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New generation semi-submersible crane vessel

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SYNOPSIS

Offshore platform operators have been trying to reduce the cost of constructing their offshore platforms in harsh environments for a number of years. The recent drop in oil prices has latterly made this requirement even more necessary. Existing semi-submersible crane vessels (S.S.C.V.s) have already shown that a number of savings can be made by employing larger-capacity cranes. The new generation of S.S.C.V.s now gives the possibility of even greater economies. The Micoperi 7000 is now the largest capacity crane vessel available. The design and construction of such a large vessel has been an achievement within itself and its operating capabilities have already influenced the arrangement of a number of platform concepts. This paper describes the Micoperi 7000 project and discusses the operational advantages the vessel brings to the various offshore tasks for which it is intended, including dynamic positioning operations, lifted jacket structures, integrated deck installation, and other associated work.

DESIGN AND CONSTRUCTION OF THE S.S.C.V. MICOPERI 7000

John Mitchell joined the Structural Engineering Department of Foster Wheeler in 1964 and was involved with the design of petrochemical plants and marine terminals. He was also involved in the management and design of topside facilities for North Sea platforms with other design contractors prior to joining Heerema Engineering in London where, as Engineering Director, he was responsible for all aspects of offshore installation involving crane vessels and other marine craft. He is currently General Manager of Micoperi in London, responsible for all North Sea activities including S.S.C.V.-related areas.

Introduction

The floating crane vessel has become the basic installation tool for offshore platform construction. This paper describes the marine activities undertaken by such vessels, and the impact of the latest generation of S.S.C.V.s of which the Micoperi 7000 is the largest. The vessel has twin cranes, each of 7000 t capacity, and a displacement in excess of 170,000 t. The design and building of such a vessel in conventional yards required innovative construction techniques, and this is the first area addressed in the paper.

Shipyard background and details

Fincantieri (Cantieri Navali Italiani S.p.A.) is a shipbuilding organization based in the Mediterranean.

For the vessel's construction, we selected the Monfalcone Shipyard and, although one of the largest in Europe, it was still necessary to build the vessel in two halves, laid simultaneously in the dry dock, bow-to-bow. The two halves were completely outfitted where possible prior to float-out and mating.

The layout of the Monfalcone Shipyard is given in Fig. 1. The yard's activities are based on two separate production lines, one serving the major dry dock where the largest units (mainly merchant) are built, the other serving the slipways which have, for the last few years, been devoted to naval ships. The production lines were completely renovated a few years ago and incorporate the latest computer controlled systems for the cutting, handling and assembling of structural components.

Method of construction

For the construction of the 7000, Fincantieri produced a detailed production engineering study before being awarded the order. During this stage, all aspects of the organization, quality and programme details of the proposal were investigated. The construction method was based on the assumption that, as far as possible, all work packages would be completed in the workshops, including equipment installation, instrumentation, painting, etc., in order to reduce to a minimum assembly work in the dry dock and when afloat.

The hull construction consisted of 1316 elementary structural blocks which were subsequently assembled into 552 'large ship sections'. During the pre-assembly, 226 of those sections, weighing up to 300 t each, were individually installed in the dock, whilst the remaining 326 were coupled together to make up 77 larger sections, weighing approximately 600 t each, for installation in the dock as complete units. The method of hull construction is shown in Fig. 2.

Construction programme

Development of the basic design of the vessel started in the last quarter of 1983 in co-operation with Gusto Engineering of Holland. Several semi-submersible configurations were developed during the preliminary design phases, until eventually the final shape was decided upon.

Whilst there are few fundamental differences from other vessels of this type, the 7000 is unique insomuch as it has both cranes on the bow, and the shape of columns is directly related to the requirements of heavy lifting operations. Following the completion of an extensive model test programme performed

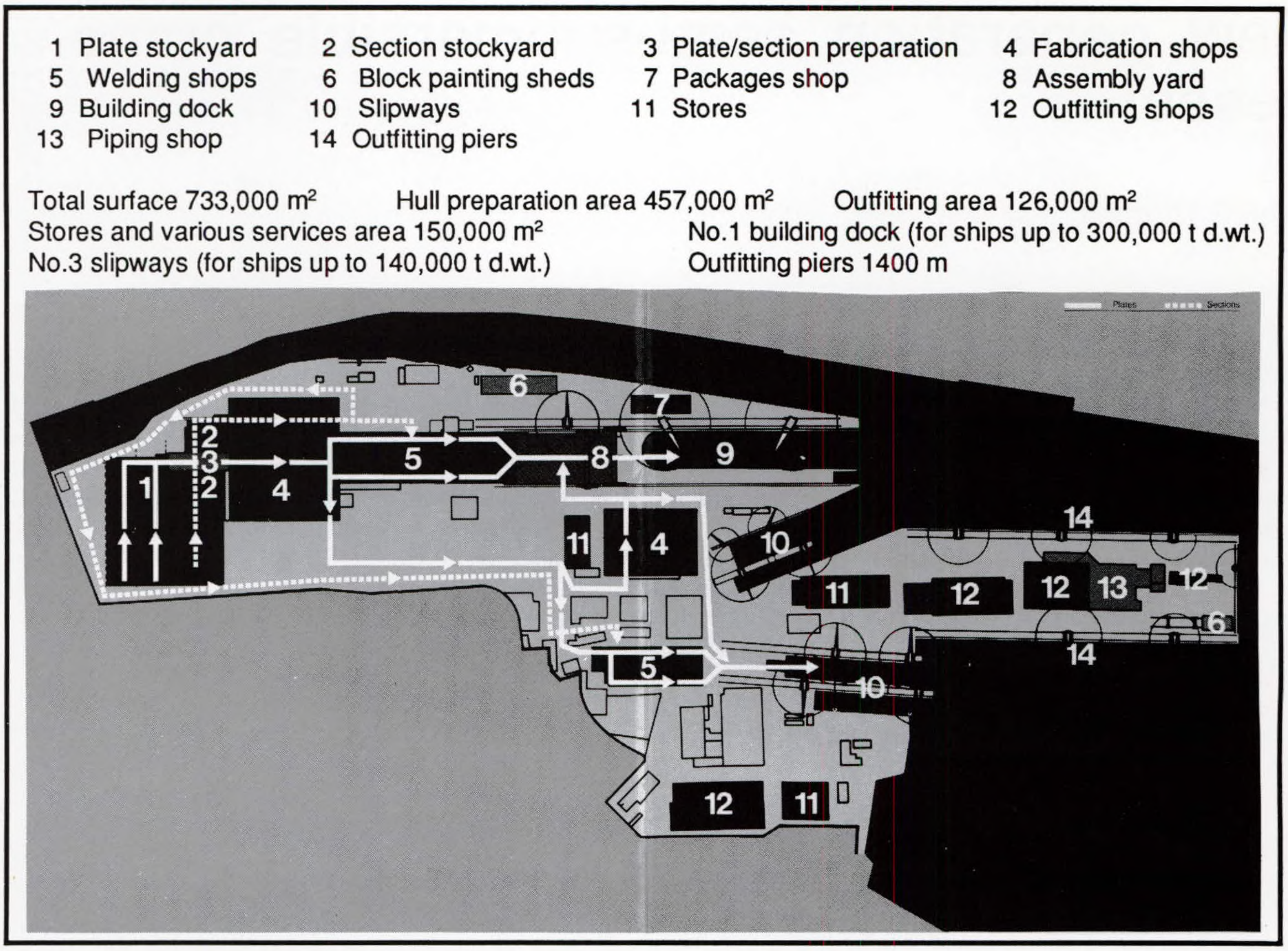


Fig. 1. Monfalcone Shipyard

by N.S.M.B. (Wageningen), the basic design was finalized in the summer of 1984. The detailed design was then developed by Fincantieri on the basis of the original design prepared by Gusto/Micoperi.

The building contract was signed in June 1985, with keel laying and the launching of the two halves scheduled for January 1986 and 1987 respectively. The overall project schedule is shown in Fig. 3.

Design aspects

There are three basic design situations for a semi-submersible vessel:

operating condition,
transit condition,
survival condition.

Each of these has been analysed in order to evaluate those elements which influence the vessel's overall operability and reliability.

In the operating condition, the key elements were:

(a) the vessel's motion in heavy seas, from which we derived acceleration values in important areas such as the crane boom tip, etc.;
(b) the vessel's motion relative to waves to confirm the absence of slamming phenomena;
(c) the ability to keep station and heading in heavy seas;
(d) the loads and subsequent stresses induced by waves and motion on the vessel's structure.

In the transit condition, it is necessary to establish the propulsion plant performance. In the survival condition, the elements to be established are similar to those relevant to the operating situation, but are especially aimed at ascertaining that, under extreme environmental conditions, the structure and machinery will not be damaged and the vessel has the ability to keep station using the mooring system (aided by azimuthal thrusters if necessary).

