WORLD'S LARGEST DP PIPELAYER UNDER CONSTRUCTION

IN 1995, 'SOLITAIRE' WILL ENTER SERVICE AS THE WORLD'S LARGEST PIPELINE INSTALLATION VESSEL. THE SHIP WILL OPERATE FULLY ON DYNAMIC POSITIONING, ENABLING HER TO LAY LARGE DIAMETER PIPELINES IN DEEP WATER. DUE TO THE LARGE DIMENSIONS OF THE PIPELAYER, AND A NEWLY IN-HOUSE DEVELOPED AUTOMATIC WELDING SYSTEM, A HIGH LAY SPEED WILL BE ACHIEVABLE. ALL MAJOR EQUIPMENT FOR THE UNIT IS BEING MANUFACTURED AND THE VESSEL IS CURRENTLY UNDER CONSTRUCTION AT SEMBAWANG SHIPYARD IN SINGAPORE.

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PIPELINE INSTALLATION OFFSHORE

The majority of offshore oil and gas pipelines have been laid by dedicated lay barges or pipelay vessels. The most common installation method is the sequential welding of a pipeline string onboard a surface unit. The surface unit moves forward on anchors as the pipelaying is progressing. The pipeline descends to the sea bottom in an S-curve, partly supported by a stinger at the stern of the lay vessel and is kept under tension to prevent bending or buckling of the pipeline under construction due to its own weight.
Constant high quality of the welding process is of paramount importance. Accurate positioning of the surface unit is required for precise laydown of the pipeline at its designated seabed location and for connecting the pipeline end to an offshore platform (see figure 1).
A typical installation project requires the deployment of a small fleet of auxiliary vessels, such as diving support-, supply-, rockdump- and bottom route survey vessels. In many cases, the pipeline has to be protected by trenching into the sea bottom. Allseas has developed a mechanical trencher, 'Digging Donald', which is remotely controlled and serviced by the support vessel 'Trenchsetter' (see figure 2). This vessel can also install concrete mattresses for pipeline stabilisation or crossing protection. Flooding, gauging and testing of the installed pipeline can be carried out using diverless operated tools.

D.P. PIPELAYING

In well-developed areas, with the attendant congestion of pipelines, flexibles and cables on the seabed, the laying of pipelines on DP (dynamic positioning) has proven to be advantageous. Safety, not endangering the infrastructure on the seabed due to the absence of anchors, was one aspect; convenience was another, as DP allows vessels to work in awkward positions and without the necessity for nearby anchored vessels to move away. This is one of the reasons for the success of the 'Lorelay' (see figure 1).
DP is also advantageous for the installation of long pipelines. If the vessel is fast, its forward speed will not be restricted by the resetting of anchors. When working in deep water, resetting of anchors becomes cumbersome and, in very deep water, anchored operations become nearly impossible.
The DP pipelay vessel 'Lorelay' was developed completely in-house by Allseas in 1985-1986 and built by the former Boele Shipyards in Bolnes. Since then, a wealth of experience has been gathered from the seven years of 'Lorelay' operations. Solitaire contains countless details resulting from lessons learnt with the 'Lorelay' (see figure 3). Yet, the concept is somewhat different and a number of innovative systems have been introduced.
In the early days, pipelines were installed offshore by first and second generation lay barges. The hulls of these laybarges

Figure 1 DP Pipelay Vessel Lorelay

were either a flat bottom barge or a converted ships-shape hull. Most of the pipelayers have a revolving crane fitted at the stern for platform installation and associated construction work. On these

'igure 2 DP Trenching Support Vessel Trenchsetter

derrick laybarges, the pipeline welding ramp is usually fitted at the (starboard) side sloping down to the waterline. This location results in weather restrictions for these units due to roll motions. The seventies saw the advent of the third generation lay barge, the semi-submersible hull with enhanced motion behaviour. These barges still rely on anchor systems for forward movements and pulling force generation. 'Solitaire' will be a fourth generation DP lay vessel.

BASIC DESIGN PARAMETERS

In order to make the vessel competitive, the primary design parameter chosen is a pipelay speed of about twice that of the best competing units on large pipelines. The main requirements for 'Solitaire' were:

- Sustained layrate of 6 km/day on large diameter pipelines;
- Vessel workability in the North Sea at least equal to the workability of semi-submersible lay barge spreads;
- Compliance to stringent requirements regarding allowable pipe stress and strain limits, therefore a large installed tension capacity;
- Compliance to the highest standards of operational safety;
- A high sailing speed, for worldwide operation.

RESULTING VESSEL CONCEPT

The first design requirement calls foı many welding stations, and therefore ᵋ very long firing line. The resulting vessel is 285 metres long. Total length including the stinger is about 353 metres.

Experience acquired with the 'Lorelay' shows that having a ship-shaped vessel with a roll period of 20 seconds or more leads to excellent workability, particularly if combined with a large length which limits pitch behaviour. The combination of these favourable vessel motions and adequate DP power will result in an overall workability at least equal to that of semi-submersible lay barges.

An additional advantage of a self-propelled monohull is its ability to sail at a relatively high transit speed, enabling it to mobilise fast to any area on the world. The availability of large pipeline jobs is not sufficient for this vessel to survive when confined to a single area.

For the laying of large diameter pipe in deep water, the decision was made to fit the vessel with four tensioners, each with a capacity of 100 tonnes; further tensioners can be fitted if required in a specific pipeline installation project. The design main particulars are listed in table 1.

In order to comply with the highest standards of operational safety, the vessel will have NMD Class 3 notation, (see table 2) which will enable it to work in the close vicinity to platforms and, if required, to allow diving from the vessel.

The design objectives have been met by selecting a large Capesize bulk carrier hull as the basis for an extensive conversion (see figure 4). Layout and construction of this 125,000 dwt hull are very favourable for fitting the projected equipment and onboard facilities in an efficient arrangement. The design has been based on both

Length, including stinger	353 metres
Length, hull	285 metres
Breadth, hull	40.6 metres
Depth to main deck	24.0 metres
Design draught, hull	8.5 metres
Operating draught, extreme	13.5 metres
Displacement	70,250 T
Pipe cargo capacity in holds	14,600 T
Fuel oil capacity	8,900 T
Diesel engine power	51,5 MW (peak)
Main engines	8 x 5,850 kW
Generators	8 x 5,650 kW
Azimuth thrusters	8 x 5,550 kW
Transit speed	14.5 knots
DP system	NMD Class 3 / LR DP (AAA)
Double joint welding stations, main firing line	7
Tension capacity	400 T (4 x 100 T)
Abandonment and recovery winch	400 T
Max. pipe diameter	60 inches
Pipe transfer cranes	2x 35 T at 35 m
Overhead cranes, single joint	5x35 T
Overhead cranes, double joint	2x65 T
Overhead cranes, equipment handling	2x30 T
Special purpose crane	300 T at 20 m, 20 T at 80 m
Accommodation in 1 and 2 pers. cabins	420 beds
Helicopter deck	Chinook 234 LR and Sikorsky S-61N

Table 1. 'Solitaire' Specification.

