

JETRIDER SES 300 PASSENGER FERRY DEVELOPMENT†

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SUMMARY

This paper presents the research and development work carried out to build the first two Surface Effect Ships at Karlskronavarvet AB. The two passenger ferries, each with a passenger capacity of 300 and a continuous speed of 42 knots, are now operating between the cities of Helsingborg in Sweden and Copenhagen in Denmark. In the paper, special attention is paid to the hull design, hull- and air-resistance at different speeds and trim angles, the propulsion system, the Ride Control System, the lift fan drive system and, finally, roll stability characteristics.

In the last sections the experience gained from the operations is reported. Despite a very tight schedule for the two vessels, with very little time for maintenance, so far only one or two departures have been cancelled for technical reasons. The need for future development especially concerning propulsion systems, Ride Control System, skirt design and maintenance are dealt with in a special section. The problem of a very short life time for the bow finger seals is highlighted.

Finally, a new SES passenger ferry design is presented. This new SES with a top speed of over 50 knots and a passenger capacity of 450 is now under construction and will enter service next summer on a 130 nautical mile-long route between Sweden and Denmark.

INTRODUCTION

Early in 1988 Karlskronavarvet AB delivered two high-speed passenger ferries to Scan Jet Ferries AB in Sweden. These two vessels were the very first to be built as Surface Effect Ships at Karlskronavarvet AB. Each vessel has a passenger capacity of about 300 and a speed of over 40 knots.

The surface Effect Ship project started in 1984 when Karlskronavarvet AB and Textron Marine Systems signed an agreement regarding transfer of technology to Karlskronavarvet AB relating to Surface Effect Ships. By this agreement, Karlskronavarvet AB came into possession of research and development work that had been carried out in the United States in this area.

At Karlskronavarvet this agreement meant the start of several research projects concerning both navy and commercial vessels, all using the Surface Effect Ship technique.

In 1986 Karlskronavarvet AB was awarded a contract for the two high-speed passenger ferries mentioned above. The project was named SES JETRIDER.

SES JETRIDER

In the pre-design stage of the project, contact was made with a large number of shipping companies and research establishments both in Sweden and abroad. These contacts gave a lot of useful information on how the next generation of fast-passenger-ferries should look. A large number of designs were produced with, sometimes, unconventional solutions.

Eventually the studies resulted in a specification for a passenger ferry representative of a number of ferry routes in Scandinavia (Figure 1). The major specifications (Reference 1) are:



The Helsingborg—Copenhagen ferry in action

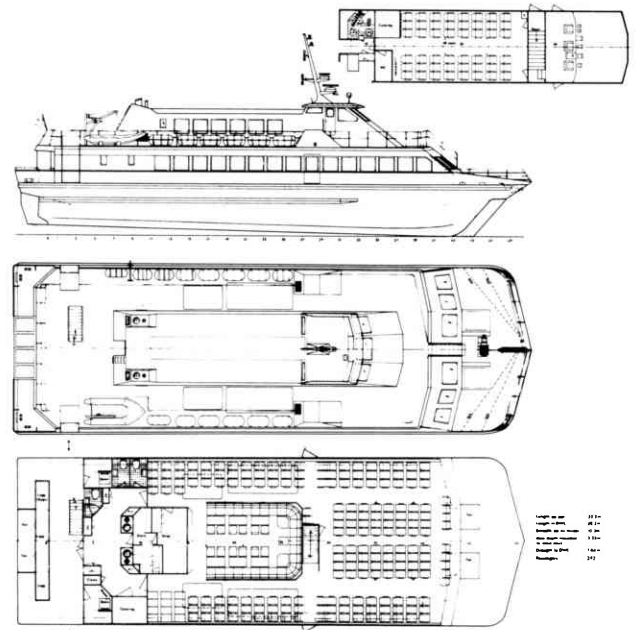


Figure 1
General arrangement of the SES JETRIDER

† Paper presented at the 1988 CACTS International Joint Conference on Air Cushion Technology, Sept. 1988, Annapolis, Md. U.S.A.

