THE VIKING PIPER

DESIGN, CONSTRUCTION AND OPERATION

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with support of the Gusto History Group

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1. Prologue

It is 2018 and everything described in this story is long past. That is true for the events, for the subject of this story, the Viking Piper, and even for several of the individuals playing a role. And that is why some of the engineers involved felt the urge to lay down their memories and collect photo's and sketches of a project that really was a once-in-a-lifetime. Imagine a medium size Dutch shipyard (by international standards it was a small yard) undertaking to build a semisubmersible of a size which did not match the slipways nor the completion quay. A construction or repair drydock was not available. The yard had until then never designed or built a semisubmersible, and now would construct the largest unit ever so far. Equally challenging was the contractual delivery time: one and half year from order. This probably was pure bluffing: on the day of contract only a preliminary design was available. But the Gusto yard had a strong engineering staff, making it a bit overconfident. Unfortunately there was not such staff on the client side, only investors who rushed to bring in a number of Americans who they thought had the appropriate experience. Maybe they had, but it soon transpired that the differences between the American and European approach to engineering were enormous and nearly impossible to overcome. And so, on November 1, 1972, the stage was set for management power play, engineering and fabrication challenges and a rush against the clock. How it all happened is described in the following chapters, based on a mix of documentation and memory.

Figure 1 Viking Piper leaving Schiedam, 1975

2. How it all started

The discovery of natural gas near Slochteren, The Netherlands, in 1959 had far fetching consequences in many respects, such as economy, industry, social conditions. It also triggered exploration of the North Sea, leading to discoveries of gas and oil reservoirs from 1965 onwards[1].
The Dutch government desired to bring the Groningen gas to the market quickly, because general believe was, that nuclear power would soon become the major source of (electric) energy supply. For gas transportation and sales the NV Nederlandse Gasunie was formed as a joint venture of NAM and the State. Immediately Gasunie embarked on the task of building a feeder pipeline system to transport the Groningen gas to all of The Netherlands and to export points at the borders with Germany and Belgium. Because know-how in this area was scarce in Holland, Bechtel from the USA was engaged for design engineering of the pipelines. Bechtel was well known to Shell: in the mid-1960s, Shell Oil awarded Bechtel a $1 million contract to develop new pipelay methods and techniques. The Bechtel study identified, amongst others, the potential for deeper water laying of the semisubmersible hull form and the J-lay method.[2] Bechtel established a Dutch office in The Hague and brought in staff from the USA, among them Robert (Bob) J. Brown.

Bob Brown, born in Ashtabuta, Ohio, on February 17, 1928, obtained a masters degree in civil engineering in 1963. Before 1963 he had worked already for Tennessee Gas in the actual construction of a pipeline and with his degree he joined Bechtel[3]. When in 1969 Single Buoy Moorings (SBM) wanted to offer an SBM installation cum pipeline to a potential Turkish client, Robert Smulders, at that time SBM president, invited Bechtel to join him on a trip to Turkey and to provide the pipeline know how. Bechtel sent Bob Brown together with George Hinkle and a third person. Robert Smulders and Robert Brown became friends during that trip, and conceived the idea of a pipeline design consultant firm within the IHC group. It so happened: IHC became the majority shareholder with 50% of the shares and RJBA (RJ Brown and Associates) was started as an operating company of the Offshore Division under Piet Verschure. RJBA was located in the “Goldfinger” building at the Marconiplein in Rotterdam, where also SBM Inc and the board of IHC had their offices.

First oil in the Norwegian sector of the North Sea was discovered at Ekofisk, in 1969. Others followed soon. To insiders it was obvious that sea bottom pipelines would have to be constructed and that the typical Gulf of Mexico laybarges owned by Brown & Root were less than ideal to work in the North Sea environment. An example: in January 1971 B&Rs laybarge H.W. Gordon started installation work at Ekofisk, and encountered a very severe storm. It was blown off its moorings and picked up by tugs just in front of the Norwegian coast[4].
Moreover the water depth capacity of existing laybarges was insufficient for a crossing of the Norwegian trench, which was around 360 metres deep in between the newly discovered reservoirs and the most nearby coast. So the idea of designing a large deep water pipelay vessel that should work in North Sea conditions was kind of logical. We do not know whether it was Bob Brown or one of his associates or somebody else who came up with it. Certain is, that Bob Brown met with Piet Verschure on October 1, 1971[5] and that this meeting resulted in a proposal for a study of a novel pipelaying vessel submitted by RJBA to IHC on 15-10-1971. On 29-11-1971 Gusto ordered this study to be executed. Bob Brown presented his ideas in a meeting on 19-1-1972 and this led to the order to perform a phase 1 engineering design of what was called the 3rd generation lay barge dated 5-4-1972.
On 4-9-1972 the idea was advanced enough for a combination of IHC Holland and Heerema Engineering Services (HES) to sign an order to IHC Gusto (appendix 3) for preparing a naval architectural design. The

[1] West Sole discovery by BP in the British sector of the southern North Sea, 17 September 1965
[2] W.J. Timmermans “A pipeline retrospective”, keynote speech at the Offshore Pipeline Technology Conference in Oslo, Norway, in 2000.
[3] Upstream, 20 December 2013
[4] “Offshore Pioneers” by Josef Pratt et al,ISBN 0-88415-138-7, page 229
[5] Memo T. Braaksma to R. Smulders, 10-8-1973, in GustoMSC archive.

basic size and shape of the vessel as well as the pipelay equipment had been defined by RJBA who had also initiated model testing to prove the superior motion characteristics of a semisub as compared to a flat barge. The first series of tests with 1:46 scale models was committed to the NSMB on 15-5-1972, after somewhat earlier computer calculation of the motions had been discussed with the NSMB by Gusto's Jan Suyderhoud and Hans Peereboom. The model tests encompassed the comparison of a catamaran type and a semi-submersible type pipelayer. Not surprisingly, the semisub appeared to promise a much better workability than two tankers welded together in a catamaran arrangement. In 1973, Viking Jersey Equipment Ltd ordered further model tests with a 1:30 scale model of the semisub only.

The appearance of Heerema in the joint venture, which was initially called Viking Offshore Pipeline Contractors i.o. ("in oprichting", legal term for a corporation being formed), was far from coincidental. Pieter Heerema had placed orders for large offshore cranes at IHC Gusto since 1969 (first was the Challenger crane). He can be seen as a guest on the Pelican movie of the launching ceremony, in August 1971. His relation with Piet Verschure was good; the Gusto yard management was somewhat careful, inter alia because Heerema was not paying the Gusto bills early 1972[6]. Indeed, Pieter Schelte Heerema overstretched his financial capacities in 1972 and in December had to make a deal with IHC, in which IHC took over 45% of the HES ownership and paid Heerema in IHC shares. The deal was kept secret, but even so Heerema was unhappy with his loss of independence and when an opportunity arose to mortgage the Champion on the London market, he bought off IHC and quickly recovered from his financial woes[7].

Heerema was an entrepreneur and interested to extend his offshore construction work to pipe laying. So he reacted positively, when Piet Verschure approached him with the proposal to partner in a pipe laying venture. Early 1972 there have been meetings between Heerema and Gusto to discuss the extreme wave conditions of the North Sea in view of model testing. By the time Viking Offshore Pipeline Contractors i.o. involved Gusto (actually the Product Development Department, Prodo) for design work, RJBA had embraced the double jointing system (which was first employed on the ETPM 1601 in 1974) as well as the stern ramp idea and had executed a series of model tests at the NSMB (later Marin) in Wageningen, as already mentioned above. The idea of the 3rd Generation Lay Barge, 3GLB, had been born and already started to move towards realisation.

[6] Memo R. Smulders to P. Verschure, 29-2-1972, GustoMSC archive.

[7] Een eigen koers, 50 jaar Heerema Marine Contractors, page 55; email Robert Smulders to Suyderhoud et al 27-12-2017

3. Conceptual and Initial Design

Summary: in 1972 a two phase feasibility study for a semi-submersible pipelaying vessel, called 3GLB (3rd generation lay barge) was performed by RJBA jointly with IHC Gusto's Product Development Department and in cooperation with Bureau Veritas of Paris. The positive outcome led to a building contract first dated 1 November 1972, given by a group of European investors, together Viking Jersey Inc., to the IHC Gusto yard. During three months the yard established a multi-disciplinary project team to perform the initial design. After that all relevant departments could continue the work based upon this initial design. That work included preparation of steel and other drawings, ordering steel and equipment and subcontracting major parts of the vessel.

In August 1973, Bart-Jan Groeneveld at the Gusto Prodo department made a revision of the original Provisional Design of the Third Generation Lay Barge, which had been laid down in a report dated 25 August 1972. The 1972 report is still present in the files of CO 928 in the GustoMSC archive but its contents have been superseded by the 1973 revision. The following quote is from the introduction of the revised report:

> The basic criteria for design, therefore, are to lay large diameter pipe more rapidly, in deeper water, and during more severe weather conditions than is possible with the original and improved concepts for pipe laying vessels.
> For these reasons, the Third Generation Lay Barge is indeed a new generation lay barge. The requirement for such a barge, however, is in the immediate future. Consequently all equipment which compromises it, while perhaps having to be extrapolated from the state-of-the-art, will be utilized from proved methods and techniques. *(original text, not corrected).*

These basic criteria are inseparable: high workability is achieved with the semi-submersible shape, which is known to be expensive and therefore should lay pipe faster (double jointing, long mooring lines) and in deeper water (stern ramp, powerful pipe tensioner, long mooring lines) than flat top barges can do. In 1972 dynamic positioning was not yet considered as a feasible alternative to a conventional mooring spread and actually, thrusters available on the market were too small for this application.
While the 1973 revision was being made, the production of construction drawings was well underway and it was clear that some of the original design criteria could not be achieved. An example is the deckload capacity for pipe joints. The original design requirement was 10 000 metric tons, a somewhat arbitrary number that was based on the requirement that the 3GLB should be capable to lay pipe in wave conditions which prohibit pipe supply to the barge and continue to do this for some days[8]. After the initial detail design had started on 1-11-1972, it soon appeared that this number was not feasible in combination with modifications requested by Viking. On 27-12-1972 Charles Bell on behalf of Viking accepted a reduction to 9650 tonnes related to a modification of deck equipment. Further reductions were related to the design reviews by ODI and ABSTech on behalf of Viking and mostly to taking the survival loading condition into account[9]. They ultimately resulted in a safe deckload capacity of 7000 tonnes (ref Viking Piper brochure). The revised Provisional Design however still mentions the original criteria, which were as follows :

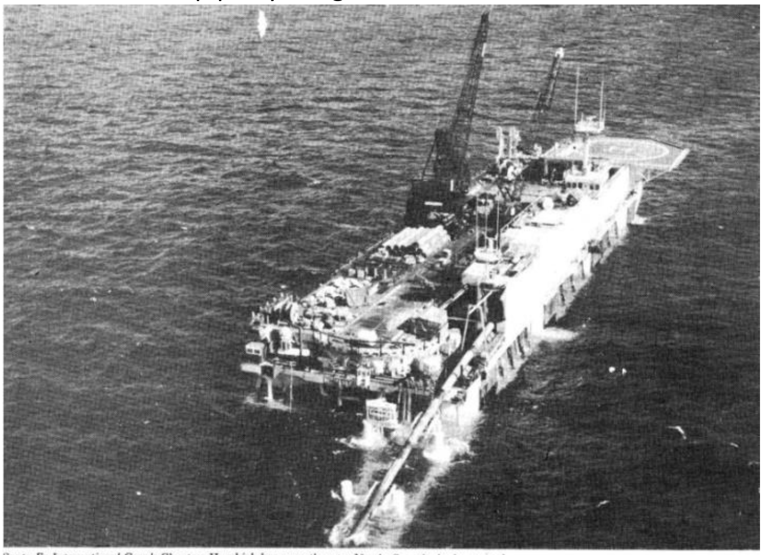
▪ Max. pipe load in storage and process at a draught of 20 m.	10 000 tonnes
▪ Pipe size belonging to max. deck load	OD 36" WT 0.625" Concrete coating 4"
▪ Max. laying depth	1200 ft
▪ Max. working conditions	waves 15 ft max, with a max. period of 9 sec; current 1.5 kt; wind 30 kn
▪ Extreme weather conditions	wind 135 kn; H1/3 = 50 ft; Tm = 14.5 sec; max. wave height 95 ft

[8] The basic requirement was storage capacity for 6 km of 36" pipe, see note by Charles R. Bell dated 24 August 1972, attachment to the Braaksma memo mentioned in footnote 5.
[9] RJBA acknowledged that the survival condition had not been taken into account and advised to dump pipes over board in preparation of survival. In the Gulf of Mexico this was normal practice, but Viking and Gusto both felt that it would be unacceptable in the North Sea.

- Allowable static heel — 3 degrees under 60 mph wind, 1.5 kn current with 40 t hanging in cranes at 16 m outboard
- Dynamic stability — according Bureau Veritas rules for floating platforms
- Accommodation — 300 persons
- Anchoring system — 14 winches

These criteria do not by themselves dictate the application of a semi-submersible hull shape. Nevertheless the idea that the North Sea was in need of a semisub pipe laying barge had been in Bob Brown's mind from the early days of RJBA. A semi-submersible vessel would make possible the application of a new stinger concept, for which the name stinger itself appeared inappropriate. RJBA had designed a conventional pipe lay barge for the Caspian Sea, the Suleyman Vezirov (built by Gusto), which differed from the US Gulf of Mexico designs in its stinger attachment to the barge. The conventional arrangement was a hinge connection, but for the Vezirov RJBA proposed a rigid connection[10]. Structurally, that is quite a challenge on a barge with a depth of the hull of only 7 m. But for pipe laying and stresses in the pipe the rigid connection had advantages, so it was implemented. RJBA wanted a rigid connection on the North Sea design too and came up with the Moment Limiting Guide or Stern Ramp, with attachment to the barge on floater level and deck level, a separation of around 25 meters in a large semi-submersible design. And of course a semi-submersible hull promised a larger, maybe much larger workability in the North Sea environment than the flat rectangular barges which were standard in the Gulf of Mexico, the Persian Gulf, the waters around Borneo, shortly in all offshore regions of the world in 1970. One exception existed: the Choctaw I, built for Santa Fe in 1969 by van der Giessen-de Noord in The Netherlands. The design requirements for Choctaw I required it to pass through the Panama canal, thus limiting its width and its static stability. IHC Gusto had supplied the 800 tons revolving offshore crane for Choctaw I (CO 726) and was well aware of the vessel's shape, dimensions and structural details; Bart Boon had visited the vessel in Amsterdam. Esso Production Research (EPR) had gathered pipe stress data during laying operations in Bass Strait (Australia) with both a conventional pipelay barge and the Choctaw I.[11] The better workability of a semi-submersible was beyond doubt. The success of Choctaw as a construction vessel was limited, because at semi-submersible draft its stability was insufficient for heavy lifting operations. Nevertheless a copy without the large crane was built by Blohm+Voss in 1974: Choctaw 2.

There was a further advantage in the large semisub shape. Conventional lay barges had their launching ramp and stinger on the side of the barge, partially because they combined derrick barge services with pipe laying. On a dedicated large lay barge it would make sense to arrange the fireline[12] at the vessel's centerline, minimizing the effect of roll on pipe stresses. This would exclude the possibility of abandoning or recovering the pipe over the side of the vessel, but placing a large abandonment and recovery (A&R) winch could solve that problem.



Santa Fe International Corp's Choctaw II, which has recently set a North Sea pipelaying record.
http://www.kombuispraat.com/viewtopic.php?f=1&t=694&start=1120

Figure 2 Choctaw 2, which is identical to Choctaw 1

It is not quite clear whether it was RJBA or Gusto Prodo, who drafted a semi-submersible vessel with flat panels in floaters and columns. Nevertheless, this was revolutionary. Drilling semi-submersibles up to 1975 were invariably designed with circular column cross sections and mostly circular or shaped

[10] Offshore Platforms and Pipelining 1976, ISBN 0 87814-069-7 page 133
[11] Offshore Platforms and Pipelining 1976, ISBN 0 87814-069-7 page 93
[12] Fireline is the term for the welding corridor on the vessel. The stinger or stern ramp is in line with it.

floaters. The first semi-submersible was a floating submersible, typically designed by civil engineers with Morison's equation for wave forces[13] in the back of their mind. All following designs concentrated on optimization of motions by fine tuning the floater shape and column positions, but before the 3GLB no square floaters or columns were applied. The rationale for going square is clear: flat panel construction provides for cheaper fabrication and easier connection of columns to floaters and work deck. It is no surprise, therefore, that subsequent designs by Gusto and MSC were applying completely or mostly flat panel construction: Narwhal, Hermod, Balder, Smit Semi's and the DSS series of drilling units.
So, a semi-submersible hull shape was adopted and the Provisional Design continues to detail a number of aspects:

Work deck layout dimensions
The work deck dimensions of the Third Generation Lay Barge (i.e. overall length and width) were derived from several considerations. The first was that the length of the barge should be such that double joints of pipe (80 feet nominal length) could be laid off each time the barge moves along the pipeline route. The advantage is that the daily production of pipe laid is virtually doubled over that of the conventional lay barge which lays off only 40 feet with each barge movement.
This high rate was necessary since the daily cost of a Semi-Submersible was anticipated to be higher than the conventional lay barge. So to make the Semi-Submersible more economical on the basis of unit length of pipe installed, the laying rate should be greater.
In laying out 80 feet joint lengths along the production line and after optimizing the procedure for pipe make-up, welding, inspection and applying the field joint material, the number of stations required for such a production line demands a length of almost 500 feet. The balance of the barge length which is necessary for operating of the vessel, including room at the ends of the barge deck for stowing anchors during tow and other such considerations resulted in the overall length of 500 feet or 152.5 meters.

Next, the width was considered. The first problem studied concerned the supply of pipe to the lay barge. Pipe is normally supplied in 40 feet nominal lengths. Although the supply of pipe in 80 feet nominal lengths is considered feasible, it is not very practicable from the standpoint of pipe handling, transport and unloading.
Double jointing of pipe on the barge was therefore indicated. Welding of pipe in double jointing essentially requires a duplication of the equipment used for welding the pipe together on the launchway. Specifically, beveling, line-up, stringer bead and hot pass welding, filler welding and cap welding are all requirements within the doub1e jointing area. A certain amount of deck area must therefore be provided for the double jointing operation.

It was then noted that although the Third Generation Lay Barge is capable of laying pipe in much higher sea states than a conventional lay barge, the supply of pipe by conventional means remained a problem. Although sophisticated systems of unloading pipe from conventional supply vessels and perhaps even a new generation of supply vessels could be considered, it was felt that no pipe supply system was likely to be developed that would match the weather laying capability of the Third Generation Lay Barge. It was concluded that a certain minimum storage of pipe aboard the lay barge itself would be necessary to bridge the periods during which supply was not possible but laying of pipe was still possible. It should be noted that conventional lay barges have very little storage of pipe on board since the limiting weather conditions at which supply of pipe becomes impossible are about the same limiting weather conditions at which laying becomes impossible.
Therefore there is no requirement for pipe storage on conventional barges.
Arbitrarily, 6 km pipe length storage of 36" OD pipe was chosen as a basis for a study of recorded weather conditions in the North Sea. The down time due to lack of pipe supply with only 6 km of storage was compared with down time due to lack of pipe supply for only 3 km of storage and also for 12 km of storage. It was found that doubling the storage capacity aboard the Third Generation Lay Barge improved the total working time per season only to the extent of less than two days. When only 3 km of storage were available approximately 15 days were lost during a working season due to lack of pipe supply.
The requirements in terms of hull size to gain stability for providing 12 km of storage were considered to be much too extensive for the benefit realized. When it is also noted that 6 km of 36 inch OD pipe storage

[13] Morison, O'Brien, Johnson and Schaaf : The force exerted by surface waves on piles, Petroleum Transactions of AIME (1950)

is the equivalent of 15 km of 24 inch OD pipe storage, then there is no question that the selected storage capacity is an optimum.

Now the beam could be fixed. The deck area for pipe storage coupled with the area needed for storage of field joint materials, a conveyor system for pipe handling and transport aboard the barge, the launchway operations and double jointing area required a minimum beam of 160 feet or approximately 50 meters.

Subsequently a model was built and tested at NSMB in Wageningen and the motions of the vessel with those preliminary dimensions were analyzed. It was concluded that certain motions including pitch and surge could be improved by placing the columns farther out from the longitudinal center of the barge. A computer run with wider placed columns was made based on the model test runs and this resulted in satisfactory results for the critical motions of the barge. As the columns were now wider placed, the superstructure had to be increased in width for structural support.

Stinger or Moment Limiting Guide.

The Moment Limiting Guide is a typical deviation from the method used by present-day pipe lay barges for supporting the pipe from the lay barge to the ocean bottom. In deep water, auxiliary support of the pipe span becomes necessary to avoid local buckling of the pipe in the sagbend portion of the S curve leading from the end of the lay barge to the sea floor. The first approach used by contractors to avoid this pipe failure was to utilize what became to be known as a "stinger" .

The stinger is simply a very long pontoon attached to the stern of the lay barge with suitable compartmentation and control of buoyancy along its length to support the pipe until it is near the sea floor.

The geometry of the solution, however, requires that in only 300 feet of water the length of a stinger is

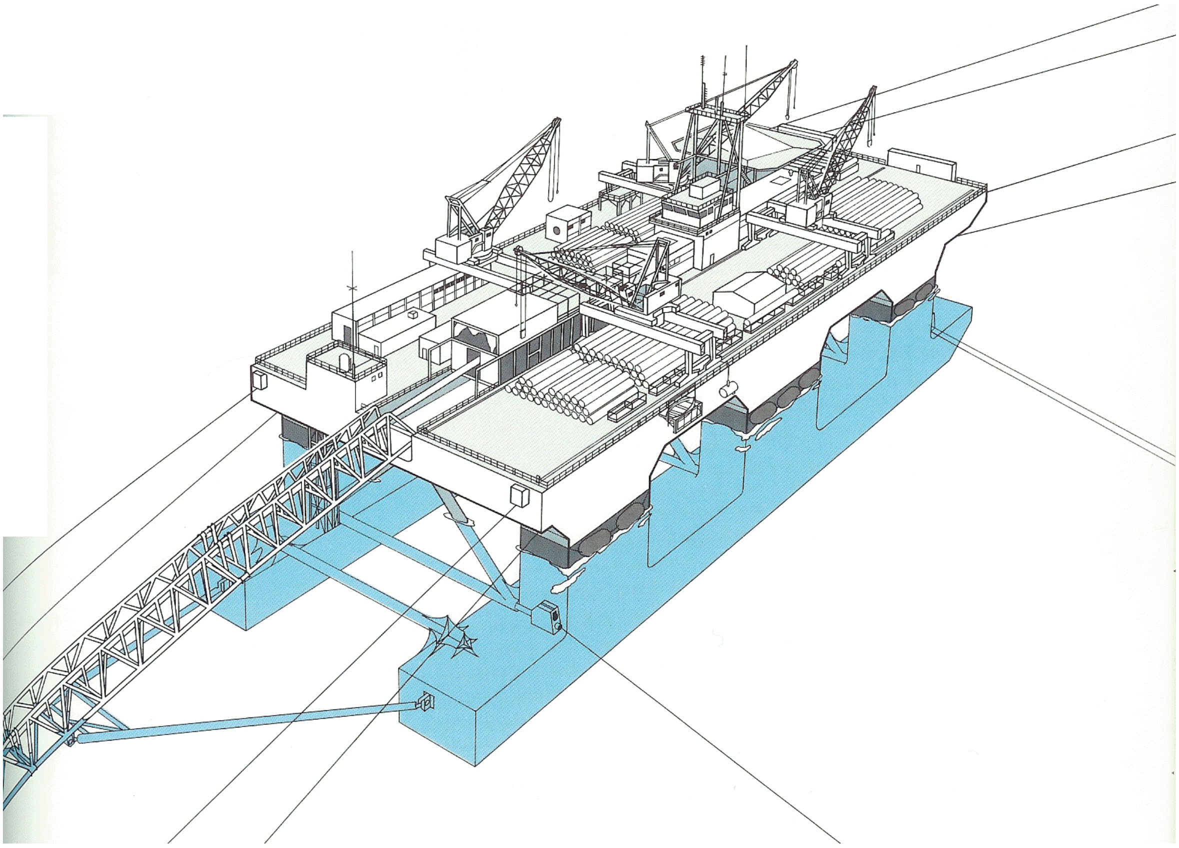


Figure 3 The Third Generation Lay Barge

approximately 1000 feet or about three times the length of the barge itself. In a heavy sea, the dynamic forces of current and waves acting on the stinger very often cause a failure at the point where the stinger is connected to the lay barge, usually termed the "stinger hitch". At other times, these dynamic forces cause a failure along the stinger length itself because of the whipping action induced by motions of the lay barge. In attempting to alleviate this problem, contractors found that the length of the stinger could be shortened by continuously tensioning the pipe during the laying operation. This pre-tensioning allows the

compressive stresses associated with local buckling in the sagbend to be offset, permitting a shorter radius of curvature
in the sagbend before local buckling occurs, but this too has its limitations. Firstly, there is a certain level above which the pipe can no longer be pre-tensioned due to dangerously high overbend stresses and, secondly, a minimum stinger length still has to be handled.
In both of the above cases, severe weather conditions still requires that the stinger is abandoned shortly after pipe is abandoned, since the stinger is not a permanent part of the lay barge and by its nature practically never can become part of it. This has proved to be a serious disadvantage since when the severe weather abates, much time is consumed during good laying weather conditions in recovering the stinger and placing the pipeline back into its supports. In an area such as the North Sea, where there are frequent summer storms of significant severity but of short duration, the contractors have found themselves using up their good weather for recovery from the storm only to be once more shut down because of another oncoming summer storm.
These various aspects of the problem, then, have generated the concept which is used for the Third Generation Lay Barge and is referred to as the Moment Limiting Guide (MLG).
Its features are that

- The overall height of the semi-submersible hull allows for a high separation of the attachment points to the barge. A radius of curvature beginning with the bottom of pipe horizontal on the top deck of the semi-submersible can be traced out from the end of the upper deck of the barge down to the lower chord member of the MLG in the vertical plane, which maximizes the angle of departure of the pipe. Since this is the case, the overbend is rigidly controlled and stresses in the overbend can be permitted up to 85 to 90 percent of yield. This maximizing of pretension in the pipe further minimizes the buckling stresses in the sagbend.