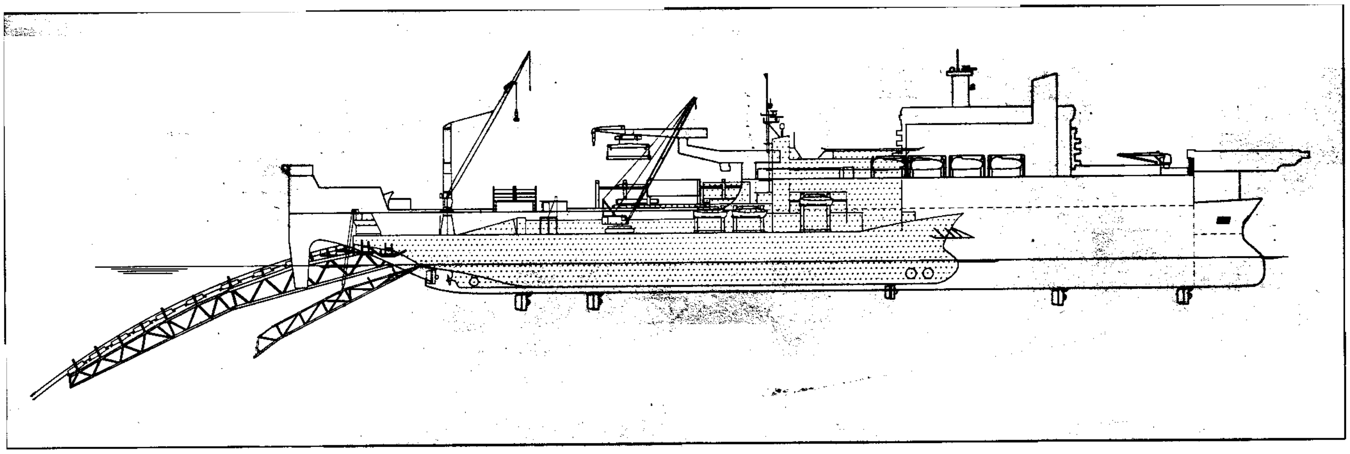


Figure 3 Solitaire and Lorelay profiles

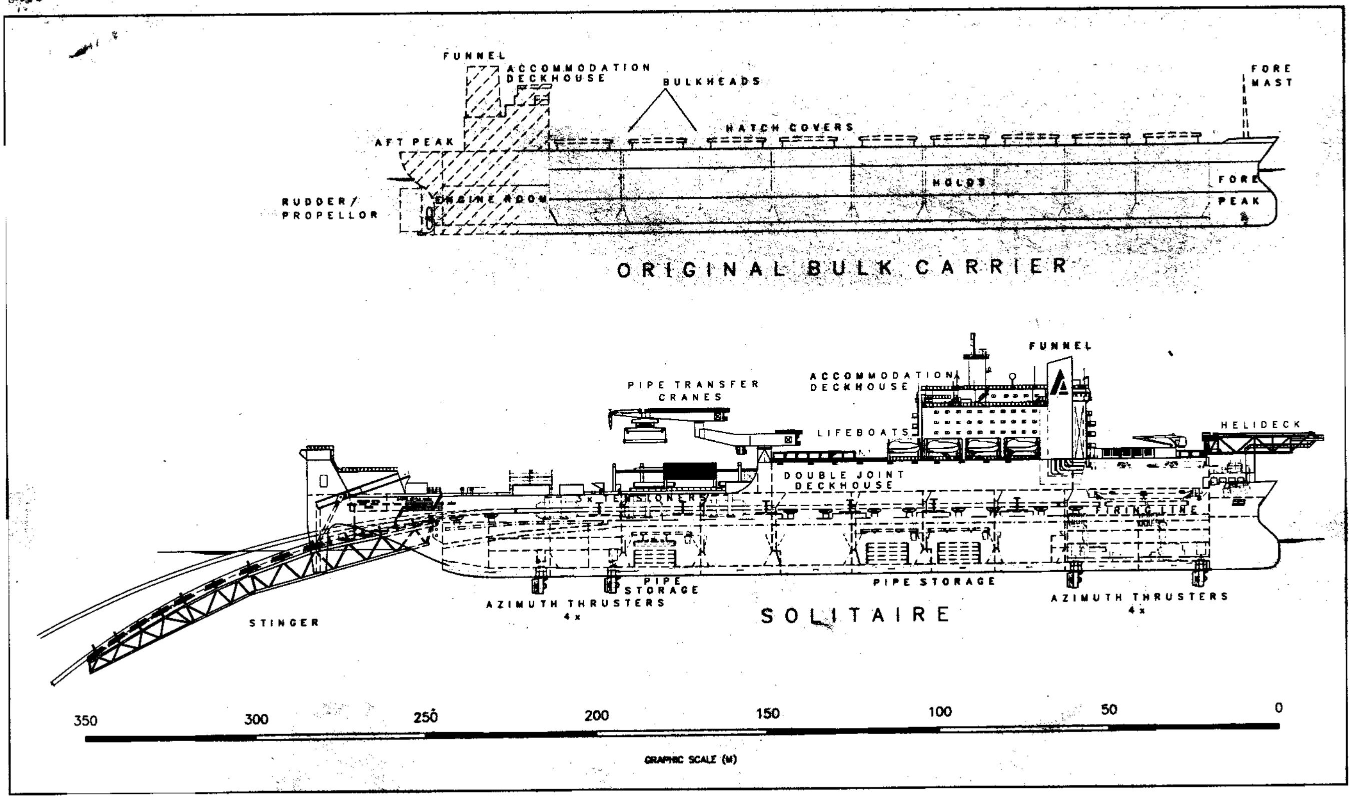


Figure 4 Conversion outline view

analytical and probabilistical methods with operational feedback from the existing DP lay vessel 'Lorelay'.

DP STATION KEEPING CAPABILITY

The use of a dynamic positioned pipelay vessel leads to the following advantages:

- No potential risk of damage to existing cables and pipelines on the seabed;
- Less interference with other activities near to platforms: possibility of working within anchor patterns of drill rigs and moored vessels; much liberty in selection of start-up and lay-down positions; quick start-ups and lay-downs, resulting in short presence in platform areas;
- Capability of fast pipe abandonment operations, in case of deteriorating weather;

Classification	Lloyd's 100 A1, + LMC, UMS, DP (AAA), PCR (98,93), LA, SHIPRIGHT (PCWBT)
Flag State/ International Certification	Panama (International Conventions) IMO Code of Safety for Special Purpose Ships plus SOLAS latest amendments, International Loadline Convention 1966, International Tonnage Convention 1969, MARPOL 73/78 incl. Annex I, III - V, COLREG 1972
UK Certification	HSE COF Offshore Installations
Norway Certification	NMD LOC Mobile Offshore Units, DP System Class 3

Table 2. Certification Requirements.

