Jetrider SES 300 Passenger Ferry Development

Ola Gullberg

Karlskrona Varvet AB, Sweden

RÉSUMÉ

Présentation des travaux de recherche et de développement en vue de la construction des deux premiers navires à sustentation aérodynamique, à Karlskronavarvet AB. Pouvant transporter jusqu'à 300 personnes à une vitesse de croisière de 42 noeuds, ces traversiers font maintenant la navette entre Helsingborg en Suède et Copenhague au Danemark. Une attention spéciale est consacrée à la forme de la coque, à la résistance hydro et aérodynamique en fonction de la vitesse et de l'assiette, au système de propulsion, au système antiroulis, au système d'entraînement du ventilateur de sustentation et, enfin, aux caractéristiques de stabilité en roulis.

Les derniers chapitres de ce document présentent les résultats de l'exploitation à ce jour. Malgré un calendrier d'exploitation très serré, ne laissant que peu de temps à l'entretien, ces deux navires ont bien fonctionné, seulement un ou deux départs ayant été annulés jusqu'ici pour des motifs techniques. Un chapitre est consacré tout entier à l'éventuelle nécessité de relever les performances du système de propulsion et du système antiroulis, et d'améliorer la jupe et son entretien. Le problème de la très courte durée de vie des étanchéités équipant les doigts de la jupe avant y est également abordé.

Enfin, un nouveau traversier à sustentation aérodynamique est présenté; il aura une vitesse maximale de 50 noeuds et pourra transporter jusqu'à 450 passagers. Sa mise en service est prévue pour l'été prochain sur la liaison maritime, longue de 130 milles marins, reliant la Suède au Danemark.

JETRIDER SES 300 PASSENGER FERRY DEVELOPMENT

BY

OLA GULLBERG M SC (NAVAL ARCH.)

KARLSKRONAVARVET AB, SWEDEN



ABSTRACT

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 payed 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 chapters the experience from the operations up till now 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 due to technical reasons. The need for future development especially concerning propulsion systems, Ride Control System and skirt design and maintenance are dealt with in a special chapter. The problem with 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 for entering service next summer on a 130 nautical mile long route between Sweden and Denmark.

INTRODUCTION

Early this summer 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 the speed is 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 taken 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 fast passenger ferries should look like. A large number of designs where produced with sometimes unconventional solutions.

Eventually the studies resulted in a specification for a passenger ferry representative for a number of ferry routes i Scandinavia (figure 1). The