- Since the MLG has widely separated points of attachment to the semi-submersible, a much higher strength connection to the barge is possible and the MLG becomes part of the lay barge itself, never to be abandoned.

The design of the Moment Limiting Guide is progressing and the initial computer runs have commenced. Three separate configurations are being considered. The alternatives which present themselves stem from the fact that there is merit in minimizing the number of members below water, thereby minimizing the dynamic forces acting on that part of the MLG below water. 0n the opposite hand, this maximizes the weight of the members above water which increases the static load on the stinger. A compromise between the two extremes will constitute the optimization of the MLG design.

The Revised Provisional Design report continues to discuss the initial shape and final main dimensions, the weight estimates and the naval architectural features of the vessel such as motions in seaway and stability. It is noteworthy that the rectangular cross section of the columns is based on the desire to bring the water plane area as far outward as possible, without extending beyond the contour of the work deck. This would have given problems with the supply of pipes to the vessel. So the best column shape was rectangular, with the longest dimension in longitudinal direction and the outer side flush with the work deck side. Likewise, the rectangular rather than circular shape of the floaters is based on the argument, that the rectangular shape will have a larger hydrodynamic, “added” mass and result in longer natural periods of heave and pitch, and consequently better motion behavior.

The ultimate main dimensions in this Revised Provisional Design report are those of drawing 267.370 :

- Length of work deck 152.50 m
- Overall vessel length 167.50 m
- Length including stern ramp 248.50 m
- Beam 58.50 m
- Depth of the upper hull 5.95 m
- Column height 19.00 m
- Depth keel to work deck 33.20 m
- Floater dimensions 162 x 13.50 x 8.25 m
- Operating draft 20.00 m

- Survival draft 13.00 m
- Transit draft 8.00 m
- Operating displacement 50 540 tonnes (brochure: 50 717 tonnes)

Based on this initial design a General Arrangement Plan was drawn, drawing number 4820-001 and a specification was written. Its first edition is dated September 15, 1972 : project number O.42999. The specification counted 93 pages and was not very detailed, certainly not against the standards of the 21st century. Revision C dated October 30, 1972, was the basis of the construction contract, which was dated also on October 30, but took some time to be fixed and finalized. The contract was based on a fixed price offer made to Viking, in the amount of Dfl 133.6 million plus a provision of 30.4 million for adjustable and target prices. Clearly Gusto received this order free of any competition. The contract price included an expected profit of just over Dfl 9 million.

A matter which was not apparent in the Provisional Design Report was the complete lack of experience of the Gusto yard in semi-submersible design or construction. The only knowledge available in the yard was the experience in designing other offshore vessels such as jack-ups and drillships. And of course what was taught about ships and engineering mechanics at university.
Gusto used hap-hazard opportunities to train their young engineers. In this context Bart Boon was sent to a one-week introductory course in offshore engineering given at the University of Berkeley. Although given before the Viking Piper contract, it showed similarities and differences between ship strength courses and structural strength of offshore units. Splitting loads and racking were not normally considered for ships, but governing in semi-submersibles. This fresh knowledge even in its condensed form, assisted tremendously in the later design of Viking Piper.
The classification society involved, Bureau Veritas, as well had very limited experience with semi-submersibles and certainly no rules. Actually the number of published design rules in existence was very small, mainly a small booklet published by ABS.
Both yard and class, who performed the early global structural analysis of the vessel with a finite plate element analysis, had no other choice than to use an approach from first principles. In a number of cases applicable existing rules could be used, for instance in determination of the thickness of plates subjected to lateral water pressure. When a plate would perform a global and a local strength role, those were analysed separately and not in combination (as became common practice in the 1990s).

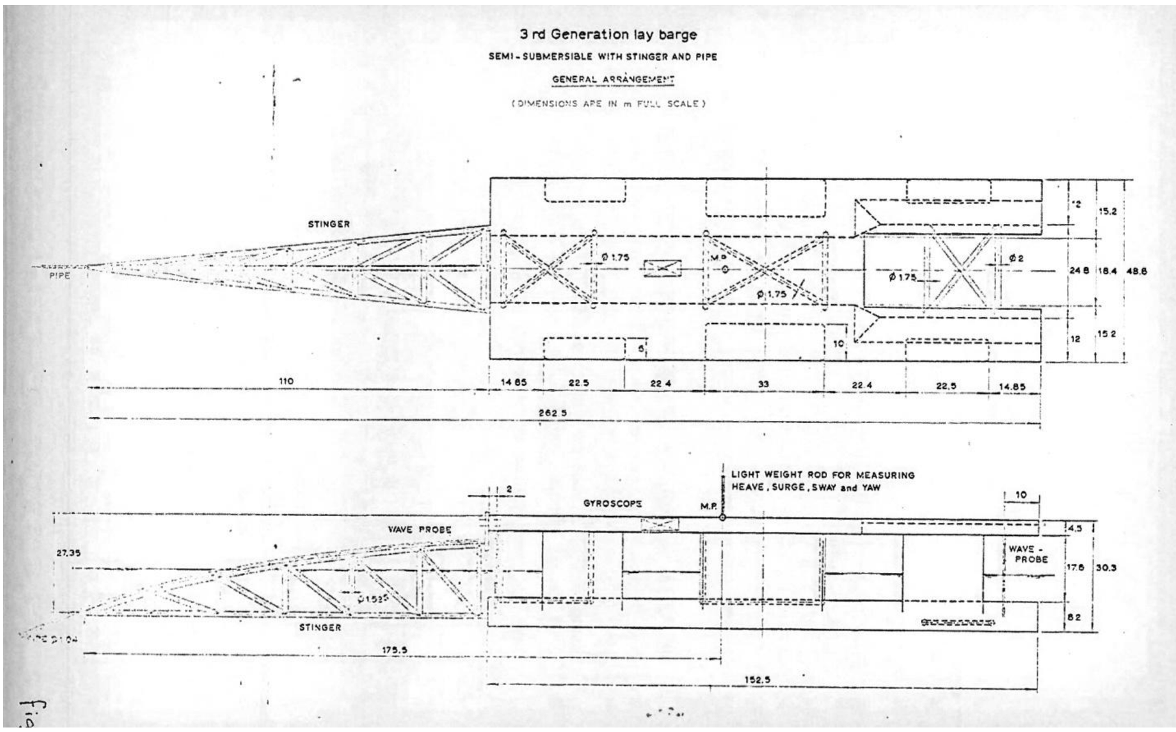


Figure 4 The lay-out of the provisional design

Anecdotes

As stated at the beginning of this section, the revision of the provisional design was made in August 1973, halfway the originally offered delivery time. Reason to make the revision probably was a formalization of the determination of main dimensions and structural aspects, because by that time the Viking staff was challenging many items of the design, see following chapters. The other reason may have been the formalization of the construction contract on 23-8-1973, which had to do with the loan facility for Viking, also concluded on 23-8-1973.

The depth of the upper hull was originally chosen to be 6 m. This appeared to conflict with a total depth of 33.2 m. Either the total depth would have to be increased by 5 cm or the upper hull should be reduced in depth by this amount. The latter solution lowered the work deck and thus the pipe storage, benefitting the total amount of pipes to be stored. Thus it was decided to adopt this solution.

In the early days of the contract, new wishes and reconsiderations of Viking resulted in modifications and changes of equipment to be purchased. One of them was the change from 9 Werkspoor diesels as included in the Gusto specification to 8 MAN diesel generators sets, requested by Piet Heerema by telex to the then project manager George Lagers (22-12-1972). The purchase order to Werkspoor had to be canceled, and Heerema simply moved that problem to the Viking Executive Committee.

4. The Contract

By letter of October 31, 1972, IHC Inter S.A. and Heerema Engineering Services B.V., represented by Guus (AHM) Smulders and Piet Heerema, placed a firm order for the design, construction and delivery of a semi-submersible, non self propelled pipelaying vessel with IHC Gusto. Viking Jersey Equipment Ltd was still in the process of formation. On November 1, 1972, the contract was signed by Viking Jersey Equipment Ltd, represented by A.H.M. Smulders and P.S. Heerema, and IHC Gusto BV, represented by Robert Smulders. It called for delivery of the pipe lay barge on 1-5-1974, or a delivery time of 18 months. In hindsight this was simply impossible. At the time the yard and the drawing offices were well occupied.
The contract was made in haste, already on 22 February 1973 it was superseded by a new agreement effective 1-11-1972. This agreement was essentially identical to the original one but this time Viking Jersey Equipment Ltd. had come into existence and was represented by its shareholders at that moment: Messrs Heerema, Smit (IHC), Gammell, Berthon (Spie-Batignolles SA), Astrup (Fearnley and Eger) and Hay (North Sea Assets or Bank of Scotland).

Viking needed project financing, for which Morgan Trust was involved. They required another review of the contract. A new, final version of the contract was signed on August 23, 1973, so almost 10 months into the building project. This contract encompasses 20 pages of text, plus two single page addenda. The last paragraph of the contract specifies that it is considered to have become valid and effective as off 1st November 1972. The contract price consisted of a fixed amount of Dfl 133 636 000 plus Adjustable (Dfl 20 991 000) and Target Prices (Dfl 9 364 000) bringing the Contract Price to Dfl 163 991 000 . The contractual delivery date was the 1st July, 1974. To insiders it must have been quite clear that this original delivery date would not be met. Viking would receive liquidated damage compensation for late delivery after a grace period of 28 days. The amount of Dfl 35 000 per day was limited to a maximum of 2½ % of the contract price, or Dfl 3.34 million. The actual hand-over of the vessel took place on 21 May 1975.

The loan facility which had been obtained from Morgan Guarantee Trust Company in New York, amounted to 66 million dollar. The loan agreement was also dated on 23 August 1973. At that point in time the project had been ongoing for more than 9 months and all major components of the vessel had been ordered. Morgan Guarantee Trust required additional comfort on seaworthiness. To this end, Viking Jersey Equipment Limited initiated in June 1973 a review of the basic design by ABS Worldwide Technical Services (ABSTECH) and Offshore Design International (ODI) of New Orleans.

On January 17 and 18, 1974, a meeting was held at the Bureau Veritas Office in Paris, in which the ABSTECH and ODI findings were discussed. On behalf of Gusto, Hans Sjouke, Bart Boon and Rik Homan attended this meeting chaired by Charles Bell. Viking had intended to show a movie of model test waves hitting the underside of the VP deck, but unfortunately for them they had taken the wrong collation of shots to the meeting, and Gusto got away without contractual consequences of this meeting. At the time Gusto estimated that the costs of implementing the requirements of the ABSTECH/ODI review would amount to Dfl 26 million, and that delivery would be delayed by 8 months.

5. Kicking off the project

Late 1972 the Gusto yard was well occupied with the construction of its second DP drillship, Havdrill, the design of the Brent storage spar and an exposed location SBM for Shell. The drafting office had no time to start on the Viking Piper design forthwith but it was clear that not a day could be lost: the contractual delivery time was 1½ year. Therefore a small group was formed, with people from the drafting offices and from Prodo. George Lagers, head of Prodo since 1 April 1972, was appointed project manager for this phase. The team's task was to prepare the basic design so that steel and equipment could be ordered. To avoid interference of the running projects, this task force was taken out of the yard offices and lodged in a house at the Nieuwe Haven, probably number 16. In splendid isolation the task force could advance quickly and did not incur the risk of being locked out of their offices by a yard strike, as had happened a year earlier. The group consisted of around 10 or 15 specialists of all relevant disciplines. Bart Boon, with half a year experience in the yard, was appointed structural specialist based upon his university graduation specialisation. It was matrix project organisation well before this became common in the industry.

Isolation did not mean a complete loss of contact. There were frequent meetings with middle management of the drafting offices and the purchasing department. And of course there were meetings with the client, represented by its president Ed Minor and project manager Charles R. Bell. Until he was recruited by the Viking shareholders in August 1972, L.E. (Ed) Minor had been Vice-President of Brown & Root, a well-established offshore construction and pipe laying company of Houston, Texas. In hindsight one might wonder whether it was big money, that motivated Ed to come over to Viking, or a sort of conspiracy with his B&R friends to keep them informed of and ahead of the Viking moves. Or maybe he was on a side track inside his old company, where he had pioneered offshore pipe laying. Charley Bell was employed by RJBA until he joined Viking and had been working on the 3GLB project. Neither was very conversant with naval architecture. Likewise the Gusto staff had no background in pipe laying equipment.

In February 1973 the Nieuwe Haven team returned to the yard and things were done in the regular way. Or maybe not: Viking had organized itself to some extent and started to challenge design assumptions and equipment choices. While this is a client's good right, the Gusto staff got increasingly frustrated by the apparent Americanism in Viking's wishes to select other equipment suppliers than those proposed by Gusto, the strong preference for American instead of European structural solutions, the lack of decisiveness and the tendency to not approve drawings without further comment. All of this hampered progress on a project of only one and half year. Indeed the delivery ex yard slipped from May 1974 as per contract to May 1975.

Coordination of the work in the yard after dissolving the Nieuwe Haven team was again in accordance with the normal line organisation structure. Office work and fabrication work fell under the engineering deputy director Hans Sjouke and the production deputy director Chiel van Housselt respectively. Within the technical departments (drawing offices under Jan Suyderhoud) a coordinator for the project was appointed, i.e. Bart Jan Groeneveld who before also was involved in the feasibility study as well was member of the Nieuwe Haven team. He got a desk in the Drawing Office Shipbuilding. He shared the office corner with Bart Boon, the structural guru. Obviously steel drawings and class approval were main items in those early days of the draughting phase. Bart Boon, with half a year experience more or less automatically became Bart-Jan's second right hand and remained deeply involved in coordinating the CO 928 (the vessel's name was not yet known) office work.

Much later in the project the line organisation was transformed in a real project organisation.

6. Structural Design

The Gusto yard combined experience in conventional shipbuilding and offshore jacket fabrication. The nodes in the jackets, that Gusto Staalbouw had produced so far, were a lot smaller than the nodes of the bracings sketched in the preliminary design of the 3GLB. Early in the project Bureau Veritas of Paris was chosen as the Classification Society to approve design drawings and calculations and to inspect the construction while it was being erected. BV did more than this:

- starting in the preliminary design phase BV determined the motions in waves, in parallel with the model tests and computations by the NSMB.
- The hydrodynamic and inertial loads following from the motion calculations were applied to a finite element model of the vessel to determine dynamic stresses
- Structural analysis of frames of the vessel was performed
- Extreme stresses and motions were predicted for representative sea states of the North Sea, as well as fatigue loads, which were particularly important for the design of the bracing nodes.

The fact that BV had the computing facilities for finite element analyses and the willingness to cooperate in the design of a novel vessel made them the preferred Class Society in this project.

In regard of fatigue loads it must be noted, that in 1972 fatigue was not a real concern of the shipbuilding community. The perishing of “Alexander Kielland”(27-3-1980) had not yet happened. Acceptable stresses, inclusive of stress concentrations, were chosen to more or less take into account an allowance for fatigue.

In the “Bulletin Technique du Bureau Veritas” of February 1976, a description[14] of the structure is given, of which some sections are used in the following:

Floaters

The floaters were designed with a longitudinal framing system, without a double bottom except in way of the winch and pump rooms where double bottoms and double shells were used with webs at every frame. A longitudinal bulkhead ran the full length of each floater for compartmentation and strength. The steelweight of the floaters alone was approximately 6800 tonnes. Plate thicknesses had to be designed for a keel draft of 20 m and for the relative large head of overflow typical in a semi-submersible floater. For proper foundation of the mooring winches, many of the floors in the double bottom of the winch rooms were attached to the tanktop by full penetration welds.

Columns

The side shell of each column is situated directly in line with the side shell of the supporting floater and likewise the other sides of the each column are in line with the longitudinal and transverse winch room bulkheads inside the floater. The floater deck is continuous. Great care was taken to avoid lamellar tear at the fore and aft column connection to the floater deck. One aspect of this was the interruption of the floater longitudinal frames at the transverse bulkheads under those end columns. As the middle column area was less highly stressed, the continuity of the longitudinal could be retained there, which of course was advantageous in view of the midship bending moment.
All columns were vertically framed and heavily stiffened by stringers and intermediate decks. Their dimensions are 18 m (end columns) or 24m (mid columns) long, 8.25 m wide and 19 m high.

Column and floater corners

The choice of position and shape of the columns was based upon transparency of the vessel side view in order to minimize wave excitation and at the same time optimization of vessel stability in order to

[14] Gladish, C.J. (1976): “Viking Piper; The first of a new generation of pipelaying vessels is classed with Bureau Veritas”, Bulletin Technique du Bureau Veritas, February 1976

maximize the allowable pipe load on the deck. These considerations led to rectangular columns sitting on the outside of the floaters (Figure 5).

Figure 5 Floaters, columns, bracings and upper deck section

This configuration at the same time made it easy to achieve structural continuity by aligning column shell with floater shell and with longitudinal and transverse bulkheads inside the floaters. The orthogonal stiffening system more or less automatically led to square corners for the columns and floaters. In 1973 this was completely new for semi-submersibles. Most had completely round columns and often round floats or at least corners with large radii. The arrangement of *Viking Piper* obviously not only offered optimal structural alignment, but at the same time was cost efficient in fabrication.

From Viking side objections to this solution were made, in particular because they were afraid of corrosion fatigue in such corners. Although such sharp corners underwater indeed were not very common in the offshore industry or shipbuilding, some special vessel types, such as dredgers, had shown that the detail performed completely satisfactory. The fact that the *VP* survived four decades proved this assumption to be completely correct.

Another special feature of *VP* was the lack of any brackets in the transition of columns to floaters (Figure 1). Again it was felt that this was justified in view of the good structural continuity at this point. Although it was recognized that some stress concentration might be caused, for instance in the plane of the outer float and column shell, it was also expected that any bracket in the corner would make the stress transfer between column transverse shell and bulkhead in the floats less effective. Nevertheless at the upper end of the columns large box-type brackets are provided in the transition to the upper pontoon structure. It was recognized that the upper pontoon would be more flexible than the floats in view of its smaller depth (5.95 meters as opposed to 8.25 meters). If brackets were to be provided, they would for that reason be more advantageous at the top end of the column than at the lower end. But the main reason to provide these box brackets was supporting the deck blocks in between the columns during assembly, as long as those blocks were not yet rigidly welded to the blocks above the columns. Figure 5 illustrates this situation.

Objections to this arrangement were raised. It was actually stated that such transition should look like the transition of a bough to a tree trunk; "that is the natural stress flow and thus will provide the most smooth transition". The Gusto designers rejected this strongly with the argument that in trees this concerns the transition of a full 3-D structure, not that of a thin plate arrangement where continuity requirements led to quite different solutions from that found in nature.
Lack of any fatigue cracks at these transitions after nearly forty years proves the correctness of the assumptions made then.
Today extensive finite element analyses replace the partly intuitive understanding of structural behaviour that was the basis of the designs in former days. Rectangular columns and floats are well accepted now. Some rounding of the corners is often applied in view of diminishing somewhat the hydrodynamic forces exerted, safeguarding ropes and wires that now and then may run around the corners and reducing the risk of damage in case of small collisions (both to the semi-submersible as well as to the colliding vessel). The actual transition itself is often fully based upon rectangular structural elements. As a consequence transition pieces must be provided between the part with the square and the part with the rounded corner (Figure 6). Note in Figure 6 that there are only horizontal transverse braces. The presence of two horizontal bracings between the columns in figure 6 means that some amount of redundancy can be provided which is a new requirement in many cases and something that was not taken into account forty years ago.

Figure 6 DSS 21 Maersk Developer

The upper deck

Structurally, the upper deck is a simple box connecting the columns and supported midway by the topboxes of the bracings. It has 5 longitudinal strength bulkheads and seven major transverse bulkheads, which run in line with the column front and stern ends and the bow bracing. There is a double bottom over the full extent of the upper deck which is entirely dry except for dirty oil tanks. All accommodation, offices, stores, workshops and machinery spaces are arranged inside the box structure.

The bracing system

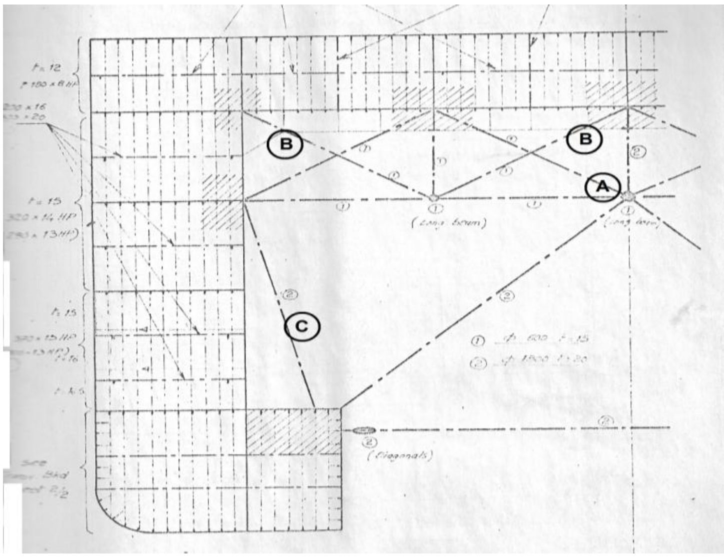


Figure 7 Bracing system in feasibility stage

Structurally, the bracing system was the most challenging part of the VP Construction. It also was the part with which the Gusto yard had no experience other than with the much smaller bracings of jacket for production platforms.
Conventional semi-submersibles consisted of a number of elements such as floats, columns and work areas tied together by a space frame generally consisting of tubulars.
The concept of *VP* was based upon the same idea: large blocks supported by a space frame (Fig. 7). Not visible in this

sketch, a longitudinal horizontal member was foreseen at point A between two cross-sections as shown at the ends of the columns (not between the brace systems in between columns).

At contract signing the diagonal braces B and C already were omitted resulting in a contract brace system as shown in Fig. 8.

During preparation of the preliminary design the longitudinal member at point A of Figure 8 was left out. Considering the force equilibrium at nodal point B in Figure 8 it was concluded that the vertical member at that point necessarily had to be a zero-member and thus could be left out. Thereafter it was concluded that at point A any vertical force from the large diagonal braces would probably be transmitted to the upper pontoon directly through the vertical member at A rather than through the shorter diagonal members at that point. Those members thus were left out. As no role was seen for the horizontal member through A and B that could be left out as well. The result was a final transverse brace lay-out as shown in Figure 9.

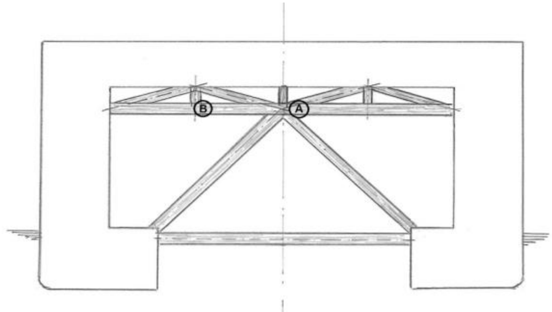


Figure 8 Sketch of bracing system at contract signing

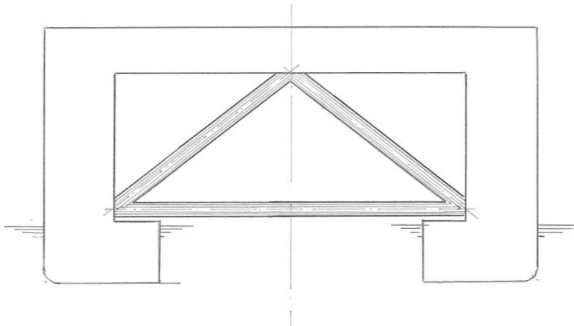


Figure 9 Final transverse bracing layout

On the other hand it was felt that raising the lower horizontal member connecting the two floats offered some advantages. First it would mean that during tow (at a design draught some 0.25 meters less than the depth of the floats) the braces could be above the still water line. This would reduce the resistance during transit. Secondly by doing so all bracing members between two columns could be pre-assembled and lifted by the *Assembler I* as one unit (Fig. 10) making assembly of the vessel easier. During the feasibility study[15] the horizontal braces were laid out as in Figure 11. In the preliminary design stage it was suggested to replace the horizontal X-braces with K-braces. This would make the braces more efficient (a better angle for accommodating any horizontal shear force between the two floats) and result in less complex nodal points. This was rejected by client and management "because everybody knows X's are more efficient than K's". In combination with the transverse bracing lay-out of Figure 9 the diagonal horizontal braces were laid-out as in Figure 12. Note that raising the lowermost braces made the horizontal diagonal braces less efficient due to their direction.