Calculations were supported by experimental tests on scale models to check the theoretical results and to acquire design data that could not be determined theoretically with sufficient reliability. Model tests were carried out with regular waves coming from four different directions in order to obtain a range of response–amplitude operators which are indispensable for predicting the vessel's behaviour in any sea state. The heights of the simulated waves were of the same order of magnitude as those expected during normal operating conditions, and further tests under extreme sea conditions were carried out to establish the vessel's response in the survival mode.

The tests confirmed the very low roll and pitch motions characteristic of semi-submersible vessels. With complete pontoon submersion, and the water plane area limited to the columns only, the vessel is particularly 'transparent' to waves, with a resulting high operability, even in seas where a conventional crane ship would be unable to work.

The 7000 has been designed to perform all types of offshore work, from the installation of subsea templates to the installation of jackets and modules, as well as hook-up and decommissioning of platforms.

The vessel, which flies the Italian flag, was built to the requirements of the Registro Italiano Navale (RINA) and

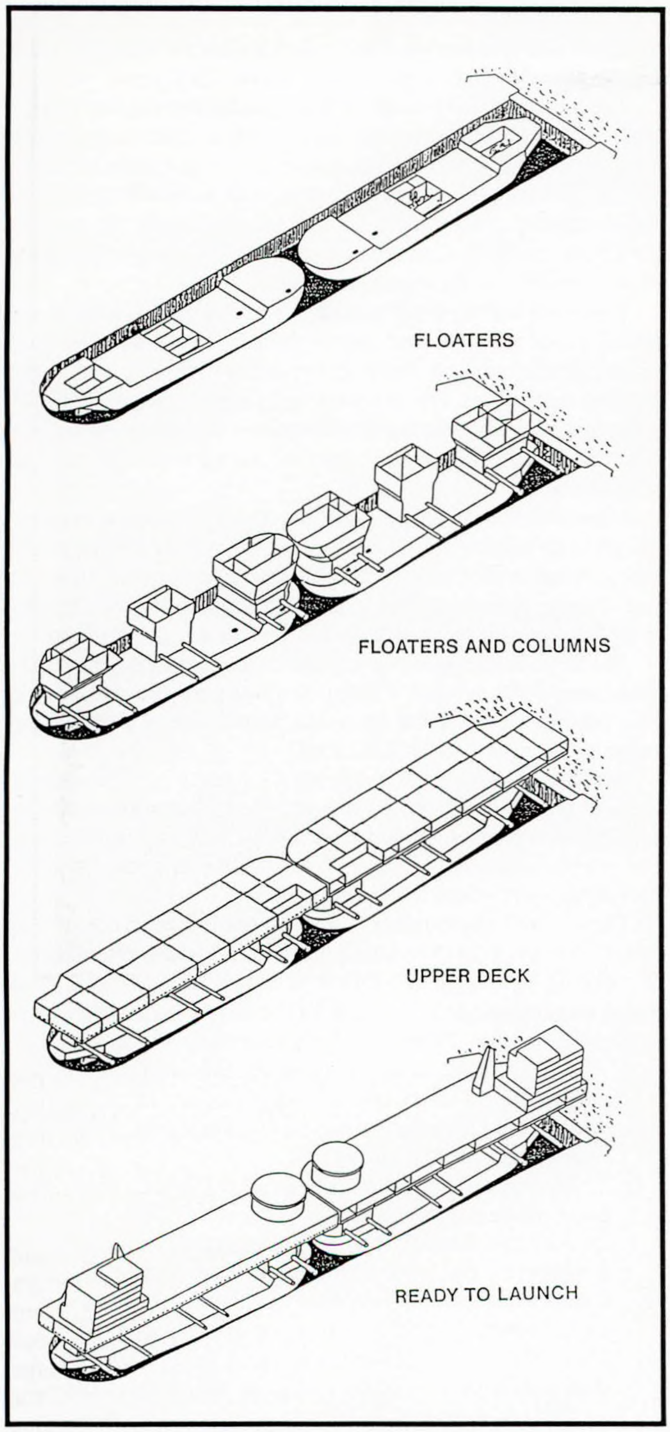


Fig. 2. Method of hull construction

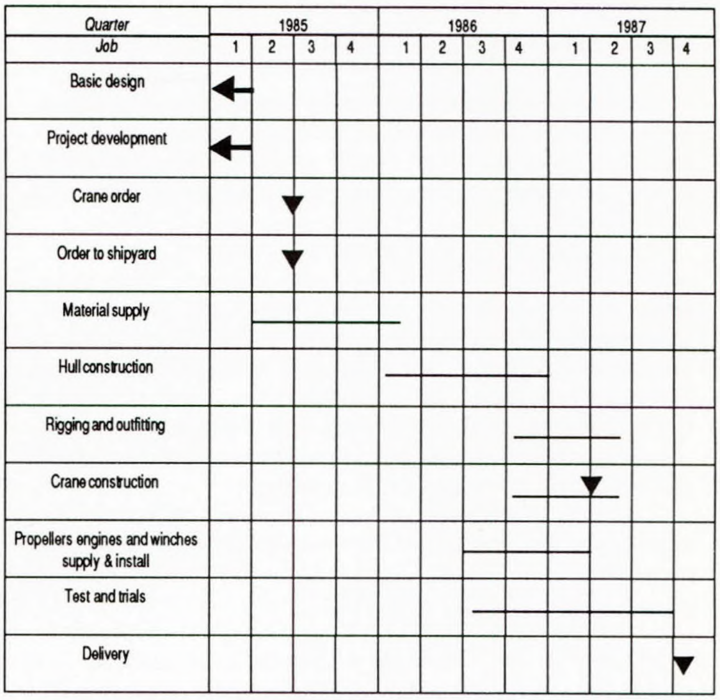


Fig. 3. S.S.C.V. Micoperi 7000 construction schedule

Lloyd's Register and has been designed to operate worldwide which includes areas with an external temperature ranging from –20 to +45°C, and a sea temperature ranging from –5 to +35°C.

The vessel has two floaters, six columns and an upper deck structure with an accommodation superstructure on the stern. Its overall length is 190 m, with a width of 87 m and a depth of 43.5 m. It has a normal operating draft range of between 20 m and 27.5 m, a transit draft of 10.5 m and a maximum displacement of 172,000 t.

Two American Hoist revolving cranes are located on the bow. The crane centres are 55 m apart, and the crane boom heel pins are 26.2 m above the main deck.

The vessel has fully air-conditioned accommodation for 800 people, mainly in one- and two-bed cabins.

Above the accommodation unit is a helideck large enough for two Boeing BV 234 LR Chinook helicopters, one landing and one parked.

The propulsion and dynamic position-keeping system consists of eight azimuthing thrusters and two tunnel thrusters, with a total installed power of 35,000 kW (47,000 h.p.), sufficient to keep the vessel on station in up to force 8 conditions. To propel the vessel at 9.5 knots transit speed, only 30% of the above-mentioned power is necessary. All ten thrusters are controlled by the dynamic positioning (D.P.) system supplied by Kongsberg.

Using various types of pre-installed reference systems (Simrad HPR, taut wires and Artemis), the D.P. system is able to keep the vessel in a pre-arranged position. Environmental forces such as waves, sea current and wind, etc., will be countered by thruster power with a calculated intensity and direction, thus maintaining the vessel in its original position.

The mooring system of the vessel consists of 16 no. 40 M.T. anchors, each equipped with 3350 m of 96 mm diameter wire rope, plus 50 m of 92 mm diameter chain. The 16 winches, supplied by Pusnes, have a single drum and two electric motors of 900 h.p. each. They are equipped with all the necessary features for safe operation in accordance with the most stringent regulations.

For control of the winches, the vessel is equipped with a position mooring system, also supplied by Kongsberg, which is able to continuously monitor all the 16 mooring lines. In the case of over-tension of one or more lines, the computer is able to propose a new anchor line configuration or, on operator request, to start thrusters in order to reduce the over-tension. The system calculates continuously the resulting ship trajectory in the event of breakage of any of the mooring lines and sounds an alarm if the vessel moves out of a pre-set safety zone.

Another feature of this system is the possibility to simulate any anchor pattern and, by inputting changes in environmental conditions, to see the effect on mooring lines and try alternative corrective action in order to avoid any serious consequences.

The 9000 m^2 deck area is able to transport 15,000 t of cargo and the majority of the deck plating has a loading capacity of 20 t/m^2.

The vessel's ballast system takes care of ballasting adjustments during crane rotation, as well as ballasting and deballasting in order to change operating draft. Water transfer is achieved by means of four water pumps, each with a capacity of 6000 m^3/h.

All operations can be controlled by means of a computer, which, by monitoring continuously the amount of water in the tanks, the vessel draft and the deck weight, can, for example, calculate the amount and location of ballast to be loaded or discharged in order to change to a pre-selected draft. During ballasting operations, the position of the centre of gravity (C.o.G.) and the stability of the vessel are calculated, and, in the case of a critical situation, the computer can stop the operation and put the ship in a safe 'hold' condition.