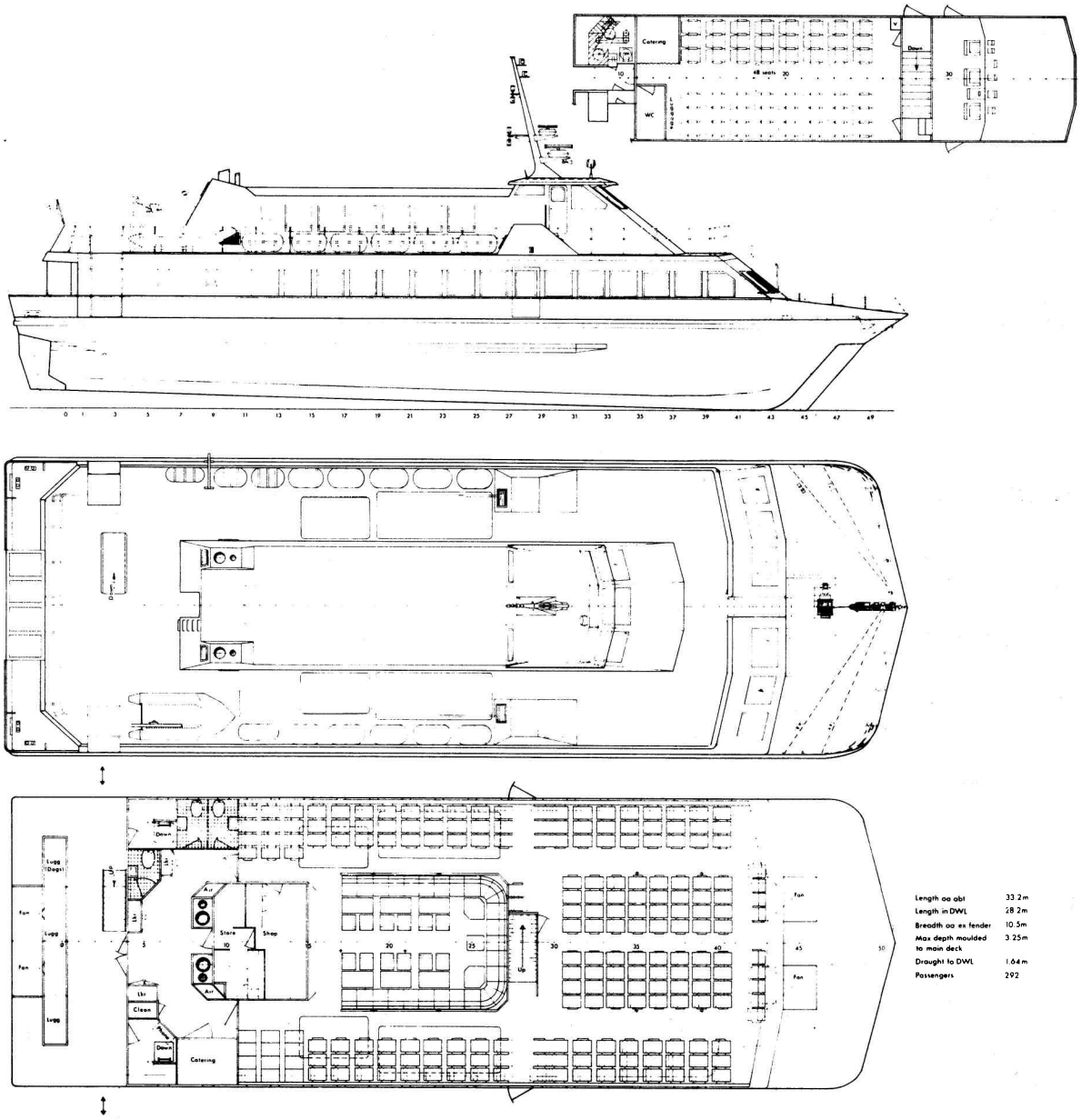


Figure 1. General arrangement SES JETRIDER.

main particulars are as follows (reference 1):

Length over all	33.40 meters
Beam over all	10.50 meters
Depth moulded	3.25 meters
Draught displacement mode	1.75 meters
Draught on cushion mode	0.50 meters
Main engines	2x1540 KW
Aux. engines	2x450 KW
Speed cont. at full load	39 knots
Speed cont. at half load	42 knots
Passengers (244+48)	292

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 superstructure 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	SINGLESKIN
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).