Figure 10 Setting a bracing assembly

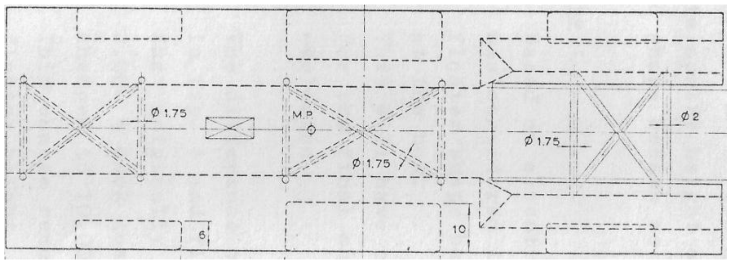


Figure 11 Lay-out of horizontal bracings in the feasibility study

Because in the final stages of the feasibility study the work deck had been shifted forward relative to the floats an additional set of vertical braces and a horizontal one were installed at

[15] B.J. Groeneveld: Revised provisional design Third Generation Lay Barge, Schiedam, 1973

frame 204 (position A in Figure 12; see also Figure 1). At the aft end of the vessel brace B was the last one. The finite element analysis made by Bureau Veritas showed that in a splitting load condition the force in this latter brace was about double of that in all other braces. The transverse deformation of the float in that situation was as sketched in Figure 12. This indicated the necessity to add an extra horizontal brace at the stern of the vessel (position C in Fig. 12). Figure 13 shows the final lay-out. Note that the additional brace is located above the float leading to a rather special attachment node.

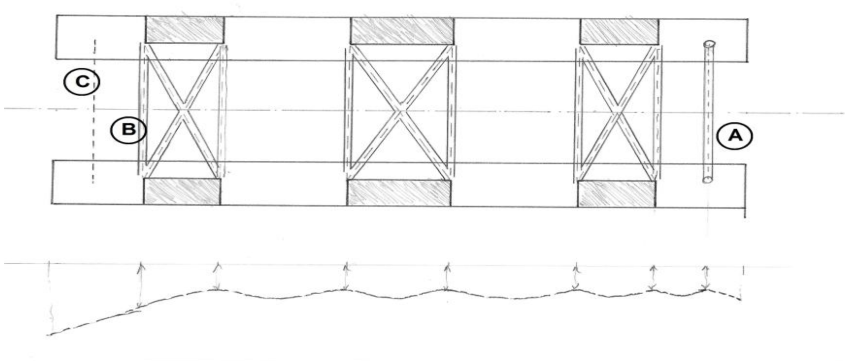


Figure 12 Necessity for an additional transverse bracing at the stern

Today most likely the vessel would have only transverse horizontal braces. That system was developed by Gusto when designing the semi-submersible crane vessels *Balder* and *Hermod* (Figure 14) and later *Micoperi 7000* (now *SAIPEM 7000*). MSC used the system on the *Smit Semi 1* and *2*. Both vertical and horizontal diagonal braces can be done without. The system was developed by Gusto as a further development along the line of thinking originating with *Viking Piper*. It may be seen as an optimum trade-off between integrated box-structures and braces. Today this transverse-braces-only system is quite common in semisub design.

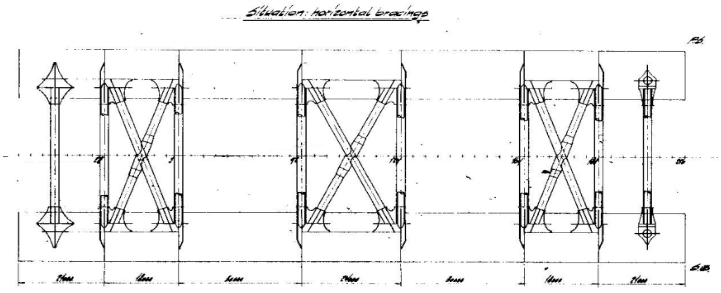


Figure 14 Final lay-out horizontal bracings

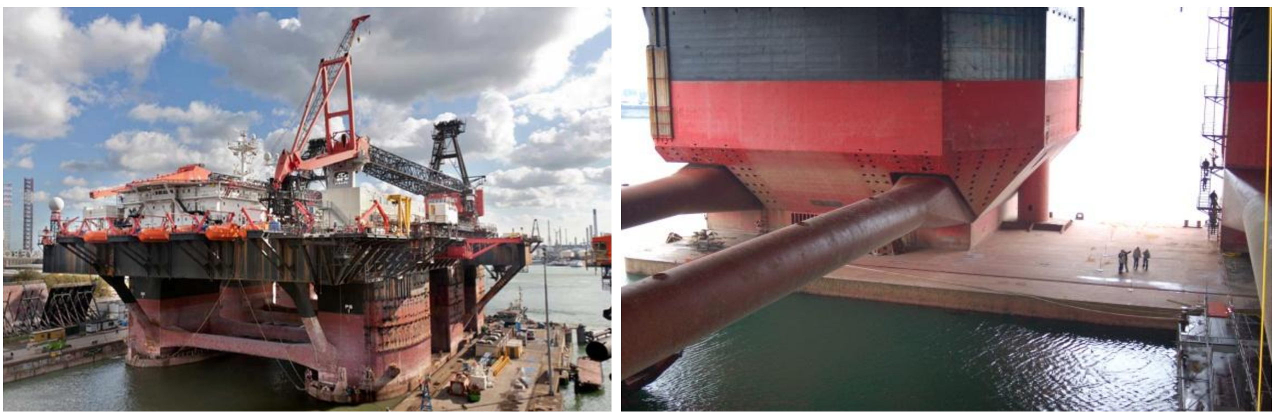
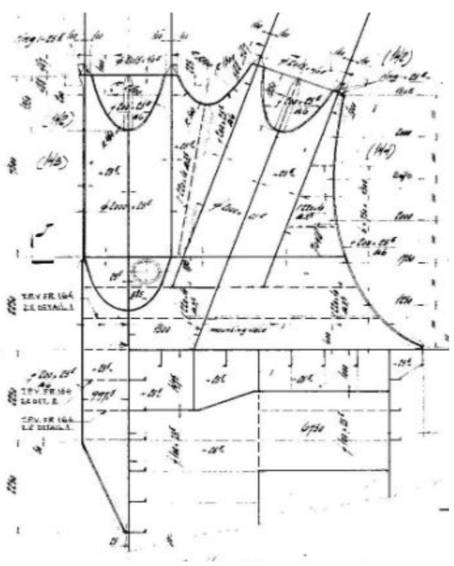


Figure 13 Transverse bracings only on Balder (left; keppelverolme.nl) and Hermod (right; Bart Boon)

Brace nodal points

Like today, also in the 1970s nodal joints of fixed platforms often consisted of tubulars joined together with or without local reinforcements. The larger diameters of braces in semi-submersibles which often were quite different in size (for instance columns and braces) meant that the nodes nearly always consisted of a combination of plates (brackets and gussets) and tubes. The actual structure sometimes was concealed inside the visible part of the tubulars and in other cases visible from the outside.

Given the assembly method of *VP* with units of connected braces (such as in Figure 10) it was clear that it would be beneficial to have the entire nodal points outside the column structure. According to the contract brace lay-out the centre lines of the transverse braces were in line with the end shells of the columns. This automatically led to the choice of large brackets at the centre of the brace tubes. In order to make load transfer to the columns more smooth, it was considered beneficial to have horizontal brackets at the brace tube centre lines as well. General engineering knowledge indicated that very gradual transition from the tube structure to the brackets would make the unavoidable stress concentration as small as possible (Figure 15). For the same reason the end of the brace tubes as well was foreseen with long bracket-like transitions.



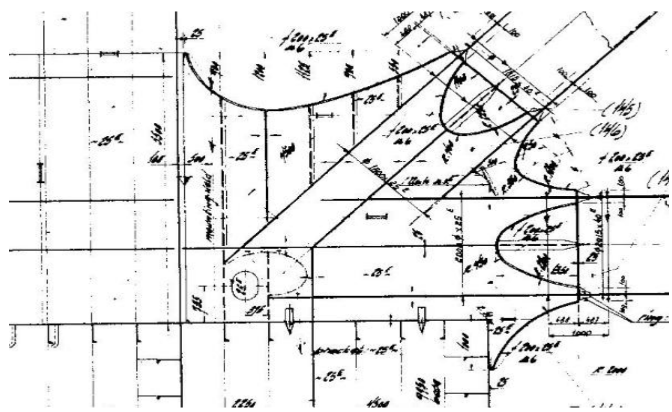


Figure 15 Horizontal section over the bracing center lines

This principle was also applied at the top boxes connecting the braces to the upper pontoon (Figure 16). Even the additional brace at frame 12 was connected to the float in the same way. For the latter it may be wondered whether for instance the horizontal brackets at some 1.5 meters above the float deck fulfilled any function. This was done as well during the design. However, as there was no way to quickly analyse this (see the finite element analysis described hereafter) it was decided that adhering to the same principle in the design was the most secure way to go.

After the concept design for the brace nodes was made, it was decided that it would be worthwhile to analyze one detail using finite elements. This was quite new in those days and had to be performed by an outside company, i.e. KSEPL (Shell) in Rijswijk, Holland. A very detailed analysis confirmed the original design ideas. The analysis was very time consuming and could be made for one node only. Under the assumption that the nominal stress in the brace tubes would be near the allowable, the target of the finite element analysis was to keep any stress concentration factor below 1.3. This factor implicitly was based on fatigue. The calculated

Figure 16 Brace top box in 2012 (Bart Boon)

stresses as such were not directly assessed. Note that the smallest elements in the FEM analysis had dimensions in the order of magnitude of 0.05 meters.

The other nodes had to be based upon the assumption that similar stress concentration factors would apply. It was found that notwithstanding the extreme gradual introduction of the brackets, still some serious stress concentration occurred at the bracket toes. As this meant high stresses at a point of a non-stiffened round plate (a fundamental horror to shipbuilders in view of fatigue initiation) it was decided to provide ring stiffeners on the outside and on the inside of the tubes at the bracket toes. Further FEM analysis still showed quite high stresses, now in bending of those rings. Providing very small triangular brackets in line with the large brackets too away practical all those stresses. Of course those small brackets again ended on an unstiffened plate, but this was considered acceptable in view of their only 15 mm thickness and the fact that they were fillet welded rather than the full penetration of all other welds. The fact that today there is not the slightest indication of any fatigue cracking at these points (Figure 17) shows how effective the original design as.

Figure 17 Nodal points on Castoro 7 in 2012 (Bart Boon)

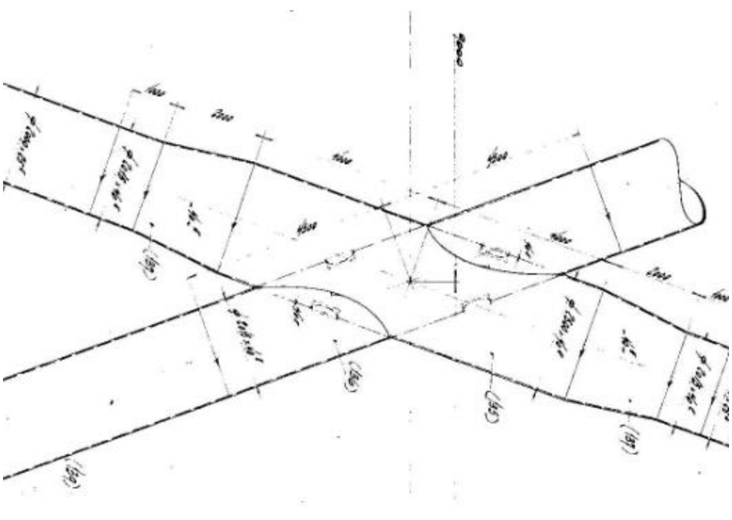


Figure 18 Node at the crossing of horizontal diagonal bracings

The other type of nodal point is the crossing of the two horizontal diagonal braces. The basis for its design was continuity of material. From a practical fabrication point of view this was considered to be impossible with the two braces having the same diameter.

Today probably no longer nodes would be designed with such an amount of external brackets. A transition from tubular to square as in Figure 14 is the more likely design. Yet with the same boundary conditions as during the construction of the *VP* a similar nodal point still might be a very good solution. Easy to use finite element analysis methods allow a much better optimization and adaptation of designs in different locations. This probably would result in some less structural elements and smaller scantlings. However, optimizing for a required fatigue life might easily lead to a solution which accepts higher stress concentrations than the minimization of those that was strived for in the original *VP* design. As a consequence a modern design m ay quite possibly have a shorter fatigue life than the *VP* nodes.

Giving one of the braces a larger diameter connected to the original diameter by conical transitions solved this fabrication problem. Providing locally 40 mm instead of 25 mm thickness reduced all stress concentrations to an very acceptable level.

Steel type

The vessel was constructed from normal strength steel grade A. The only exceptions are the braces and their nodal points. Because in the 1970s some fatigue problems showed up in nodal points of fixed North Sea platforms it was decided to minimise the risk of fatigue. Normal strength steel thus was selected and the best quality of steel available, which meant that grade E was selected both for the brace tubes as well as for the plates in the nodal points. Those steels came from different suppliers.

All welds of the braces and the nodes were fully penetrated as this again was supposed to minimise the risk of fatigue. It was chosen to let the plate material be continuous and the tube material discontinuous (Figure 19). Unfortunately this "best" plate material was found to possess very limited through thickness properties. Extensive lamellar tearing was the result. Proper repair meant gouging out and nearly replacing all plate material in between the tubular material by weld material. Further buttering was applied. And all nodes were heat treated in large protection tents. The latter measure was considered by the specialists to be hardly effective, but management decided that "we must show the client that we did everything within our possession to obtain the best quality possible". Certainly in a costly way finally very good quality for the nodes was achieved.

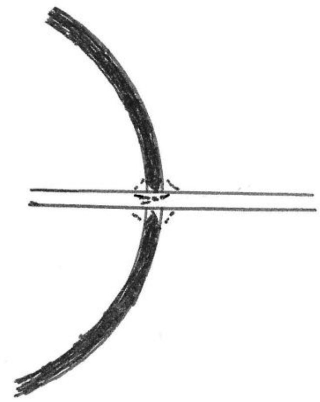


Figure 19 Lamellar tearing under full penetration weld in a bracing node

Note that in this particular case making the tubular material rather than the plate material continuous probably would have been beneficial. But this is due to the coincidental material properties only.

Moreover using fillet welds or partial weld penetration would have reduced the risk of lamellar tearing albeit at an increased risk of fatigue starting from the weld root (which in this case with welds mainly transferring in-line shear loads probably would have been minimal).

Today because of better steel fabrication the risk of lamellar tearing has decreased significantly. Special steel with through-thickness properties, Z-steel, is readily available. That steel contains very little sulfur and phosphor by vacuum-degassing during production. Classification societies give rules for fabrication, testing and marking of such materials. Their application is generally restricted to "structural details subject to strains in the through thickness direction in order to minimize the possibility of lamellar tearing during fabrication"[16]. Many designers interpret this as meaning that Z-steel must be used when there are significant tensile (operational) stresses through the thickness of a plate. The effect of weld shrinkage during fabrication is often underestimated. The material today is better, but it is doubtful whether the design efforts to avoid lamellar tearing are much better than in the 1970s. See appendix 2 for more detail on the lamellar tearing.

[16] ABS Rules for Materials and Welding, Part 2, 2012.

Anecdotes

Inside the node tubular, welds had to be made. Given the size of nodes, gusset plates etcetera, it was nearly impossible for an average Dutchman to perform quality welding inside. Fortunately, thanks to the presence of Ambon people in Holland, good welders could be found who were small enough and willing to do the job.

Bart Boon once showed a photograph of Castoro VII, the former Viking Piper, to his grandsons of 5 and 7 years respectively, and told them that their granddad had helped to build that vessel. Their reaction: "did you do that with LEGO ?"

The heat treatment was costly but satisfied Viking. Shortly before delivery ex yard it was discovered that, invisible at the surface of plating, may meters of lamellar tearing had occurred. After lengthy discussion it was decided to repair some places but to leave most of the lamellar tearing untouched. One year later, while the VP was at Blohm and Voss in Hamburg for repair of the mooring winches, it was found that the tearing had not increased in size. Gusto concluded that apparently there had been no unacceptable risk in letting the vessel depart for the high seas with the (invisible) tearings. Read more in appendix 2.

7. Main Systems

7.1. The Mooring System

In operation, the Viking Piper was maintained on station and maneuvered by a total of 14 steel wire rope mooring lines, see figure 3, each with a diameter of 3 inches. The design of the selected mooring system was based on the assumption that the barge would be adequately moored in wind, waves and current approaching from random directions without exerting a vertical pull on any of the anchors. Breaking strength of the 76 mm anchor lines was 360 ton. Length of the four bow-anchor cables and the two stem cables was 3350 meters each; all breast lines were 2450 m. long. During pipe laying operations, the additional 900 m of bow lines lying on the bottom after the anchors had been set, could be taken up - during vessel advance - before the bow anchors had to be relocated. This situation was more important for work at deep water depth; when working in shallow water, the amount of vessel advance before anchor relocation was necessary, was substantially greater. In combination with the application of double joints the long length of bow and stern lines should result in the relatively high pipe laying rate necessary to compensate for the high investment in the Viking Piper. Moreover repositioning the anchors as the vessel closed in on them was a very risky activity. By moving the anchors far out, the need for repositioning would be reduced, and the vessel could move forward very slowly while paying out the just-welded pipe.
Rated maximum operating tension on the cables was 115 ton; each of the 14 winches had been designed to exert maximum pull at a line speed of 67 m/min. at mean wrap. The winches were installed in the lower hulls of the barge, three on each side beneath the amidships columns and two under each of the four end columns. Cables from the winches were carried through casings inside the individual columns to a sheave in the upper hull; cables then passed through the hull to the fairleads located at the four corners of the barge.

One of the salient features of the mooring system was that tension on each line, and line departure angles at the fairleads, were measured. While this information was required primarily for operation of the automatic winch control system, it was also used in the form of a display to provide the operator with a status report on the total anchoring system. It provided warning of impending alarm conditions as might occur when any of the anchors started to slip. Closed circuit TV was provided to monitor individual equipment since the barge operator in the central control room was unable to physically see the winches and the fairleads.

Several modes of winch operation were available to the barge operator. In one mode, individual winches could be controlled manually from a remote control desk in the central control room. In the group control mode, a group of winches could be controlled by a single action of the operator. Prior to this, the operator had to pre-select the speeds of the individual winches using individual control panels.

The third mode available to the barge operator enabled him to semi-automatically control all winches simultaneously. A single lever only was actuated to move the vessel in a straight line ahead or astern, another lever moved the vessel to port or starboard, while a third lever caused the barge to be rotated around its centre. For this mode of operation, a computer was employed to check the status of the available winches. Normally, two winches were not available because their anchors were being re-located at that particular time. The computer calculated the torque and speed required at the given moment and transmitted this information to the individual winches. This mode of operation relieved the operator of the necessity of re-adjusting line speed settings after each individual or more moves made by the barge.

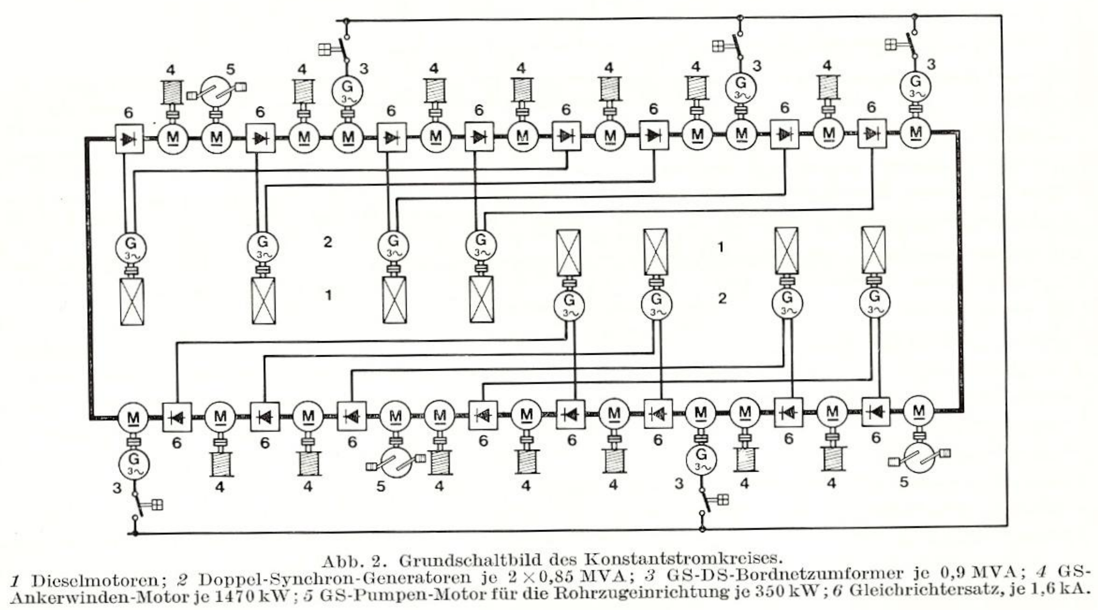
The fourth control mode available to the barge operator was one in which the winches were controlled fully automatically. In the automatic winch control (AWC) mode, the operator initiated a start command; from then on, the computer plotted and executed a cycle of operations which moved the barge forward along the right of way at an optimized speed. At the same time, the computer ensured that the correct line of departure of the pipe from the Stem Ramp was maintained. For the type of operations foreseen for the Viking Piper, automatic winch control was considered as being a significant advantage for two prime reasons:

- in deep water an anchoring system becomes springy, with the result that any procedure for optimum and precise advance will, of necessity, become too intricate to be controlled efficiently by an operator at the desirable high advance speed.
- even without the added complication of deep water, the number of winches to be controlled would impose a great strain on the operator so that it would be most unlikely that the system would be used to the best advantage. This is aggravated by the fact that the operator cannot actually see the fairleads and has to rely on instruments. Result, he would have difficulty in developing 'feeling' .

The automatic winch control system took repeated fixes of the barge position. It then compared the actual with the desired position along the right-of-way and initiated suitable corrective action if this should be required. During both station keeping and vessel advance, the system checked the alignment of the pipe being launched over the stem of the vessel; it initiated corrective measures if required. A further duty was to monitor tension on anchor lines and on the pipeline; the computer also checked the angle of departure of all anchor lines, and read the length of line paid out on individual anchors. It scanned all systems for safe operation and warned the operator should an undesirable situation develop. The whole system was aimed at providing the barge operator with valuable operational backup; it also played a major role in adding to the speed and safety of the total operation. (Ref. OTC paper 2348, 1975)

Gusto had proposed to Viking that it would furnish the 14 winches. Viking however insisted to buy winches from Intercontinental Engineering, a fabricator from Kansas City, Missouri, with a reputation for large winches for mining lifts. Gusto had to accept this but in agreeing to take the winches out of its supply, it declined responsibility for Viking’s choice. The Intercon winches were taller than the IHC proposed winches, which caused some concerns for their fitting into the floaters. In any case, only two instead of three would fit under the midship columns. Therefore a winch room had to be created out of way of the columns. Whatever, 14 winches were ordered in the US on 11 december 1972 for a contract price of $ 3 165 905.
Sometime in 1973 George Lagers visited the Intercon fabrication plant while he was in the USA for other business. The shields of the winch drums were being welded, very impressive. Later, in operation, it appeared that the drum shields were not strong enough to withstand the outward pressure of the anchor wire under tension. Already in July 1975, during testing, the drum shields of 6 winches (nrs 1, 2, 3, 4, 7, 14) showed outward spreading. This outward bending had to be repaired on board and the shields stiffened.

The winches required drive motors which could deliver full torque at zero speed as well as while running forward and backward. Gusto’s electrical power subcontractor, AEG, proposed shunt-wound motors in a constant current ring, whereby 1600 amps DC was running through all motors in series and each individual motor could be controlled by variation of the stator magnetic field. The full power running speed of the electric motors was 1200 rpm. The system seemed to provide a perfect match for the desired winch characteristics at a high efficiency. This was explained to Ed Minor during a meeting in Heerema’s office at the Scheveningseweg in The Hague, sometime early 1973. Ed was not impressed – or did not understand the system – and wanted individual Ward Leonard drives for each of the winches, of course to be supplied from America. The discussion became more and more tense until Piet Heerema said: Ed, you should understand, that the Ward Leonard system has been invented in Europe and that we have progressed since. Ed Minor jumped up, left the room and banged the door shut. And Pieter Heerema grinned and said: so, that has been decided.



Figuur 20 One-line diagram of the constant current ring

With the constant current ring, the computerized control system for the 14 winches combined was ordered at AEG-Schiffbau, the Automatic Winch Control (AWC) system[17]. Since this was new for both Gusto and AEG, there was a lot of communication on the ins and outs of such a system. Our counterpart in AEG was dr.ing. Werner Droste, who spoke an imperfect English and lisped heavily, which made us always think of dr. Strangelove in Peter Seller's famous movie "How I learned to love the bomb". His colleague ing. Kai von Thienen was less of a caricature, but equally smart.

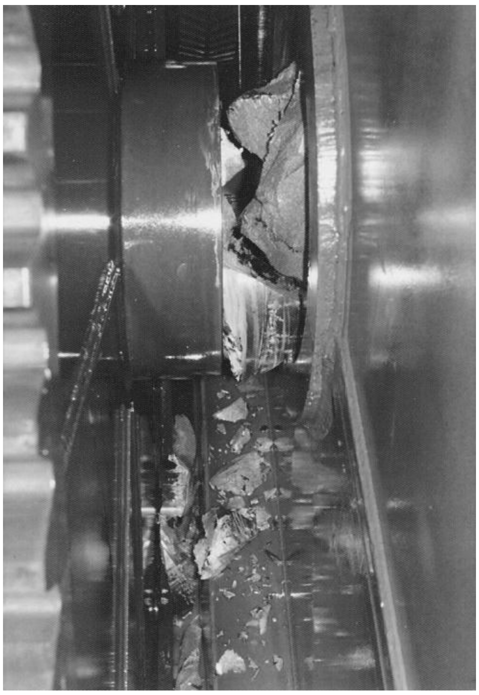


Figure 21 To the right: drum shield; left bull gear

The AWC had been developed to take full advantage of the operation of the constant current ring. That included power recovery when slowing down a winch and certainly not using the mechanical brakes, which were a band brake for locking the winch drum and a drag brake for low braking force while paying out line. Once the VP was delivered, it appeared that the Texans operating the winches would rather work with manual controls.

