi has been used as an example pusher. It fulfills well the given requirements and thus gives a good basis for the study. The 4 generator DE machinery gives flexibility in icebreaker use and the azimuth thruster propulsion gives maneuvering, backing and ice management power in ice.

However the presented design can be easily adjusted according any suitable pusher vessel requirements and even (by rebuilding the aft part of the removable bow) the bow section could be relatively easily changed to suit for another pusher if necessary.

1.3 Removable bow

To reach required power/icebreaking capability the removable bow should have about 6 MW propulsion power. This gives total propulsion power of 11,4 MW with the selected pusher.

The design is based on DE-propulsion in removable bow either with azimuth thrusters or conventional shafts because in all alternatives ice torque in propellers is high and DE-propulsion gives high flexibility and efficiency in icebreaker use.

The studied propulsion alternatives for the removable bow were (see appendix 1):

- 1*6 MW pulling azimuth thruster at bow, Alt. 1A and Alt. 1 B
- 2*3 MW pulling azimuth thrusters at bow, Alt 2
- 2*3 MW conventional shafts at bow, Alt 3
- 2*3 MW conventional shafts at reamer areas, Alt 4

For model tests, an innovative Alt 4 with conventional shafts at reamer areas, was selected.

General arrangement and main dimensions of the removable bow icebreaker Alt 4 is presented in appendix 2.

2. Summary of the performance of the concept based on the model test results

2.1 General

2.1.1 Tested hull form and propulsion design

The removable bow with pusher vessel results in an icebreaker hull form with a wider reamer bow with propellers in reamer area and highly inclined sides. The bow has also higher draft than the ship to which it is attached to.

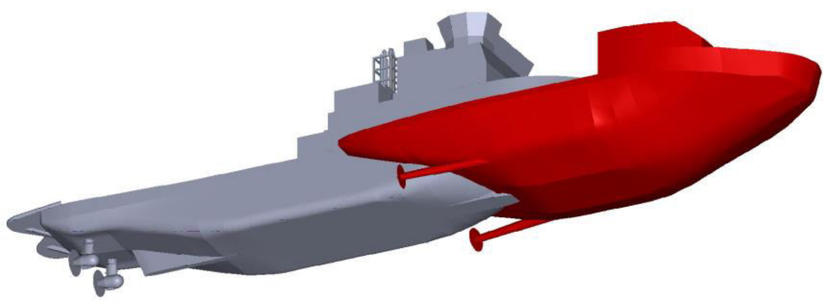

Fig. 1 Model tested removable bow icebreaker hull form

2.1.2 The target of ice model tests

The target of ice model tests was to study the characteristics of:

- Removable bow icebreaker concept generally compared to conventional icebreaker designs and

- To test the novel propulsion arrangement with the propulsion shafts exceptionally at both sides of the removable bow

2.1.3 The new operational characteristics tested in ice

The new operational characteristics which were especially tested in ice model tests included:

<u>In heavy channels and ridges</u> the bow propellers have direct interaction with ice and also the suction and flush effect of the propeller flow are used to

- Break heavy channel /ridge at vessel sides
- Flush the vessel sides and push the ice floes aft

This, together with the wide smoothly shaped reamer bow makes it possible to go through heavy ridges continuously without ramming by turning the pusher steering units from side to side.

<u>In maneuvering</u> the use of the high steering moment, given by bow propellers at sides when driving them to opposite directions together with wider removable bow, adds vessels maneuvering performance.

<u>In ice model test special attention was also paid to</u>

- How much ice is going to bow propellers in different ice conditions and how it influences the performance
- What is the influence of novel removable bow concept to ice interaction of the pusher propulsion

2.2 Summary of the model test results

2.2.1 Open water model tests

The main target of the open water model tests was to measure values needed for ice model test analysis.

Tests included:

- propeller open water tests
- bollard pull and towing tests both ahead and astern
- resistance tests
- self propulsion tests

Open water propulsion tests were done also because it is interesting to see the power needed and max transit speed for this kind of special design. Open water power has as well a big influence when going in light ice channels.

Power comparison between the novel concept and Atle/Urho is shown in Fig 2.