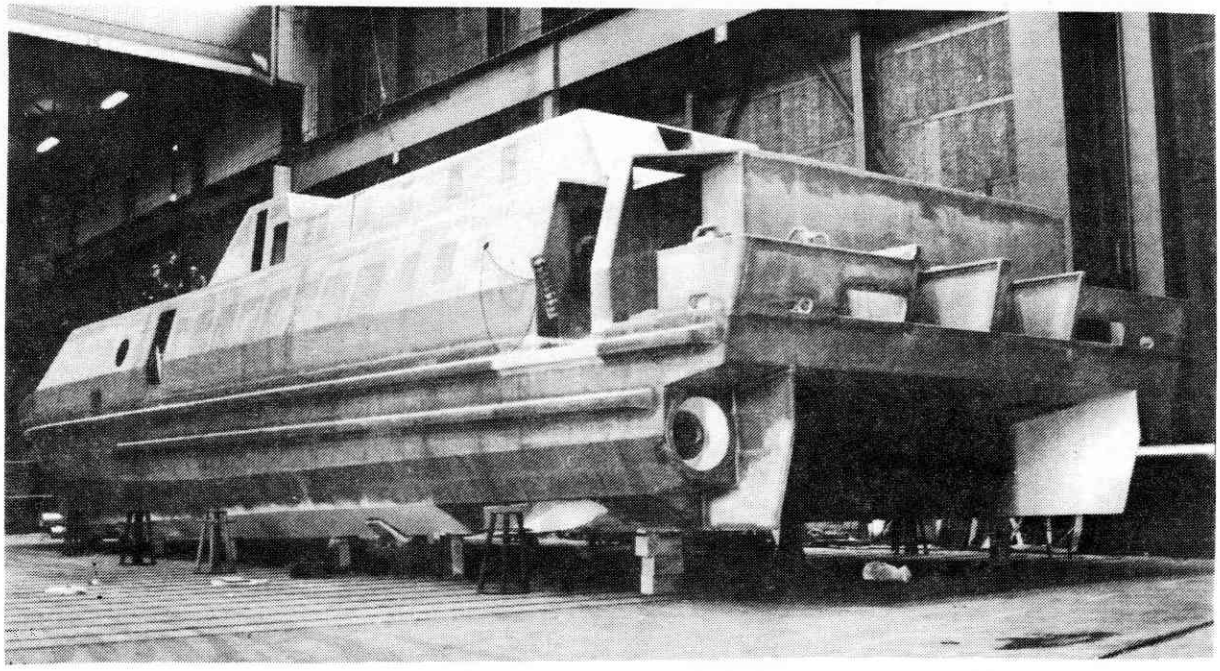


Figure 2. The complete hull and superstructure built i GRP-sandwich.

Hull resistance in water

An extensive tank test program was carried out to find out the most efficient way to operate the craft. A model in 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 under-water 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).

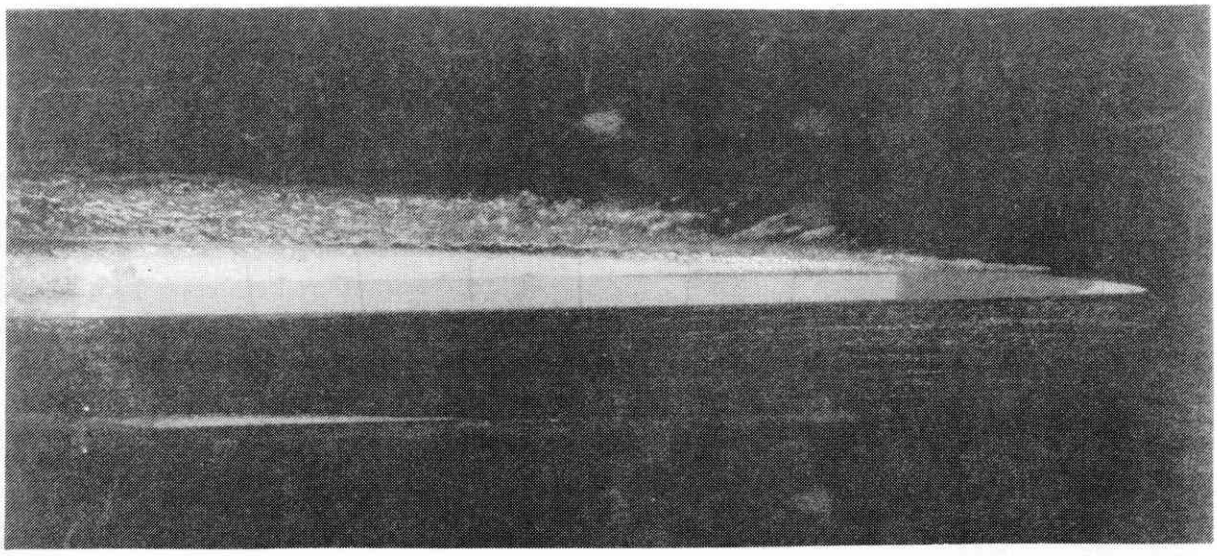


Figure 3. The frictional drag was calculated from the knowledge of the wetted surface.