Pipelaying started mid July 1975. On Wednesday July 16, Cees Willems (who was on board for the start-up and testing of the AWC system) called the yard and reported that the shaft of winch 7 had broken. That same evening Cees returned to Holland with a splinter of the broken shaft in his luggage. On Thursday July 17 the shaft of winch 10 broke. Bart Groeneveld was sent to Aberdeen immediately. It quickly appeared that the shaft steel was extremely brittle. This in combination with a key slot with sharp edges in the shaft and the braking impact loads proved disastrous. After Viking had completed a part of the Ninian pipeline for BP the Viking Piper moved to Blohm and Voss for repair of the winches.

Of course the question arose who's fault the shaft damage was. A meeting between Viking, Gusto and Intercon was arranged on 19 July. Bill Sales, president of InterContinental, tried to maintain that poor

[17] See OTC 2348 "An automatic winch control system for a pipe lay barge", 1975

alignment of the gear wheels driving the shaft was the culprit. Indeed it could be seen, that the teeth of bull gear and pinion did not engage ideally. But Bart Groeneveld had occasionally seen the Viking operators throw in the bandbreak while the winch motor was still running, and felt this was the cause. Anyway, Gusto did not feel responsibility for winch problems because InterContinental had been chosen against its advice. Bart Boon happened to be on board as the yard representative. When he returned to Schiedam, he had a piece of shaft steel in his hand luggage. Safety inspection at the Lerwick airport used a then quite new metal detector which did not see the huge piece of steel. Hans Sjouke and George Lagers were called to a meeting in Brussels, in the new head office of Viking, on 21 July 1975, to discuss the problem and potential solutions. A segment of the broken shaft was on the table and it was absolutely clear that the fracture was nearly 100 % brittle. It was decided to seek advice of the British Welding Institute and accept their analysis. On 22 July Gusto asked the British Welding Institute to investigate the cause of the shaft failures. One aspect of their analysis was that the shaft steel was unfit for purpose: very strong but brittle as glass. And of course the design of the key slot was found to be inappropriate.
We were never told who picked up the final bill of replacing 14 shafts at Blohm & Voss or whether InterContinental went out of business or not. Also we do not know anything about use of the AWC system. Rumor has it, that the operators preferred manual control and never used the automatics, even removed it from board. The fairlead angle measurement system, which had been tested by TNO, apparently also was not used, because problems with the measurement persisted.

Anecdotes

On www.oilrig-photos.com/picture/number 2595.asp the following statement by a certain Don Creamer was found:

> *I was captain of the tug Gulf Brent the only tug tending the Piper when she blew off location in 1978. Sea conditions reported to be as high as 50 ft. Seven anchor wires snapped or let go but later retrieved after returning to location. This is a short version of how that night went but….one that I'll never forget.*

Viking needed to be convinced that AEG was a knowledgeable fabricator of electric systems. So a delegation of AEG people including dr. Droste came to the Gusto yard to give a presentation. They were very knowledgeable and very German, stiff in attitude and poor in English. The Viking reps demanded from AEG to give references for their constant current system. With some diffidence the Germans told them, that their U boats had such systems. The Americans were stunned and dumb for a while.

In March 1975 a meeting was organized between Viking and AEG in Frankfurt. The subject of the meeting has faded out of memory, but George Lagers had to assist Viking and organize the trip. When the party Bell – Lagers and some others arrived at Schiphol, it appeared that the flight to Frankfurt was delayed for an unknown time, because of fog in Frankfurt. Fearing that when the fog would lift, traffic might be in turmoil for some time, Charley Bell asked George to arrange a charter flight. And off we went with a six seater operated by Martinair.

The July 20 issue of The Sunday Times reported on the shaft problems under the title "Pipeline snag hits Britain's oil hopes". Their reporter Roger Eglin happened to board the Viking Piper just after the shaft of winch 7 had broken. He wrote that 2 miles of pipe had been laid when on Thursday morning the pipe end was laid down and abandoned, in view of the winch problems. During this abandoning operation the second shaft snapped.

From 14 to 18 August 1975, Gusto's Mr. Kuiper, electrical specialist, was on board of the VP near Lerwick for some electrical modification. He saw how high waves could flush water into the mooring wire ducts, which would then flow into the winch room and onto the winch motor. No comment on how this problem was solved.

7.2. The Stern Ramp

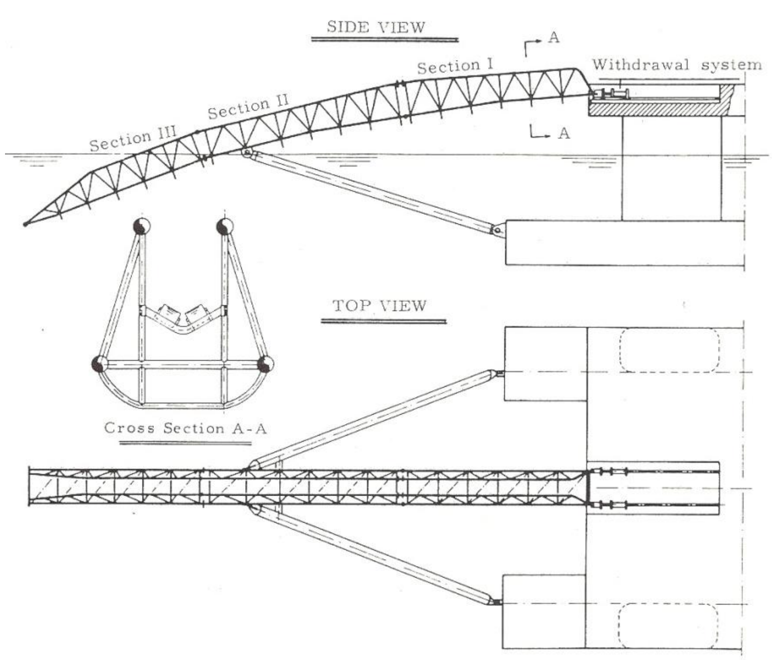


Figure 22 The Stern Ramp

Based on the experience of RJBA with the Suleyman Vezirov project, a rigid extension for launching pipe into the sea was conceived consisting of a curved space frame structure that was connected to the barge deck and supported by two cylindrical booms mounted on the pontoons of the vessel. The pipe was contained inside the structure, supported on roller sets which prevented lateral movement. The curvature of the pipe on the roller boxes could be adjusted by varying their vertical positions within the space frame and by adding or removing spacers between the three sections of the space frame. Since this differed much from a traditional stinger, the contraption was named Stern Ramp. Because of its rigidity it would move with the vessel. The most critical vessel motions would be heave and pitch, which caused the pipe to lift off and set down on the rollers as the point of contact between pipe and ramp curve moved up and down the curved structure as the vessel moved. However, the pipe could never bend more than the preset curvature of the roller sets, so that the bending stress in the pipe overbend could not surpass a known and acceptable limit. For any pipe diameter and water depth combination an optimum radius of curvature could be set. Water depth plays a secondary role, determining the normal stress in the pipe.

Analysis and subsequent model basin tests at NSMB determined the impact forces between pipe and roller supports, which were found to be acceptable. Not everyone was in agreement with that. Willem Timmermans, the actual designer of the Stern Ramp, attended a meeting of the Board of Viking in which some so-called Houston expert (could have been Murphy Thibodeaux) stated that the impact of the pipe on the roller supports could be compared with hitting one of the plate glass windows in the conference room with a big hammer. Willem responded that the impact velocity would be equal to that of a pencil being dropped onto the conference table from 10 cm high. This shows how arguments were conducted on the basis of populist propaganda. Fortunately there were enough engineers among the board members to make sure that science won out.

The design criteria included the capability to lay a 36-inch pipe across the dreaded Norwegian Trench with up to 1000 m depth. When the vessel moved to the Shetlands to lay its first pipe, and the first video images of the rough sea conditions came back, Timmermans shuddered (and probably so did the Stern Ramp) as huge waves crashed through the ramp structure. This design of ramp is considered to be the first design that would not require abandonment in adverse conditions, because it was an integral part of the vessel and not a semi loose appendix.

Figure 23 Stern Ramp elevated

As sort of insurance a second copy of the Stern Ramp was built and stored at Viking's base near Bergen. The thinking behind that was experience with stingers on conventional barges that had to be frequently changed out or abandoned during a project. When a storm has passed, a considerable portion of the good weather period which follows is lost recovering the stinger and relocating the pipeline in its support; this lost time could better be employed laying pipe. In areas like the North Sea, where severe but short summer storms are commonplace, contractors often find that almost as soon as they have recovered and replaced the stinger, they may have to abandon this again simply because another severe storm is imminent. This proved to be past history on the Viking Piper, where use is made of the ramp connected rigidly and permanently to the vessel. Even so, sea conditions may get too severe to keep the pipe on the stern ramp. In such survival condition, the pipeline would be abandoned and section I of the ramp was partially retracted to take up a position in a slot in the work deck. This caused the tail end of the ramp to be elevated above the level of the water by the retraction unit (Fig. 22). With the vessel in the survival mode there are no hydrodynamic forces acting on the ramp end, so eliminating the need for any special or exceptional reinforcement to meet this out-of-the-ordinary condition.

When visiting ETPM's headquarters near Paris one day many years later (ETPM had meanwhile become the owner of the Viking Piper), Willem was interrogated about the design philosophy of that structure. Apparently some cracks and other signs of wear and tear had shown up at the joints, particularly where the struts from the pontoons connected to the Stern Ramp structure. As he remembered, ETPM had made the repairs they thought necessary, and that was it!

The Stern Ramp was built at various places, among which the yard of Netherlands-American Pipeline Contractors (NAPC) below the dike near Vlaardingen. This company was owned and operated by an American who had set up shop in The Netherlands, and started doing work for the Gasunie pipelines in the late sixties.

Anecdotes

Willem Timmermans visited the NAPC yard with his little son Jeroen to show him what daddy had designed. “Actually”, he wrote later, ”I was quite impressed myself when I saw the huge structure being built, which looked so much bigger that what I had in mind when I put the concept on paper. I had the same impression when I saw the vessel moored in the Hartel Canal where it dominated the landscape”.

The engineers of both RJBA and Gusto were mostly young and opinionated. Those at Gusto Prodo felt that it would be wise to double check the stern ramp hydrodynamic loads, because their calculation is a bit complicated. So Dirk Manschot got deeply involved in modeling the space frame and computing the flow velocities and accelerations normal to each member of the frame. The relative flow was a result of stern ramp motions through the water (driven by vessel motions), current velocity and wave orbital motions. The force on a member was calculated by the empirical formula of Morrison, combining drag loads and acceleration loads in a non-stationary flow. There was difference of opinion whether one should first calculate the hydrodynamic force in the flow direction and then decompose it in line with and normal to the structural member under consideration, or decompose the flow vector and neclect the effects in line with the member.

Of course there were discrepancies between Dirks results and those of Willem Timmermans. Result: angry faces. George Lagers was befriended with both Dirk and Willem, and as head of Prodo in between the two. He does not recall which set of results was accepted as correct; probably the RJBA data, because RJBA had the design responsibility.

Figure 24 Castoro 7; mark the mid column modification

7.3. The Upper Hull

The design of the stem ramp was such that the pipe was launched from the centre of the vessel; therefore the welding and the various other fabrication stations were grouped on the topdeck along the centerline of the vessel, leaving a work deck area available on both sides (Fig. 6). The equipment installed along the fabrication line was conventional except that it was designed to meet the very specific requirements of the Viking Piper. The pipe laying plant was designed by RJBA and was not included in the fixed contract price. It formed part of the adjustables.

The equipment involved included a 160 ton pipe abandon/recovery winch; the drum of this winch had a capability of holding 1300 m of 3 inch diameter wire rope. The two tandem track type Western Gear pipe tensioners had a continuous pull of 135 ton at a payout speed of 0.9 m/sec, Storage areas totaling 2885 sq. meters were available to port and starboard of the fabrication line. Supply boats moored to the vessel on port and starboard sides without entangling the anchor lines, since the anchor fairleads were located 12 m below the surface of the water.
Four swell-compensated Manitowoc 240 Seacranes on travelling gantries unloaded pipes from the supply vessels and placed these either in the storage area or on roller conveyors; these were arranged to transport the single joints first to the double jointing areas and from there to transverse conveyors and the main line-up table. All systems were geared for a rapid laying cycle, but obviously both the experience and the training of the crew played a decisive role in determining the actual rate of pipe laying. A central control room was located slightly ahead of mid ship and directly over the fabrication line. This was a large room (10.7 X 7.3 m floor space) in which all the major instrumentation of the barge was assembled.

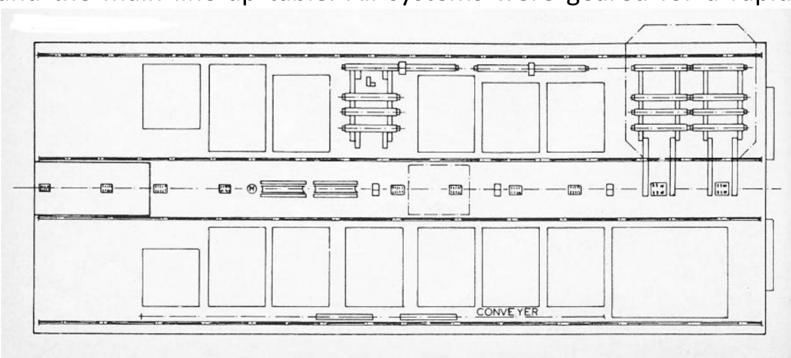


Figure 25 Workdeck schematic

The most important items in the control room were:

- radio position ranging equipment
- satellite navigation system
- automatic winch control desk
- manual winch control desk and television monitors for all winches
- automatic ballast system desk for automatic control of draft, heel and trim
- displays of the pipe attitude on the stern ramp
- various alarms monitoring safety on the barge.

The operator had a view of the work deck on all sides. Located at about 21 m above the surface of the sea, he was able to follow easily the work of the anchoring and supply vessels, as well as the pipe handling and other activities on the deck.


Figure 26 Workdeck in reality

Only one deck level was provided in the upper hull below the work deck. A large part of this deck was allocated to crew's quarters. The total number of men on board was approx. 300, based on 24-hour operation in two shifts. A recreation room, a cinema, cafetaria and messroom and several other facilities were provided. The power plant was located ahead of the crew's quarters; it contained eight diesel generator sets producing a total of 18,800 HP of primary power. Most of the installed power on board was used to drive the winches for advancing the barge. With an eye to power economy, a 1600 amp constant current system had been selected primarily because this substantially reduced the number of stages between generators and drive motors while still retaining stall properties which are ideally matched to the winch requirements . A total of five converters was incorporated in the two individual constant-current circuits which provided 440 volt AC power to the general circuits and to the pipe laying equipment. See figure 20 for the schematics

7.4. The Automatic Ballasting System (ABS)

During the design stage, it was anticipated that control of trim and heel, and to a lesser extent draft, would be improved by using an automatic ballast control system. The Viking Piper would be the first

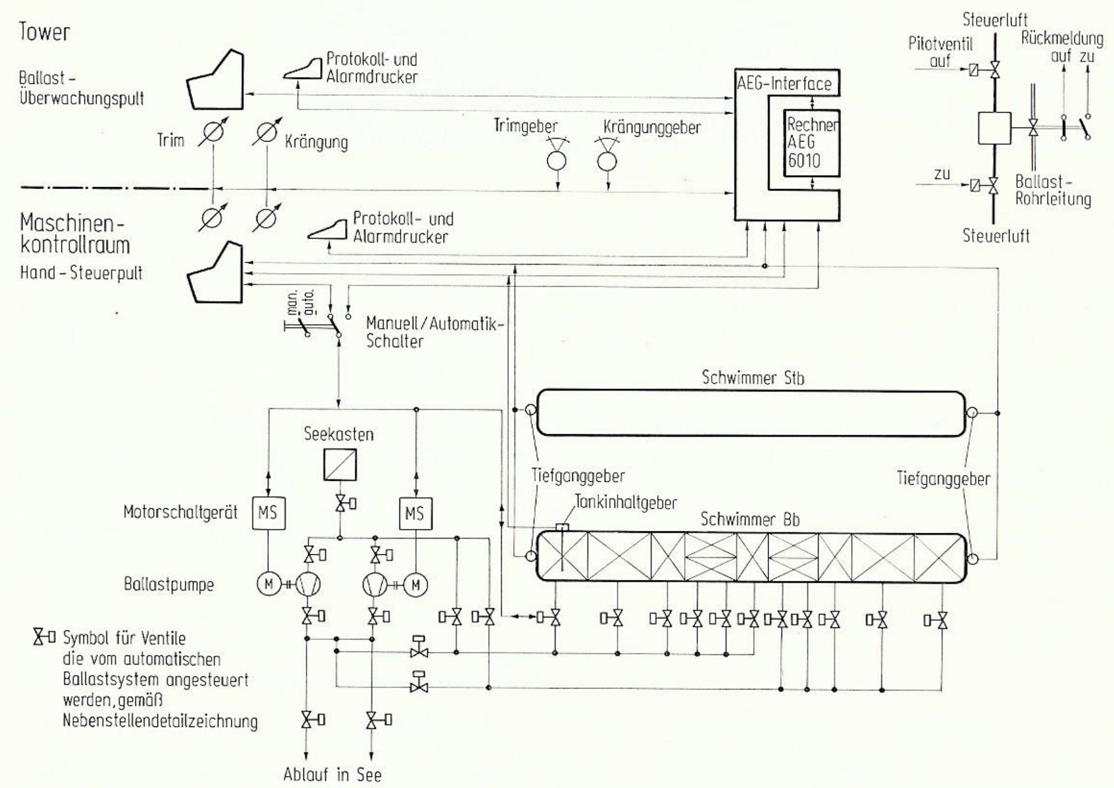


Abb. 9. Schema des automatischen Ballast-Systems.

Figuur 27 Automatic Ballast Control System

large pipelaying semi-submersible, much larger than Choctaw, and would have substantial weight shifts over its work deck during pipelaying and/or charging pipe. For a semi-submersible such weight shifts would result in relatively large trim and heel in view of the moderate static stability. Moreover the wind load on the large above-water body of the Viking Piper would also cause heel, possibly some trim, which would be undesirable in view of crane movements over deck and all work on deck in general. Therefore it was anticipated, that multiple ballast water shifts between tanks would be used to compensate for cargo and/or deck crane movements or wind induced heel. The required procedures would be facilitated and made efficient by using computer control of ballasting operations.
Bart Jan Groeneveld made a feasibility study and wrote a short specification of such computer control and the development of a system was entrusted to AEG in cooperation with Norcontrol, who provided the basic pump and valve controls. At AEG, again dr. Droste and ing. Von Thienen were involved in the development of the control algorithms[18]. During the trials in summer 1975 the system worked to full satisfaction, observed by Kees Willems who had attended to its implementation and testing. Whether the system has been used by the Viking Jersey operators is unknown to us. Probably the ABS underwent the same fate as the AWC: not to the liking of Texans, not used.

[18] Jahrbuch der Schiffbautechnischen Gesellschaft 1975, page 382; Hansa 1975 nr 22 page 1853-1862

7.5. The Horizontal Position Reference System (HPR)

RJBA had in an early design report recommended that monitoring and automatic control of the touch-down point of the pipe being laid should be implemented. For monitoring, a good position measurement system should suffice. In the mid seventies, satellite navigation was coming but not yet available at high position accuracy. In the North Sea use could be made of several radio ranging systems such as Decca. Norcontrol has delivered such systems to the Viking Piper.

Control of the touch-down point is a matter of controlling the mooring winches and the pipe tensioners. The task to develop the necessary system and software was logically given to AEG, to become part of the overall winch control system.

8. Relation between client Viking and supplier Gusto Yard

“No decision also is a decision”

The Viking Piper was a completely novel type of vessel requiring exceptional fabrication methods. The design could to some extent rely on experience, but required innovative thinking in many respects. Apart from all the unavoidable special technical features involved also the relation between yard and client during fabrication of the vessel was quite exceptional. This probably was not inherent to the novel vessel type or the construction methods, but had more to do with the different mindsets of the Viking and Gusto staff people. Whatever the cause, it has had quite an impact on the construction time and cost.

The scene was set immediately after the contract signing, when Viking requested to exchange the main Werkspoor diesel engines as specified for GM engines. No reason for this request was given, but it is not difficult to dream up one. The GM engines were 20 cm too high for the engine room, less powerful and heavier than the Gusto proposed engines, but all of this did not impress Viking. Only after a drawing of the consequences had been made and the enormous additional costs had be clarified, Viking abandoned their plan. But then Gusto changed its mind and ultimately 8 MAN diesels rating 2300 HP each were procured, with agreement by Viking.

This chapter attempts to illustrate the yard-client relation from the memories of the authors. It is largely restricted to private experiences and therefore unavoidably incomplete and subjective. Most of the memories reflected here are Bart Boon’s, who is the I person whenever “I” is used.

Summary and reflection

Soon after the contract was signed and while the Gusto Project Team members were returning to their regular departments, Viking established their own project Supervisory Team located in Rotterdam with Charles R. Bell (former employee of RJBA and member of the feasibility phase study team) as Project Manager. The team mainly consisted of American engineers with pipe laying or more general offshore experience in the Gulf of Mexico. An understandable decision of the Viking management, which at the time was under strong influence of its President, Ed Minor, an outspoken American who had worked a lifetime with Brown & Root. However, the late moment of forming the team plus the technical culture differences between Europe and the USA rapidly created problems in the cooperation between the supervisory team and the shipyard. The Viking team wondered whether the vessel design complied with their SAS-criteria (Safety and Seaworthiness) and thus would be sub-standard or not. To the yard (supported by Bureau Veritas) that question was no issue. Moreover the yard felt that given the state of design and construction of the vessel there was no room for the sort of discussion started by the Viking team.

In retrospect one might wonder why the Viking shareholders did not recognise the problem and try to solve it before it would grow more serious. The confidence of the Viking shareholder representatives in the competence of Ed Minor was large, certainly in the beginning. It had to be, because with exception of Pieter Heerema, nobody among the shareholders was experienced in offshore construction work, let alone pipelaying.

Anyhow, the antagonism rapidly grew and culminated in a Basic Design Review initiated by Viking and performed by their subcontractors ABSTech (a consultancy subsidiary of ABS) and ODI (Offshore Design International) mainly in the period December 1973 – April 1974. Clearly it would be difficult if possible at all to implement the conclusions of the review at the advanced stage of construction of the 3GLB.

ODI strongly voiced the opinion that many modifications were needed in the design in order to make the vessel Safe and Seaworthy. ABSTech initially in general agreed with them although they considered the changes more recommendations than requirements. Bureau Veritas participated in the discussions and in general considered the design as produced to give an adequate SAS. Viking themselves and Gusto yard participated in discussions, but their arguments are hardly reflected in the synopsis[19] of the Basic Design Review. In the end the modifications implemented were mainly those recommended by Bureau Veritas.

In addition (or in complement) to the Basic Design Review Viking ordered large-scale model tests at the NSMB (now MARIN), which were executed in the period 11-15 March 1974. The outcome of those tests was heavily discussed and caused quite a bit of uncertainty. In the end they were said to be incorporated in the ODI, ABSTECH and Bureau Veritas recommendations.

Parallel to these actions Viking disapproved all drawings submitted to them by the yard. Often hardly any reason was given. The yard felt that they could do no better than writing a response letter roughly saying: *We reviewed your disapproval, consider the arguments inadequate and will continue our production as if you had approved the drawing*. It never came to test the legal validity of such letters. When delivery of the vessel was approaching, all drawings were reviewed once again by Viking and the yard and in general as yet approved by the client with very few comments.

The strange situation makes one wonder what the motivation for the various parties was. For the yard this was obvious: they simply wanted to build the barge within budget and within delivery time, performing as it should. Viking personnel (such as Charlie Bell) probably had the same intent but were seriously worried whether indeed they would get a safe and seaworthy vessel. Their fear may have been based upon the American tradition and experience based culture against the young European approach that necessarily had to rely far more upon a design from scratch using basic principles from mechanics in addition to experience from traditional shipbuilding. Viking hired American consultants that possibly felt that they would better show their consultancy value by expressing criticisms than by stating their acceptance of the design of Europeans[20]. ABSTech probably felt that they entered into a challenging technical advisory role. Soon, however, they realised that in fact they became involved in a discussion with a colleague classification society. Some years afterwards one of the ABSTech people told Bart Boon that they regretted very much ever to have gotten involved in this Basic Design Review. They tried to get out without too much damage to the relation ABS-Bureau Veritas. Altogether a situation built upon suspicion, not upon trust as it should have been.

Figuur 28 Pipeline operations under way in the early 1960s aboard Brown & Root's lay barge L.E. Minor. Inset illustrates how weighted pipe is handled before welding it into the line. (Courtesy of Halliburton)

As mentioned, it still surprises that the Viking owners did not take any action to prevent this situation and in particular let it develop and grow bigger and bigger. It must have cost Viking a very large sum of money, frustration and work. Similarly it did so for the yard. It might easily have led to a tremendous financial drama, for both owner and the Gusto yard. It is a surprise that in the end the impact on cost and delivery date of the vessel remained limited. The fact that Viking received the order to lay the Ninian line with the vessel immediately after delivery probably helped to reach this end good, all good result[21]. It may be noted that the more than 40 years technically successful operation of the vessel proved that the original design provided a completely safe and seaworthy vessel.