The twin bow-mounted American Hoist cranes are the largest ever built and each of them has the following nett lifting capacities.

Main hook	7000 t @ 40 m radius fully revolving
	7000 t @ 41.5 m radius in tie-down
	2 x 7000 t @ 41.5 m radius in tandem lift
1st Auxiliary hook	2500 t @ 75 m radius
2nd Auxiliary hook	900 t @ 115 m radius
Whip hook	120 t @ 150 m radius

The nett lifting capacities include all crane tackle, and allow for loadings due to wind, impact and other dynamic forces (Fig. 4). The two cranes were built in Italy by Officine Meccaniche Reggiane under American Hoist supervision and have been tested to meet the requirements of RINA and Lloyd's Register for Cargo Gear Certification.

The tie-down equipment is a 40-part block, which can be connected between the rear of the crane and a pad-eye on the deck of the vessel. The pull on the line is achieved by a pre-installed self-tensioning winch, and a slew of 4 deg. in each direction under load is possible.

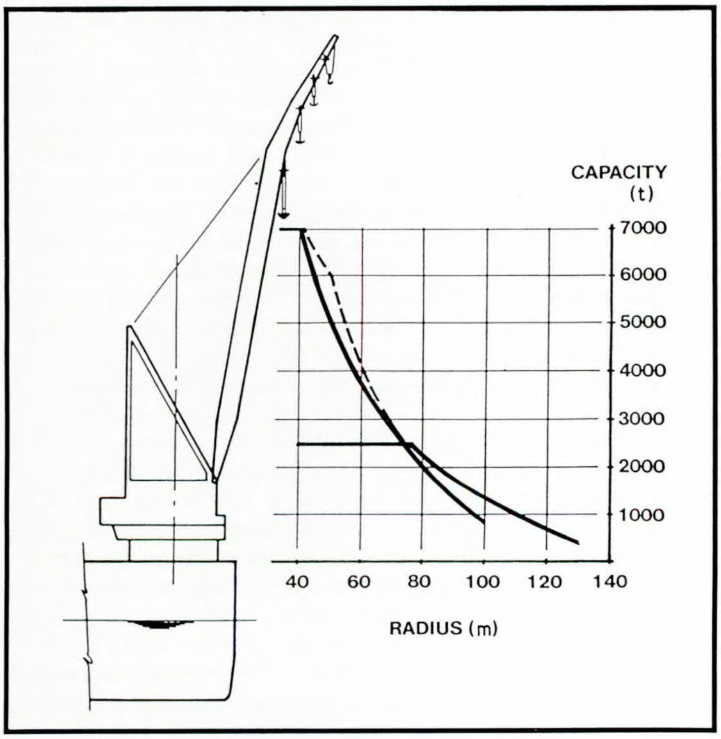


Fig. 4. Crane capacity curves

The first auxiliary hook is very useful for medium-sized loads, whereas the second auxiliary hook is fitted with enough cable to enable it to be used under water at depths of up to 450 m. This hoist is normally reeved with a travelling block of 900 t capacity. Alternative blocks are also available, and all have been specially designed for underwater operations and for Menck Hydraulic Hammer handling.

The crane booms are 140 m long from heel pin to whip block which gives a height and outreach unmatched by any other vessel. Both cranes are fully equipped for hydraulic and steam hammer operations. For this purpose, supports for power packs and umbilical winches are provided, and hydraulic and steam pipes are installed along the boom for above-water pile driving operations.

Main electric generators are driven by low-speed engines designed to burn IFO 380 heavy fuel oil, which gives significant savings in the daily running costs of the vessel. Sufficient fuel storage is provided to allow continuous offshore operations for a period of more than 60 days without refuelling.

The fresh-water generation plant is designed to produce approximately 500 m^3/day, which makes the ship autonomous for long periods of time, and gives the possibility of transferring water to other barges or platforms.

In order to reduce costs, the above fresh-water generators can use, as fuel, the steam produced by gas boiler exhaust or the heat of the engines' cooling water. In case of low power output, two reverse-osmosis generators are available, with a production capacity of about 160 t/day.

The vessel is also equipped with a modular saturation diving system for up to 14 divers and includes a hyperbaric lifeboat. The diving system is rated for 450 m water depth, and three locations are provided on board for the diving package in order to allow maximum flexibility for underwater work.

All the above equipment and all other ship's auxiliaries are driven by electric motors, and therefore electric power production, transformation and distribution is of vital importance for this vessel.

In terms of generated power, the 10 A.C. generating sets installed on board can deliver over 50 MW of power. In order to guarantee maximum continuity of power to the consumers, the generators are placed in five different rooms separated by fireproof bulkheads. Also, the main switchboard is split into four similarly protected areas. This solution significantly reduces the possibility of a total blackout in the case of fire in one or more areas.

Electrical power is widely adopted for the control systems of the large D.C. motors, and micro-electronics are extensively used, not only for the computers which process data relevant to ballasting and D.P. mooring, but also for the automation of electrical power and generation. This micro-electronic technology, adopting programmable logic circuit systems has also substituted the traditional electro-mechanical logic starters in the motor control centre.

For support of construction work, the vessel has a large inventory of tools, equipment and workshops, together with a large welding plant made up of more than 50 static welding machines.

The major installation equipment includes a range of the latest Menck hydraulic and steam-driven pile driving hammers, including two of the latest and most powerful MHU 3000 models for driving piles of up to 102 inch diameter. The hydraulic hammers are fully equipped to allow 'free-riding' or 'slimline' modes of use both above and below water.

For efficient pile handling, the vessel is equipped with a range of internal and external hydraulically operated handling tools with rated capacities of up to 1000 t, the use of which avoids any requirement for external pad-eyes or internal lifting rings in the piles.

Dynamic ballast system

The vessel is equipped with two ballast systems. The first, which can be called 'conventional', may be operated manually or via the computer and uses the four ballast pumps.

The second, which can be called 'dynamic', is operated normally by the computer, which calculates the necessary amount of water and selects the tanks to be filled by free flooding through 2 m diameter valves that are open to the sea.

This dynamic ballast system counteracts the mean trim and heel movements imposed on the vessel during lifting and setting of loads with the cranes.

By flooding tanks in the corner opposite the crane while operating the system, when activated, this enables the load to be freed from the transportation barge in a relatively short time, thereby reducing the risk of impact damage. This effectively extends the allowable weather limits for lifting from cargo barges offshore.

The same results are achieved during the setting down of loads by free flooding the tanks that are under the crane. In practice, this system doubles the speed of the hook during lifting and lowering operations.

Before carrying out any lifting operation, the following simulations can be executed by means of computers. The first is relative to the crane slew and ballasting operation, and can highlight or verify any critical aspect of a particular lifting situation. The second is used to simulate the lifting operation of a load from a cargo barge. Taking into consideration the relative crane hook motion, the lifted load and the anticipated cargo barge motion, we can establish the maximum parameters for the sea conditions to be considered for such a lift, thus minimizing the risk of damage due to impact of the barge with the lifted load.

We consider the possibility of simulating and establishing, in advance, the necessary sea conditions for carrying out a safe operation to be a very important feature. With the vessel on location, the actual sea conditions can be fed into the computer and the operation simulated just prior to execution.

OPERATIONAL ADVANTAGES OF THE S.S.C.V. MICOPERI 7000

Introduction

As offshore lifting capacity has increased over the years, platform designers have been able to further maximize their designs to produce more economic developments. The 7000 doubles the maximum lifting capability previously available until a few years ago.

This section reviews the development of offshore construction vessels and highlights some of the operational advantages that this larger lift capacity and more sophisticated vessel design brings to offshore platform construction. As well as improvements in steel-piled jacket and modular topside installations, other associated areas of work, including future platform removal, is reviewed.

Installation vessel development

When the search for hydrocarbon resources first moved offshore, the floating construction equipment necessary for installation consisted mainly of flat-bottomed barges with relatively small cranes. This was all that was required for the initial development areas of the U.S. Gulf and similar mild environments. When more hostile areas, such as the southern and central areas of the North Sea, were developed, larger crane capacity ship-shaped vessels proved far more capable, and quickly emerged as the minimum requirement for working at such locations. Crane vessel lift capacity soon increased from less than 800 t to over 2000 t as it became obvious that the bigger vessels with greater module lift-weight capacity and longer pile-handling capability were the most cost-effective methods of installation.

However, when very hostile waters such as the northern part of the North Sea were encountered, with complex platform arrangements, increasing size (and consequently weights), even with the use of the more sophisticated monohull crane vessels, it was found that it took a whole season to complete a single platform installation (Fig. 5). Associated with this was the large amount of hook-up between the numerous topside modules, these two factors considerably delaying the platforms production start-up. Operators could not afford these project delays, and the industry started looking for ways of reducing installation times, extending workable weather windows and reducing hook-up time.