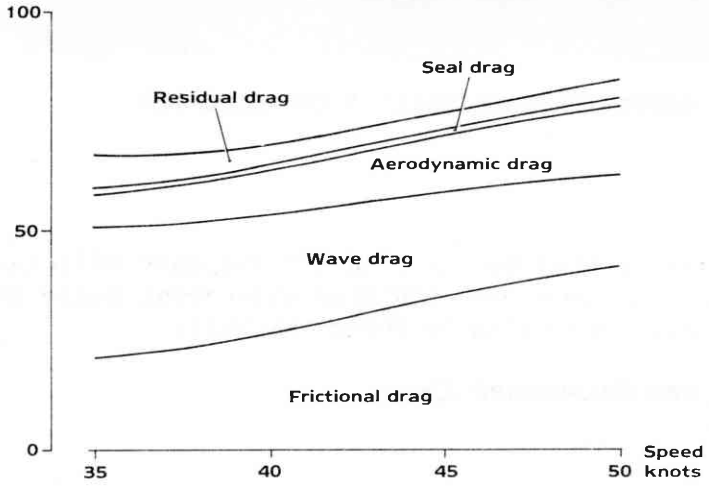


Figure 4. The total drag for SES JETRIDER in its components.

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

Another parameter carefully examined was how the cushion pressure influence on the performance of the craft. The model was towed at different speed, trim angle and cushion pressure.

The results was 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 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.

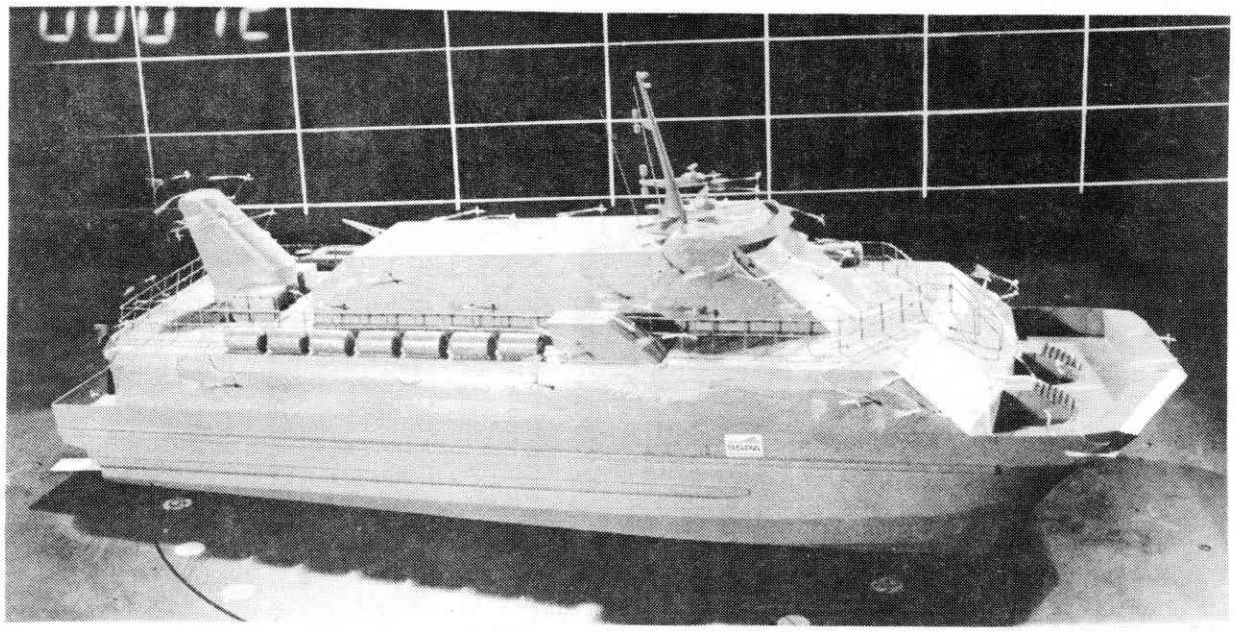


Figure 5. A model in scale 1:200 was built for wind tunnel tests.