[19] Synopsis of Reports on Basic Design Review – 3GLB, Rotterdam 1974 (in GustoMSC archive)

[20] Personally Bart Boon always had this feeling about ODI's Mr. G. Roger Smith, probably the most important consultant to Viking. Roger Smith was involved already during the Engineering Phase II by RJBA in spring 1972.

[21] This leaves unaffected the tremendous value of the impact this history had on the experience and knowledge of the authors.

Viking Supervisory Team

Clearly the Viking owners decided to bring in experienced people. Most of them came from the Southern USA and had gained experience in the Gulf of Mexico scene. They were well aware of how things were done there, but did not fully realise the difference in conditions between GoM and North Sea or the level of applied technical/scientific thinking in Europe.
As mentioned before, the President of Viking Jersey Equipment Ltd was Ed L. Minor, till then one of Brown and Root's top people. Actually the first pipe laying barge in the GoM was named after him. Maybe that barge was renamed after his move to Viking; we never checked.

Some time after the yard's Nieuwe Haven team was dissolved Viking established their own Supervisory Team. They were housed at 161 Industrieweg in Rotterdam.
Team leader, project manager was Charles R. Bell. According to his son John, Charlie considered this *a project of a lifetime.* Of course he, probably together with one or two colleagues, was the first real "Viking man" we met. To us those "high-heeled, Stetson wearing, just no spurs or guns, Texas cowboys", were some sort of a culture shock. They addressed us using our first names[22], something not yet common in Dutch yards. But rapidly taken over by us, thus stimulating the yards transformation into modern times. In the beginning Charlie met in particular with Bart Jan Groeneveld, Bart Boon and Bart van Rijnsbergen (specification writer) leading him to think that Bart in Holland was some sort of a nickname for shipbuilders. Meeting many other people later corrected his idea in this.
Soon arrived Walter Adler, a former Kriegsmarine U-boat Kapitän, who after his WWII POW decided to stay in the USA. Later he became the first captain of the Viking Piper[23]. To us he was known as the man of the black Oldsmobile with the family of ducks and ducklings at its rear. Probably he was the ultimate Texan in behaviour and appearance.
Some other members of the Viking Supervisory Team are mentioned in chapter 10.
From the early beginning the Viking team started wondering why we did things differently from the GoM designs and felt that possibly what we did was not good enough and even might endanger the safety and seaworthiness of the vessel. We, the yard, rejected those feelings and felt that we were doing things approved by the classification society Bureau Veritas and in accordance with general standards of mechanical engineering. Viking thereupon started to bring in "specialists" from the GoM who mostly supported their feelings. A strong difference in American/Texan and European technology culture existed. Unfortunately this became clear when the state of design, subcontracting, procurement and fabrication had advanced such that the yard considered implementation of most of the suggested design changes impossible. Moreover, even when implemented the price and performance consequences (generally meaning adding more steel, thus more weight) could not have been in accordance with contract and specification.
Most of the topics mentioned hereafter were the result of this technology difference.

Topic 1 : Plate thickness

From the early contact with Viking's project team till more than a year later, thickness of plates subjected to lateral loads was a main item of discussion. This concerned hydrostatic and hydrodynamic loads, tank loads etc., but concentrated mainly on the thickness of the barge's work deck. The thickness of this deck, designed for a distributed load of 5 tons/m^2 based upon the standard formula of Bureau Veritas was 15 mm. Their formula upon that time[24] probably took into account not only the midspan maximum bending moment but also the clamping moment at the sides of the plate panel, the 3-D rather than 2-D effect and possibly even some membrane effect.
Two incidents regarding plate thickness are mentioned. Unfortunately I am not sure in which sequence they took place.

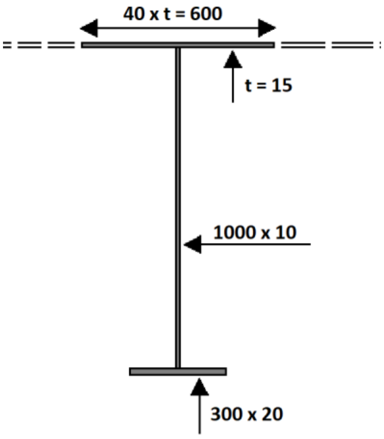
[22] Later, when the relation was not always as friendly, Bart Boon knew that whenever Charlie addressed him as "Mr Boon" something was completely wrong.
[23] Although the deck foreman, responsible for the pipe-laying process, was more important than the formal boss, the captain.
[24] This does not suggest that today's formula would be much different.

Plate thickness incident 1: Thibodeaux calculations

One of the first consultants brought in by Viking was Mr. Thibodeaux[25]. I remember that he was introduced as (retired?) professor from Rice University[26]. The two of us met. Certainly he was a friendly man. He had recalculated the thickness for the work deck and concluded that the plates should be 40 mm instead of our BV-approved 15 mm. There was no problem in handing me a copy of his hand calculations (3 or 4 pages).

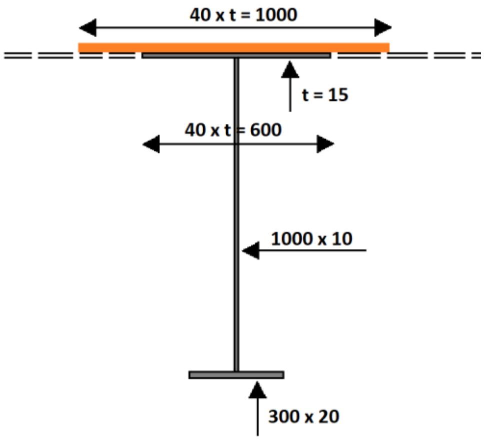
The calculations indeed were typical hand calculations as would be used by many engineers for a quick order-of-magnitude check. Nevertheless after reading his calculations, I found that some 10 mistakes were made, 2 or 3 of them serious. Basically he calculated a bending moment, calculated a section modulus and based upon these he found a bending stress which then was compared with an allowable stress (probably as given in ABS' Rules for Mobile Drilling Platforms). In itself this is a good approach. Probably he used a beam simply supported at both ends, which is rather conservative for a continuous beam supported at multiple points as is normally accepted for web frames such as those supporting the work deck. This may explain why his check of the original design resulted in too high stresses and thus the need to increase the section modulus.

The cross section of the web frame for which the section modulus was calculated was as shown.



From this point on I remember some of my comments as follows.

The section modulus needed to be increased. Thibodeaux did this by adding material to the deck plating. The entire cross-section needed was then distributed with again an effective width 40 times plate thickness. He distributed this as if the effective width of the added material could be determined separately of that for the original material.



If only one effective width would have been used for the combination of original and added material, this width would have been much larger, hence the added plate thickness would be less.

- Thibodeaux calculated the position of the neutral axis of the upper (original) cross section. When adding the material in the second cross-section he kept the same position for the neutral axis. *"I assumed the impact of the change in position of the neutral axis on the section modulus would be minimal"*. I had recalculated the situation following Thibodeaux's method taking the shift in neutral axis into account and concluded that in such way the new plate thickness did not have to be 40 mm but something like 80 mm!
- Of course, the main mistake of Thibodeaux was that, in order to increase the section modulus, he added material to the effective plate rather than to the flange. Possibly this showed a lack of practical design experience.

All my comments were put down in a technical note sent by Gusto to Viking together with the rejection of increasing the work deck plate thickness. I never got any further written calculations from Viking again.

Plate thickness incident 2: The large meeting

[25] Possibly Murphy H. Thibodeaux who in 1951 wrote his Master Thesis for Rice University https://scholarship.rice.edu/handle/1911/89340

[26] However not found in the Guide to the Rice University past faculty and staff records, 1961-1996 UA 008 http://www.lib.utexas.edu/taro/ricewrc/00609/rice-00609.html Was he really a retired university professor?

The second incident took place in a large meeting at the office of the Viking Supervisory team. I had to go there accompanying one of the Gusto directors, probably Hans Sjouke. The reason for the meeting I do not remember.
Upon entering the meeting room we were confronted with microphones and tape recorders. Our objections were not accepted and in the end, we gave in, provided we would get copies of all tapes. Of course, we never took the trouble to listen to those tapes.
In which way the meeting started I do not remember. After a short time my director said he had to discuss something with Viking's management (probably Ed Minor) and left the room. So it was me sitting opposite some five or so Viking people, all well experienced in the offshore industry, as far as I knew. Whether Thibodeaux was one of them, I do not remember. But probably Rogers Smith was one of them and most likely the one who did most of the discussion.
Soon the discussion once again concentrated on the thickness of the work deck plating. Again I stressed that I trusted Bureau Veritas in their rules and approval mentioning that the topic of laterally loaded plates probably was the most general subject of classification societies on which they had at least a century of experience. After some more discussion I was asked "Now tell us, are you going to increase that plate thickness or are you not?". I did not get time to answer, because to the question was added, stressing every word with a pointing finger: "Before you answer you must be aware that the lives of three hundred people working onboard that barge depend upon what you decide **now**. Now what is your answer?". Meekly I felt I could not answer anything else than that I still relied completely upon the expertise of the classification society and thus would not increase the plate thickness. This was not the way of discussion I had been trained for at university. But it constituted an extremely valuable lesson of life for me.

Topic 2 : Technical notes

In meetings and in letters Viking regularly came up with unexpected technical questions. An example: *Did you take into account corrosion fatigue when you decided upon those square corners of the columns?* We had no idea what was meant with corrosion fatigue. In those pre-Google days the only thing we could do was visit the library of the Technical University in Delft trying to find something with that word in book title or similar. Note that the only search possibility was going through the cards drawer trying to find something applicable. Our answer mostly was given in the form of a technical note. In the example containing something like: *Yes, corrosion fatigue exists. However, it is a problem in special technical applications such as space craft. In our application the impact is practically zero.* The point was not raised again.
This sort of thing, often with the same outcome, happened quite a few times. Technical notes became a daily thing in our lives. And I learned a lot thanks to them.

Topic 3 : Not approved drawings

Contractually Gusto could start implementation of any drawing only after obtaining approval from Viking (I presume). So lots of drawings were submitted to them for approval. As mentioned above, quite a few discussions had started on various issues. Within the Viking team uncertainty clearly existed whether Gusto's design was as safe and seaworthy as the yard claimed (see also the section Basic Design Review hereafter). In those circumstances it may be understood that Viking was hesitant to approve any drawings. So they all were returned stamped *"Not approved"*, sometimes with comments, but often without any further explanation. Much later I learned from Finn Michelsen (then working with Heerema in Leiden) that indeed a special "Not approved" stamp had been made and that it was a standing order to disapprove all submitted drawings.
The yard obviously had different drivers. Considering the contractual delivery date and the performance guarantee for the vessel, the consequences of all that drawing non-approval were unacceptable. Soon we developed a sort of standard reply letter stating something like: *We received drawing so-and-so not approved by you. Your comments* (if applicable) *we respond to as follows: ……. Consequently we disagree with your non-approval. We will continue our production process as if you had approved this drawing.* Luckily the legal value of such letters was never tested in court.

When delivery of the vessel was approaching, the Basic Design Review was finished rather well (see hereafter) and Viking obtained from BP the contract to lay the Ninian Line, everybody realised that the drawing situation was quite unacceptable. Led by Finn Michelsen, then the main technical man at Viking, the Supervisory Team and the yard once again went through all those not-approved drawings. Now and then some small comments were accepted, but in general Viking as yet approved all drawings.

Topic 4 : The Basic Design Review and SAS

In August 1973 a meeting was held in Paris between Viking, Gusto and Morgan Guaranty Trust Company of New York[27]. This meeting gave a further definition of the yard's responsibilities under the contract. An agreement was signed that the "safety and seaworthiness" (SAS) of the 3GLB had to be assured[28]. While construction of the vessel continued, Viking hired ABSTech (ABS Worldwide Technical Services Inc.) and ODI (Offshore Design International Inc. of New Orleans) to perform a Basic Design Review in order to establish the *safety and seaworthiness* of the 3GLB. A synopsis of various reports in the period December 1973 – April 1974 was compiled by the Viking Supervisory Team. This synopsis is present in GustoMSC's archives. This section summarizes some of the main technical discussions.

From the reports it is clear that ODI performed several independent calculations such as motion analyses and stress calculations. ABStech evaluated their results and did some additional calculations. The results of the calculations in the design review obviously were in many respects more pessimistic than those performed by Gusto/BV in the initial design stage. As far as we know never the calculations and their basis were compared and the reasons for those discrepancies were never established. Whether ABSTech/ODI availed of the Gusto/BV analyses is not known. The detailed finite element analyses of the bracing nodal joints a few months earlier performed by Shell on behalf of Gusto[29] also seem not to have been available to the review team. These could have shed light on the stress concentrations in those joints and possibly changed the opinion of the review team.

A protocol dated April 11-12, 1974 was drawn up in which the number of required modifications was grossly reduced as compared to the Synopsis. Even so, IHC-Gusto, represented by Hans Sjouke declined to agree with that document. Possibly the yard still did not want to implement some of the more difficult recommendations of the protocol.

Additional model tests.

On request of RJBA and IHC Gusto model tests were performed by NSMB during the initial design phase to demonstrate the motion behaviour of 3GLB in operating and survival conditions[30]. The decision in the Basic Design Review to let NSMB redo model tests came as a surprise. Of course the yard felt they were superfluous. As far as is known the opinion of NSMB about the use of such additional tests was not sought. The tests were run in the period May 29 till June 4, 1973. From the ABSTech/ODI reports of December 1973 it is understood that the wave clearance with some margin of the upper structure in survival conditions was one of the main reasons to do the tests. In addition slamming pressures were to be measured.

The tests were set up and carried out without any Gusto involvement. However one day Bart Jan Groeneveld and Bart Boon were summoned by Viking to come to NSMB and see one of the survival tests. It was a test in head waves as it was done in one of the narrower tanks so any other direction was hardly possible given the large size of the 1:30 scale model. The large model size probably was selected by Viking with the idea that "the larger the model, the more accurate the test results". Indeed, what we saw was a dramatic behaviour of the model in the tests: a large 100-year wave came in, the model rode the wave quite well. But then the first wave immediately was followed by a second wave of similar

[27] Morgan was the lead party of the banks providing a facility of $ 66 million to Viking.
[28] Synopsis Report
[29] Visser, W., Krogt, A.H. van der (1973): "Joint calculations for IHC Gusto", Technical Service Report RKTR.0154.73, Shell, Rijswijk, April 1973 (in GustoMSC archives)
[30] B.J. Groeneveld : Revised provisional design of the 3GLB, 1973, page 25.

height. The vessel bow was still pitching downward due to the first wave. This time the wave crest hit the upper pontoon and actually ran up the workdeck till about half length. A terrible sight.

After some reflection Gusto felt that two facts might cause this deviation from the earlier tests. The first one was that the model was so large that the test basin actually became quite shallow, certainly in respect to the height of the 100-year waves used. In that case the wave steepness would be exaggerated. Secondly NSMB had (or happened to have) chosen a wave train with two 100-year waves in sequence. In order to discuss the latter point our director Hans Sjouke and me visited Mr Groen and Mr Dorrestein of the Dutch meteorological institute KNMI. They were the authors of the book *Zeegolven*[31], at that time considered to be the best information source on sea waves. Our question basically was: "*We know that a hundred-year wave occurs once in a hundred years; but what is the probability of two hundred-year waves occurring immediately after each other?*". They understood our problem, but could not answer the question. But the outcome certainly helped to convince Viking, the review team and Bureau Veritas to be aware of the very low probability of such situation occurring in full scale situations.

Of course the model test results played an important role in the discussions held at the Bureau Veritas offices January 17-18, 1974. The main discussion item was sea hitting the upper pontoon in survival conditions. Viking showed a film containing part of the model tests. A large wave appeared. "It hit the upper pontoon". Gusto responded " No, we didn't see it". The film was rewound somewhat and shown picture by picture. And indeed the wave just missed the upper pontoon. The same thing happened three or four times with later waves. Then Viking decided to stop showing the film. We, Gusto representatives, were surprised because we had seen the frightening situation described earlier. The discussion continued based upon the oral and written test results, but no more film material. Much and much later I learned from somebody within Viking that they had clipped all upper pontoon hits from various films and pasted them together into one convincing film. Hurrying not to miss the plane, they picked up a movie from which all the hits had been removed rather than the one now containing them all. In the meeting in Paris they suddenly realised this. We do not know whether Viking had decided not to show the work deck being awash, as Bart Jan Groeneveld and Bart Boon had witnessed, as this possibly also in their eyes was far too unrealistic.

From this point on discussion focussed on the possibility that the upper pontoon would be hit, the consequences of wave run-up against the columns, slamming pressures measured around the top of the columns and the forward rake of the lower pontoons and similar.

As a consequence of the January meeting further model tests were performed 11-15 March 1974. They concentrated on air gap, wave run-up on the middle columns and in particular the possible wave impact and the loads resulting thereof.

Again the results were discussed in a Paris meeting at Bureau Veritas April 11-12, 1974, in which also Mr Jo Pinkster was present, who had managed the tests at NSMB. Bureau Veritas had stated before that they considered the tests as representing un extremely unlikely situation (see above regarding the two consecutive hundred year waves, the shallow water etc.). Impact pressures were measured but resulted in an extreme scatter and thus their value might be disputable. Anyway, most of the impact loads could be accommodated by the original structure. Only the most extreme ones required some additional stiffening. Providing horizontal stiffeners between the regular vertical ones made the plate panel dimensions so much smaller that they would be strong enough. This relatively easy modification was accepted by Gusto.

Note: hitting the upper pontoon was something to be avoided according to ABSTech and ODI "as this could result in severe structural damage". In actual operation of Viking Piper, at one point in time the decision to raise the vessel in an upcoming storm was taken a bit too late. During several hours the upper pontoon regularly was hit by serious waves. This caused a lot of noise inside the big box that the upper pontoon is. When the sea was calm again immediately the underside of the pontoon was checked from a small boat. No damage was seen[32]. In retrospect this showed how well the structure could withstand such wave impact. Probably this had to do with the flat plated closed double bottom

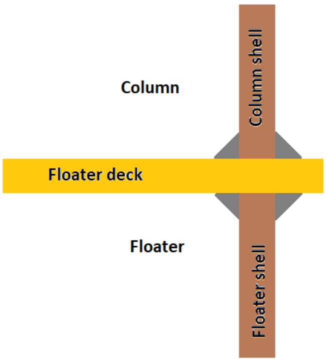
[31] Groen, P. and Dorrestein, R.: "Zeegolven", KNMI, de Bilt, 2nd edition, 1958 (3rd edition 1976 available from KNMI http://bibliotheek.knmi.nl/knmipubmetnummer/knmipub111-11.pdf)

[32] Verbal information from Viking to Bart Boon.

underside of the upper pontoon as opposed to the open stiffened structure of the single plate decks of semisubmersibles as at that moment were common in the Gulf of Mexico.

Column height.

Already in their December 1973 reports both ABSTech and ODI claimed that possibly insufficient clearance between the maximum wave crest and the underside of the upper pontoon existed. Additional model tests were strongly recommended and performed as described above. In case of insufficient air gap a logical step was increasing the height of the columns. The consequences on allowable pipe load on the deck are obvious. Together with some other comments on stability the only way to counteract this would be increasing important vessel dimensions such as width and column dimensions. The increase in weight would then also change the dimensions of the lower hulls. In other words, the entire vessel of the which all steel was well underway in construction would have to be modified.
As mentioned under model tests above, in the end it was accepted that adding some stiffening in the top of the columns leading to smaller plate panels allowing them to take some wave impact loads, was a good solution.



Structural continuity and local thick plates.

Correctly ABSTech and ODI noted that the block sections as chosen by Gusto were optimal from the point of assembling the vessel. In places, however, they introduced structural non-continuity where not absolutely necessary. For instance at the side of the vessel both the shell plating of the lower hulls as well as that of the columns landed on the floater deck which protruded slightly outside the shell (see detail). This detail indeed introduces the risk of lamellar tearing and probably could have been designed in such way that the shell plating would have been continuous. That risk would even have been greater with fully penetrated welds instead of the fillet welds shown[33]. On the other hand ABSTech/ODI did not take into account the careful (and in this position easy) good alignment, the pre- and post-weld checks performed and the low, mainly compressive stresses at that location. The 40-years of operational life of the vessel have proven that Gusto's execution was completely reliable. And again, the comments came at a stage of construction that such modifications were no longer realistic, irrespective whether they made sense or not.

Bracing nodal points

The review team made many comments regarding the design of the bracing nodal joints. They regarded continuity, stress concentration points and local thick plates and inserts. Strangely Viking seems not to have availed of, or not taken into account, the detailed finite element analyses performed by Shell Rijswijk mentioned above. Those analyses contained answers to many of the questions raised by the design review team. Even continuity of the plates as chosen in the Gusto design could well be defended based on the Shell results. But such discussion was never held.

Other structural aspects

Similar comments were made with respect to many other details of the structural design. Again they all came far too late to realistically be taken into consideration. For instance it was stated that round corners for the lower hulls and the columns would be a good attribute. The main reason was that such corners would be less liable to corrosion than the square corners used by Gusto. No real support for such statement was given and actual operation of the Viking Piper showed this not to be a valid point.
Similarly thicker brackets were requested at the lower end of the side in plane with the side shell. No support for such statement was given by calculations. Again it was simply stated that otherwise rapid corrosion would lead to weakening the brackets.

[33] To be honest: I am not sure that we did not provide full penetration welds.

Meetings at Bureau Veritas

As mentioned extensive meetings were held at Bureau Veritas in Paris at January 17-18, 1974 and April 11-12, 1974. Additional smaller meetings were held in between and at other locations, such as NSMB. The aspects described above were extensively discussed following amongst others a telex sent by BV[34] with their point of view dated. After the meeting the discussion led Viking to write a letter to ABSTech explaining what Viking considered by the term “Safe and Seaworthy”, asking what ABSTech meant by it and asking ABSTech to distinguish between requirements absolutely necessary for SAS (the vessel must not capsize and not fall apart) as against recommendations they would require for classification but which were not absolutely needed for SAS. As no such requirements existed for SAS, the Design Review Action in Gusto’s eyes ended with a sizzler. The modifications were minimal. The yard tried to adhere to the building schedule. But it had cost yard, Viking and Bureau Veritas a lot of time and money. At the same time everybody involved in it learned tremendously from it. It was an extreme case of colliding technical cultures.

Topic 5 : Anchor winches

From the moment Ed Minor had been retained as president of Viking, he tried to influence design and procurement decisions, either directly or via his cohorts he kept hiring from among his old Brown and Root friends. Willem Timmermans was present one day, probably during July or August 1972, in Pieter Heerema's office on the Scheveningseweg when he overheard a discussion between Pieter and Ed Minor in which Minor got his way to award the mooring winch contract to InterCon in Kansas City by reminding Heerema that he had gotten his way on another contract award. Whatever the other award[35], the choice of InterCon had far reaching consequences as discussed in chapter 6.1 and summarized here:

The contract specification called for the 14 anchor winches to be supplied by Gusto. They would be purpose designed to fit into the floaters of which the dimensions were final upon the contract date. The InterCon winches basically were mining winches, also capable to store long wires on their drums, but not designed for typical offshore operations. Their size implied that under the midship columns one of the three winches required a separate room. During commissioning and testing near Lerwick, prior to the start of the Ninian pipeline, the shaft of winch nr 7 broke. Gusto representatives were called to the Viking office in Brussels, to explain how this could have happened and what Gusto would do. Hans Sjouke and George Lagers went there after consultation with Bart Groeneveld, who was on board. The fracture of the shaft was completely brittle, indicating a material problem, which was aggravated by the sharp corners of the key slot in the shaft. But most of all, Gusto could explain that the winch brand had been Vikings choice and that Gusto could not be held responsible. Grudgingly Viking had to accept this position.

Topic 6 : Anchors

The anchors proposed by Gusto were considered not to be the most priceworthy option by Viking. They knew a supplier from Scotland who could deliver much cheaper. So the anchors were taken out of the yard supply and became owner’s delivery. Of course the yard had to adjust the anchor racks on the vessel, but that was no major item.

The anchors were to be tested together with the anchor winches when laying off the Shetlands just outside the Bay of Lerwick. Bart Boon was yard representative onboard when those tests were performed on a Sunday in July 1975. In a calm sea all 14 anchors were laid out in a spread mooring. Once done each anchor winch started to pull on its anchor, basically to test the mooring winch. Gradually the pull on each anchor in the spread was increased. Till on one anchor the pull did no longer increase notwithstanding hauling in the anchor line. Conclusion was that the anchor had started dragging and hence the holding capacity in the local sea bed was insufficient. It was decided to raise the

[34] Unfortunately this telex is not (yet) found, but its contents follow from the April protocol contained in Viking’s synopsis report.

[35] Could have been the constant current power system supplied by AEG, see chapter 6.1 anecdotes.

anchor. I (Bart Boon) do not remember the details for this anchor, but anyway it was found to be severely damaged. Several of the other anchors showed similar problems in holding capacity and were raised. In the end it was found that more than half of the fourteen anchors were damaged during the test: flukes broken off, stocks bent, arms missing, etc. Immediately Viking picked up the supplier from one of the Scottish cricket fields and flew him by helicopter to the *Viking Piper*. And I had to tell anybody, practically everybody, commenting on the anchors “No, it was not Gusto’s supply; Viking took them out and had a better supplier”.
The week thereafter showed Viking at its best. They availed of quite a bit fairly thick plates onboard and had more than enough qualified welders. Immediately they started finding all around Scotland small diesel-driven electricity generators and brought them onboard. Somebody made a reinforcement scheme for the anchors. When a few days later after having been ashore I approached the vessel by boat, a clear huge cloud of heated air and welding fumes hang above the Viking Piper. Within a week or so, all anchors had been reinforced and could be used to full satisfaction.