- No downtime as a result of the weather limitations of an anchor handling spread;
- Reduced mechanical downtime;
- The possibility of continuous vessel movement during pipelaying. 'Solitaire' has been designed for a system of continuous pipelay, in addition to the

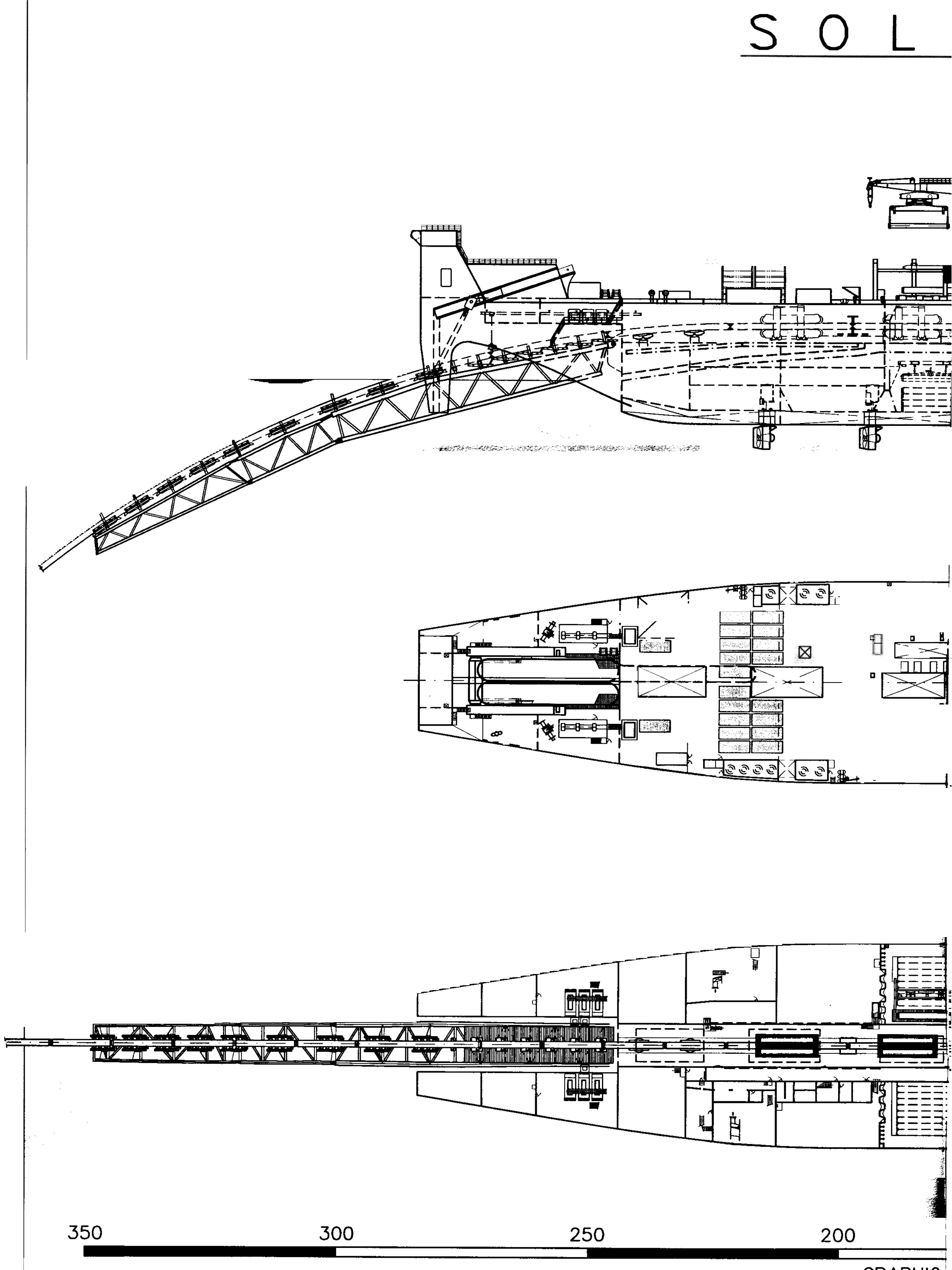
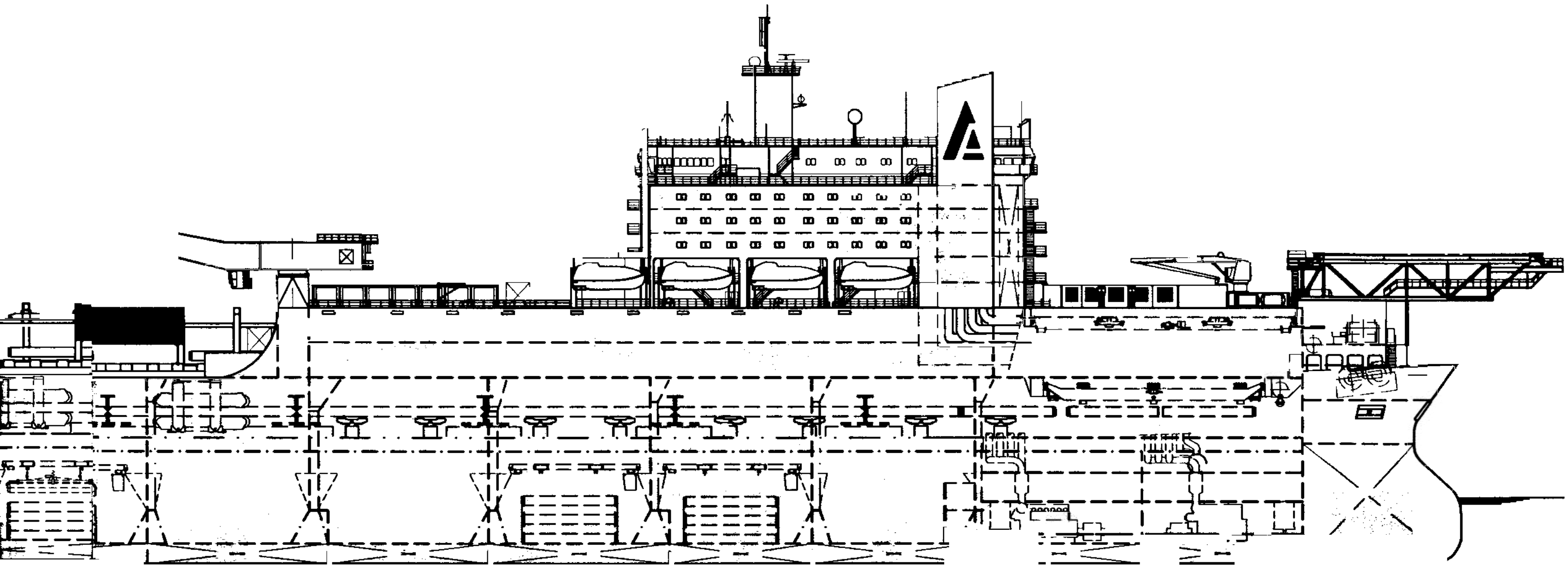
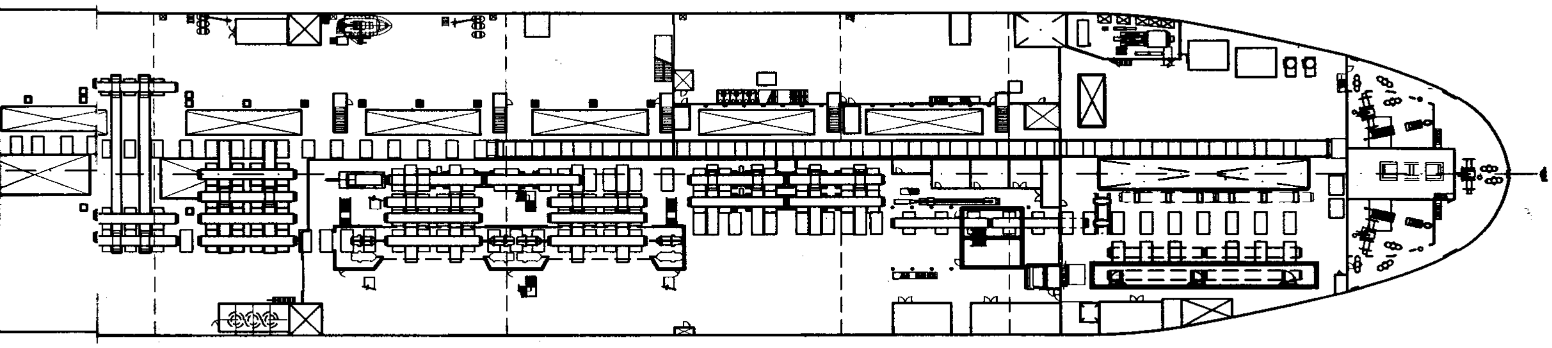