The semi-submersible has long been known as one of the most stable platforms from which to operate in hostile environments, but until the mid 1970s, this form was only used for drilling rigs or hook-up support vessels, with relatively light immobile deck loads. Now, with the aid of dynamic ballasting systems, large eccentric loads are able to be handled by semi-submersibles, and hence they are ideal for heavy lifting operations in harsh environments.

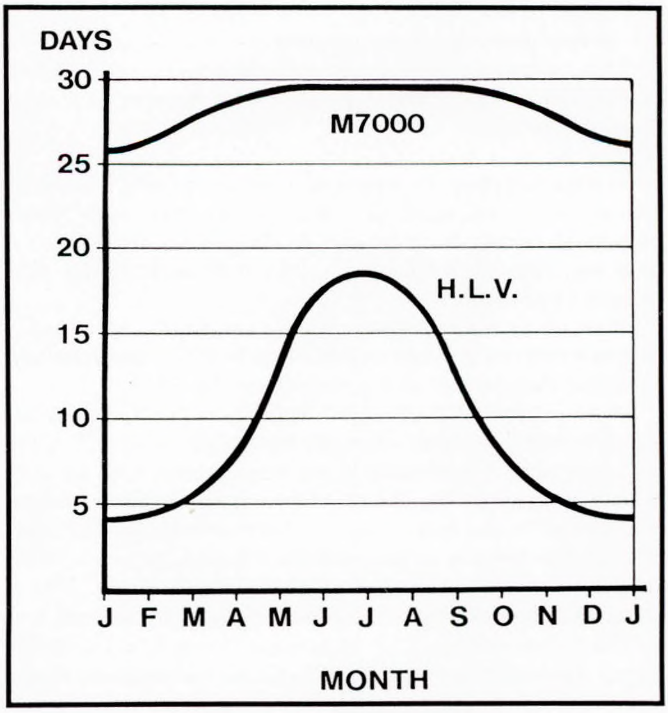


Fig. 5. Comparative vessel workability (northern North Sea)

Individual offshore crane capacities have increased 10-fold in the last 15 years, with total vessel lifting capacities growing from 700 t on monohull ships to 14,000 t on S.S.C.V.s in the same period (Fig. 6). This provided operators with what they desired, and both jacket and module sizes have grown. Individual topside packages weighing in excess of 5000 t have already been installed, and lifted jackets of up to 10,000 t are planned to be installed next year.

In addition to just larger crane capacity, other features are also required of the latest generation of S.S.C.V.s. These include dynamic positioning for operations in congested pipeline areas and deep water, large decks with high loading capacity for transport of modules during winter installations, ability to operate larger hammers for more efficient piling, and higher standards of accommodation for offshore personnel. All these features are being incorporated into the latest generation of S.S.C.V.s now entering service.

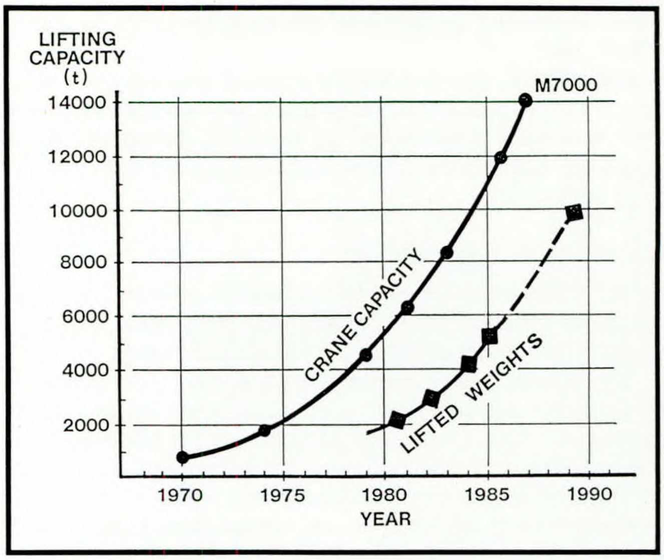


Fig. 6. Crane capacity trend

Operational advantages

The 7000 has a number of technical advantages over conventional derrick ships and small S.S.C.V.s. These are as follows:

larger size and displacement with better motion characteristics,
larger operational draught range without loss of shallow water operability,
greater deck area and loading capacity,
higher transit speed,
fast ballasting systems,
greater lifting capacity (Fig. 7),
greater crane lifting height and reach,
deeper underwater auxiliary block capability,
fully redundant D.P. system,
greater mooring system capacity and depth,
integrated mooring and D.P. system,
larger crew accommodation with higher specification,
larger helideck for dual Chinook operations,
larger power plant,
deeper dedicated diving system.

These technical advantages will, of course, give greater operational advantages over the other vessels, especially in the following areas.

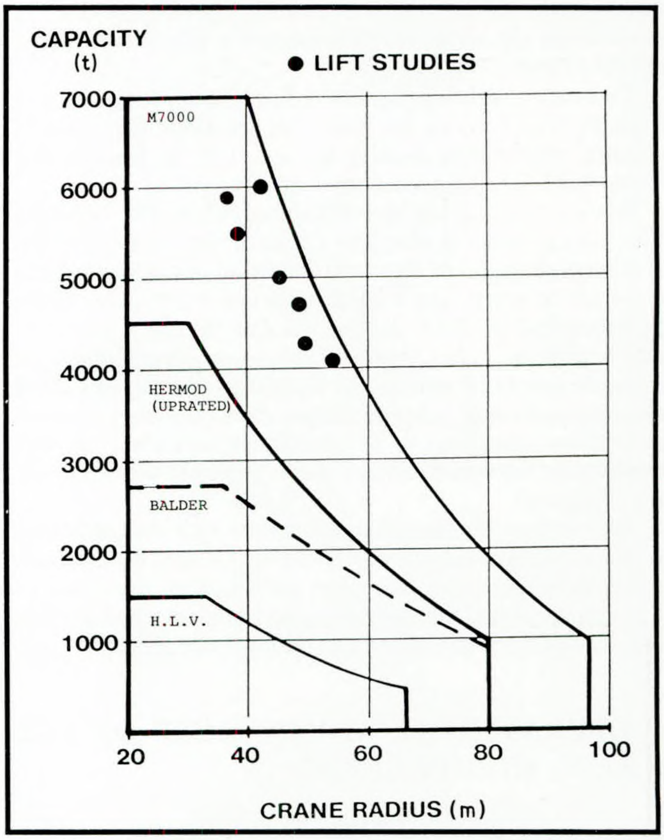


Fig. 7. Crane capacity comparison

Station keeping. By virtue of its mass and efficient semi-submersible configuration, the vessel has very good motion–response characteristics, leading to less weather down time and reduced added mass effects when lowering submerged structures.

With 16 anchor wires of over 3 km in length, the vessel is able to moor out in water depths of up to 450 m and maintain station in the harshest of environments (Fig. 8).

In very deep water, or at platform sites with very congested pipeline configurations, where anchor moorings are difficult to lay, the vessel can accurately maintain station with its D.P. system referenced by either seabed transponders, satellite positioning or taut-wire systems. Alternatively, the D.P. system can complement a reduced anchor spread, the two systems working together using an integrated control system. This is ideal for short duration jobs on existing field complexes.

The software in the D.P. system can be modified to incorporate the direct mooring of another vessel or structure alongside the S.S.C.V. This is ideal, for example, for T.L.P. tether installations when very precise positioning is required in very deep water.

Jacket and pile installation. In the past, jackets with operating weights in excess of 2000 t have had to be launched from special launch barges. This entails building launch runners on the jacket and providing it with additional buoyancy in the form of tanks or tubes for both the launch and up-ending operations. With twin matched cranes of high capacity at a large outreach, jackets of 10,000 t operating weight can now be lifted, saving considerably on the expensive fabrication of launch runners and buoyancy tubes (Fig. 9).