Topic 7 : Delivery time

The delivery date of the original contract was 1 May. It is doubtful whether or not that was ever feasible, but the indecisiveness of the Viking project team quickly made this date unrealistic. In a lengthy letter tot Ed Minor, Robert Smulders hints to possible delay into 1975[36]. This letter and other complaints had no effect and the delivery shifted gradually to July 1975, after christening on Saturday April 19, 1975.

Anecdotes

At the yard we were well aware that the Basic Design Review was taking place, were awaiting the outcome and in the meantime continued our work as if the review would have no impact.
Probably it was December 1973 that the first report came to the yard. I (Bart Boon) still remember that I went dining with some other yard employees in the restaurant “de Klok” nearby. Under the drinks Hans Sjouke handed me the report saying “Do have a look into the report; I could not yet do so”. Probably it was the ABSTech report dated 3rd December, but possibly it also contained the ODI report with the same date. After scanning it for 10 or 20 minutes I returned the report holding it between thumb and index finger with the words “170 million, I estimate”. This simply because that was the published contract price for the vessel and I felt that if the report would be implemented we should start all over again. The official estimate made shortly after resulted in a similar price. Purchased equipment could be left out, but on the other hand some interest for time lost was included.

In an e-mail John Bell, son of Charles Bell, stated that “Charles Bell admired IHC Gusto and the job they did on the construction. I remember he said that the Dutch were considered some of the best shipbuilders in the world, both historically and in the present day when it was built”[37]. This illustrates the finally positive feelings of Viking about the vessel. Moreover more than 40 years of successful operation of the vessel underpin the “safety and seaworthiness” attained in the design and fabrication performed by Gusto Yard.

The consultants called in by Viking were a pain in the neck for the yard staff. It seemed that they first of all served their own interest, probably in the form of provisions by suppliers that they recommended. Hans Sjouke later had similar experiences with American consultants when he had to handle the APMC contract for the jack-up Maersk Explorer.

[36] Letter DR-RS/nu to Viking Jersey Equipement Ltd. dated September 25, 1973.
[37] E-mail from John Bell to Bart Boon dated 8 December 2017

9. Fabrication and Assembly

From day one it was obvious that the Gusto yard alone would never be capable of delivering the 3GLB 18 month after the order without substantial help of other fabricators, not just for equipment but also for major portions of the vessel hull. For instance, the volume of steel used in the hull was greater by some several hundred percent than the annual steel throughput capacity of our yard.
To make possible a concerted building by several parties, the hull was subdivided in a number of building blocks which could be prefabricated by Gusto or other yards. The largest and heaviest blocks were the lower hulls, each with a steel weight of 3,300 metric tons; these were built in Ireland by Verolme Cork Dockyard. The order was placed on 12 December 1972, 6 weeks into the project, for an amount of Dfl 7.4 million. George Nikkels was dispatched to Ireland to monitor the fabrication on behalf of Gusto. Actually, the floaters were constructed as a single body which was towed from An Cobh to Rotterdam and then split in two before delivery to the Gusto yard.

Block	Weight, tonnes	Date of placing	Fabricator
53	575	6-4-74	Vuyk
54	575	6-4-74	Vuyk
59	600	20-4-74	NAPM
77	80	20-4-74	Gusto Staalbouw
63	1223	18-5-74	Gusto Schiedam
56	520	14-6-74	Vuyk
58	510	14-6-74	Vuyk
57	525	15-6-74	Vuyk
55	510	15-6-74	Vuyk
60	560	16-6-74	NCM
64/65	1485	6-7-74	De Kleyn (IHC)
68	1425	13-7-74	Gusto
61	560	20-7-74	NCM
66/67	1588	10-8-74	Gusto Slikkerveer
62	260	11-8-74	Gusto Staalbouw
70	1290	24-8-74	Gusto Slikkerveer
69	1313	14-9-74	Wilton
Stern ramp	500	19-4-75	NAPM

Other blocks were the columns, the bracings and parts of the upper hull. Six Dutch shipyards and steel fabricators were involved in the fabrication of these blocks. Gusto Schiedam and Gusto Slikkerveer built 4 of the 6 deck blocks.
Obviously, splitting the work up among contractors physically separated by long distances from each other demanded a great deal of coordination and supervision and accurate size control. The most significant problem in the construction was the assembling of all blocks into one single structure. No slipway or dock of sufficient size was available to us, which would enable the assembly of this barge to a length, width and height of 167.50 x 58.50 x 33.20 meters. Moreover, the fact of subcontracting in blocks of significant size, some of them weighing up to 1,600 tons, made impossible to use one of the very few existing big dry docks (e.g. Verolme Rozenburg) for lack of sufficient lifting gear capacity. The only solution available was to assemble the barge afloat. The original idea was to install the bracings between the floaters, then the columns on top of the floaters, and finally, the upper hull blocks on top of the columns. It was considered at that time that all these operations could be carried out by making use of a number of floating sheerlegs known to be available in Rotterdam harbour. It soon became apparent that some of the deck blocks would be so heavy in their final state that the four most powerful

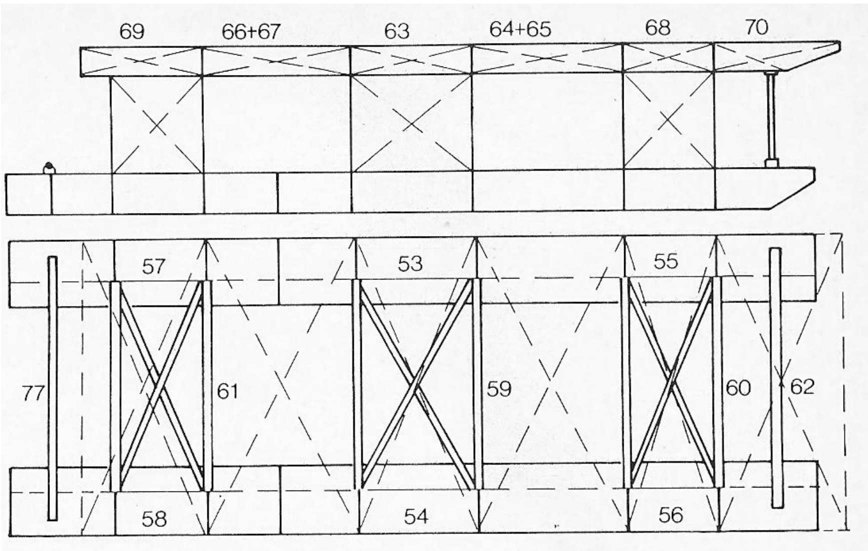


Figure 29 Definition of the building blocks

sheerlegs available would only just be able to lift them. Breaking these huge and heavy blocks down into smaller units was not an attractive solution since it would necessitate the use of a great deal of temporary supporting structures (for instance, mid-span support of the originally separate blocks 64, 65, 66 and 67); moreover, this approach would have an undesirable influence on the arrangement of the upper hull.

Obviously, being completely dependent on four sheerlegs was not the ideal solution, the more so since even a relatively small increase in the weight of the upper hull blocks would make the method no longer feasible. Fortunately a solution was found that provided a large margin in lifting capacity. The solution was simple and involved the construction of a jack-up platform very similar in design to the eight platforms that Gusto had already supplied to civil engineering contractors. The idea came from Jaap Sprenger and became acceptable cost wise by assuming that the jack-up platform, which received the name Assembler 1 (CO 943), could be sold afterwards. And indeed it so happened: see appendix 1.

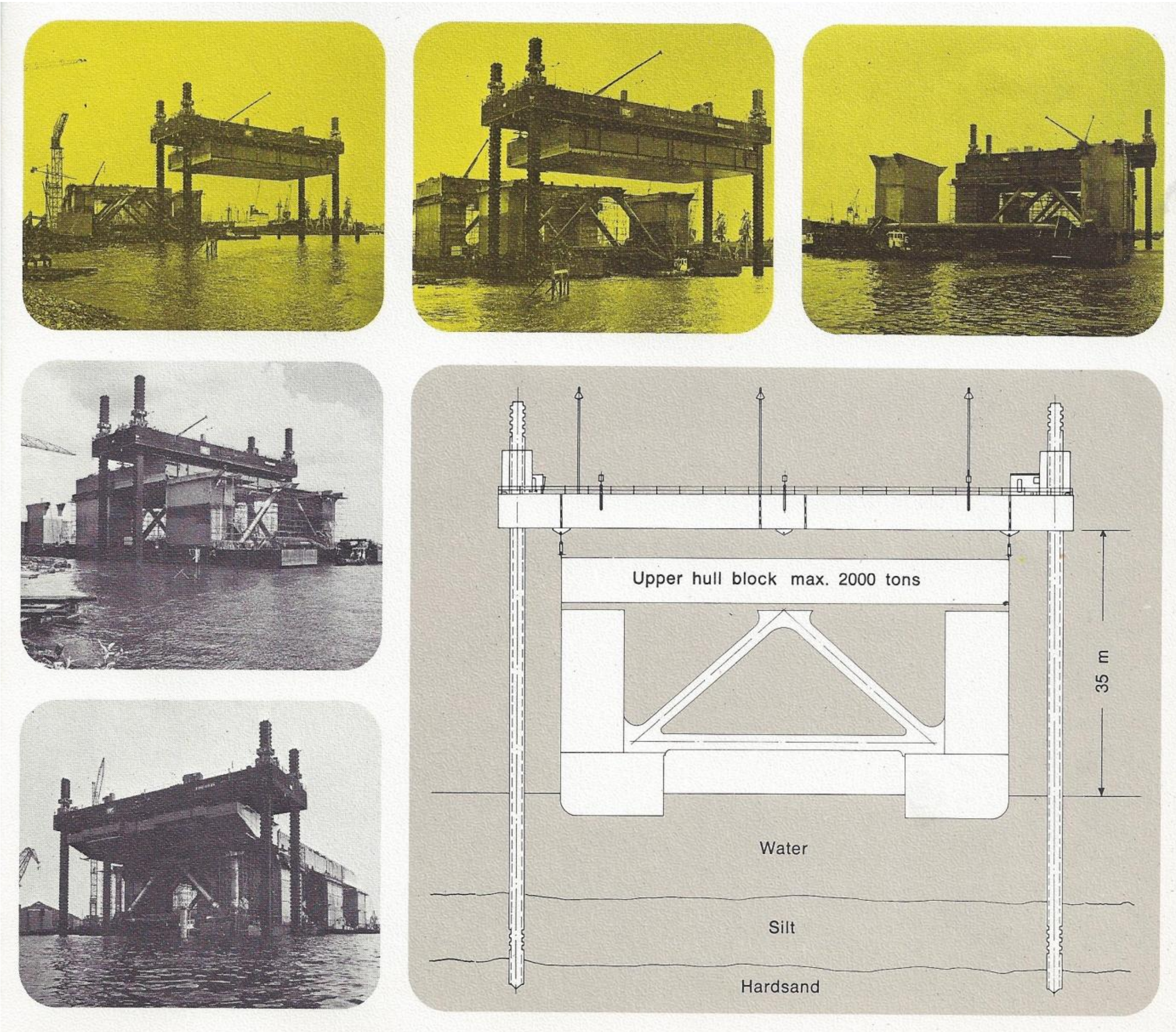


Figure 30 The Assembler method

The Assembler 1 (Fig. 10, 28) was placed in the water on its legs in a position close to the yard's quay. At each assembly operation, the deck of the platform was jacked up high enough to allow a deck block, or other piece of equipment, to be floated in underneath. After attaching the deck block to the platform deck, platform and block were jacked up to give a clearance of 25 to 30 m between water and deck. At the start of the jacking procedure, the green pin shackles and lifting lugs were tested at an overload, in some cases nearly 100%, by releasing the load on two diagonally opposed legs of Assembler 1.

The lower hulls and columns of the 3GLB were then towed between the platform legs for lowering the deck block into position. In this way, the yard handled construction blocks up to 1600 tons in weight, still with a margin in lifting capacity, because the design lift capacity of Assembler 1 was 2000 tons. This unique method of construction allowed the individual blocks to be partially equipped, outfitted and tested before they were installed 'on board'.

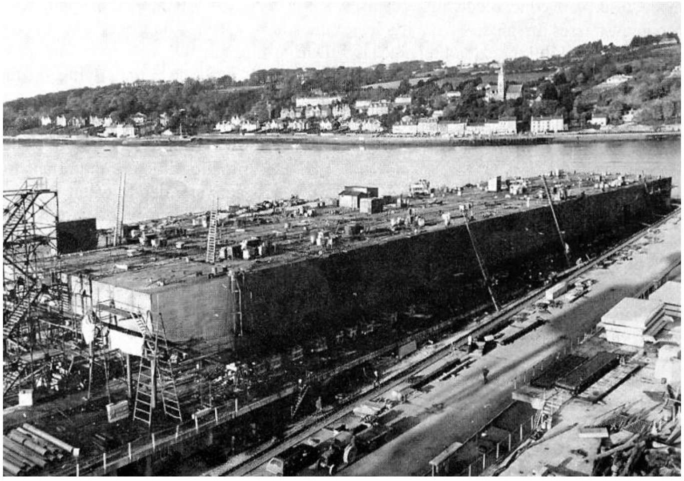


Figure 31 Floaters under construction in Ireland

The solution is the more attractive since it substantially reduces the amount of work to be done after assembly. This can be readily understood when one realizes that any additional work would have to be carried out 30 m above water level and almost 60 m away from the quay, with all the inherent problems of communication, supply, crane support, etc. Equipping and testing before installation, or even before the launching of the block, is relatively easy compared with having to do this work after installation. Of course, in practice things were not as ideal as they were planned to be. Due to late delivery of components and equipment, the various blocks of the upper hull were not as complete as they should have been when they were added to the barge. In spite of this the assembly, which lasted from March to October 1974, was successful. The assembly schedule and various action pictures are given in Figures 28-33. All assembly procedures took place during weekends, because traffic to the nearby Merwe harbour was virtually blocked during the procedure. All operations took place under the responsibility of Leo van Putten.

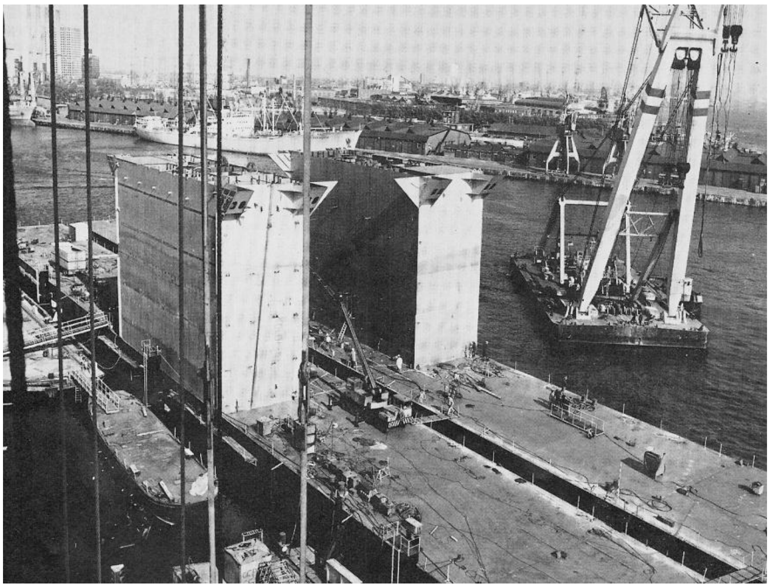


Figure 32 Columns placed by sheerlegs

Figure 33 First deckblock placed on 18 May 1974

Reflecting on the project, Leo felt that the first phase, i.e. the interconnection of the two floaters by means of bracing blocks 59 and 77 on the 20th of March 1974 was the most challenging one. This crucial assembly was the test of communication between and coordination of the work of tugs, sheerlegs and the yard. The accuracy during this assembly activity would be decisive for the overall accuracy of block positions. The two floaters had to have exactly the same trim, absolutely zero heel, complete parallelism and the correct spacing. Moreover they should be correctly positioned lengthwise.

A specialized firm had been chartered to measure all relative positions and give green light when they were correct. These persons were working very accurately, not always to the liking of the Gusto Eindmontage staff who wanted to make progress. Everything seemed to work out very well, but much later during installation of the deck blocks it appeared that the port floater was positioned slightly aft with respect to the starboard floater. The specialist with their theodolites and other measurement gear had, after all, not achieved 100% accuracy! Thus all deck blocks ended up slightly rotated around their vertical axis. This caused “zig-zagging” of the upper hull side wall, invisible to the unprepared eye, but creating extra work in the interconnections. To correct the resulting misalignments, “tons of doubling plates were installed” according to Peter Mackenbach, assistant to Leo van Putten. Amongst others, the underdeck girders for the deck crane rails could not be aligned properly. Doublers on the girder webs had to be installed in order to properly support the crane rails.

Coordination of the activities was achieved by using “walkie talkies” to communicate with all staff involved. Preceding an assembly operation, Leo van Putten and Bart Boon got together to review the need for ballasting and other technical issues. George Lagers had the somewhat undefined responsibility to check everything before giving a “GO” for set-down of the block to be added.

The operations usually started Friday evening by jacking-up the Assembler 1, after the section to be placed had been moved under it and connected to it with 2 times 4 Green Pin shackles, each capable of 500 tonnes safe working load. Gusto had its own jackmen in Jan de Vries, Joop Wittmaekers and Joop Hage. They had to take care of lifting the Assembler I pontoon strictly horizontally, to avoid overloading the shackles and pad eyes by carrying the load over a single diagonal. Fortunately the rather limited torsional stiffness of the deck blocks contributed to load sharing.

Around 5 o’clock on Saturday morning the assembly operations started. Maneuvering the big barge, precisely lowering the bracings or deck blocks in place and adjusting the floater trim and bending by ballasting all proved to be less of a problem than one would expect at first glance. The required precision of alignment of plates, girders and frames was 2.5mm, which is a tough requirement for a structure of this size. Nevertheless everybody understood the importance of proper alignment, parallelism of the floaters, precise distances between blocks. While block weights were transferred from the Assembler 1 to the floaters and columns, the attitude of the floating unit would change, complicating the problem.

Figure 34 Wood buffer block to prevent damage

In order to hoist the deck blocks, not less than two transverse bulkheads are needed between the side shells in which the pad eyes are incorporated. This means that in the final situation there are two bulkheads close to each other at the block interfaces, one of which structurally is superfluous. This is something that with a traditional way of building would not be necessary. Wherever possible this situation was used in the general arrangement by making corridors. At other locations where the space was needed, the temporary extra bulkhead was removed after the adjacent blocks had been welded together.

Anecdote:

The jacking engineer on watch aboard the Assembler called Bart Boon one day: “Bart, they are cutting into the end bulkhead of the block”. I said: “No problem if a door opening or something like that is put in already now”. “OK, but it seems to me that this door is intended for a hangar letting a Boeing 747 through”. I hurried to the vessel and indeed the Eindmontage guys had started to cut away the temporary bulkhead whilst the block was still hanging underneath the Assembler. Some harsh words and explanation why this was unacceptable, stopped them. A clear case of miscommunication between design office and fabrication department.

Communication was much better when the aftmost deck block was placed. All other deck blocks were box shaped. The aft block, however, contained at its centre line a large recess, often called *dug-out*, in which the retraction unit (*locomotive*) for the stern ramp was to be located. When lifting the block the maximum bending moment would load the cross-section as shown. Clearly the top of the bulkhead and adjacent deck strip forward of the recess would be highly stressed in compression. Originally the idea was to replace the missing deck structure with temporary compensating material. A quite expensive procedure.

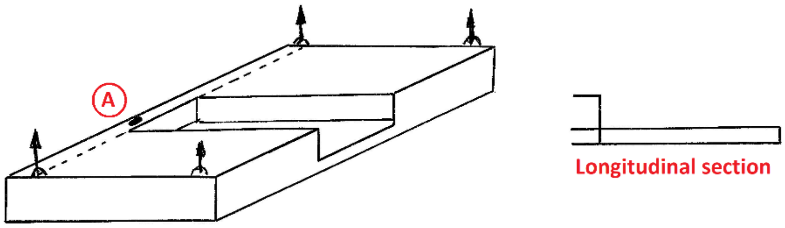


Figure 35 Block 69 lay-out

Figure 36 Buckle in block 69

Analysis showed that if only the double bottom of the block would be present sufficient strength was available to accommodate the bending entire moment. Of course the block would be more flexible leading to a larger sag during lifting. Without temporary reinforcement it was calculated (as could be done in those days) that the deck strip came close to buckling, but would not reach the limit. But any small deviation could cause buckling. Realising all of this it was decided not to install any temporary reinforcement. It would be much cheaper to repair any buckling that might occur. It was important to communicate this very well with the fabrication department because otherwise some panic might easily come up when buckling would occur.

The weakest point was identified at a manhole and indeed there a buckle occurred. Everybody was prepared for this and the procedure simply went on. Repairing this buckle was relatively easy and cheap.

As mentioned above, in order to lift the individual deck blocks temporary transverse bulkheads were provided parallel to structural bulkheads.

Optimising the temporary bulkheads meant providing them with horizontal stiffeners (probably in case of bulkheads kept as corridor wall the stiffeners were located outside the corridor itself). A typical situation at the top of the braces is shown in figure 35. Block seam, temporary and permanent structural bulkheads and braces are indicated.

In the design we did not take into account the effect of flexibility when lifting the blocks. Because of the extreme separation between the lifting points (58.5 meters) the blocks sagged relatively quite much. Setting down meant a first

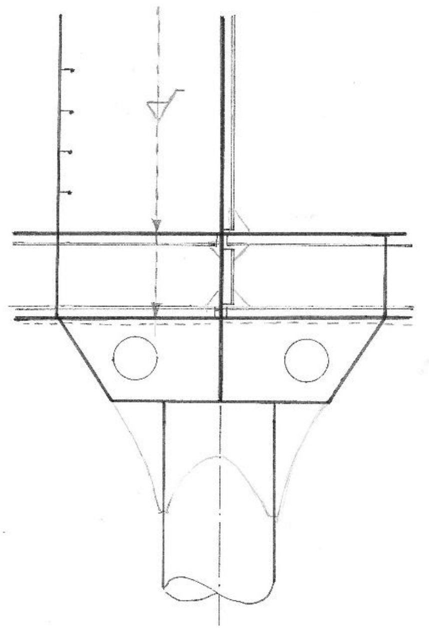


Figure 37 Arrangement of temporary transverse bulkhead

contact with the bracing top boxes at the vessel centre line. Hence a load between the temporary block bulkhead and the bracing top box developed. The sketch illustrates clearly that the structure had not been designed for such. No wonder that at one location a fairly large buckle developed in the temporary horizontally stiffened bulkhead. Considering that after assembly the bulkhead had no structural role anymore and that the function of the corridor was not impeded by a buckle, it was decided (with approval of owner and class) to leave the situation as it was and not to repair.

Anecdote:
Years later the vessel had a new owner. Bart Boon was called by Gusto Engineering where somebody thought to remember the incident and wanted his confirmation. The new owner had noticed the buckle and was afraid the vessel started to fall apart. They were happy with the explanation.

The first deck block set was the one on top of the middle columns (see figure 31). The second one had to span the open space between the centre and the forward columns, figure 36.

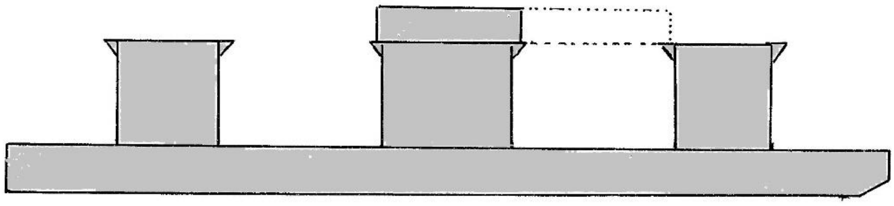


Figure 38 Situation block 64/65 on 6 July, 1974

The entire operation of lifting block 64/65 with *Assembler*, manoeuvring the 3GLB under it and lowering the block went smoothly. Fit-up to deck block 63 was excellent. Until the *Assembler* completely lowered the hydraulic pressure and set the block in its final position. The good fit of the block seam disappeared and opened considerably; maybe something like 12 mm. To repair the weld all around the block perimeter of the block within the one week before the scheduled next block setting, was deemed unrealistic[38].

Soon we realised not to have taken into account the relatively large deformations of the floating structure occurring with the significant load changes during the block setting. In this case the vertical block weight exerted on the forward columns bent the floaters and the support point (the box brackets at the top of the columns) were pushed downwards. Thus the block rotated and the weld seam opened.

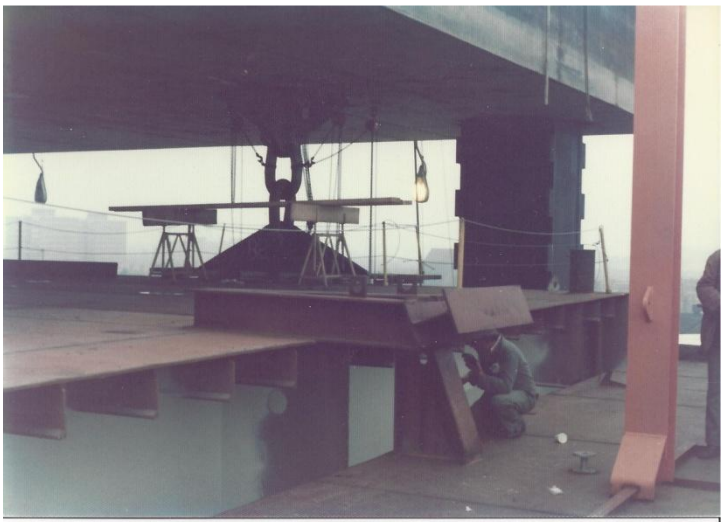


Figure 39 Guiding a deck block into position

Connecting the deck plating of the present and the new deck block by welding steel strips was thought to provide a solution. Multiplying block weight and half block length gave a clamping moment to be absorbed. Dividing this by block height (depth) and allowing something like 1 tons/cm^2 as maximum shear stress, soon led to the amount of weld length needed. The *Assembler* picked up the weight of the

[38] Actually it was good that this was impossible as it would have meant building-in deformations that could have led to various different complications later-on.

block again, steel strips and welding machines were quickly found, and everybody capable to weld did so. Even one of the directors was seen welding. One or two hours later the two blocks were connected. Now *Assembler* could release pressure again and lower the new block and indeed the system worked. The perimeter weld could be made within a week without any problem.