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 of the vessel. After the tests 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 experience from this 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 system was studied for the vessel. In the final evaluation semicavitating controllable pitch propellers and waterjet propulsion were studied. Surface piercing propellers was excluded since no reliable system in appropriate power range was available on the market at the time for the project. 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 as an integrated part of the hull. Comparing building water inlets in steel or aluminium with

GRP-sandwich from cost point of view was much in favor for GRP-sandwich.

Another problem that was much more complicated than expected, was air leaking into the waterjet inlet. Air in the waterjet pump causes reduced thrust or at worst engine shout 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 resistance point of view.

Ride Control System

At an early stage of the project the Ride Control System was found to be of great importance necessary for the SES concept. 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 there own.

The design of the Ride Control System was very straight forward. 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 performances micro computer (figure 6).

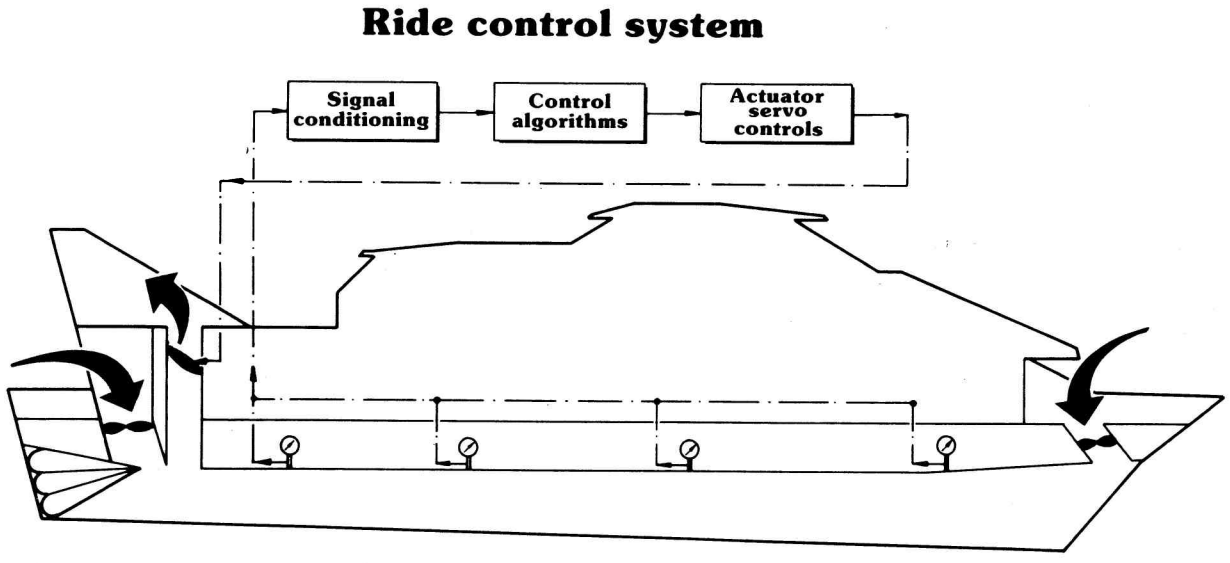


Figure 6. The SES JETRIDER Ride Control System.

The control law was designed together 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 gives heave motions caused by resonance in the air cushion the heave accelerations are reduced to about 10% of the level without RCS in operation (figure 7).