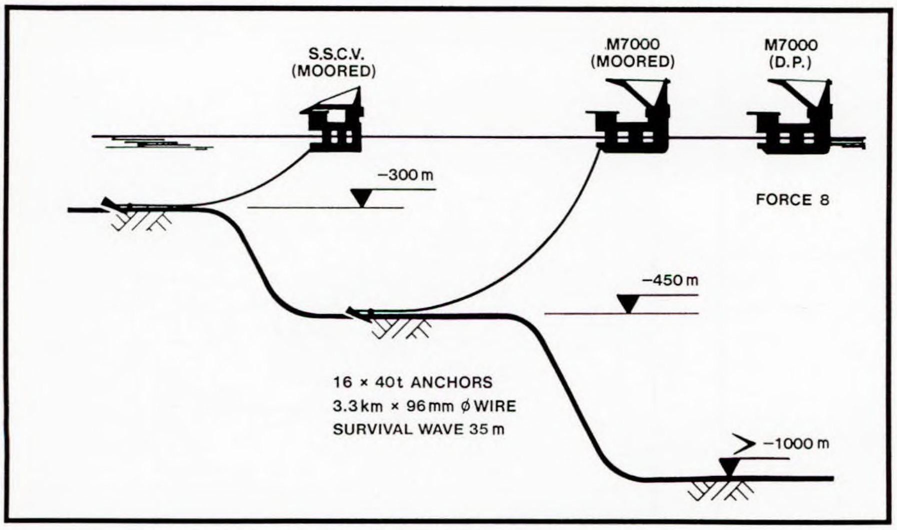


Fig. 8. Station keeping

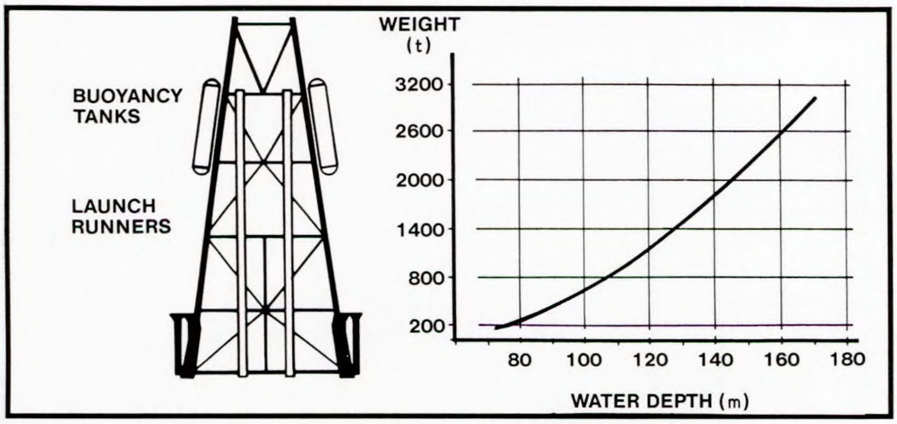


Fig. 9. Weight saving on lifted jackets

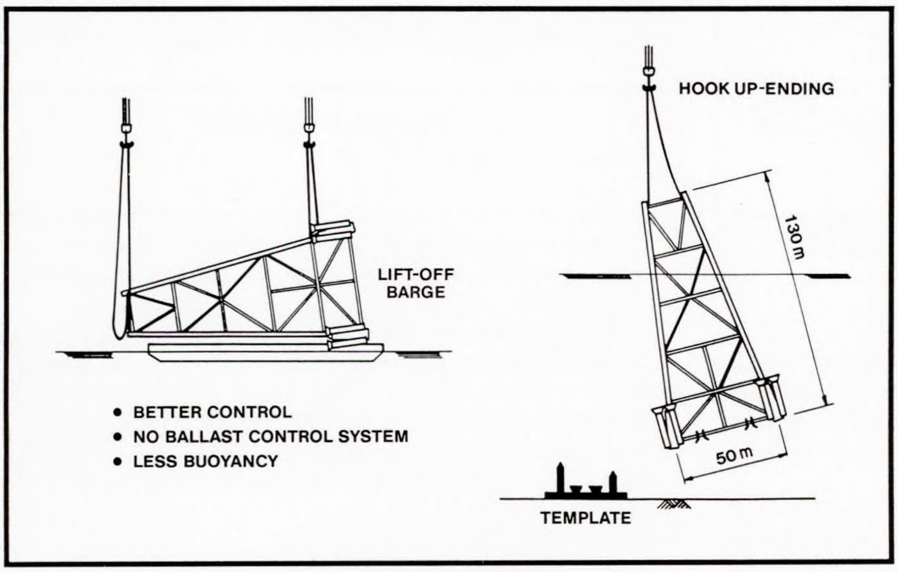


Fig. 10. Hook-assisted up-ending

The larger hook capacities also allow for greater hook load to be applied to jackets during up-ending, thus reducing the need for complicated up-ending control and ballasting systems, as well as the up-ending buoyancy previously mentioned (Fig. 10).

The underwater auxiliary block enables longer and larger piles and underwater hammers to be quickly lifted and lowered in a single operation, making more efficient use of pile foundations and savings in jacket pile guides and bottle legs. This is extremely effective when vertical pile sleeves are used, completely eliminating the need for pile guides.

Equipped with the latest range of Menck underwater hammers, including the MHU 3000, the spread is capable of driving larger-diameter piles to deeper penetrations, with consequent savings in pile cluster fabrication and pile installation time.

Subsea installations. The underwater blocks allow templates to be lowered onto the seabed in a single operation, without any sling change-overs or hang-off requirements.

The twin underwater blocks also allow for dual lowering operations to be carried out, giving better control and positioning possibilities.

The high block elevations achieved through the long boom length allow for a greater length of initial slings, enabling templates to be lowered to over 500 m under the water (Fig. 11).

Topsides installations. The much greater lift capacity of the 7000 allows for larger deck and module lifts with consequent reduction in hook-up and structural steel-to-equipment ratios (Fig. 12).

The large, revolving, capacity cranes allow modules of up to 7000 t to be transported on the deck of the S.S.C.V., as opposed to cargo barges, which enable modules to be installed all year round, thus extending the operational weather window tremendously.

The twin matched cranes allow greater possibilities for C.o.G. position for dual crane lifts and are less sensitive to C.o.G. movement than vessels with cranes of unequal capacity (Fig. 13).

Greater lift height allows steeper sling angles to be used and more efficient use of rigging. This also transmits less horizontal loads into module roofs, and gives further structural steel savings (Fig. 14).