A similar incident happened when a further block was set; possibly the most forward block. Again the block weld seam opened after release of the *Assembler* lifting force. For some reason (now forgotten) it was decided that the same procedure as in the previous case could not be used. Possibly the new block slid over the supporting box brackets at the column rather than only rotating as before. This may have caused that both the upper an the lower block seam opened. Something that would be difficult to correct in the previous way.

Anyway, it was decided in the remaining week to install temporary tank rollers in the box brackets on the columns, to elevate those hydraulically and in that way to lift the block from the brackets. Ballasting the floaters brought the block at its intended location with acceptable weld seam openings. Again a successful operation.

In September 1974 the last upper deck section was placed, after which the Assembler 1 could be removed. The stern ramp was lifted by sheerlegs and fitted to the vessel in May 1975.
Once the hull had been completely assembled, all effort was directed towards outfitting and completing the barge. A new challenge arose: the large size of the vessel at the outfitting quay meant that a lot of time could be lost by walking toward ones work, going back to a shop at the yard to get tools or materials, etc. On the deck of the Viking Piper therefore toilet and lunch facilities were installed and a mechanical elevator at the side of the vessel provided easy access to the deck.
On 19 April 1975 the yet unfinished barge received its name: Viking Piper. On 12 May she left the yard and on 21 May the ownership was officially transferred to Viking.

Anecdotes

Late 1973 several things went wrong. Some examples:

- *In October1973 block 55, a column, was launched by Vuyk Shipbuilding in Nieuwerkerk aan den Ijssel. It did not float up after the launch, and rested on the bottom of the river Ijssel. A sheerleg had to come to the rescue to salvage the 510 tonnes weighing column.*

- *The nodes of the bracings appeared to resist welding: every new weld on one side could make another weld to burst open. Gusto was not familiar with pre- or postheating and such treatments. An American specialist was flown in: Alpo Tokola, originally from Finland. He advised certain sequences of welding, and buttering of difficult weld positions. When the problems appeared persisting, Tokola was consulted again, together with prof. Jack Bouwkamp (Berkeley, Ca), Freek ter Avest (TNO Metaalinstituut) and a representative of Bureau Veritas. Gillis Westdijk got involved for Gusto and Bart Boon was heading the task force. It was then understood that lamellar tearing was the main cause of problems, a phenomenon that was hardly known at the time. Viking insisted that the nodes would receive post heat treatment and although the task force did not expect any improvement from such treatment, it was done in large tents erected for the occasion. It did not help at all, tearing continued to be found but was mostly not visible at the steel surface. Just before delivery of the vessel, Bart Boon travelled to The Welding Institute to discuss the Gusto vision, that the (invisible) tearing was acceptable and needed no repair. Most fortunately parties agreed. See also appendix 2.*

Alpo Tokola had given management another advice. There should be one person at the yard who should inspect the preparation and execution of every major fabrication and assembly event and give or withhold his approval. Since the head of Prodo had no direct production function, he was appointed to be this factotum. No major mishaps happened after the appointment, probably because everybody in *production now had an increased awareness of how important good care was. It helped to create closer relations between white and blue collar workers, very much so between George Lagers (product development) and Leo van Putten (eindmontage).*

The floaters arrived at the yard early 1974. First assembly was lifting the midship columns onto the floaters, which was achieved on 6 April 1974. Since they were placed in an eccentric position, counterballasting of the floaters was done in preparation of the set down. To double check on weights and ballast, George Lagers had installed an inclinometer and pen recorder on the deck of the floater, see figure 38.
After placement of the first column everybody went off for lunch happily. During lunch in the cafeteria on shore, Bart Boon and George Lagers looking through the window got the feeling that the column was listing slightly. They ran outside and checked the recorder, which was still running and indeed showing a slowly increasing heel of the floater. It appeared that the water ballast inside the floater was flowing back into the side tanks, because after pumping over to counterballast, the valve between the tanks had not been closed. The situation was redressed well before the column could slide off.

Figure 40 Measuring the heel caused by the column set-down

Two of the six deck blocks were built on Gusto's western slipway. The lower one was wider than the upper one. The central launching way was fitted under the centerline of the wider section and was therefore eccentric under the narrower section. Balancing ways were fitted as well on both sides, but no thought had been given to the unusual load on the balancing way of the narrower block caused by its eccentric position. It took a lot of pulling force to get the narrow block start moving and then it pushed and tore away the balancing way sections and started bumping over the concrete side of the slipway. The deck section ended up with very little damage, some dents and paint damage, but the eastern balancing way partially was pushed into the river and was a mess. The sleds, ground ways and balancing ways had been borrowed from the yard Piet Smit, where one was not amused.

It must have been one of the later Saturdays for setting down an upper deck section. The job was well done, within the 2.5 mm margin that we had adopted. On Monday morning Bart Boon and George Lagers went back to double check a few things before welding would start. To their dismay they found that the 2.5 mm were lost. Re-lifting the section was no option. What we in cooperation with Leo van Putten did is: have the floaters ballasted and deballasted to slide the deck section into position by flexing the vessel. It worked! I am not sure that we ever told our bosses. Maybe the sunshine during the weekend had caused the problem.

In block 69 two toothed tracks were mounted over which two locomotives should be installed to withdraw the stern ramp upper end, typically in bad weather after pipe abandonment. These locomotives had been ordered in the USA and were delayed in delivery. When they finally arrived, they looked awful, so that Gusto asked their painting subcontractor to give them a face lift. After some hours the painting foreman showed up in the yard office, bewildered: "my guys are gouging out the welds!". It appeared that a number of important welds were actually not welded, but filled with putty. Imagine that this had not been discovered….

10. The Costs

Prior to contract, the parties who took the initiative for Viking have of course looked at the economics of the venture. IHC had already chartered consultants from the USA to obtain advice on the further development of the Offshore Division. On April 12, 1972, Frank Thomas[39] presented a report to Piet Verschure , Pieter Heerema, Bob Brown and a certain mr Barge, comparing a conventional and a semi submersible pipelayer. He referred to an earlier report by RJ Brown, also discussing this comparison. Assuming automatic welding (which RJBA did not) he concluded, that conventional techniques are cheaper up to about 200 kilometers pipe to be laid, and the semi is offering better economics for longer distances. As a matter of fact, Thomas referred to shareholders, so in April 1972 the project already had supporters outside IHC and Heerema.

The report does not specify the building cost of the pipelayers, but the estimated cost follow from the interest and depreciation. At that point in time the estimated investment was US$ 30 million or in the range of Dfl 105 million, double the amount of a conventional lay vessel. On November 1, 1972, the construction contract for Viking Piper was signed with a contract amount of Dfl 133.6 million and a provision for adjustable prices and target prices of Dfl 30.4 million. The final calculation for settlement of adjustable and target prices, dated 24-7-1975, specifies Dfl 30 574 756, quite close to the contractual amount.

A recent standard procedure at Gusto was to have a weekly meeting with clients to discuss additional prices. Without agreement on additional price and delivery time, no changes would be made. The result was a penalty-free delivery, although the delivery was one year late with respect to the contract.

In September 1975 the total of the original contract amount inclusive of adjustable, target prices and additional work had risen from Dfl 164 million to Dfl 183.4 million, plus further adjustable and target prices of 22.3 million, which were financed by Viking directly, not through Gusto. The total cost to the yard at that point in time had been Dfl 193.2 million, thus resulting in a loss of Dfl 9.8 million. Maybe there had been some further losses to the subcontractors of Gusto, such as Intercontinental. No numbers are available in this respect. Interestingly, a further cost report dated 20 January 1976 shows a loss of Dfl 7.0 million but also mentions that further costs are to be expected for guarantee claims. The major component in this is the repair of the Intercon winches, at Dfl 8.5 million, basically the responsibility of Intercon but possibly not fully recoverable.

Shortly before delivery of the barge to Viking, Lex van Gunsteren, the then managing director of Gusto, tried to convince Dick Smit (president of IHC) to claim an additional 10 million guilders from Viking based on the contractual escalation clause. If Viking would not accept, the delivery would not take place, while Viking at that moment had a contractual obligation to BP to start pipe laying. However, Dick Smit did not like this approach and withheld his approval. IHC was – or desired to pose as - a gentlemen company. Maybe Dick Smit as a former shareholder of Viking did not want to upset the old partners in business.

[39] Representative of the US consultants Touche Ross Bailey & Smart, who had Verschure's full confidence. Starting 1969 Frank Thomas was Secretary of the Board of IHC. See: 70 jaar IHC Merwede page 153.

11. Operations and Owners

Immediately after completion of the sea trials and commissioning tests, Viking Piper set off to build the Ninian pipeline for BP, starting from the Shetland Islands[40]. In their brochure of early 1976, Viking proudly announced that over 40% of this 36" pipeline had been completed in the first season, from August to October 1975. In October, the barge continued laying pipe during a gale with 60 mph winds. Because of the deteriorating autumn weather, pipe laying was then abandoned to be resumed in April 1976. There had been serious problems, in particular with the mooring winches (see chapter 5.1) but the achievement was remarkable and showing the potential of this large, semi-submersible lay barge.

Who was Viking Jersey Equipment Ltd.? The originator was IHC Holland, Offshore Division, who believed in the ideas of Bob Brown and already had experience in creating a company to subsequently sell one of its products. The Havdrill contract was an example in case.
For the semi-submersible pipe lay barge idea, Piet Verschure got the cooperation of Pieter Heerema. Jointly they started Viking Offshore Pipeline Contractors io, the predecessor of Viking Jersey Equipment Limited and its associated companies. They got the Bank of Scotland and the French GTM (Grand Travaux de Marseille) interested to join them.

When Viking Jersey was established, its seat was at Martins Chamber, St. Hélier, Jersey. Ed Minor, former Vice President of Brown & Root's pipeline division, was named president of the company, with Charles Bell, former RJBA employee, as his right hand.
On 22 February 1973, when the contract was signed by all shareholders, the Viking group consisted of IHC, Heerema, Spie Batignolles, NSA, Bank of Scotland and some Norwegians. After Heerema withdrew in spring 1973, the remaining shareholders were:

- IHC Inter 29.17%
- Spie Batignolles 25%
- North Sea Assets Ltd, Scotland (NSA) 20%
- Group of Norwegian investors 10.41%
- Norske Aksjeselskapet Garonne Glitre 10.42%
- Bank of Scotland 5%

By summer 1973 a supervisory team had been formed by Viking, consisting of:

- Charles R. Bell[41] Project Manager
- J.C. Richardson
- Walter Adler
- Bill Hotchkiss
- Sam Posner
- R.J. Person
- Ekrem Özel
- Jan Knudson
- Finn Michelsen who afterwards moved to Heerema, Leiden

In addition Viking hired some consultants who were supposed to bring in expert knowledge, but in daily practice appeared to be a negative force: Roger Smith and mr. Korkut, jointly ODI (Offshore Design International Inc of New Orleans).

[40] The original client for this job was Chevron, but even before the contract with Viking Jersey was signed, Chevron sold Ninian to BP.
[41] Charles, who was central in the development, died in 1990 of leukemia, at the age of 59.

Early 1973, Heerema backed out of the venture, probably because of personal incompatibility of Pieter Heerema and Ed Minor, but it is likely that also his financial situation played a role. IHC stayed in the partnership through its financial branch IHC Inter established in Switzerland. Daily matters passed through the IHC Offshore Division headed by Piet Verschure, until 1973 when Verschure moved to the division Participations and was followed in Offshore by Bob Schuil. The relation Gusto – IHC Inter (represented by Robert Smulders – Piet Verschure) was at arm's length in order to avoid conflicts of interest; after all IHC played a dual role in the project.

On the 6th of December 1974 during a Board Meeting in Copenhagen also IHC Inter withdrew, which of course always had been the intention: the whole set-up was to keep the Gusto yard occupied, not to enter into offshore contracting work. At the time of delivery ex yard, the Viking shareholders were:

Fearnley and Eger (Norway)
Spie-Batignolles SA (France)
North Sea Assets (Great Britain)
Bank of Scotland (Great Britain)

In 1977 Viking Jersey became a 75% affiliate of Santa Fe International Corporation[42].

In 1976 the Ninian pipeline was completed. The market proved to be smaller than anticipated. Viking Piper became idle and was chartered out to Occidental as an accommodation platform for some time. In 1980 Viking Jersey Equipment Ltd sold the vessel for $ 85 million to McDermott International Inc. who renamed her McDermott Lay Barge 200 (shortly and from 1998 onwards officially, LB 200) and continued use as an accommodation vessel for the hook-up of Statfjord B. McDermott seemed to be quite happy with its procurement but implemented a number of upgrades during fall 1982 and winter 1983. To this end the LB 200 was docked at Verolme Rozenburg. New deck equipment was installed; 10 new mooring winches; the remaining 4 Intercon winches were refurbished; the deck was extended at the port bow, making the overall deck length increase to 164.7 meters and providing support for a forward shift of the helideck; a third pipeline tensioner was fitted as well as a new A&R (abandonment and recovery) winch; and a new saturation diving system. In its home journal *JARAMAC* of 1983, number 2, McDermott calls the LB200 the finest deepwater pipelay vessel in the world. Starting April 1, 1983, the LB 200 built two pipelines from Kalsto in Norway to Riser Platform 1 and Statfjord respectively, both crossing the Norwegian Trench, the ultimate design requirement of Viking Piper.

In 2006 McDermott transferred the ownership to Stolt, who shortly thereafter was restructured and renamed Acergy. As the Acergy Piper the vessel continued to work until 2009 and was then sold to Saipem, its last owner, who renamed it Castoro 7. In December 2015 Castoro 7 started her last voyage from the Curacao to India, where she was demolished.

[42] Maritime Reporter January 1981

12. The long arm of Santa Fe

During the winter of 1976, Gusto received a message from Santa Fe, Orange, California. Santa Fe claimed that the Viking Piper was infringing on their patent which essentially described the Choctaw I. The yard reacted in a maybe somewhat simplistic way: not our problem. Even so, we could not completely neglect the patent problem. The yard's lawyer, Arthur Roell, and George Lagers accompanied Charles Bell on a trip to California, to find out how serious the Santa Fe claim was. During the flight to Los Angeles, Charly filled up with booze, and the next morning when we had the meeting with Santa Fe, he was not really contributing anything. Of course we tried to explain to Santa Fe that their US patent was too simple and too obvious to hold when really challenged in court. The lawyer with whom we spoke made clear, that litigation would be in a US court and that a US judge would never condemn a US company confronted with a non-US entity. Arthur and George hardly believed what they heard, but maintained that the whole thing was Viking's problem. And so they returned to Holland, after passing the afternoon in a wildpark just south of Los Angeles. We later heard that a settlement had been reached between Viking and Santa Fe, so that the validity of the patent was not challenged. In 1977 Viking Jersey became a 75% affiliate of Santa Fe International Corporation.
Years later, Santa Fe attacked Heerema Engineering Services with the same patent. They requested US$ 300 million plus demolishment of the Balder and Hermod, because these vessels were infringing on their patent. Also in this case a settlement was reached, as far as we know at a much higher price than in the Viking case, but for a fraction of the original SF claim (ref: blz 98, "Een eigen koers, 50 jaar Heerema Marine Contractors").

13. The end of the Grand Old Lady

Figure 41 Castoro 7 at her last mooring

On 25 June 2016 the Castoro 7 was beached at Alang, India. It was night in Europe, but Dirk Allewelt caught the news and relayed it to the Gusto History Group right away, at 1:29 in the morning. It meant a lifetime of 41 years since first delivery from Schiedam. Her last voyage commenced from Caracasbay, Curacao to Port Natal, Brazil, on Tuesday 22 December 2015. Towed by the Skandi Amiral, she continued to the breakers in India, arriving 16 June 2016. Her last project had been in 2014 in Venezuelan waters; after that she had been idle at Curacao for 13 months, with little or no prospects in a poor market where Allseas had positioned itself as the market leader. Saipem had planned to scrap 4 offshore construction vessels in 2016 as part of a "cost optimization program"; in addition to Castoro 7 also the semi-submersible pipelayer Semac 1 was to be released. So the final curtain fell for the 40 year old lady. She had been known as: – VIKING PIPER – McDERMOTT LAY BARGE 200 – LB 200 – ACERGY PIPER and finally – CASTORO 7, owned by Saipem.

Figuur 42 Vaya con Dios

14. Conclusion

In the 1970s Gusto yard designed and built the semi-submersible pipe lay barge *Viking Piper*. Using common sense and a first principles approach it was possible to develop a vessel that even after 40 years of operation performed completely satisfactory. Modern computer analyses might have optimized the structural design as far as weight is concerned without altering fundamentally the safety of the vessel. *Viking Piper* made Gusto known worldwide in the offshore community.

APPENDIX 1 : THE ASSEMBLER I

Design and operation

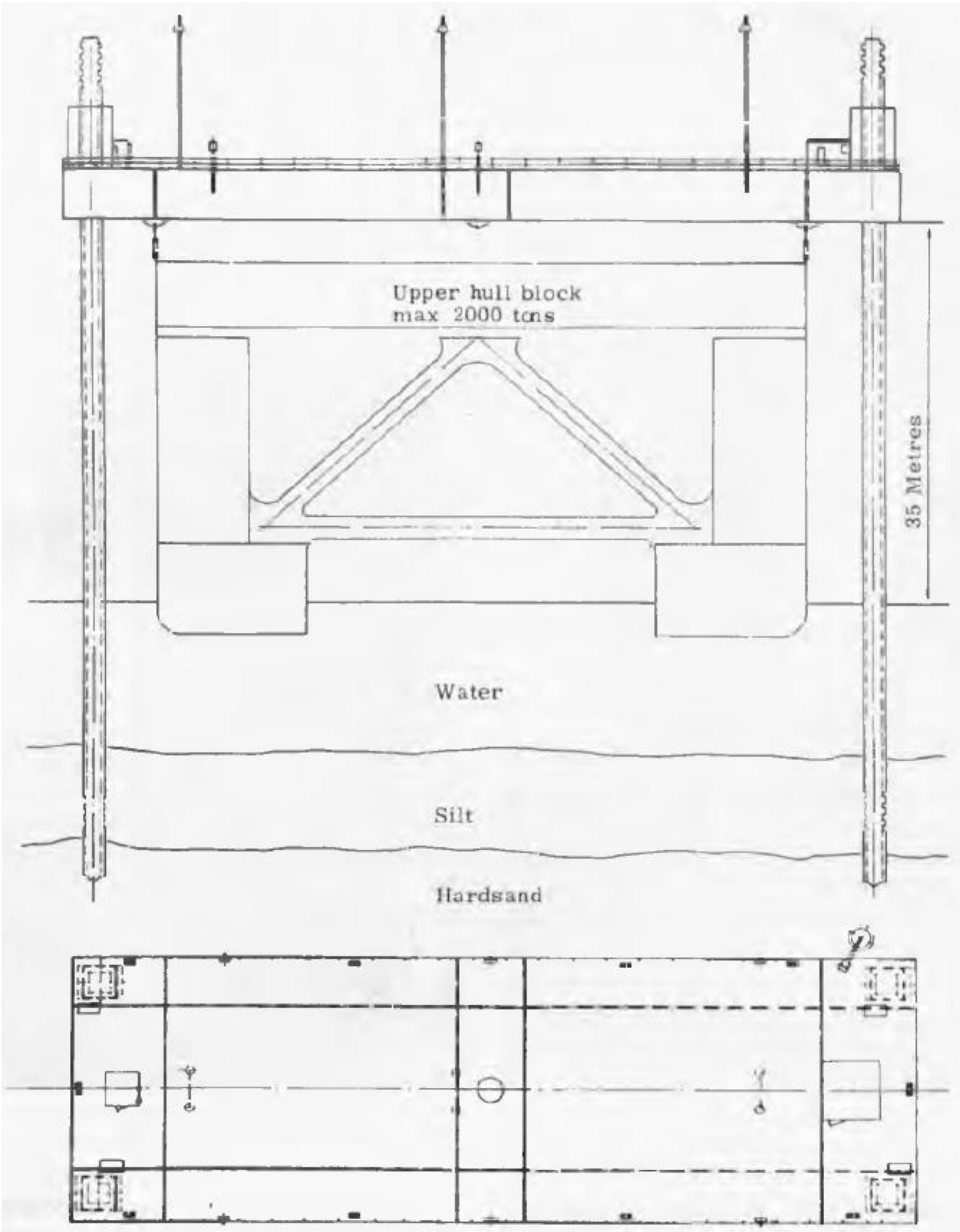
When on November 1st 1972 the design and construction contract was signed for Gusto yard number CO 928 (later called *Viking Piper*) immediately the question arose how to build this vessel which was far too big for the yard and its equipment. Of course thought had been given to this point during the preliminary design phase prior to the contract. The large graven dock at Verolme Rozenburg was shortly considered, but rejected as impracticable in many respects. The chosen idea was that the vessel should be assembled afloat from large blocks that would be lifted in place by a combination of three or at most four floating sheerlegs. The largest one in the Port of Rotterdam in those days had a lifting capacity of around 400 tons (*Matador*). RDM had just finished the *Smit Tak 1* with a lift capacity of 800 tons, but its availability probably was limited because of its role in wreck raising. Even more important was the limited outreach and lifting height for such capacities. On top of this an accident happened at Gusto Staalbouw leading to a ban by the Port Authority to use more than three sheerlegs on one job (see note at the end of this appendix). Given size and weight of the blocks, those in between columns would have to be split in two. This meant that a substantial temporary support structure would have to be built in between the columns, possibly comparable to or even exceeding the brace block later installed at frame 204 (foreship). Taking into account that the actual construction weight normally sooner increases than decreases, it was decided that the use of sheerlegs was not a realistic option. After some brainstorming the idea of using a self-elevating platform came up. Or rather, Jaap Sprenger suggested that the large blocks could be lifted in the same way as the railway bridge in central Rotterdam (the "Hef") was lifted when large ships had to pass. This suggestion quickly transformed into the decision to use a jack-up platform, a structure which was very familiar to Gusto.

The design office was tasked with further development of the idea and the design of the platform. It was based upon the concept of quite a few jack-ups that Gusto had built for various civil engineering purposes. With some margin for weight increase the maximum lifting capacity of the jack-up was set at 2000 tons. An extra design requirement was formed by the wish to sell the platform to a civil engineering contractor after it would have served in the completion of the *Viking Piper.* Given *Viking Piper*'s dimensions, the length of the platform obviously would be outside the common range. This led to the idea to cut the platform in two parts after completion of the *Viking Piper.* Each part would be extended with two more legs and surrounding structure and sold as a conventional self elevating platform. In view of the block dimensions and the future use as two civil platforms, following main dimensions were chosen:

length 75 meters, width 24 meters and depth 4.5 meters.

The internal bulkheads were arranged such that they could incorporate the lifting points. Outside those bulkheads a normal arrangement typical for a jack-up platform could be made including the four leg well sections. For instance the internal transverse bulkheads adjoining the leg wells are located 58.5 meters from each other, commensurate with the width of the *Viking Piper*. The pad eyes of the blocks formed part of the side shell of the pipe layer. Those of the jack-up were part of its longitudinal internal bulkheads. It meant that the pad eyes had a perpendicular position relative to each other which was favourable for the use of the *Green Pin* shackles. The nominal capacity of the pins was 1000 tons each providing a factor of safety 2, normally required for lifting appliances. Given the lifting accident at Gusto Staalbouw shortly before (see anecdote at the end of this appendix) the pad eyes were not made in the normal way, i.e. with a doubler around the opening. Instead full thickness was used over quite a part of the pad eye height, after which the plate thickness tapered. Coincidentally some normal strength steel was available at the yard with a thickness of 150 mm. This was very suitable for the required pad eyes.

In a similar way pad eyes were arranged on the longitudinal bulkheads at a position according the width of the columns which were to be used to lift the bracing blocks. At the centre of the platform some were arranged to hook up to the bracing top boxes if desired.