Length overall	33.40 meters
Beam overall	10.50 meters
Depth moulded	3.25 meters
Draught displacement mode	1.75 meters
Draught on cushion mode	0.50 meters
Main engines	2 × 1540 KW
Aux. engines	2 × 450 KW
Speed cont. at full load	39 knots
Speed cont. at half load	42 knots
Passengers (244 + 48)	292

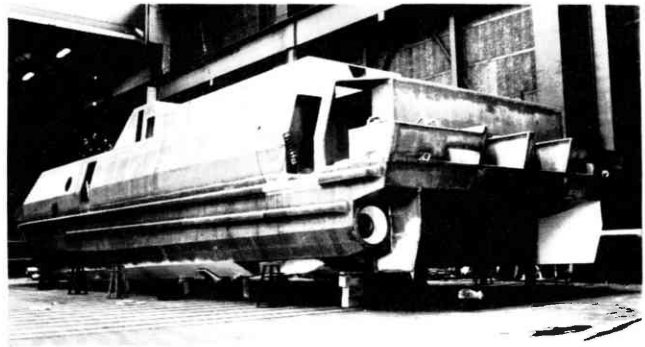


Figure 2
The complete hull and superstructure built in GRP-sandwich

RESEARCH AND DEVELOPMENT

In the pre-design stage, an extensive research and development program was started. Areas of special interest were:

- Hull design
- Hull resistance in water
- Aerodynamic resistance
- Propulsion
- Ride Control System
- Lift fan drive system
- Roll stability characteristics

Hull design

Very early during the design work the importance of choosing the right building material for hull and superstructures was obvious. The possible options were aluminium, stiffened single-skin GRP and GRP-sandwich. Karlskronavarvet has long experience in building ships both in aluminium and in GRP. In a study, the three building methods were evaluated:

	ALUMINIUM	SANDWICH	SINGLE-SKIN
LOW TOTAL HULL WEIGHT	+	+	-
LOW HULL MAINTENANCE COSTS	-	+	+
TOTAL COST	+	+	-

After the evaluation it was decided to build both hull and superstructure in GRP-sandwich (Reference 2) (Figure 2).

Hull resistance in water

An extensive tank test program was carried out to determine the most efficient way to operate the craft. A model (scale 1:10) equipped with model seals and liftfans with correct characteristic according to scale was built.

The total 'in water' resistance was determined from:

- Frictional drag
- Wavemaking drag
- Seal drag
- Residual drag

The frictional drag was calculated from the knowledge of the wetted surface. The wetted surface was calculated from underwater photos of the model at speed (Figure 3). The wavemaking drag generated by the air cushion and the seals was calculated using existing theories. Finally, the residual drag was calculated by subtracting the frictional drag, wavemaking drag, seal drag and the aerodynamical drag from the total drag measured in the towing tank (Figure 4).

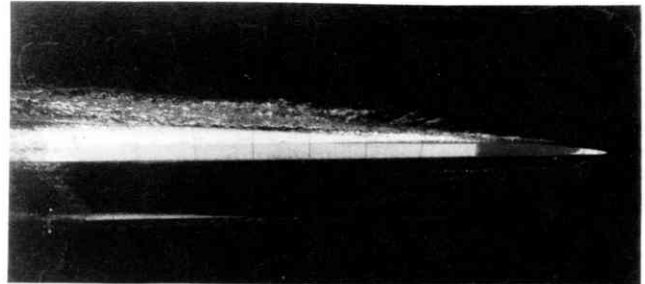


Figure 3
The frictional drag was calculated from a knowledge of the wetted surface

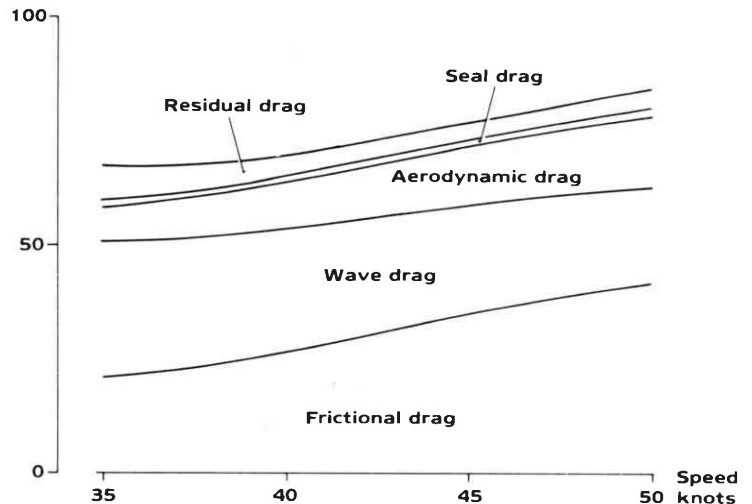


Figure 4
The total drag for the SES JETRIDER, showing its components

In the test program, the model was towed in the towing tank on different displacements, trim angles and speeds. During the model tests it became apparent that a Surface Effect Ship is very sensitive to changes in trim angle.