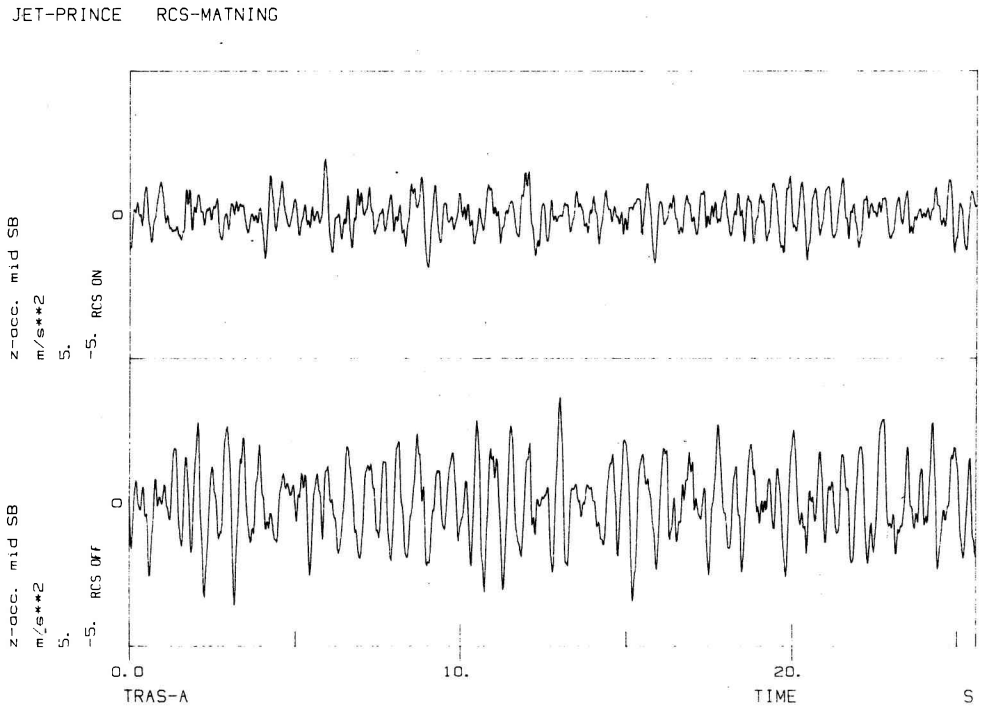


Figure 7. The Ride Control System reduce the heave motion to about 1/10 of the level without RCS at the natural heave frequency.

Lift fan drive system

At the contacts with potential customers a desire for a flexible passenger cabin without casings etc. were expressed. Therefore the vessel was designed

with liftfans only fore and aft. The next question the design office had to face was how to drive the liftfans.

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 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 forecastle as with the other system. The hydraulic transmission made it possible to arrange the lift fans flexible according to the desire mention above.It was also a desire to reduce the moment of inertia as much as possible from seakeeping point of view.