Figure 6 General layout

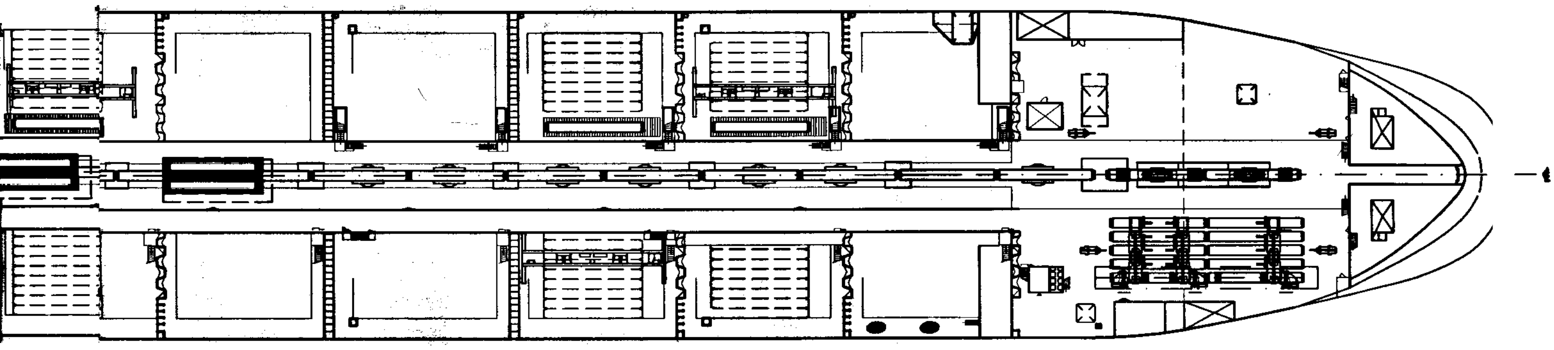
I T A R E



ELEVATION



INDECK / DOUBLE JOINT PREFABRICATION



MAIN FIRING LINE

150 100 50 0

APHIC SCALE (m)

conventional intermittent pulls of double joint length (24 m) after completion of each weld.

During the early design stages of 'Solitaire', an extensive test and computational programme was initiated in order to determine the thrust requirements of the vessel. Design criteria for the station keeping capability were derived for waves with a significant height of 4 to 4.5 m with simultaneous 30 knots wind and 1 knot current.

In addition to numerical models, extensive full scale testing was performed with Allseas' vessels 'Lorelay' and 'Trenchsetter', serving as 'scale models'. On the basis of these tests, performed late 1992, the computational models were validated and used for Solitaire'.

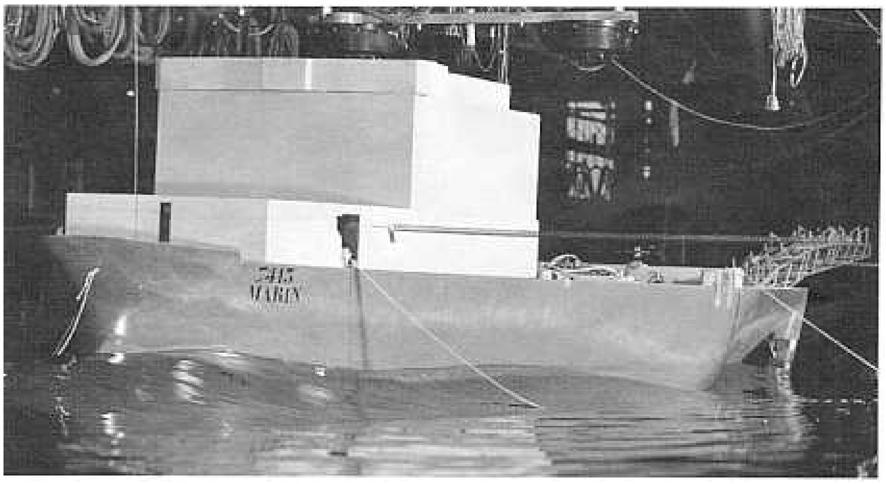


Figure 5 Model tests at MARIN; scale 1:42

Project Management and basic design	Allseas Engineering
Mechanical and structural engineering	Maritime Engineering
Structural analysis	IV-Marcon
Electrical engineering	GTI Marine & Offshore
Ship conversion, equipment installation and outfitting	Sembawang Shipyard
Main engines	Wärtsilä Diesel
Azimuth thrusters	Lips Thrusters
High voltage equipment	STN Systemtechnik Nord
Dynamic positioning and vessel automation system	Simrad Albatross
Pipe transfer and overhead cranes	Liebherr - Werk Nenzing
Tensioners and A&R winch	Westech Gear
Pipe handling equipment, double joint and firing line	CRC Evans
Stinger	HSM
Stinger handling equipment	Huisman-Itrec
Low voltage switchboards	GTI Marine & Offshore
Life saving appliances	Schat Watercraft
Navigation and communication equipment	STN Systemtechnik Nord
Waste management system	Deerberg Systems
Thermic oil installation	Wiesloch Marine
HVAC	ROM-Novenco
Electrical cables	North Sea Cables
Sewage treatment plant	EVAC
Fire fighting, safety and gas distribution systems	Unitor

Table 3. Main contractors and system/equipment suppliers.

Finally, in early 1993, model tests were performed at MARIN (see figure 5) to confirm the calculations and to finalise the selected thruster arrangement.

VESSEL LAYOUT PARAMETERS

The layout of 'Solitaire' is briefly described by the following main areas (see figure 6):

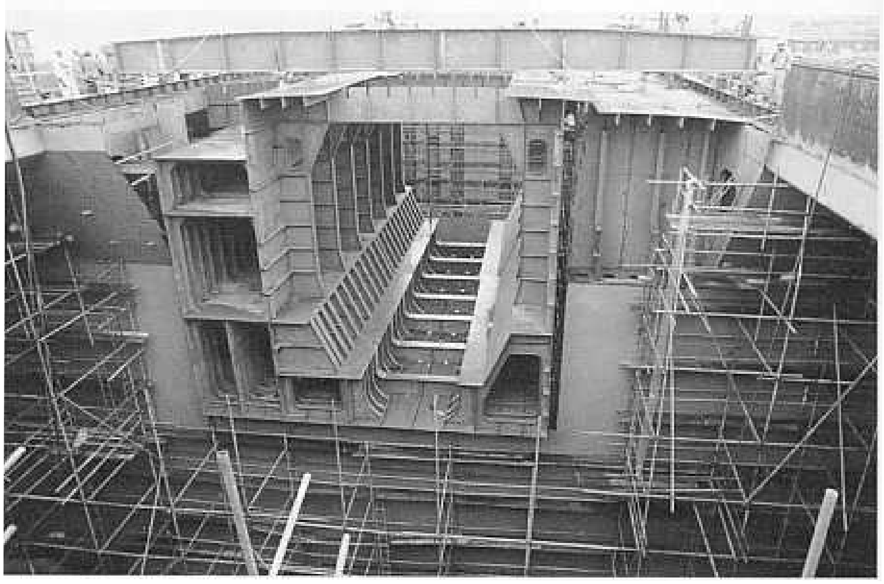
- Firing line, situated in a tunnel structure below deck in the centre line of the vessel, extending from forward to aft;
- Double joint pre-fabrication area, situated at main deck level, starboard side;
- Accommodation, above C-deck, with DP bridge on top and helideck at the bow;
- Engine rooms, situated in the forward and aft compartments of the vessel;
- Pipe storage holds in the mid body.