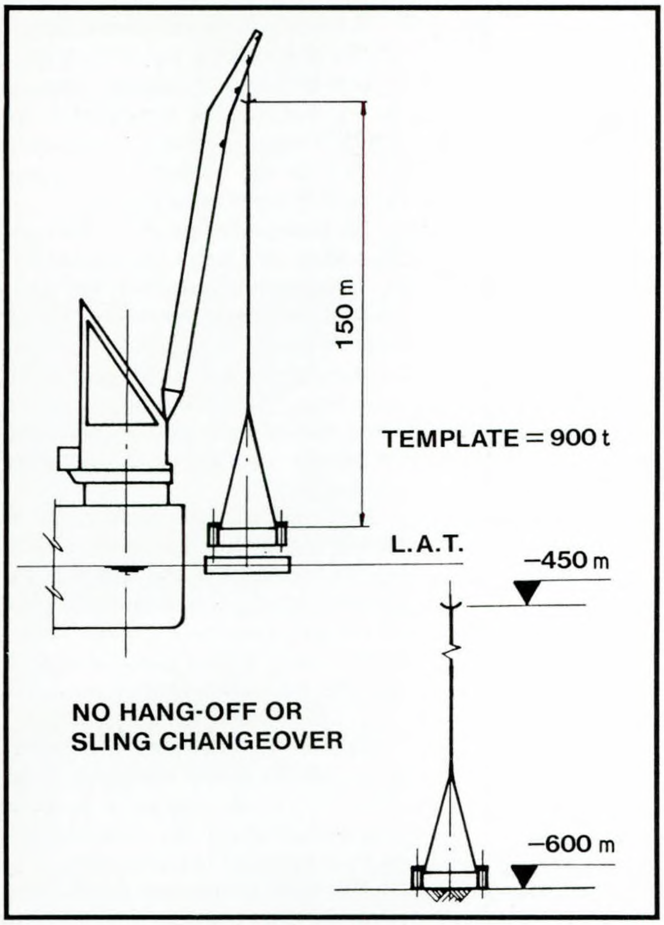


Fig. 11. Template installation

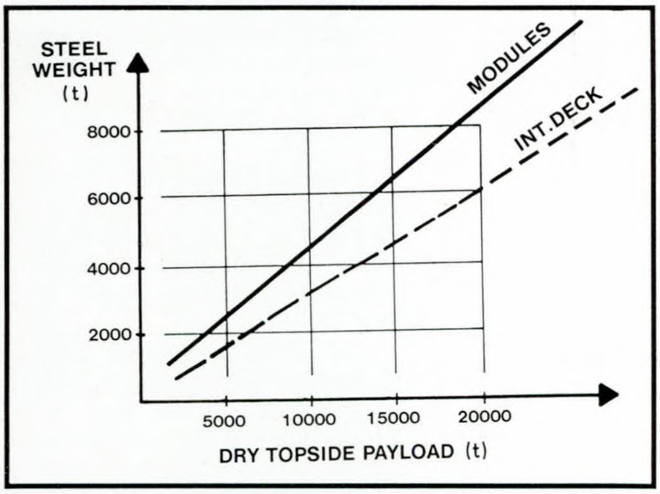


Fig. 12. Structural weight-saving trend

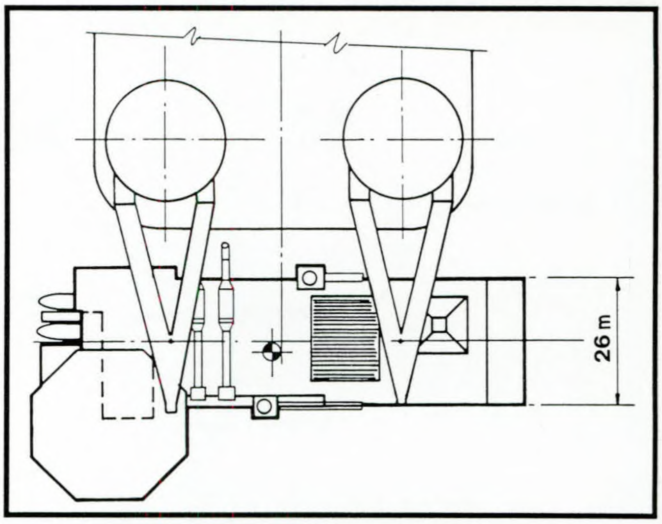


Fig. 13. Integrated deck installation

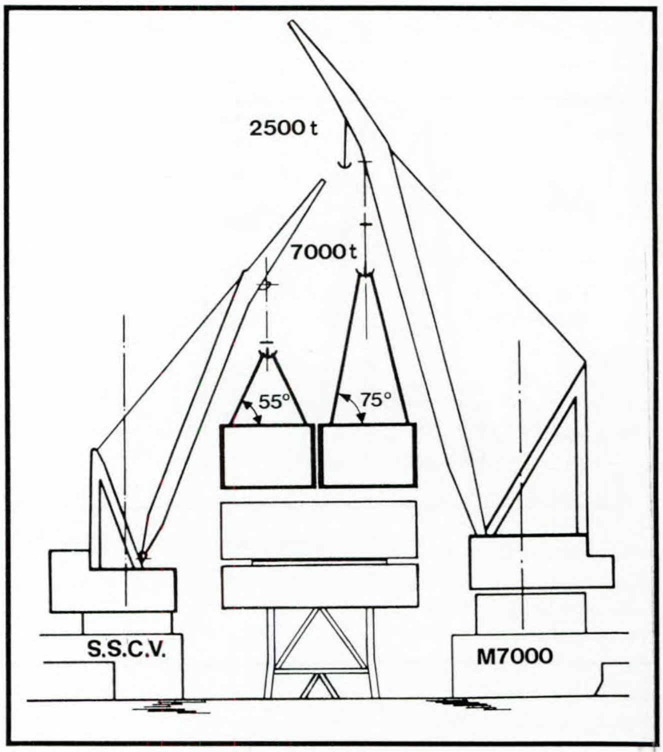


Fig. 14. Lifting height

The long reach allows most modules to be placed from one side of the platform, saving time-consuming vessel movements or re-anchoring, and also removes the need for any form of module skidding, as all modules can be directly placed (Fig. 15).

The dynamic ballasting system enables modules to be quickly lifted from a cargo barge and set down on the substructure without the need for excessive block travel. The ballast system also enables large heavy modules to be lifted and rotated with very little vessel heel or trim.

The 2500 t 1st auxiliary block has a fast hoisting speed, good lift height and reach, and is ideal for the large range of medium lifts, normally associated with a major platform installation.

Deck transportation. The vast deck area and high loading capacity allow for a larger number of modules to be transported during winter installation and a reduction in the number of trips to be made to complete a platform topside. The high uniform deck loading capacity means that modules can be placed on the deck using the same grillage from the cargo barge transport and negates the need for any special module support or skidding grillage (Fig. 16).

The transit speed of 9.5 knots means transportation and mobilization can be effected in a shorter time. This is extremely important when working in a worldwide market.

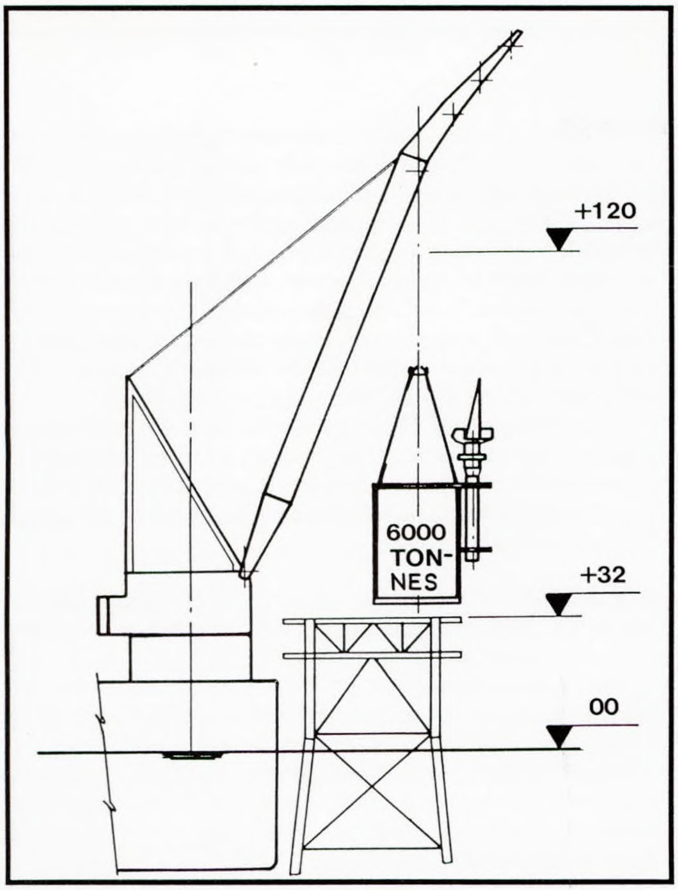
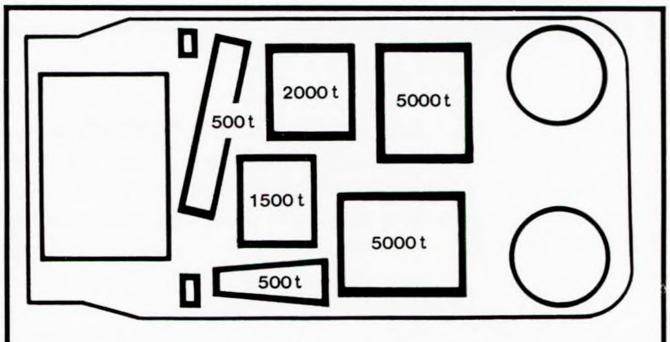


Fig. 15. Module installation



DECK AREA	9000 m^2	TRANSIT SPEED 9.5 kn
LOADING CAPACITY	20 t/ m^2	NO SPECIAL GRILLAGES
DECK LOAD	15000 t	WINTER INSTALLATION POSS.

Fig. 16. Module transportation

Associated works.

Hook-up accommodation

The 800 man accommodation and the good station keeping mean winter hook-ups can be performed more efficiently. The accommodation is also ideal for providing hook-up support to 'minimum life-support' status directly after topside installation, allowing for integration of both the hook-up and vessel construction crews. The accommodation layout enables clients to have adequate dedicated areas for their personnel and also less disturbance of crews by providing possibilities for segregation of conflicting shifts or trades.

Platform removal

The higher lift capacity of the underwater blocks enables larger pieces of jacket structure to be removed, with enormous reductions in the amount of underwater cutting and vessel support time.

Due to greater crane lift capacity and reach, removal of weight growth of modules during their operational lives will not be a problem, even if they are only marginally liftable during initial installation.

With the ability of the cranes to revolve and place large packages on its own deck, the delicate operation of loading packages onto cargo barges offshore, can be delayed until suitable conditions are found or eliminated by travelling to an inshore location.

SUMMARY

The 7000 is the most advanced S.S.C.V. currently operating, and the construction of such a large complex vessel has been a great achievement in management and shipbuilding skills. It meets all of the latest worldwide regulations and operating requirements, has the largest revolving cranes built, and hence has been designed with a long operational life.

The vessel offers operators and designers a wider scope of options for platform and template arrangements with reductions in development costs.

The cost savings in reduced topside structural weight, offshore hook-up, jacket launching steel and project installation times are significant and therefore should not be ignored. Hence this vessel has the potential of turning a financially unattractive project into an attractive one.

Discussion

A. BURNETT (President and Chief Executive, Offshore and Marine International Services Associates): Thank you very much for a fascinating paper on a very interesting subject. You have covered a great deal of ground pretty comprehensively. There are some points I would like to highlight and comment on.

The first one I think is fairly obvious to us all: how much bigger do we go? I presume the answer to this is in the crystal ball and assume we will know when we come to that point if the vessel is too big to really earn a return. On this matter, you have obviously done a great deal of research in covering as many aspects as you could think of, including pipe laying and various other aspects of interest.

We hope you will not be in the position, like Viking Piper was, which was a marvellous vessel, where it could do exactly what was needed in its work profile but when it came to the work use factor it could not earn a profit. The vessel, therefore, had to be placed in reserve. Later she became a rather sophisticated accommodation barge which nobody really wanted.