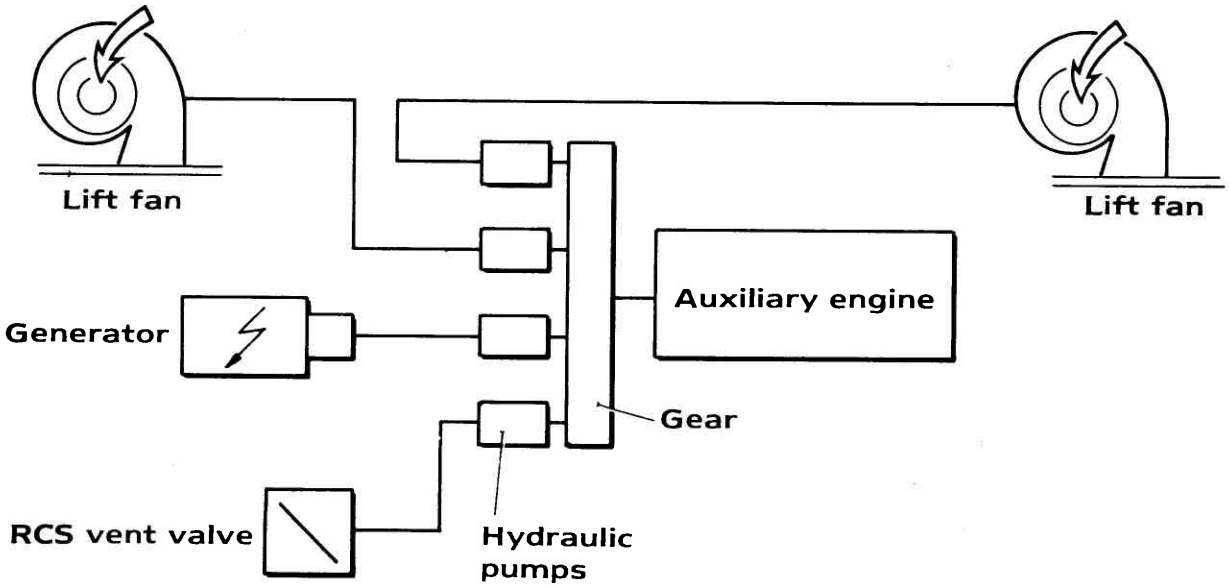


Figure 8. The lift fans, RCS and generator hydraulically driven by a diesel engine.

The disadvantages with the hydraulic transmission were the higher costs and a more complicated system.

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 and 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 executed in the UK where also the research program is carried out on which results the JETRIDER study was based (reference 3).

This study indicated that the SES JETRIDER has 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 behavior is expected to be very similar in the whole speed range 25-45 knots.

IN SERVICE EXPERIENCE.

The two vessels have been in service during the whole summer 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 due to 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 break down should occur the seal can be replaced over night and no departures have to be cancelled.

The service has also brought into light the importance of an effective Ride Control System on air cushion vehicles. The wave height in the operation 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 causing 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 service aboard the ferries.

FUTURE DEVELOPMENT

A research and development program is 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 studied.However the benefit of such a system has to be related to the cost and complexity of the system.

Further test of different propulsion systems including water jet 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 new suitable designs.

The life time of a bow finger seal is much to 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 bee as much as 10 percent.

SES 3900 PASSENGER FERRY

This summer the production of two new SES passenger ferries has started (figure 9). The two ferries will be operating between the cities of Gothenburg i 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 to complete three single crossings a day.