EQUIPMENT DELIVERY, CONSTRUCTION AND INSTALLATION

Using detailed specifications prepared by Allseas Engineering, the contract for final Solitaire outfitting was awarded to Sembawang Shipyard in Singapore on 1 November, 1993. Detailed design and equipment manufacturing have progressed to a stage where all main components (see table 3) are being delivered and shipped to Singapore for installation. The first stage of the steel conversion work has been completed: fitting of the firing line tunnel as a new construction under the maindeck (see figure 7).

The hull has now been prepared for the conversion work; the construction and outfitting is being undertaken in 13 main blocks (figure 8). Once the installation

Figure 7 Firing line construction at Sembawang Shipyard



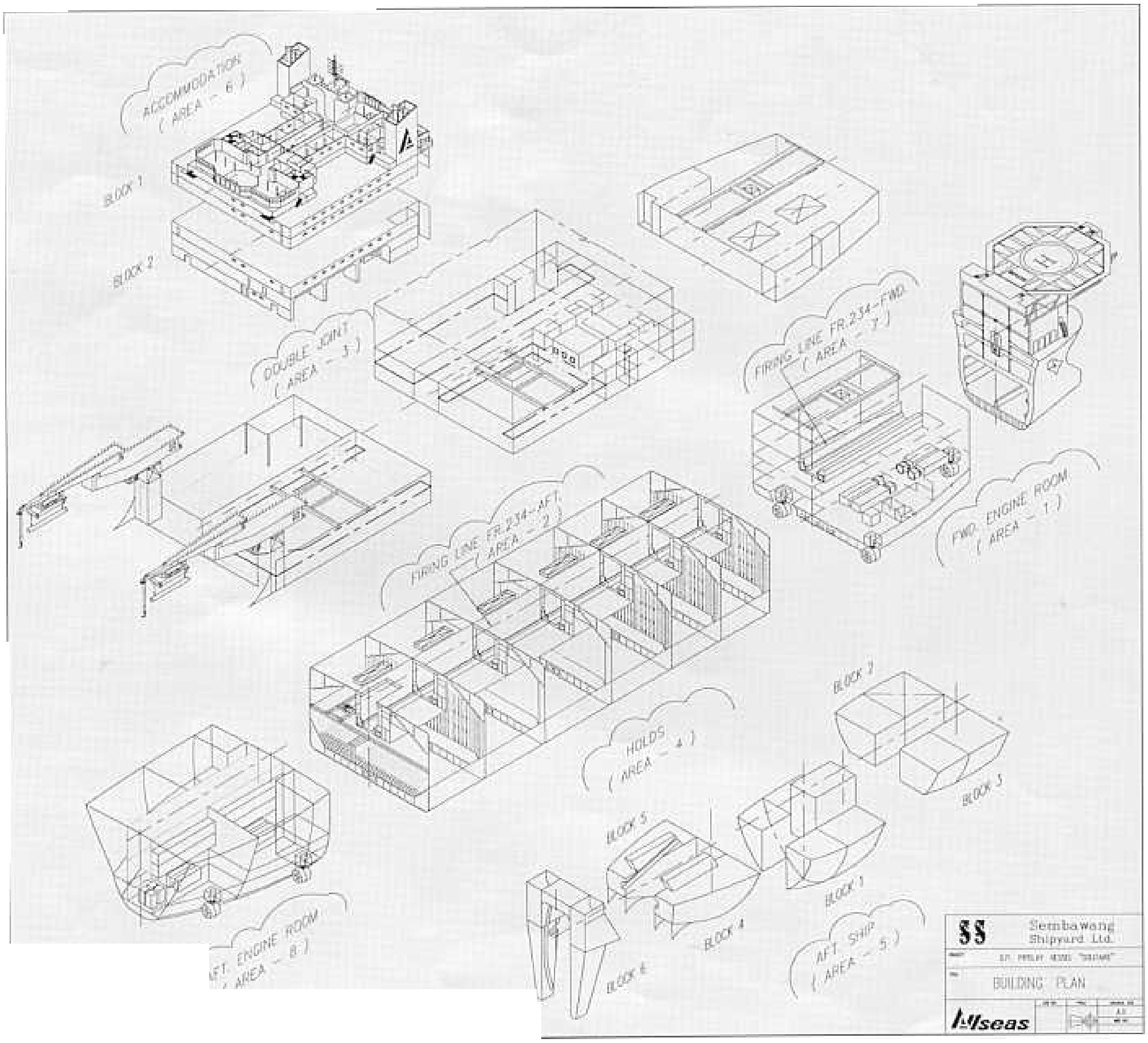


Figure 8 Building plan

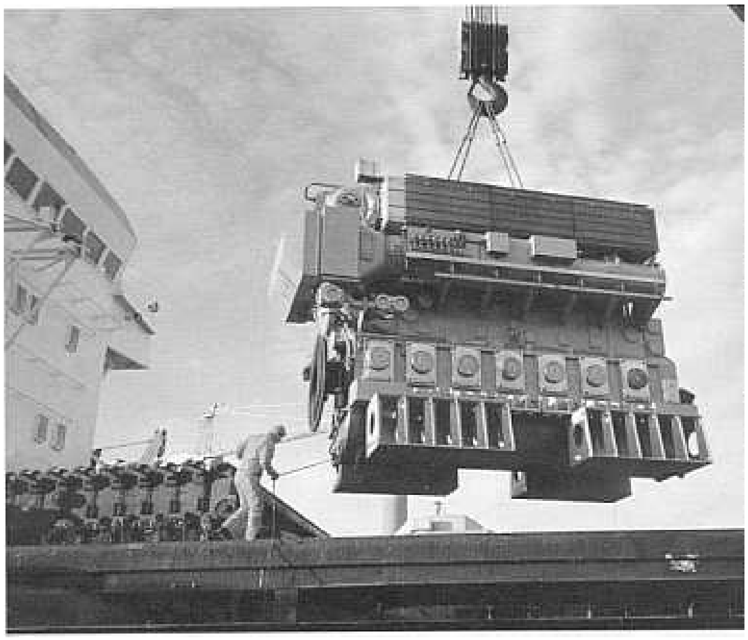
works near completion, a full test program will be run. After component and equipment testing, the system testing, commissioning, quayside trials, sea trials, DP and pipelay trials will take place.

POWER GENERATION AND CONTROL

Power generation and distribution will be diesel-electric. Eight identical main engine sets have been manufactured by Wärtsilä Diesel. The first shipments have arrived (figure 9) and eight identical azimuth thrusters are being delivered by Lips Thrusters (figure 10).