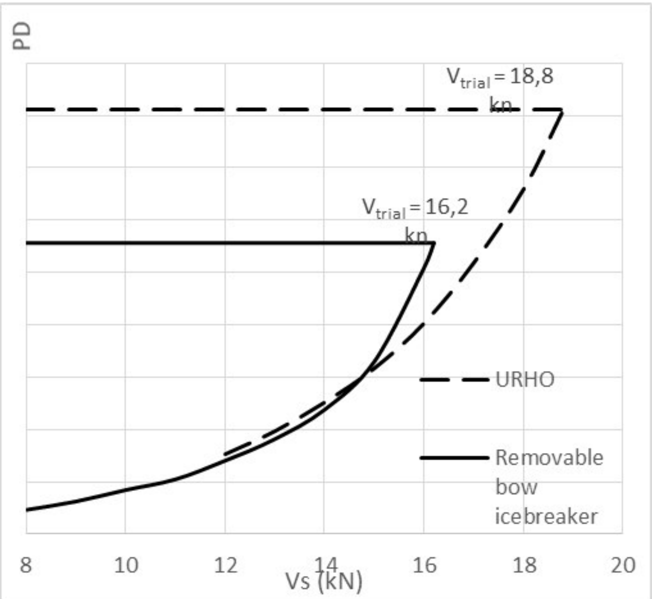

Fig. 2 Delivered power comparison of removable bow icebreaker and Atle/Urho

It can be seen that

- the propulsion power is at the same level as in Atle/Urho class
- the max speed of the removable bow icebreaker is over 16 knots

It can also be noted that the power needed in open water is lower than that of multipurpose icebreakers.

The pollard pull values of the removable bow icebreaker compared to Atle/Urho class are given in the table below.

	Bollard pull ahead		Bollard pull astern	
	t	t/kw	t	t/kw
Removable bow icebreaker, P_D=11,1 MW	130 t	11,7 t/kw	106 t	9,5 t/kw
Atle/Urho, P_D=16,2 MW	189 t	11,7 t/kw	127 t	7,9 t/kw

From the results it can be seen that the vessels have same bollard pull/power value ahead while astern the removable bow icebreaker gives higher thrust/power value mainly because of the azimuth propulsion.

2.2.2 Ice model tests

General evaluation

Generally it can be said that the reamer hull form with propellers in reamer area worked very well. However in level ice ahead quite high ice interaction of bow propellers was noted.

Ice model test program and result table, see chapter 2.3

Comparison of ice performance of all new concepts studied in Winmos and Atle/Urho class icebreaker, see separate report.

Level ice ahead

- Level ice tests ahead were done in 0,6 m and 0,87 m thick icefields
- In level ice tests ahead the ice interaction of bow propellers is quite high (ice floes lean against propeller supports and turn to propellers) and further development of the concept in this respect would be useful
- Less ice is coming to pusher propellers compared to situation where pusher is going in ice alone
- Bow shape made a wide channel in level ice
- Channel was quite clean
- The speed ahead was lower than calculated/predicted i.e. speed based on model tests is 5,7 knots in 0,8 m level ice ahead, when the target was min about 6 knots and calculated value was about 7 knots. Main reason to this is the bow propeller ice interaction.
  Botnica and Tor Viking class have a speed of about 8 knots in 0,8 m level ice ahead.

- In the table below a comparison of the speed in level ice between removable bow icebreaker and Atle/Urho class is presented. Also an estimate of speed of removable bow vessel with same power/waterline breadth is given. This way icebreaking efficiency in level ice can be compared directly.

Vessel	Speed in 0,6 m level ice	Speed in 0.87 m level ice
Atle/Urho (P_D=16,2 MW, B=22,5 m)	9,5 knots	7,7 knots
Removable bow icebreaker (P_D=11.1 MW, B=24,0 m)	6,8 knots	5,3 knots
Removable bow icebreaker with Atle/Urho power	8,6 knots	6,9 knots
Removable bow icebreaker with Atle/Urho power and breadth	8,8 knots	7,1 knots

Level ice astern

- Level ice speed astern was 6,6 knots in 0,6 m level ice. This is almost the same as e.g. Botnica performance and considerably higher than Atle/ Urho speed astern.

- In level ice astern only quite little amount of ice reached the removable bow propellers.

Ridge performance

- Ridge tests were done in so called Urho ridge (5-8 m consolidated ridge) and even about 6 m thick consolidated ridges. The ridges represent well big ridges in the planned operation area.

- Ridge performance was excellent meaning that the vessel could go directly through the ridges with initial ramming speed of 8 knots and using dynamically aft thrusters when stopped.