Another parameter carefully examined was how the cushion pressure influenced the performance of the craft. The model was towed at different speeds, trim angles and cushion pressures.

The results were then used to train the crew how to operate the craft in the most efficient way at different loading conditions and at different speeds.

Aerodynamic resistance

At speeds of 40–50 knots, the air drag is not negligible. In fact the air drag and the wave drag are about equal at this speed. (Figure 4). To evaluate the design, from an air resistance point of view, a model in scale 1:200 was built (Figure 5). The model was equipped with all necessary details such as stacks, lifeboats, lift fan inlets, masts and railing.

The tests were carried out in a wind tunnel and included:

- Flow studies
- Force measurements

The flow studies were conducted in order to optimize the shape of the superstructure and other equipment on deck. In the tests, the stack configuration was studied to avoid polluting the vessel. Later, some design changes were made on the stack configuration partly as a result of the tests. In many cases, the extra resistance due to weight increase by using spoilers, is bigger than the reduction in aerodynamical drag.

Force measurements were conducted to determine the aerodynamic resistance coefficient of the complete above-water part of the vessel. One finding from these tests was that it is very difficult to reduce the drag coefficient below a value of between 0.5 and 0.6. Spoilers of different designs were tested on the model to reduce the resistance coefficient. However, the results of these tests were not very encouraging. The very low benefit from it in reducing the resistance makes it not worth the costs.

Propulsion

Different propulsion systems were studied for the vessel. In the final evaluation, semi-cavitating, controllable-pitch propellers and waterjet propulsion were studied. Surface-piercing propellers were excluded since no reliable system in the appropriate power range was available on the market at the time for the project. The following parameters were evaluated:

	WATERJET	PROPELLER
LOW PRICE	–	+
LOW WEIGHT	–	+
LOW MAINTENANCE COST	+	–
HIGH OVERALL EFFICIENCY	+	–
HIGH AVAILABILITY	+	–

As a result of these studies, waterjet propulsion was selected for this project as being the most advantageous propulsion system.

The capacity of the system was dimensioned not only to give a high calm-water speed but also to give good performance at higher sea states.

The shape of the water inlets to the pumps became quite complicated and, therefore, it was decided to build the inlets in GRP-sandwich form as an integrated part of the hull. Building the water inlets in aluminium with GRP-sandwich was shown to be much more cost-effective than building them in steel.

Another problem that was much more complicated than expected, was air leakage into the waterjet inlet. Air in the waterjet pump causes reduced thrust or, at worst, engine shut down. Different solutions with air fences and scoops were examined. However, the best performance of the waterjets came at a trim angle which unfortunately was not the very optimum from a resistance point of view.

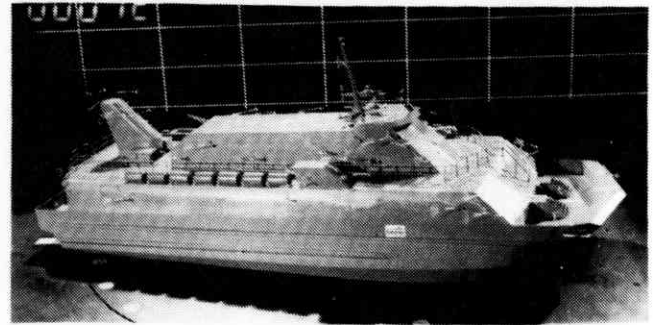


Figure 5
A model (scale 1:200) which was built for wind tunnel tests

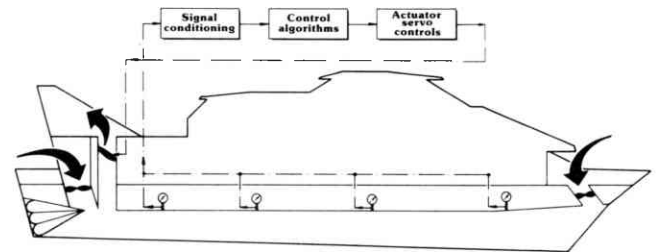


Figure 6
The SES JETRIDER Ride Control System

Ride Control System

At an early stage of the project, the Ride Control System was found to be of great importance to the SES role. The ride comfort of a Surface Effect Ship is hardly acceptable without a well-functioning Ride Control System. Because of the fundamental roll of the Ride Control System in the SES technology, it was therefore decided that Karlskronavarvet AB should develop a system of its own.