You have obviously done some research into the size of the vessel to ensure it can be docked at various locations in the world, but it was not quite clear whether it could traverse major canals and waterways of the world, and clear bridges. I think you have done some research on passage under most bridges, but one or two come to mind like the Bosporous bridges – did these enter into your calculations?

You have described work programmes connected with platforms but little concerning template operations. Now, however, in the offshore market, we are also using converted tankers, take-off systems and floating production systems. I know you have done work in-house and with Tecnomare and others to get people thinking of new designs which match the facilities of your vessel, which leads me on to the comment that a number of people will surely be designing their subsea systems to take into account your vessel rather than the other way around.

Some years ago I heard a very interesting paper given by the French on ETPM1601 whereby they had put the vessel in high-wind conditions in test tanks at every conceivable angle, and had produced results of what happened to the vessels when the wind was at many different angles. Perhaps you did something similar, or are you assuming that your ballast system will cope with any particular wind problem?

There are one or two other points such as the turning circle. You might like to comment on that, and also you mention in the paper it can operate between –20 and +45 °C. Is that not limiting you from some of the possible future markets of North Russia and North Canada where I am sure the temperatures go below –20 °C, to –60 °C or lower?

Finally, you might also like to comment on mobilization cost. In going from place to place for various contracts you have to mobilize the vessel, and you need to refuel and re-provision. These factors are all items in the budget for which you probably use a computer so that you have got the best optimized solution of which contract you take and which one you will not take because you cannot make a profit on the mobilizing and other associated aspects. Is this correct?

I think we have all been treated to a very fascinating paper, and I think we ought to give our best congratulations to John Mitchell and his colleagues for bringing all these details to our attention.

D. ROWAN (Noble Denton): I have two questions. Firstly you have got the capability to lower 900 t into very deep water. We have been doing a number of studies ourselves in this area for various clients and I was wondering if you have come across any problems? When you get very close to set-down with these very large loads in very deep water, with the gentleness of the lowering system, you can get resonance problems. Even though the motion may be very low at the surface, there may be high dynamic tensions down at the sea bed. I wonder if you have come across this and if you see it as a problem?

The other question I have got is relating to the rapid ballast system. I was wondering whether, when you were designing it, there were there any patent problems. Can it maintain level trim during the transfer of all this ballast, or do you in fact get a slight heel of trim of the vessel?

D. S. ALDWINKLE (Lloyd's Register of Shipping): I should like to add my congratulations to Mr. Mitchell for his very interesting paper and presentation.

Marine lifting capacities have certainly increased over the last decade or so. In the late 1950s at Cammell Laird (Shipbuilders and Engineers), when I started my apprenticeship, it was astounding to see the Mersey Docks and Harbour Board's mammoth floating crane towering above the many ships in the wet basin. Depending upon the radius, it had, what was in those days, a colossal lift of about 100 t.

In comparison, the Micoperi and her total lift of 14,000 t seems light years ahead. She represents a vessel of considerable achievement and sophistication.

This sophistication reflects many novel features. For such a design to be operated efficiently and safely, it is sometimes necessary to analyse the reliability of the various parts of the vessel. Can the author say whether or not he sees a need for formal reliability and risk analysis for this type of vessel?

It is noted that the paper does not include information on the stability of the vessel. Perhaps the author could give some details of the GZ curves and comment on the stability in the lifting mode of operation. You referred to force 8 being the maximum for the D.P. design, but please could you advise on the maximum wave height recommended for lifting operations?

J. W. HARRISON (Three Quays Marine Services Ltd): In the paper, the main generators are described as 'driven by low-speed engines designed to burn IFO 380 heavy fuel oil'. Could the author please amplify on this with respect to the following.

It is understood that the GMT engines installed ran at about 500 rev./min. Today 200 rev./min is considered to be stretching the term 'low speed'. The fuel 'norm' today for low-speed engines is 700 cSt at 50 °C; even cheaper than IFO 380. What are the experiences to date on what fuels have been used?

How has the fresh-water generator plant performed and has this been on engine cooling water or steam?

The normal ballast system has been described as 4 x 6000 t/h. What is the mean rate of the 'fast' ballast system?

J. McCANN (John Brown Engineers and Constructors Ltd): I would first like to congratulate Mr. Mitchell for an interesting and illustrative paper.

As someone involved in lifted jacket studies, I would like to ask Mr. Mitchell to comment on the differences between the frequently voiced theoretical lifting capacity and actual lift weight. Comments on the factors used to differentiate between the theoretical and restricted capacities would also be appreciated.

M. BLAND (Atkins Oil & Gas Engineering Ltd.): Do you feel operators are now willing to design their platforms for the higher capacities of the Micoperi 7000 (or the DB 102) even though this gives reduced competition, and will this lead to reduced cost, or will lower cost come from maximizing competition? Can you also expand a little on the fast ballast system of the vessel, for example, when lifting a 10,000 t jacket in a sea state of $H_s = 2.5$ m?

R. GARSIDE (BP International): Please describe the shallow water capabilities of the Micoperi 7000. Please also describe any operational experience gained to date. What hoist speed do the blocks achieve under load?

Author's reply

In reply to **Mr. Burnett**'s questions, firstly, any bigger vessel will have to be justified in the same way this vessel was justified. Your comment on Viking Piper's early days is valid insomuch as it was superb at what it did – ie laying large diameter pipelines – but it really only did one thing. We have tried to develop a vessel which not only reduces the cost of offshore platform installation but also, can perform a wide variety of other tasks, which brings us onto bridges and canals. One of our aims was to build bridges rather than just go under them, but obviously there are limitations to the mobilization possibilities of the vessel.

You will probably find, however, that a vessel which for example can easily go through the Panama Canal will not give very good operability in the northern North Sea. You have to decide where your basic market is, and our aim was to provide a vessel which would perform well when installing large structures in harsh environments rather than one that would be used for regular voyages through canals or under bridges.

On floating production systems and subsea structures, we think you are correct in saying that now, when someone designs a floating/subsea production facility, they can use the construction capability of this S.S.C.V. to make their project more economical than if such vessels did not exist.

For the installation of TLP foundations, initially, we foresaw very little work for large construction vessels. However, the installation of both the Hutton TLP and the Conoco Jolliet TLWP S.S.C.V.s have played a very significant part.

With regard to the high winds, similar analysis has been performed for the 7000. We do find that we would not normally be lifting in very high winds, but they would be ridden out at the vessels survival draft, together with, we assume, the associated high seas. The vessel does have a high windage but this is in proportion to its very large displacement.

The vessel's fast ballast system (FBS) is not designed to cope with the effects of wind at all but is used really just for better load separation from cargo barges or set down onto platforms. More details of this ballast system are covered later.

With respect to turning circle, although we do not know if it has actually been tried, the vessel should be able to turn on a six-pence! The vessel is equipped with eight fully azimuthing Schottel–Lips thrusters; four of the S 4500 ZSU (4500 kW) underwater mounted type and four of the S 2501 LSV (3000 kW) retractable type. In addition there are two of the FT 34 (2500 kW) tunnel thruster type, giving 35,000 kW total power.

One interesting point is that when the vessel was first conceived, it was considered that the power required to propel her at 9.5 knots could only be provided by fixed propellers. But after the first model testing the fixed propellers were replaced with two azimuthing thrusters at the stern of each pontoon set side-by-side and slightly displaced.

Concerning operating temperatures, I think you will find that the vessel has been designed for a greater temperature range than any other vessel of its kind and if the 7000 cannot operate in a particular area, you will probably find no other vessel that can either. Obviously, the –60 °C mentioned applies to winter temperatures and one would probably try to work in these areas during the summer months.

In response to the questions of work planning and mobilization, the decision on which contracts we take and which ones we do not, unfortunately, is not ours; that is decided by our clients.

There is no doubt that there is a cost for moving the vessel around and if you are competing with a similar vessel already working in a distant location, you are at a disadvantage. However, the vessel is fully self-propelled and does run on cheaper heavy oil and the cost of mobilizing is very competitive with similar vessels. Should we find ourselves setting out from the same starting point and making for the other side of the world, we do not feel the 7000 would be uncompetitive, and finally, yes, we do use a computer for such analysis.

In response to **David Rowan**'s first question, to date we have not found resonance problems at set down but this may be because we have been dealing with relatively heavy weights.

In fact, rather than at the sea bed or through the splash zone, where we thought problems may occur, we have found that a more governing area occurs when the object is just below the sea surface. We have performed dynamic analysis work on lowering templates from approximately 900T to 2000T in both single and dual crane modes and found the worst phase is just after entering the water.

Dual crane lowering gives better positioning possibilities and other operational advantages, but when going through the sea surface you can relieve the load on one crane in high seas and this is not a favourable condition. Therefore, this sets the limits for the initial part of the operation. Once past this point, worse sea states can be accommodated for the remainder of the operation.