- Bow propellers direct interaction with ice and the suction and flush effect of the propeller flow broke efficiently ridges and flushed the vessel sides and pushed the ice floes aft when same time the pusher was turning azimuth thrusters from side to side.

- The vessel was able to penetrate also astern the 5,7 m ridge with one attempt.

Channel performance

- Channel tests were done in 1,2 m consolidated channels both ahead and astern and also 1,8 m unconsolidated channel ahead

- The speeds in 1,2 m channel were 12,8 knots ahead and 11,5 knots astern (Atle/Urho 12,1 knots ahead)

- Speed in channels was high, however the tested channels were light so direct comparison of heavy channel behavior is difficult, and due to high speed only low power levels could be used in tests

- Test in box shaped ridge with 6 m even thickness however showed the capability of side propellers to break and flush heavy channel sides

Manoeuvring performance

- Maneuvering capability was at the same level as that of multipurpose icebreakers with azimuth thrusters aft and better than conventional icebreakers. The vessel was able to turn in practice on spot in tested 0,6 m thick level ice.
- The use of the high steering moment (given by bow propellers at sides when driving them to opposite directions) together with wider removable bow with inclined sides, worked well making the excellent maneuvering performance possible. Bow propeller flow lifts water onto the ice surface which also breaks ice.

Pressuring ice field

Although the tests were not carried out in pressuring ice field, it can be considered that the following factors would be beneficial:

- Clearly wider removable bow compared to the breadth of M/S Louhi gives space for closing of the channel before ice is pressing against the sides of M/S Louhi
- Removable bow has only a short straight midbody and strongly inclined sides
- Bow propellers break the pressuring ice mass and flush vessel sides

Thus it can be considered that in the pressuring ice field the performance is relatively good taking into account the low propulsion power.

On the other hand, in this kind of situation there will be quite a lot of ice interaction with the propellers decreasing the propeller thrust because bow propellers are on the sides and propellers of M/S Louhi are quite near the waterline.

Widening of the channel

Although channel widening tests were not carried out, it can be considered that because the bow propellers break efficiently heavy channel at bow area sides, the broken ice floes can be pushed aside quite effectively by pusher azimuth units when they are directed outwards.

2.3 Table of ice model tests and corresponding results

Test	Ice thickness	Results (speed/comment)
Level ice ahead	0,87 m	5,3 kn
	0,6 m	6,8 kn
Level ice astern	0,6 m	6,6 kn
Consolidated channel ahead	1,2 m	12,8 kn
Consolidated channel astern	1,2 m	11,5 kn
Unconsolidated channel ahead	1,8 m	Resistance 15% higher than for 1,2 m consolidated channel
Consolidated ridge ahead	9-5 m	Vessel could penetrate ridge with 8 kn ramming speed and turning aft azimuth thrusters
	6 m	The vessel penetrated the ridge with one attempt
Consolidated ridge astern	5,7 m	The vessel penetrated the ridge with one attempt
Breaking out of channel ahead	0,87 m	The vessel breaks out of channel easily
	0,6 m	The vessel breaks out of channel easily
Breaking out of channel astern	0,6 m	The vessel breaks out of channel easily
Turning test ahead	0,6 m	Almost on spot
Turning test astern	0,6 m	On spot

The ice flexural strength in all tests 500 kPa

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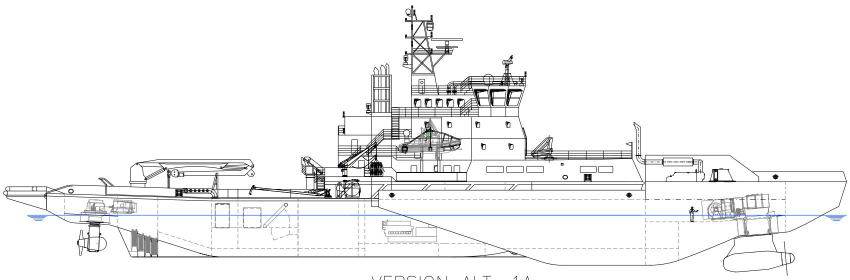