High voltage equipment is being delivered by STN Systemtechnik Nord. The DP control system, including position reference systems and sensors, is under delivery from Simrad Albatross. The symmetrical layout of eight identical main hardware components in the DP

Figure 9 Main engine shipment to Singapo



system obviously maximises the redundancy, should any single failure of a main component occur. The requirement for a maximum redundancy after any single failure is dictated by the governing regulations. An overview of the main equipment particulars for power generation, distribution and position control is given in table 4.

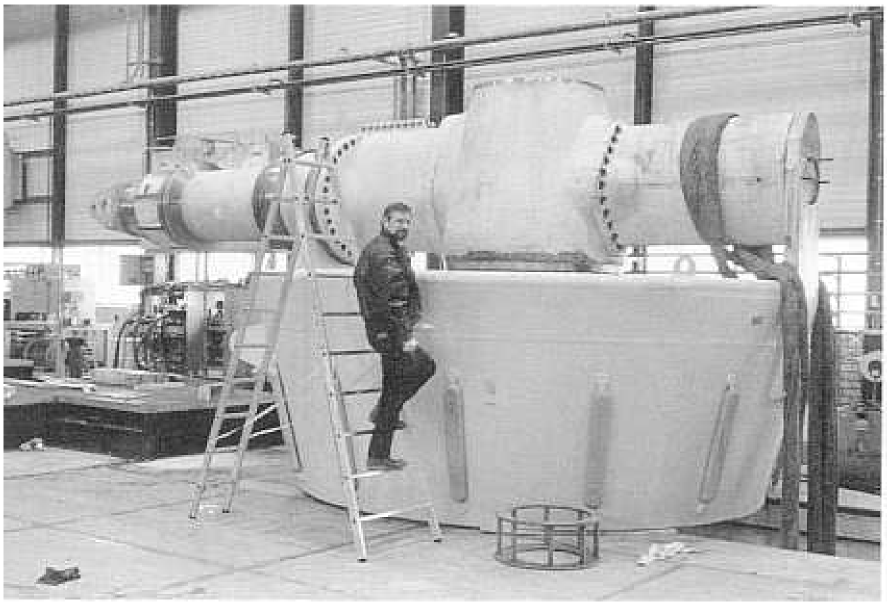


Figure 10 Thruster unit ready at Lips

INTEGRATED VESSEL MANAGEMENT SYSTEM

An integrated system for dynamic positioning, thruster control and power management will be installed. This will be a network based system with a high degree of local distribution. All information and control functions for the process elements are processed and stored locally in integrated Process Stations. These are located physically as close as practical to the actual processes. The number of I/O signals to be interfaced by the Process Control Cabinets will range between 6000 and 7000. Between the distributed Process Stations and the different operator consoles, and among the distributed Process Stations themselves, a dual high speed communication network will be arranged using fibre optic cabling. Control stations will be located on the DP bridge, the Navigation Bridge and Bridge Wings, the forward Main Engine Control Room, the aft Computer Room and the Harbour Control Room.

The integrated vessel management system's principal installation layout (see figure 11) complies with the overall redundancy requirement and is in accordance with the vessel's fire zone structure. The following sub systems will be integrated:

- Dynamic Positioning system
- Thruster Control and Monitoring system
- Marine Automation system
- Power management
- Fluid management
- Alarm management

The unified system will eliminate extensive interface cabling and give full optimal control over the power producing machinery and the power consumers onboard. A higher utilisation of the complete plant will be achieved as well as a high degree of protection of the various machinery. The level of hardware units and interfaces will be minimised. A uniform man/machine interface will be provided and the overall need for service and spare parts will be reduced. One supplier will be responsible for the complete marine automation system, and therefore the engineering and cabling costs for the shipyard will be reduced.

PIPE ROUTING, HANDLING EQUIPMENT AND PRODUCTION ACTIVITIES

The vessel is equipped with two fast loading cranes, one on portside and one on starboard, to transfer pipes (single joints) from pipe carriers or barges onto the vessel. The cranes will deliver the pipes at the load-out stations on the main deck. From these stations, pipes will be transferred either to one of the six storage holds or to the double joint pre-fabrication facility.

The bevel station is situated in the double joint factory at the end of the incoming conveyor. In the bevel station, two single

Table 4. Main equipment for power generation, distribution and position control.

Main Engines (8)	
Type	Wärtsilä Vasa 6 R 46 B
Power	5850 kW / 514 rpm (MCR)
No. of cylinders	6 in line
Bore x stroke	460 x 580 mm
Max. firing pressure	195 bar
Weight	109 T

High voltage equipment	
Generators (8)	8000 kVA / 514 rpm
Main switchboards (2)	10 kV, 60 Hz, 3 phase, 18 panels
Converter transformers (16)	10 kV, 2 x 800 V, 3000 kVA
Thruster converters (8) and motors (8)	5550 kW / 520 rpm
Transformers misc. distributions (12)	2000 - 3500 kVA

Thrusters (8)	
Type	Lips FS 3500-671 / NU mountable underwater
Drive	L-driven by vertical rpm controlled synchronous AC-motor
Propeller	Fixed pitch five blade moderate skew, dia 3.75 m, steerable nozzle
Reduction ratio	1 : 2.615
Input power	5550 kW / 520 rpm (Peak rating)
Max. steering speed	720° / min
Steering power	130 kW
Dry weight thruster underwater mountable unit	58 T

joints are machined at the same time at both ends. After machining, the two single joints are transferred, pre-heated and aligned at the first double joint welding station. After welding of the first layer, the double joint is transferred forward on a longitudinal conveyor to the second, third and fourth welding stations for internal welding and fill plus cap pass welding. Upon completion, the conveyor transfers the double joint through a Non Destructive Testing (NDT) station for examination of the weld area, and further to the elevator waiting area.
From this conveyor, the double joint is lifted and loaded onto the elevator by an overhead crane, and lowered to the line-up tweendeck where the ready-rack is located. A walking beam will move the pipe towards the centre-line of the vessel. A special overhead crane will finally lift the double joint from the walking beam conveyor and lower it onto the line-up station. At the line-up station, double joints are aligned and welded to the main pipeline. After welding of the first layer, the firing line is moved forward relative to the pipe string to allow line-up of the next double joint.
In the main firing line, up to seven welding stations are accommodated, each equipped with Allseas' Phoenix automatic welding system. Upon completion of the welds, a full NDT inspection is carried out at the X-ray station and the bare pipe ends near the welds are covered with an infill of hot mastic poured into a collar mould at the field joint coating stations.