From G.H.G. Lagers *Design and Construction of the 'Viking Piper'* Schip en Werf **44**(12) 10 juni 1977

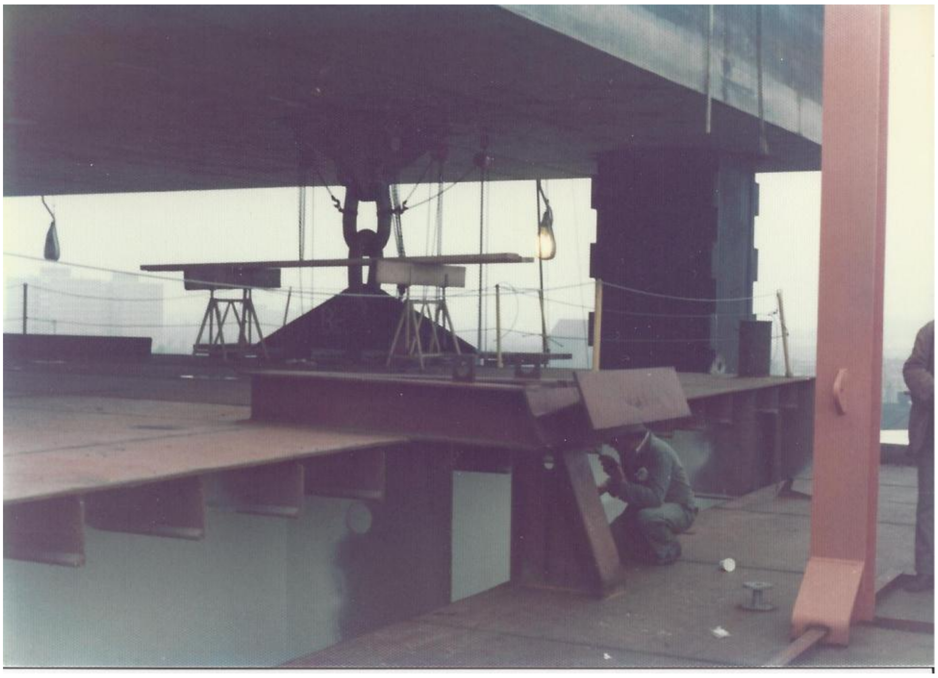
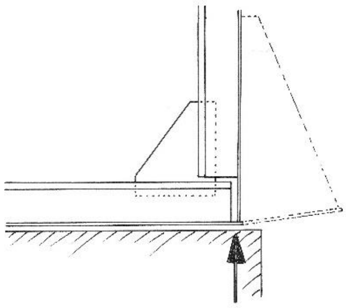


Photo Bart Boon

The hull of the jack-up was subcontracted to the Verolme Yard in Heusden (yard number 879) and delivered on 5 March 1974.

During launching of the hull on a single centreline sled an incident happened. The Assembler 1 was designed without centreline girder or bulkhead. Quite a high force was exerted on the front side when the stern side started to float up. The local structure looked more or less as shown and obviously was not suited to accept this point load of nearly half the hull weight. No wonder some local buckling resulted straight above the sled front end, including some of the vertical stiffener. The shell plate separated from the stiffener. Fortunately the water tightness of the hull remained intact. The damage was not extensive and could easily be repaired. However it made us rethink the launching of all *Viking Piper* blocks that still had to follow. Since then they were all provided with launching noses as indicated by dotted lines in the sketch above. No further problems in this sense occurred.



After launching the platform hull was baptised *Assembler 1*. This name was based upon the function of the platform and in line with the vessel recently taken into operation by SBM for installation of their buoys and named Installer 1.

Legs and elevating systems were constructed at Gusto Staalbouw in Geleen. On its way to Schiedam the *Assembler I* was used as transportation barge and loaded the first bracing block (block 59, page 41), probably at NAPM in Rozenburg. After setting and discharging that block the legs were installed in Schiedam.

The platform was designed and built in accordance with Bureau Veritas classification rules. In addition the platform being used as lifting appliance in the Port of Rotterdam had to comply with the regulations of the Port Authorities. We called them and obtained their confirmation of compliance. Then they asked what the lifting capacity of the new appliance would be. Hearing 2000 tons, they only said *Oh, Gusto again*. They wished to see the drawings, but did not intend to review them: *Nobody knows better than you at Gusto how to design such thing. Just use the applicable rules of the Havenarbeidsbesluit*[43]. After checking these rules, the only thing we could use was *Every lifting appliance should clearly indicate its maximum lifting capacity in kilograms.* Hence the large sign on the side of the *Assembler I* saying 2.000.000 kilograms.

The structural concept of the *Assembler I* took into account the flexibility of the hull.

The main lifting points, those for the large deck blocks, were located relatively close to the four legs The assumption was that in this way most of the load would directly flow to the nearest leg. No flexibility considerations are needed to understand this. This conclusion can as easily be based upon symmetry consideration.

Testing the structure is different. According to authority prescription all pad eyes must show a proof strength of twice their maximum lifting load. Commonly this is done using test weights. With the loads used in this situation such was practically impossible. The common way of preloading a 4-legged jack-up, as in all Gusto civil engineering platforms, opens possibilities. The platform weight is normally distributed over four legs. During preload the weight taken by two opposite legs is released simply by taking hydraulic pressure from the elevating system, releasing the brakes or similar. The torsion flexibility of the platform hull makes that the total weight is taken by two legs only, thus leading to the required preload. In this situation some twist occurs in the hull. In the particular use of the Assembler 1, the deck block to be lifted is much stiffer than the jack-up platform because of its larger depth (5.95 against 4.5 meters). Consequently the lifting force tends to concentrate on two diagonally opposed pad eyes which in this way are tested to double their lifting load.

This test procedure is very fast. It was performed for every block to be installed just after raising the block out of the water. This was in order to contain damage during the test: if something went wrong, the block would drop over a small distance only. For the subsequent jacking to 35 m above water, the weightr of the block was supposed to be equally distributed over four pad eyes/shackles. If the jackman on Assembler 1 was not careful to move all four jacking systems simultaneously, then one might imagine that the load would be carried on two instead of four corners. Prodo suggested to measure the load in the green pin shackles indirectly, by mounting a strain gauge on one of the Assembler pad eyes and calibrating it. The moment of fitting the tiny strain gauge has been photographed. Karel de Werk (with

[43] The title "Havenarbeidsbesluit" may be incorrect

sunglasses) is the job supervisor. Some able hands look on with interest. During the lifting operations it appeared, that the flexibility of pontoon and blocks was such that load sharing occurred more or less automatically.

Anecdotes:

After testing and raising somewhat, the undersides of the blocks were cleaned because they had been in the water for some time. Once the subcontractor started doing this when the test procedure still was in progress. It took quite some persuasion to convince them that testing meant that something could go wrong and the block theoretically could fall down. After all you did not see anything dangerous.

It was found that one of Assembler's lifting cylinders leaked a little leading to a slow gradual loss of hydraulic pressure. When a block hung underneath it was necessary to correct this regularly. To that end one of the jacking engineers slept onboard and was regularly raised by an alarm clock. At one occasion a jackman (not to be named here) slept through his alarm clock and when he awoke, the full load of platform deck and load was mainly carried by two legs. So actually the block hung on two pad eyes only at some 35 m above water. Luckily no damage had occurred.

As mentioned above, the intent was to make two separate jack-ups out of the *Assembler I* and sell those separately after finishing the work for *Viking Piper*. That is why at half length two transverse bulkheads were provided. The separation was meant to take place adjacent to those bulkheads. New end sections were to be fabricated identical to the existing ones and installed next to the bulkheads. This would result in two platforms with an overall length each of 45 meters.

Indeed in 1976 Assembler 1 was cut at mid-length in two halves by shipyard Slob, new sections provided with jacking systems and legs were welded to the bare ends of the platforms and the two jack-ups were sold. Unfortunately communication between the design group and the sales department appeared not to be optimal. Sales (Joop Hage) sold two islands of 37.5 meters length to Sam Postan in Rouen who transferred them to Bouygues Offshore. It meant that leg wells had to be incorporated into an existing structural arrangement. Something that certainly was much more complicated and probably more expensive than the original idea, new-built additional sections. The two jack-ups operated successfully as *Mer d'Iroise 1* and *Mer d'Iroise 2* (CO 951)[44].

Today the building method as described is no longer considered realistic. Now a building dock would be used with a large gantry crane. But when a few years after *Viking Piper* Heerema decided to build a large semi-submersible crane vessel (the *Balder*; *Hermod* came into sight only after receiving the Japanese offers) Dutch shipbuilding industry, i.e. the combination of Gusto Yard and RDM, a similar way of

[44] Sales price around Dfl 12.5 million, original Assembler costs abt. 6.5 million and conversion by Slob 1.63 million, not including the Gusto supplied legs & jacks.

assembling that vessel was considered. The use of a self-elevating platform and construction afloat obviously was not a bad way of doing, even when nowadays considered out-dated.

> *Why Gusto could not use four sheerlegs at the same time,* *memories of Peter Mackenbach.*
>
> *While the conceptual design of Viking Piper was still ongoing, Gusto Staalbouw was engaged in the construction of jackets and decks for North Sea production platforms. The boss of the Staalbouw team was Toon Hermans (not the comedian). Most of the time the people at the shipyard were unaware of what their colleagues at Staalbouw were doing, everybody was so busy. Until Toon Hermans had to unload a deck which was so heavy, that four floating sheerlegs were required to lift it. Everything went fine until the deck was hovering above the barge which would take it to sea. Then disaster struck: one of the padeyes broke, the production deck fell on the deck of the barge and perforated it with its support tubular. One tubular was stopped by the barge deck and was pushed upward through the production deck. Three of the four sheerlegs received damage in the accident. The fall of the production deck was stopped a few meters above the barge deck. This saved the life of Toon Hermans who was present on the middle of the barge, under the cargo being lowered. Even a hard hat would not have saved him in such case. The result of this accident was that the Harbour Authority no longer would give permission to lift objects with more than three sheerlegs at a time.*

APPENDIX 2 : LAMELLAR TEARING

Lamellar Tearing during fabrication of Viking Piper

Bart Boon

Summary

At two moments during the fabrication of *Viking Piper* serious problems arose with lamellar tearing in the steel plates of the brace nodal points. The first moment was during pre-fabrication of the individual nodes at Gusto Yard itself and at the facilities of several subcontractors. The second moment was shortly before delivery of the vessel. The latter had a continuation a year or so later in Hamburg.

Bart Boon, considered to be the structural strength specialist at the design department/drawing office, was involved in all of these occasions.

This appendix reports his memories of what happened. Clearly the memories are subjective and probably incomplete. An earlier publication on this subject was presented in 2013[45].

Introduction

Viking Piper was assembled in front of the yard from large blocks weighing up till about 1600 tons. They were hoisted into position using the dedicated jack-up *Assembler I* having a nominal maximum lifting capacity of 2000 tons. Amongst those blocks were five which were called “bracing blocks”. Three of these consisted of two vertical brace triangles horizontally connected by two diagonal braces. They were placed each between a pair of SB and PS columns onboard.

At frame 204 the block consisted of only one vertical triangle plus at each side a vertical tubular column. At frame 12 the block consisted of a horizontal brace only sitting on top of both floaters.

The blocks were accurately positioned upon the float decks and against the column inside shell and well aligned with plates inside floats and columns. However floater deck plating and column plating were continuous (apart from the column transverse shell which continued slightly bringing the connection seam just outside the column at the centreline side of the column.

The fabrication of the blocks was subcontracted to

- **NCM**, de *Nederlandse Constructiebedrijven en Machinefabrieken N.V.* in Delft belonging to *Nederhorst Staal*. Probably they did some fabrication in Delft, but assembled the large pieces at their location in Gouderak near Gouda);
- **NAPM**, de *Nederlandse Amerikaanse Pijpleiding Maatschappij b.v.* in Rozenburg. This company was established in the 1960s by an American pipe welder Bill Cooper who previously worked for NAM;
- **Gusto Staalbouw** located at the yard itself (check, possibly also Slikkerveer participated).

[45] Boon, B. (2013): “Revisit of a 1970s semi-submersible pipe layer”, MARSTRUCT 2013, Espoo

Gemeentearchief Schiedam part of NL_SdmGA_0386_0318_0373 (GustoMSC)

Gemeentearchief Schiedam NL_SdmGA_0386_0318_0207 (GustoMSC)

The bracing blocks in turn were assembled from large units, in particular the brace nodes as shown below.

Gemeentearchief Schiedam NL_SdmGA_0386_0318_0137 (GustoMSC)

Incident no. 1

During fabrication of the nodes late 1973 lamellar tears were visible from outside as they progressed to the plate surface, mainly adjacent to the welds. The tears occurred, as far as I remember to have heard, some time (hours, even days) after welding and even when no work took place (at night). It is unknown to me how much of the node fabrication was finished when we realised that a serious problem had arisen. As a drawing office member, I was informed about but not really involved in evaluating the problem or finding solutions. This was the responsibility of subcontracting, fabrication and quality control (Gilles Westdijk). In a later stage of this incident and its solutions, advice was also sought from us at the drawing office.

When *Viking Piper* was designed, problems had appeared in the North Sea and the GoM with fatigue cracking in nodal points of fixed platforms. Intending to prevent similar problems in the *CO 928* and knowing that high strength steels performed no better, actually worse, in fatigue than lower strength steels, it was soon decided to use normal strength steel for braces and nodes. In accordance with class requirements the structure had to be built from the best steel grade available, i.e. *Grade E* to prevent brittle fracture by its high impact resistance. Tubulars for the braces came from Germany (Mannesmann?) and plate material from a Belgian supplier. Both complied fully with the class and yard requirements.

Although known somewhat longer it was in the 1970s with larger structures that lamellar tearing began to pose a problem[46]. A few publications appeared prior to “our incident”, most after that. Yard nor classification society was (sufficiently) aware of the risk and the way how to tackle it.

Once the yard was aware of the seriousness of the problem they formed an advisory committee consisting of Carl O. McCullin (General Manager IHC Marine Corporation, Texas), J.W. Steenhuisen (Director NIL Nederlands Instituut voor Lastechniek), Alpo J. Tokola (Construction Consultant) and Jack G. Bouwkamp (committee chair and Professor of Structural Engineering and Mechanics, University of Berkeley). Their findings[47] were accompanied by two recent reports on lamellar tearing issued in the USA[48],[49] showing how topical the subject was. The committee report was based upon visits, discussions and review of drawing and welding procedures end January 1974.

The report concentrated on avoidance of restraint during assembly of the nodal points by choosing optimal welding sequences, in accordance with recommendations from literature although in the literature, plate thicknesses in general were larger and overall dimensions smaller than in our case. Those differences were not addressed. In addition better weld details and welding procedures were recommended again as seen in publications. The committee confirmed that material properties were in accordance with yard and class specifications and that work procedures in general were rather good although some improvement was possible, in particular at NCM. Also they gave some recommendations for repair and replacement of plate patches when found defective. Stress relieving the nodes was thought to be good. Given the stage of construction it may be wondered whether many of those recommendations could be adhered to.

From some comments in the report it is clear that at the moment of writing the yard already had implemented several of the repair procedures and had started stress relieving the nodes in large tents in the way described in the report. Ordering the committee report probably was justified by the yard because they wanted to strengthen their position to the client Viking by showing that the yard’s decisions were in accordance the best possible state-of-the-art.

A similar attitude had been taken by yard management when discussing the need of stress relieving. Some, including myself, thought that stress relieving would make no sense given the dimensions and thicknesses of the joints and the probable cause of the lamellar tearing, i.e. poor through-thickness properties of the steel plates and the use of fully penetrated K-welds, probably with a small nose. Management nevertheless decided that the rather expensive stress relieving in tents of entire bracing nodes would be performed “to show Viking that we do our utmost to guarantee the best vessel”.

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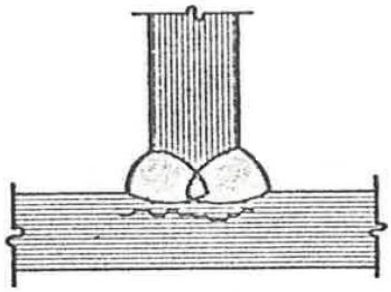
[46] Brandmeier, C.J.: “Overview of lamellar tearing failures and representative case studies”, 2014, https://failures.wikispaces.com/Overview+of+Lamellar+Tearing+Failures+and+Representative+Case+Studies

[47] McCullin, C.O., Tokola, A.J., Steenhuisen, J.W., Bouwkamp, J.G.: “An assessment of the welding procedures and sequence of the bracing-system joints of a third generation pipelaying barge”, Rotterdam, 29 January 1974

[48] Thornton, C.H.: “Quality control in design and supervision can eliminate lamellar tearing”, Engineering Journal AISC 4th quarter 1973

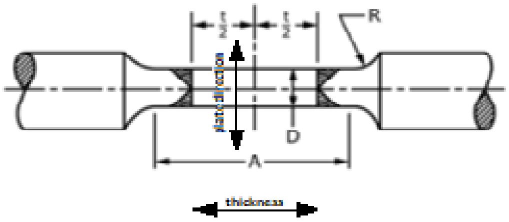
[49] AISC: “Commentary on highly restrained welded constructions”, Engineering Journal AISC 3rd quarter 1973



Joint showing typical lamellar tear resulting from shrinkage of large welds in thick material under high restraint

(From AISC: “Commentary on highly restrained welded constructions” [6])

Even before the committee report was received, the yard was aware that the cracks were lamellar tearing. Also it was found how to test the plate material for its susceptibility to such tearing. First material is welded to both plate surfaces. Test pieces as shown below are made thereof. Note in the sketch below that the original plate and rolling direction is vertical whereas plate thickness is horizontal. As with normal tensile tests necking is expected to take place at rupture. At necking the cross-section reduces compared to the original cross section. This is the RAZ value, reduction in area in z-direction. When more than about 0.25, the plate is hardly susceptible to lamellar tearing, but the smaller RAZ is, the higher the risk of lamellar tears. Gusto had such tests performed by Wilton-Fijenoord both with the (German) plate material of the tubulars as well as with that of the (Belgian) flat plates. The tubular plates had good RAZ values. But the flat plates were very poor; RAZ sometimes was nil. Rupture then took place without making any noise.



Standard test specimens per ASTM A770 testing procedures

As mentioned no through-thickness properties had been set by yard or class. Better quality probably had to do with more modern steel fabrication methods at the German steel mill than at the Belgian one. Today most mills produce steels that are hardly susceptible to lamellar tearing.

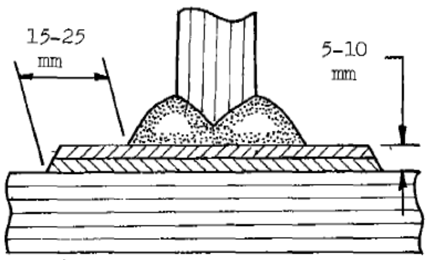
Repair of the cracks mainly involved gouging out the crack and rewelding.

Anecdote :

For the extra gouging and welding activity the yard did not have sufficient people available. A gentleman from The Hague, with an oversized shiny automobile, a certain Mr. Delmonte, offered to help with skilled labour from the UK. Indeed some of the new arrivals were skilled, but many were immediately after a skill test send back to the ferry to Harwich.

Several times during gouging it was observed that the crack actually seemed to progress in front of the molten material. At locations the end result was that an opening was created right through the plate thickness over the width of the attached (tubular) plate. This opening was then completely filled with weld material having, of course, better properties than the original plate material. This was the way in which the nodal points were repaired. After that they were connected with the brace tubulars into the bracing blocks mentioned earlier.

The bracing blocks subsequently were installed on the floater decks. At those locations again the "good" Grade E plate material was used. Aware of the susceptibility to lamellar tearing buttering could, and most likely was, applied as an effective means to reduce the risk[50].



From J Sommella: "Significance and control of lamellar tearing of steel plate in the shipbuilding industry [46]

Incident no. 2

Shortly (a few months, weeks?) before vessel delivery and its leaving the yard to sea, the decision was taken to ultrasonically check some of the nodal welds. Visually there were no problems at all. Much to the yard's frustration many cracks were found. They all remained inside the plate. It was assumed that again they were lamellar tearings. Given the experience with the first incident it was felt that insufficient time would be available to perform all repairs before the vessel was supposed to leave. Moreover a feeling had developed that not all repairs really meant a structural improvement: the steel was very badly treated.

A committee, chaired by me, was set up to determine the best action to be taken. Other members were Gilles Westdijk (manager yard quality department), Freek ter Avest (TNO Materials department), someone from the classification society Bureau Veritas (possibly two members: one from Holland and one from Paris), possibly Al Tokola (if still around in the Netherlands), probably Finn Michelsen from Viking[51] and maybe still others. Extensive discussions were held in particular on the probability that the existing cracks would grow under influence of stresses developed during operation of the vessel. It was decided that the subject welds mainly had to transfer longitudinal (in weld direction) shear from one plate onto the other. Given the step-wise shape of lamellar tears in that direction it was felt (and certainly not known) that such growth possibly would not be very likely. Based on this the committee unanimously decided to repair only part of the defect welds, i.e. mostly that adjacent to the tip of the large gussets (if I remember correctly it was only 1 meter in length). The remaining cracks would be left. Repaired and non-repaired welds would be accurately mapped. After about one year the situation

[50] From SSC 290 J Sommella: "Significance and control of lamellar tearing of steel plate in the shipbuilding industry", SSC-290, 1979.

[51] Viking had obtained the order to lay the Ninian pipeline; since then the relation between Viking and yard had improved tremendously; the objective was the same: *get that vessel in operation, as soon as possible*.

would be re-checked and action taken based upon the outcome. Of course, whenever possible in the meantime visual checks would be made. This solution was acceptable to all parties involved: owner, class, external experts and yard and could be implemented within the available time frame.

Of course as committee chairman I was very satisfied with this outcome. During a short period I felt to be the most knowledgeable person in Holland, if only because "In the land of the blind, the one-eyed is King". Then I went to yard management: "Of course I am glad with the result and that I could convince everyone. But now I would like to be convinced myself before te barge sails to sea. To that end I wish to go to TWI, the Welding Institute because the people who know best are located there". I got permission to visit them. Probably I met with Farrar and Dolby, authors of some publications on lamellar tearing[52]. They understood our problem and our reasoning. No research was available to support or reject our arguments. But its validity could well be true. Experiments were suggested to proof the assumption. But such would take quite a few months. Months during which the vessel would already be operating at sea. So real experience would be available and I took the decision not to perform testing. But I felt that our committee had come to the right solution.

I am still grateful to yard management of those days for allowing me to visit TWI. If they would have rejected our arguments, the yard would have been in a very nasty situation with unpredictable consequences.

Some time later *Viking Piper* had to go to Blohm & Voss in Hamburg to repair its mooring winches. It was a good opportunity to do the checks agreed upon. Some people from Gusto went to Hamburg to make the investigation. It was found that all cracks were completely conform the earlier maps. Except in one location: there all repaired cracks now were present again, but strangely all non-repaired cracks now were in order. Obviously a mistake had been made during the repairs. The good side-effect was that we got to know that even in more highly loaded parts of the welds, lamellar cracks did not propagate. So everything was left as it was.

Hearsay suggests that later also the remaining cracks were repaired, but I have no certain confirmation thereof.

Anecdote:

The Gusto personnel present in Hamburg went to spend an evening at the Reeperbahn. Doing so was far more expensive than we had anticipated. We had to call a colleague who would come the following day, to bring some extra money allowing us to pay the hotel.
Back in the yard we all were called into the office of Hans Sjouke, technical director, who wished to hear the reason for the high financial claim filed by us. Hearing the good outcome he was willing to foot the bill "this time".

[52] Farrar, J.C.M., Dolby, R.E.: "Lamellar tearing in welded steel fabrication", TWI, 1972

APPENDIX 3 : FIRST LETTER to VIKING

IHC Offshore Division

IHC GUSTO NV

P O Box 11
5 Maasdijk
Schiedam Holland
Telephone (010) 26 04 20
Telex 23159 ihco nl
Telegrams ihcgusto
Trade register Vlaardingen 8731

Viking Offshore Pipeline Contractos i.o.

c/o IHC Holland	c/o Heerema Engineering Service N.V.
Offshore Division	Attn.: Mr. P.S. Heerema
Attn.: Mr. F.J.M. Verschure	Scheveningseweg 64
P.O.Box 11	THE HAGUE
SCHIEDAM	

Your ref. Our ref. PO-GRO/le 0.42999 Schiedam, August 29, 1972

Re. 3rd Generation Lay Barge.

Dear Sirs,

We herewith confirm having agreed with you as follows:

IHC Gusto will undertake the naval architectural work for phase II of the engineering of the 3rd generation lay barge, as far as not provided for in Proposal No. 1175.2 from R.J. Brown and Associates, dated June 8, 1972.

The work to be taken care of by us under this agreement comprises 13 items as per the attached list. This work was initiated on July 24, 1972 and will be finished mid-September, 1972.

Price

The total price for our services, including calculations to be made by Bureau Veritas, will amount to . . . . D.fls. 400.000,-- excluding added value tax.

As agreed upon the costs of engineering performed and drawings prepared prior to July 24, 1972 will be charged extra on a cost-plus basis.

Payment

D.fls. 400.000,-- before October 1, 1972.
The remaining costs within two weeks from the receipt of our invoice.

NO: 5100	FILE:
ONTV: 01 SEP 1972	
INF:	
PTR:	
DEF:	
ANTW:	

./.

The "IHC GENERAL CONDITIONS" filed at the Clerk's Office of the District Court in Rotterdam on April 29, 1971 shall apply to our offers and to orders accepted by us.

IHC

Page No.2

August 29, 1972
PO-GRO/le
0.42999

Viking Offshore Pipeline Contractors i.o.

c/o IHC Holland
Offshore Division
Attn.: Mr. P.J.M. Verschure
P.O.Box 11
SCHIEDAM

c/o Heerema Engineering Service N.V.
Attn.: Mr. P.S. Heerema
Scheveningseweg 64
THE HAGUE

Please confirm that the above is in accordance with the agreement made during our discussions by signing and returning one executed copy of the present letter to us.

Yours faithfully,
IHC GUSTO NV

R. Smulders

Accepted this fourth day of ~~August~~ September, 1972

For IHC HOLLAND

P.J.M. Verschure

For HEEREMA ENGINEERING SERVICE N.V.

P.S. Heerema

Encl.

IHC

DESCRIPTION OF WORK

Items to be provided.

1. Evaluation of the optimization of the semi submersible shape.
2. Determining the final dimensions based on the optimization and maximum wave heights in the North Sea.
3. Construction drawings.
4. General arrangement drawings (executed workdeck)
5. Strength calculation.
6. Weight calculation and centres of gravity.
7. Stability calculations.
8. Power requirements.
9. Schemes and description of electrical installation and switch gear.
10. Piping and pumping system.
11. Ventilation system.
12. Price estimate.
13. Preliminary specifications.