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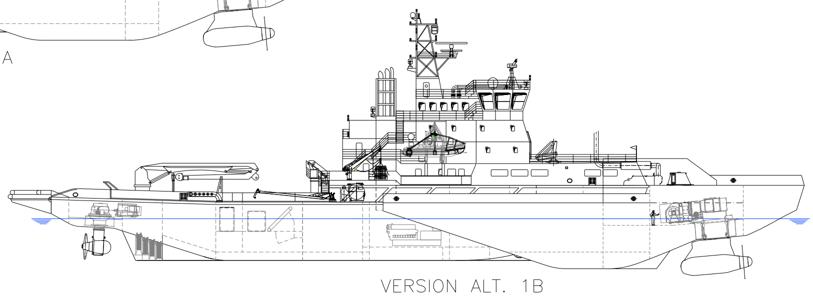

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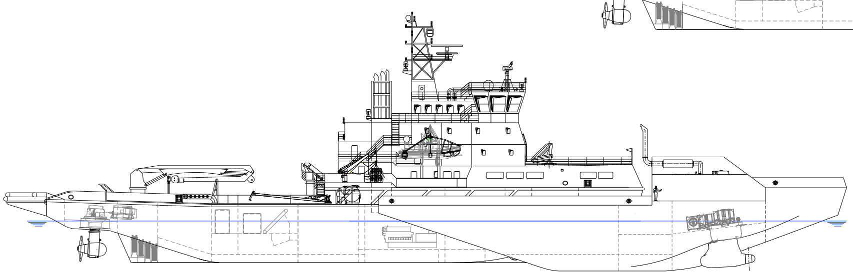

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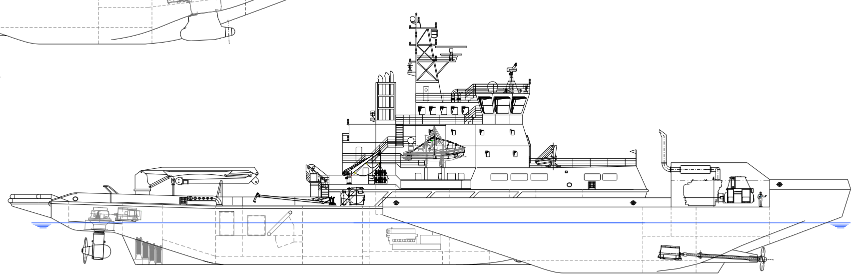