The design of the Ride Control System was very straightforward. The air cushion is vented by vent valves and the pressure from the cushion is measured by pressure transducers. The control process is executed by a high-performance micro computer (Figure 6).

The control law was designed jointly with SSPA Maritime Consulting. A mathematical model of the vessel, air cushion and surrounding water was created in a computer. In the mathematical model different control laws were studied to find the most efficient one.

- The vent valves were designed as vane valves with two on each side of the vessel. Each valve is hydraulically driven by an actuator to achieve best possible performance. The full-scale tests carried out showed that the RCS improved the ride comfort substantially. In the sea states that gave heave motions caused by resonance in the air cushion, the heave accelerations were reduced to about 10% of the level without RCS in operation (Figure 7).

Lift fan drive system

At the meetings with potential customers, a desire for a flexible passenger cabin without casings, etc. was expressed. Therefore, the vessel was designed with lift fans only fore and aft. The next question the design office had to face was how to drive the lift fans.

Different alternatives were evaluated and, in the end, two different drive systems were suggested.

- Direct driven by diesel engines
- Hydraulic system driven by diesel engines in the engine room

Difficulties were found with both systems but eventually it was decided to use an hydraulic transmission (Figure 8). One advantage with this system was that it could be placed in an engine room with fire equipment and control system in each hull instead of having an extra engine room in the stern and forecabin as with the other system. The hydraulic transmission made it possible to have a flexible lift fan installation according to the desire expressed above. It was also desired to reduce the moment of inertia as much as possible from a seal-keeping point of view. The disadvantages with the hydraulic transmission were the higher costs and a more complicated system.

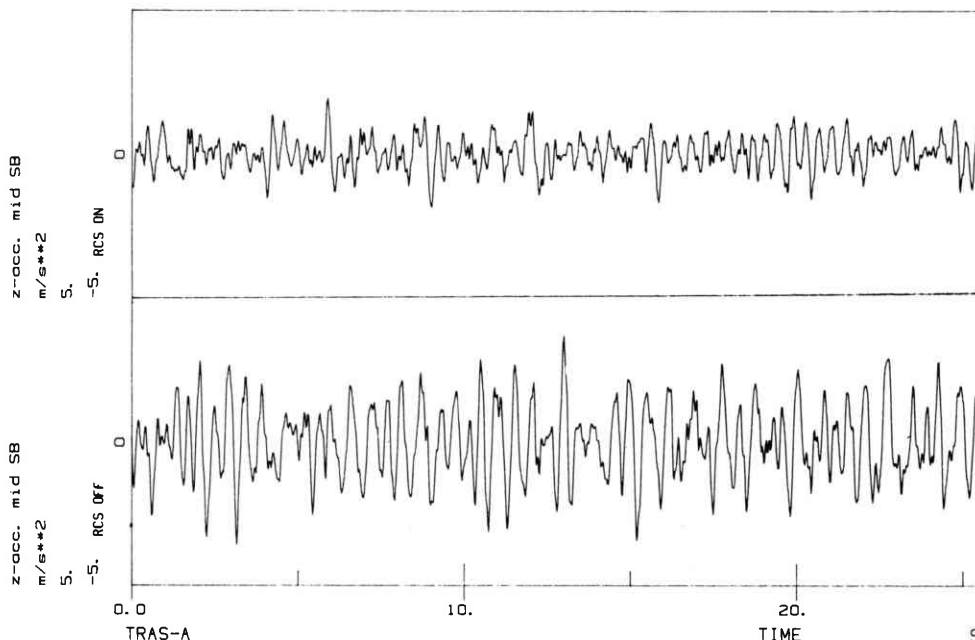


Figure 7
The Ride Control System reduces the heave motion to about 1/10th of the level without RCS at the natural heave frequency

Roll Stability characteristics

To investigate the on-cushion stability of the vessel, a study was carried out to find out the on-cushion roll stability characteristics. The basic reason for this investigation was the lack of stability standards available for this type of vessel in the on-cushion mode.