On the rapid ballast system, we have used a number of existing components and combined them to produce a very effective ballasting system whereby we either take on or dump water, unlike other systems which transfer water within the vessel.

The vessel has its own computer control system which makes our particular FBS unique to the 7000.

With regard to heel and trim, maybe it would be better to elaborate further on the working of the two ballast systems on the vessel.

Our FBS does not account for slewing the cranes. With light loads in the crane, no ballasting is performed as the vessel remains within approximately 1 deg. heel and trim. For heavier loads, the computer controlled ship's ballast system with a pumping capability of 24,000 t/h is used and, in theory, the speed of slewing is limited by this together with the trim and heel angle you accept for the operation. In practice, though, the slewing of a lift is a relatively slow operation to stop the load from swinging and it is unusual for the rate of ballasting to be the actual limiting factor.

The basic philosophy of the FBS is to effect better lift of the packages from cargo barges whereby, effectively, the speed of lifting is doubled, typically adding 3–5 m/min to the main hook speed. The FBS comprises a number of 2 m diameter valves connected to dedicated ballast tanks at the bow and stern of the vessel.

To achieve a clean separation when initially making a lift, we can consider using the FBS which takes on water in a tank diametrically opposed to the load, effectively trimming the vessel. The same system can effect better setting down of a package by similarly ballasting a compartment under the crane which is lifting.

While using the FBS, theoretically, the vessel wants to change its angle of trim (or heel) by more than 1 deg., but as the system is computer controlled, the FBS keeps up exactly with requirements of the imposed crane load.

The limits on heel and trim are usually governed by the capabilities of the crane rather than the vessel. The cranes operate with a certain cross heel angle on the A-frame and the limits on heel are less when lifting over the side than over the bow. For trim, the opposite applies.

In reply to **Mr. Aldwinkle**, risk analysis has been performed both for our own safety requirements and to ensure compliance with statutory rules and regulations. On safety of systems, for example, the 10 generators on board which produce 50 MW of power to the vessel have been placed (in pairs) in separate fireproof compartments.

If there was a fire or other hazard in one compartment, all vessel operations could still continue. The same has been applied to the power distribution system and also the D.P. system where, for example, the force 8 limit for D.P. operations takes into account the risk of one thruster being inoperable and only 80% power being available.

The vessel also complies with one column damage to satisfy NPD requirements and operational risk assessment for each project is also carried out.

Reliability was a major factor in evaluation and selection of equipment suppliers with proven systems being used where possible.

On stability and lifting operations, whilst we can maintain station in force 8 conditions with D.P. and even worse conditions when anchored, you are correct that it is unlikely we would be lifting in these circumstances. Obviously, we try to work at the optimum conditions which vary depending on the combination of wind, waves, current and their respective strengths and directions. Unfortunately, most of the time the limiting condition tends to be when lifting from a cargo barge, where a 2.0 m significant wave is a very rough rule-of-thumb limit.

When lifting from the vessel's own deck, higher wave heights can be accommodated. However, the important thing about being able to remain on station in severe weather is that when conditions improve you are ready to start work immediately rather than having to remobilize or re-anchor.

The stability of the vessel is of course related to the use of the cranes. When working at its normal operating draft the cranes can basically work unrestricted. At other drafts, especially below 20 m, we check vessel stability on a case-by-case basis. Usually, single crane operations are rarely effected but for heavy dual crane lifts at light drafts, a check on intact and damage stability is made where such items as deck cargo and other live loads are taken into consideration.

Operational sea states are determined based on predicted boom tip motions and the chances of realizing such conditions are evaluated.

In the past, that risk was taken by the client but now this risk is with the vessel operator and, unfortunately, there are days when even a sophisticated vessel such as the 7000 cannot work.

To answer **Mr. Harrison**, we respond as follows.

The GMT engines do run at 514 rev./min on either IFO 380 heavy fuel oil or marine diesel. While this speed is greater and the fuel grade is higher than for today's very low speed engines, the power units were chosen for their particular duty especially considering the possible higher maintenance requirements allied with the use of lower grade fuel.

The vessel has been burning mainly heavy fuel oil to date with no real problems.

The fresh water generation plant has performed well to date although this has not worked anywhere near its maximum capacity due to our current offshore operations not requiring large amounts of potable water (i.e. grouting/steam hammers, etc.). Initially, recycled heat was used during water generation but latterly the steam boilers have been used. When a constant supply of water is required the reverse-osmosis water makers are used.

The ship's ballast system has a maximum pumping capability of 24,000 t/h. Effectively, during recent operations, actual pumping capacity used has been nearer 14,000 t/h, this depending on numbers of tanks which need filling simultaneously.

The FBS, as previously mentioned, is effected by pairs of 2 m diameter valves in each FBS tank, located in the lower columns. The actual ballasting rate depends upon the pressure under which the water is forced through (i.e. operational draft) and the number of tanks being filled, but we feel generally the maximum figure to be considered is in the region of 4000 t/min. The valves are computer controlled and can be operated simultaneously or in a particular sequence so that not all valves open at the same time. This provides an even rate of ballasting and reduces the possibility of over-ballasting any one group of tanks. The system is operated by the crew and not automatically by movement of the cranes, for example.

In response to **Joe McCann**, the actual lifting capacity of the vessel is 14,000 t which is the static load we would hang on the cranes at up to 41.5 m radius and this was in fact done during the crane testing programme. However, large jackets tend to have a natural width and we, therefore, find ourselves lifting at say 50 m radius where we are down to 12,000 t combined crane capacity.

If jackets could be designed to be long and slender, higher lift capacities could be achieved. Also, if your jackets came with a British Standard Kite Mark guaranteeing weight and centre of gravity, we would be more confident of lifting the full load, but as no such guarantee exists, we must make allowances for inaccuracies or unknowns. Typically, this ranges from 10% to 3%, depending on the stage of design and whether weighing by an approved method is contemplated.

When lifting jackets with two cranes, further consideration has to be given to the centre of gravity, where more load would be attributed to one crane if the C.o.G. for example was not in the centre as predicted. This allowance is in the region of 5% which again can be reduced subject to confidence in a weighing exercise.

Finally, to allow for some operational inclination of the lift and associated C.o.G. movement, we usually apply a factor of approximately 3%. This then brings the 12,000 t capacity down typically in the region of 10,500 t. However, this said, every jacket has its own unique parameters and each lift should be separately reviewed preferably by experienced installers.

Replying to **Mike Bland**, there is a willingness by operators to use the new higher capacities available and a number of contracts have already been awarded for offshore platform installations which cannot be installed by smaller vessels, and the main reason for this, as you point out, is due to overall cost reduction.

The first thing to remember is that so far, no operator has built something which at most only two vessels can install, and then asked for the price.

The basic rule has been to involve the installation contractor early in the project and then once having an agreement, to take full advantage of the vessel's capacity.

With regard to lifting a 10,000 t jacket in 2.5 m significant waves, we feel that such a sea state may be a little optimistic, and we would suggest a lower wave height be considered especially with respect to mooring the cargo barge to the S.S.C.V. As already mentioned, the rapid ballast system assists in faster separation at lift-off by effectively doubling the speed of the main hooks.

There are several simulators and operating aids to assist the captain and crew in their decision making and whilst the final choice is still made by experienced mariners, they now have a great deal more information available to them.

In reply to **Mr. Garside**, on the question of shallow water capabilities, obviously, the deeper the draft of the vessel, the better operability we have, and when lifting heavy loads we prefer to see the vessel at its heavy operating draft of 27.5 m. However, due to either the configuration of the lift or the requirement to work in shallow water, we have found it necessary to consider using lighter drafts.

Generally speaking, one crane can work almost unlimited throughout the range even down to the vessel's transit draft, albeit this probably being inshore.

If we use both cranes simultaneously at light draft, we have to reduce the 14,000 t down to something less. This depends on deck cargo, radius of the lift and anticipated environmental conditions, etc., and needs to be studied on a case-by-case basis. But as an example, we are planning to make a 10,000 t dual crane lift at 13.5 m draft in the near future.

The main blocks of the crane achieve a speed of 2.75 m/min under full load. The 2500 t and 900 t blocks have a much higher lifting and lowering speed.

Finally, the operational experience gained to date indicates that the vessel is working at least as well as expected and has already fully tested most systems under operational conditions. Whilst working for Petrobras Offshore recently, the vessel successfully carried out a 6000 t single revolving crane lift and has placed other packages weighing up to 4700 t on complete D.P.

After loading two very large modules and several smaller packages onto its deck inshore, the vessel transited to two offshore sites with 15,000 t of cargo on deck. It has also remained on D.P. for a number of days while assisting with fire-fighting operations, and ancillary equipment such as pile driving hammers, have also been tested, with the Menck underwater hammers successfully driving closed-ended piles.