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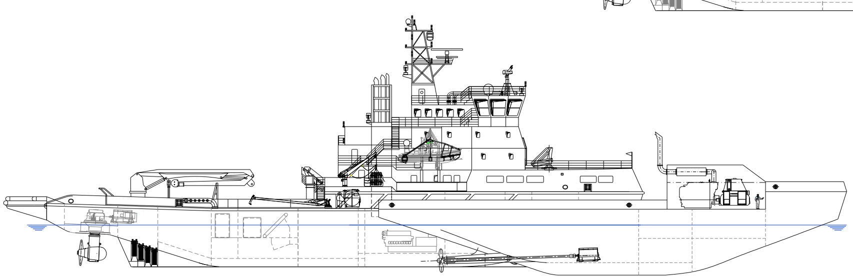
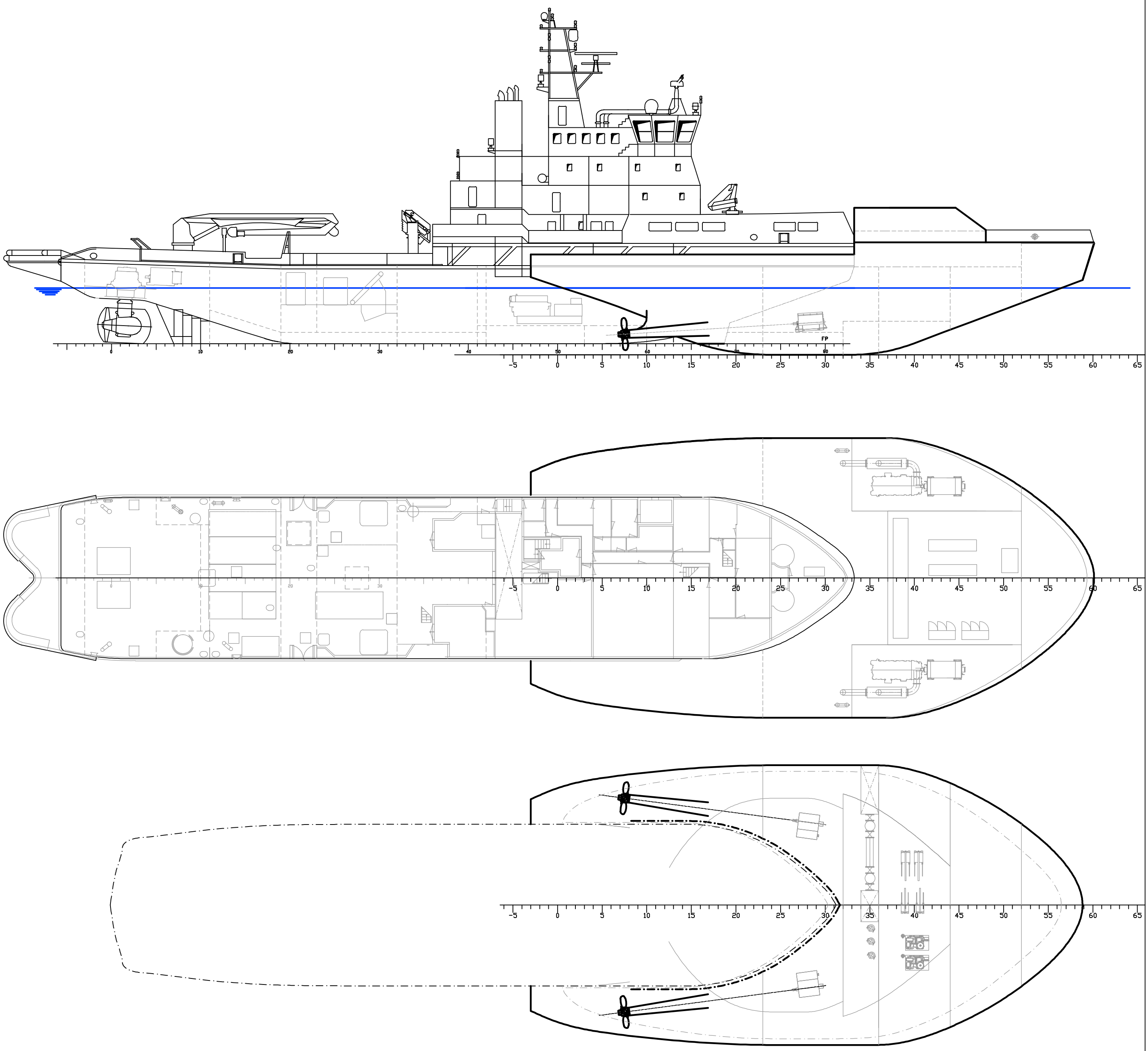


VERSION ALT. 4

ILS OY
Puutarhakatu 45, 20100 Turku, Finland
Telephone +358 2 417 22 00
Telefax +358 2 417 22 10
ils@ils.fi
www.ils.fi

APPENDIX 2



"LOUHI" MAIN DIMENSIONS

L steel hull ~71,4 m
Lcwl ~67,4 m
Bmld =14,5 m
Bwl =14,5 m
T =5,0 m
H =7,0 m
V =14.0 kn
BP =64 t
MAIN GENERATORS:
4 x Wärtsilä 9L20 1800kW /engine
PROPULSION UNITS:
2x Rolls-Royce 2700 kW/unit

CLASSIFICATION:

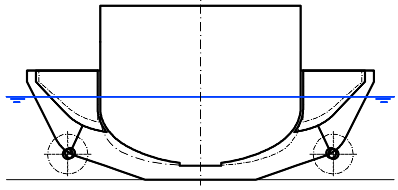
GL ✠ 100 A5, E4, Supply, NAV-OC Tug,
Marine Pollution Response Vessel,
Oil Recovery Vessel, Chemical Recovery Vessel.
MC, E4, AUT, FF1

REMOVABLE BOW

Lhull =50,6 m
Lcwl =44,8 m
Bmld =25,1 m
Bwl =24,0 m
T =6,0 m
H =7,9 m
PROPULSION POWER 2x3 MW

COMBINATION

Loa =93,0 m
Lcwl =88,6 m
Bmld =25,1 m
Bwl =24,0 m
T =6,0 m
PROPULSION POWER 11,4 MW
BP FORE =130 t
BP ASTERN =106 t
Vtrial = 16,2 kn



MODEL TEST VERSION
2x3 MW CONVENTIONAL SHAFTS AT
STERN REAMER AREAS

899-010-005-1 9.9.2015

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