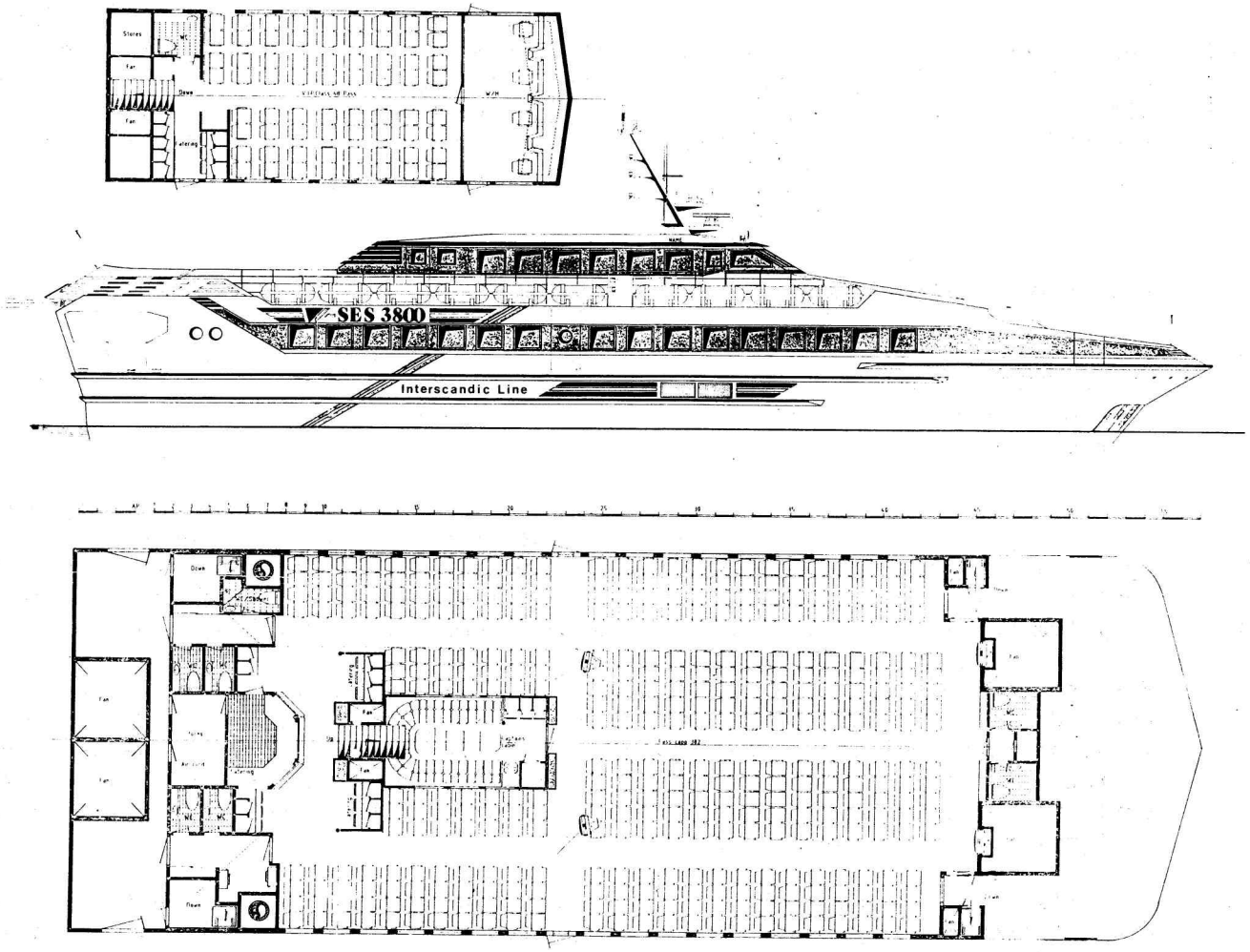


Figure 9. General Arrangement of the new SES 3900. The passenger capacity is 450 and the top speed is over 50 knots.

The technical data are:

Length over all	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	2x2640 KW
Lift fan engines	4x116 KW

Each main engine is connected to a Liaan Speed Z-drive controllable pitch propeller and 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.

REFERENCES

(1) Gullberg Ola "The development of SES JET RIDER", The sixth international high speed surface craft conference, London January 1988.

(2) Hellbratt Sven-Erik and Gullberg Ola", The high speed passenger ferry SES Jet Rider", Second international conference on marine applications of composite materials,F.I.T. Melbourne Florida USA, March 1988.

(3) Blyth A.G. "Recent Research into the Ultimate Stability of Surface Effect Ships", RINA International Conference on Ship Stability and Safety, London, June 1986.

Discussion on presentation by Ola Gullberg

Q. Will the new ship be built of composites?

A. No. The new one will be built in Aluminum. New IMO rules make it possible for countries that do not want new shipping companies to come in to prevent them from operating new craft. So its mostly because of the IMO rule that they will be built in Aluminum.

Aluminum has a tradition that is accepted. GPR-sandwich is not accepted by all countries. Scandanavia has a lot of passenger ferries built in GRP-sandwich.

Q. Is there to be a Naval version?

A I don't know exactly what you mean. We have a program for a paramilitary version of the JETRIDER. It is not in production.

Q Is the ride equivalent to that of a catamaran?

A In my experience a catamaran is very stiff. The SES is not that stiff at all, much more like a monohull. My opinion is that it is difficult to have an absolute figure which describes whether the motio good or bad.

Q How does it compare to a catamaran at high speed?

A We must compare at the same speed. Its hard to find a catamaran at 40 knots to compare with.

Q Will the ships operate only in summer?

A They are going to operate year round. There might be difficulties due to icing in cold winters in February.

Q Do you recommend hydraulic transmissions for fans?

A For 258 passenger ferry there is a technical reason for that solution. But for bigger ones and for bigger fans it is a problem. It is hard to find hydraulic transmissions that can cope.

Q Can you comment on the propulsion system?

A Waterjet is not without problems nor are semicavitating propellers. From my point of view, we need a lot of R&D to find a suitable propulsion system for SES's for speeds over 40 knots. We look mainly to semicavitating propellers, although we might look at some surface piercing propellers as well.