Figure 12 Phoenix automatic welding system

THE PHOENIX AUTOMATIC WELDING SYSTEM

With the required production rates of 'Solitaire' and the impact of weld repairs and related vessel downtime in mind, it is important to strive for assured weld quality. Adherence to strictly controlled, prequalified welding parameters maximises the vessel's sustained production rates.
Phoenix was developed in-house for au-

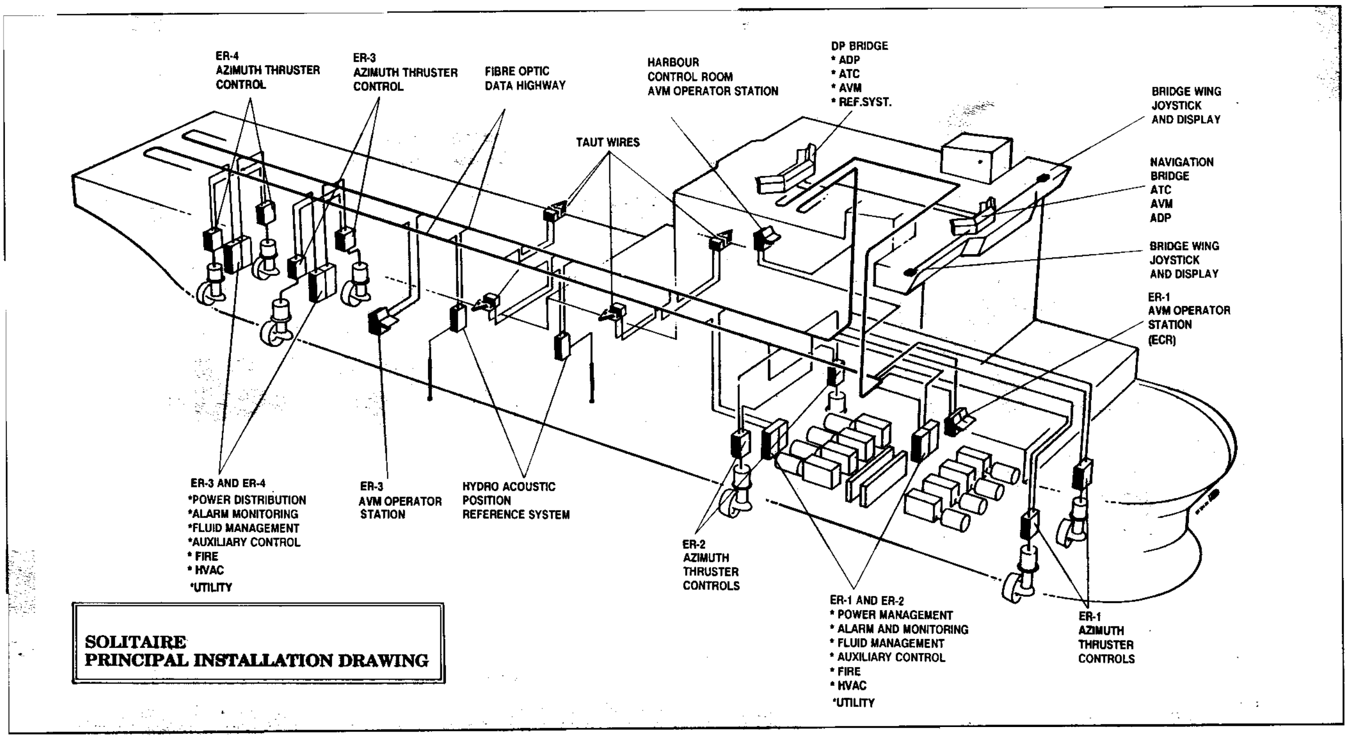


Figure 11 Vessel integrated automation system layout

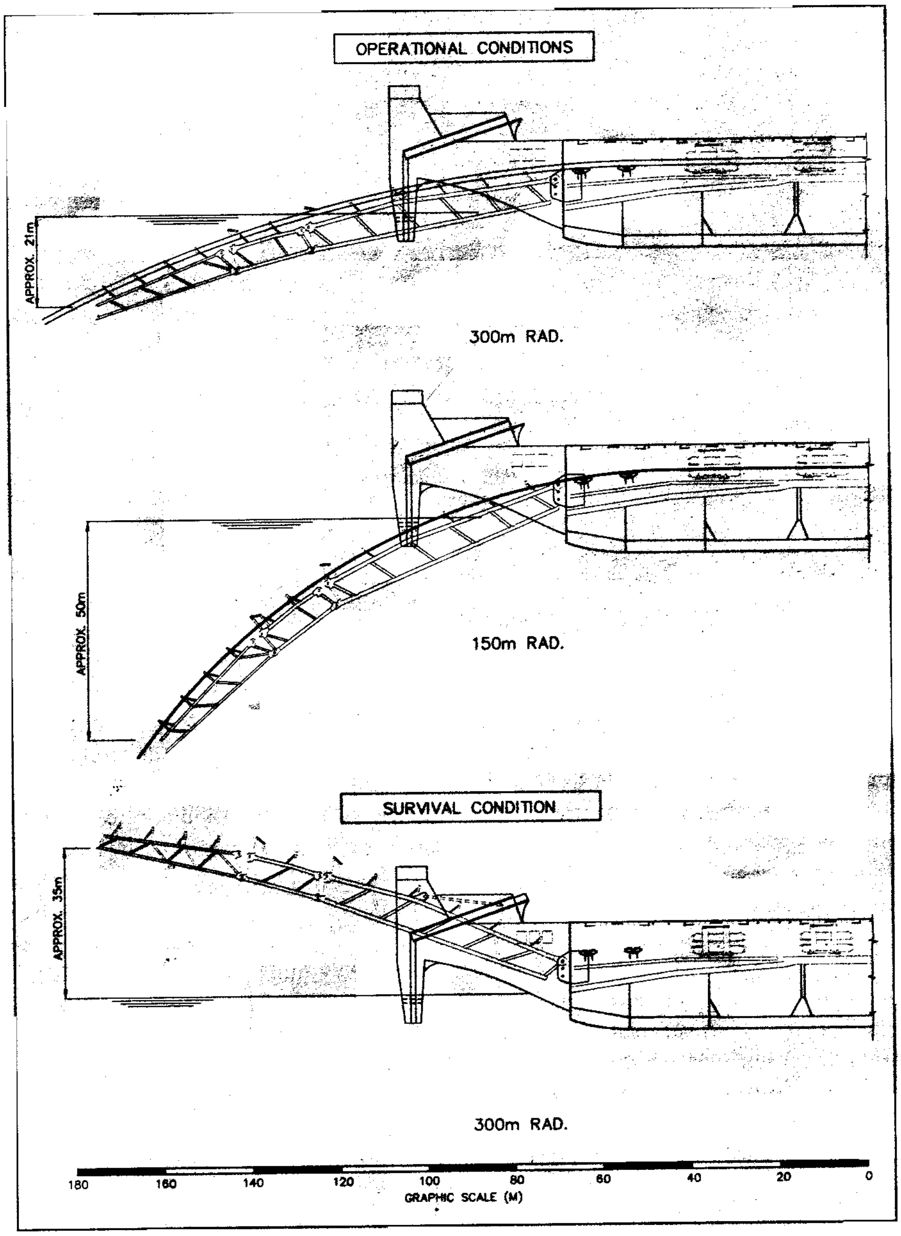


Figure 14 Stinger configurations

Phoenix was first utilised on board the 'Lorelay' in the summer of 1993, installing a gas export line for Amoco as part of the P15/P18 gas development project, welding 36 km of 26" carbon steel pipe with a wall thickness of 16 mm, achieving favourable production and repair rates.

TENSIONERS

The pipeline should always be kept under tension during the welding and forward movements of the vessel. If no tension were applied, buckling could occur at either bend in the S-curve due to the underwater weight of the pipeline.

The constant tensioning devices or 'tensioners' clamp the pipeline surface with tracks crawling over the pipe coating surface. The pipeline is kept under constant axial pre-tension regardless of vessel's longitudinal movements. The 'Solitaire' tensioners have two vertical mounted track bodies.