The study included the behavior in high-speed turns and in beam wind sea conditions. The stability limitations in terms of maximum-allowed centre-of-gravity height for both these circumstances were determined by a continuing program of model tests in the controlled conditions of the towing tank backed up by some limited full-scale trials. The study was conducted in the U.K. where the research program on which the results of the JETRIDER were based was also carried out. (Reference 3).

The study indicated that the SES JETRIDER had good roll stability characteristics. The conclusions drawn were:

- The vessel should turn with a slight inward heel angle.
- No indications of neutral or negative roll stiffness was found. In all cases, roll restoring moments increase in a progressive manner with heel angle.
- The loaded condition is marginally less stiff than light-ship condition
- Roll moments and behaviour is expected to be very similar in the whole speed range of 25–45 knots.

IN-SERVICE EXPERIENCE

The two vessels have been in service during the whole summer of 1988 with a timetable that has not given any possibilities for major maintenance work to be done. Each vessel has been in service for an average of 13 hours a day, 7 days a week, with an average of 9 departures a day. During this time only one or two departure has been cancelled for technical reasons.

In August, one stern seal had to be replaced. This operation took about four hours to carry out with a work force without any previous experience in this operation. The stern seal weight is about 400 kilos and the work was carried out in a drydock. The operation confirmed that if a complete seal breakdown should occur, the seal can be replaced overnight and no departures need be cancelled.

The service also brought to light the importance of and effective Ride Control System on air cushion vehicles. The wave height in the operations area is mostly low but a strong current, in combination with waves and surge from ships passing in different directions, makes the sea very choppy. This means that an encounter frequency that corresponds to the natural heave frequency of the vessel is very often found and causes the vessel to start heaving with a 2 hz dominant heave motion. The Ride Control System has effectively reduced the heave motions making it possible to carry out the catering services aboard the ferries.

FUTURE DEVELOPMENT

A research and development program continues running at Karlskronavarvet AB to improve the SES-technology. Areas of special interest are the Ride Control System, alternative propulsion systems and skirt design and maintenances.

The performance of the Ride Control System will most likely be much improved, especially at the frequency area outside the resonance frequency with new hydraulic components and improved vane design. An integration of a fan flow control system for the lift fans is also being studied. However, the benefit of such a system has to be related to the cost and complexity of the system.

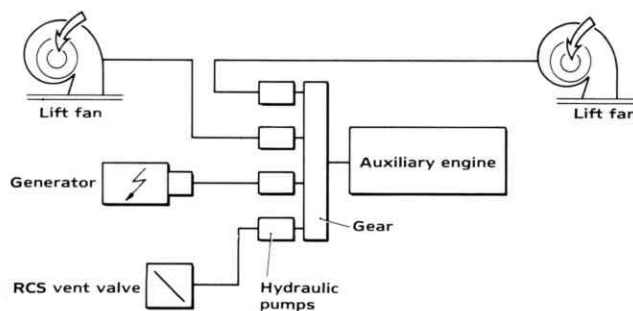


Figure 8
The lift fans, RCS and the generator are hydraulically driven by a diesel engine

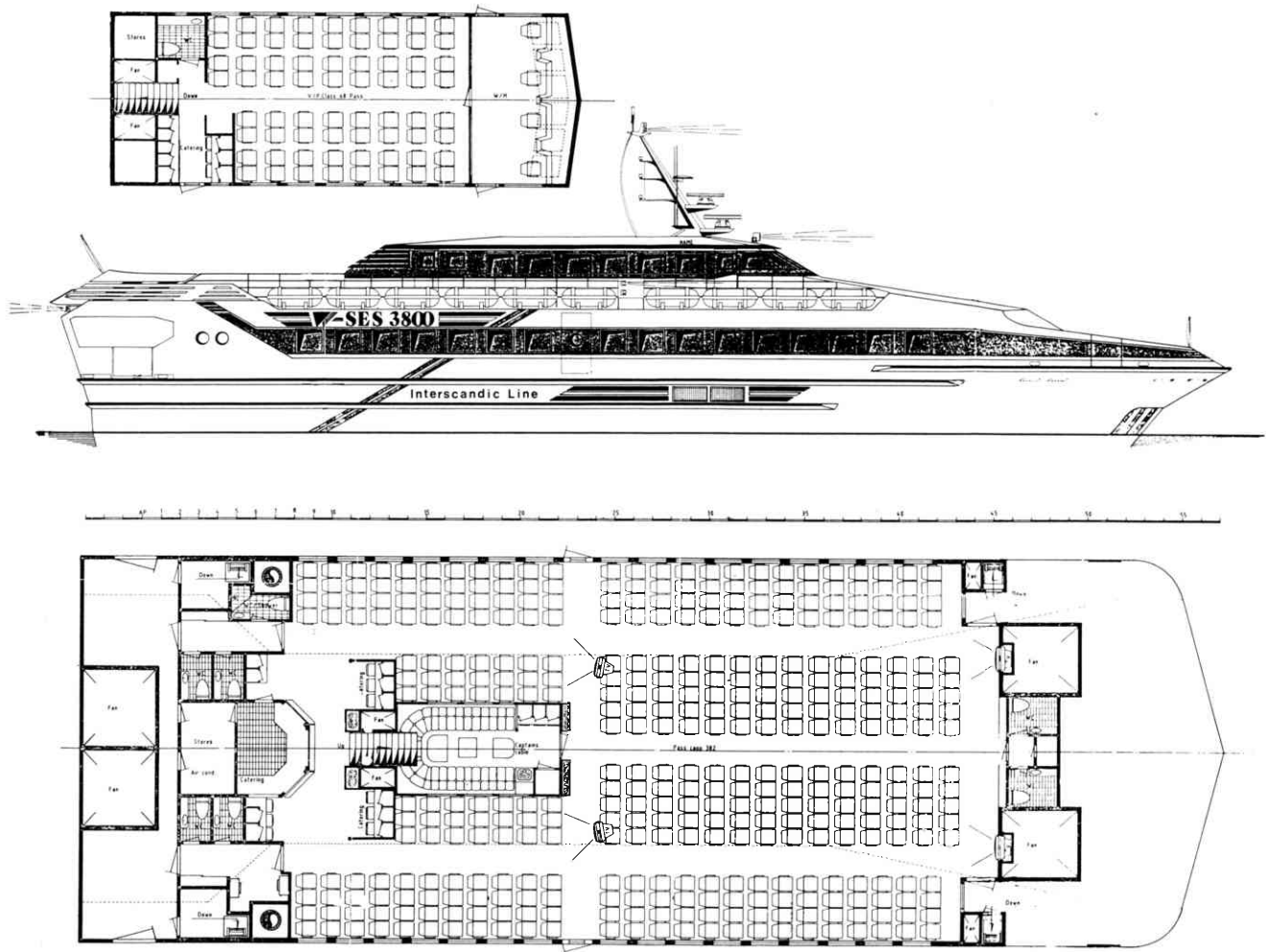


Figure 9
General arrangement of the new SES 3900.
Passenger capacity is 450 and the top speed is over 50 knots

Further test of different propulsion systems, including water jets, will be carried out to find the best solution for each application. One very interesting propulsion system now available for a SES at high speed is the surface-piercing propeller. The new interest for those propellers on high-performance craft has encouraged the manufactures to develop more suitable designs.

The life time of a bow finger seal is much too short to be acceptable. The benefit from lower fuel oil consumption for a SES compared with a catamaran is partly eaten up by the high maintenance costs for the seals. Another disadvantage with short life time on bow finger seals is the drop of speed. The difference in speed between a new seal and one used about 800 operational hours can be as much as 10 percent.

SES 3900 PASSENGER FERRY

The production of two new SES passenger ferries has started (Figure 9). The two ferries will be operating between the cities of Gothenburg in Sweden and Copenhagen in Denmark. The route is about 130 nautical miles and the crossing will take a little more than three hours. The continuous, calm-water speed is over 50 knots. The service speed in operation on the route will be about 45 knots. The high speed will make each vessel capable of completing three single crossings a day.

The technical data are:

Length overall	39.00 meter
Length between PP	33.80 meter

Breadth moulded	12.60 meter
Draught, DWL	2.00 meter
Depth to main deck	3.76 meter
Displacement full load abt.	200 tonnes
Passengers	450
Main engines	2 × 2640 KW
Lift fan engines	4 × 116 KW

Each main engine is connected to a Liaan Speed Z-drive controllable pitch propeller and each of the four lift fans are directly connected to its own diesel engine. The two SES passenger ferries will be built at the Norwegian yard Westamarin AS and will be delivered next summer to JKL Shipping in Norway.

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