All tensioners are controlled by a system integrated with the Abandonment and Recovery (A&R) winch and interfaced with the vessel's dynamic positioning system. The tensioners can be opened one-by-one to let a large pipeline appendage, such as a T-piece or flange, pass through. Each 100 T capacity tensioner has a fully controllable speed for paying out and hauling in.

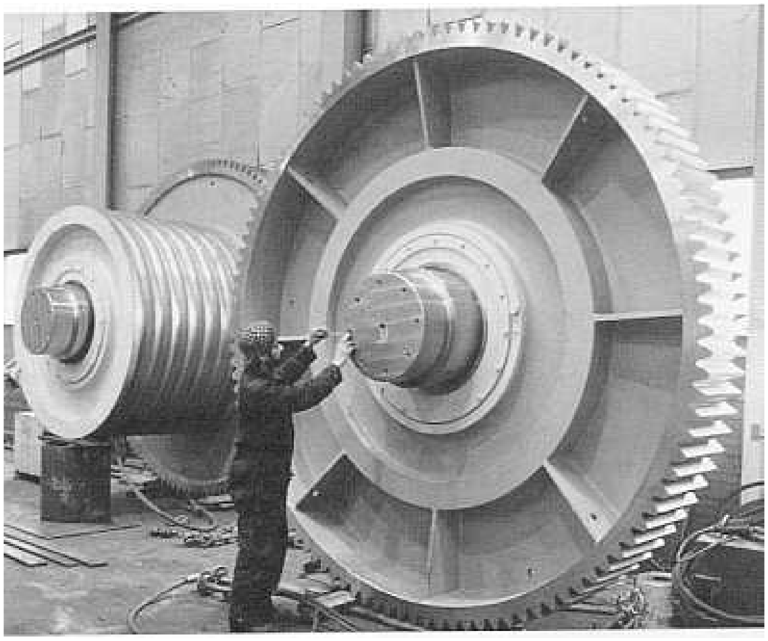
All tensioners are located in the aft part of the main firing line. The pipeline is supported by track type pipe supports in the rest of the firing line. These pipe supports are individually powered and interfaced with the tensioners.

tomatic welding of offshore pipelines of 6 inches diameter and over (see figure 12). The system features pre-programmable welding parameters, which allows repeated use of these parameters for each joint.

The operator uses a hand-held remote control unit to select the pass number, to position the torch, and to start and stop the process. Minor adjustment of some parameters is permitted within the limits defined by the welding procedure to allow for small variations in the geometry of the aligned pipe ends. All passes are applied externally, with the root pass using retractable backing shoes positioned on the internal line-up clamp.

The system is suitable for Gas Metal Arc or Fluxcored Arc Welding in the uphill or downhill welding direction. The system is modular; Phoenix is also suitable for pulsed MIG or TIG welding applications.

Figure 13 A&R winch under construction at Bodewes



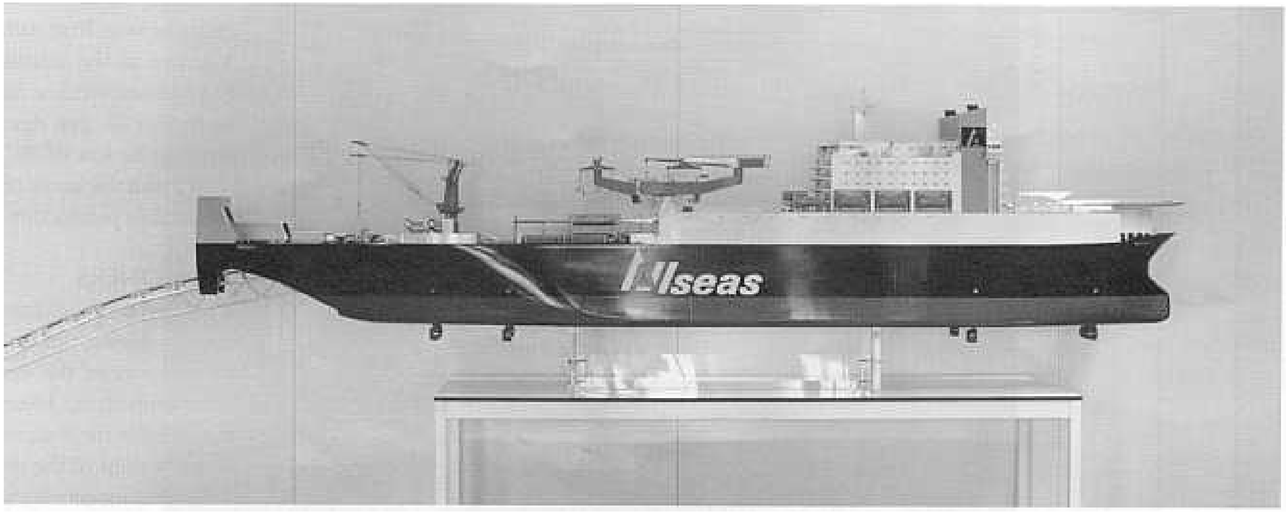


Figure 15 Solitaire scale model

ABANDONMENT AND RECOVERY

The beginning and the end of the pipeline installation on the seabed is carried out with the assistance of the A&R winch system. Start-up and lay-down require full tension on the pipeline end to prevent the pipe from bending. A comprehensive winch system will be installed in 'Solitaire's' bow.

The A&R traction winch system (see figure 13) revolves around a double drum capstan. The necessary back tension is generated by a hydraulic tensioning cylinder and one of the two wire storage reels. The stroke of the cylinder is used to control the storage reel. The hydraulic cylinder compensates the fast movements while the storage reel does the actual payout or haul in of the wire.

STINGER

Aft of the firing line tunnel, the pipeline is supported by the stinger and guided overboard.

The stinger is a large space frame construction with a total length of 108 m. The truss framework has a box-shaped cross section with an external width of approximately 8 m. The stinger is connected to the aftship by two hinges, whereas horizontal plus vertical supports are situated between the two aftships outriggers.

The stinger and associated handling systems are designed such that a large variety of water depths and pipeline materials can be covered (see figure 14). The stinger comprises three sections, coupled by means of hinges and pup pieces. These sections and the aft part of the firing line can be rotated and adjusted relative to each other, as can the 12 individual roller boxes giving support to the pipeline bend. These adjustments facilitate an optimal curvature and departure angle for each pipeline installation, depending on pipe dimensions, water depth and tension level. The pipeline, in its overbend of the S-curve, is further guided in transverse direction by means of vertical rollers.

The entire stinger will be lowered, raised and fixed with a hydraulic skid mechanism, which is located in the skid track: a straight U-shaped guiding slot, mounted at an inclination of approx. 20° at the inner side of the aftship outriggers. The mechanical locking system is capable of tying the stinger at any degree in the pipelay mode. When sailing in transit and during survival condition the stinger is hoisted from the water and fixed in raised position under the crossover.

CONCLUSION

The world's largest pipeline installation vessel is currently under construction to meet a high standard of specifications. As a purpose-built unit, it will bring together first class innovative systems and state-of-the-art equipment (see figure 15).

With the introduction of the fourth-generation pipelayer 'Solitaire' in 1995, the offshore industry can expect to witness the laying of very large pipelines at sustained high production rates. Operating on DP will enable the laying of such lines in deep water. The self-propelled monohull allows fast mobilisation world-wide and high workability even under adverse weather conditions.

'Solitaire' will set new standards for pipeline installation operations. The ship is expected to serve the offshore oil and gas industry well into the next century. □