Instituto Panamericano de Ingeniería Naval
XII Copinaval - Setiembre /Octubre 1991

STUDY OF A MINIMUN MOTION DEEP WATER PRODUCTION VESSEL

João Batista de Aguiar, Ph. D.

ABSTRACT

A hull shape to operate in very deep waters under conditions of minimum motion is considered. Dimensions and principal hydrostatic characteristics are initially prescribed to guarantee large storage space and enough area for crew and equipment. Drilling/explorations tasks may be accomplished with the mooring system chosen. A total displacement of 100000 ton with a 8000 payload on the main deck is assured. The structural arrangement and design presented are followed by a first order finite element analysis of the vessel. Operation in conditions that resemble the ones in Campos may be met.

RESUMEN

La estructura de una plataforma destinada a operar en aguas profundas bajo condiciones de movimiento mínimo es presentada. Un desplazamiento total de 100.000 ton con una carga útil de 8000 ton es contemplado. Un análisis de primer orden a través del método de los elementos finitos verificó la resistencia estructural. Con la resistencia obtenida queda asegurada la operación en la base de Campos, por ejemplo.

INTRODUCTION

It was thought until very recently that the Tension Leg Platform Concept [TLP] would meet the very deep water requirements of the offshore industry. Nowadays, however, there is a crescent amount of skepticism about the viability of TLP installations for deeper than 1000 meters sites. Minimum Motion based platforms are being investigated as a promising alternative for very deep waters. The Minimum Motion Platform Concept [MMP] / 1 /, though not new, could well be the solution to this very next depth layer / 2 /.

Several facts are pointed when it comes to the explaining of this preference. A MMP with storage capacity does not require the offshore pipelines, of very thick walls necessary in these depths / 3 /. Installation and abandonment costs of such a unit are, then, comparatively small. As a consequence, MMP units may be designed for longer life as they may be used in several fields, even in marginal fields. Furthermore, in predictably very intense storm situations, this type of platform may be disconnected from the field and taken to a safe place. Self-propulsion is a plus in this situation.

CONCEPT

The proposed form of the floating structure is presented in figure 1. Different views of the vessel are included in figure 2. Operationally, the vessel is based on a minimum motion idea. Loosely, it may be identified as a catenary anchored, ballast/ storage stabilized structure with four columns and a central moonpool area for risers. This floating structure may operate in larger than 500 m depths, without the amount of structural stiffening required for tension leg platforms or guyed towers. The vessel provides space for production and drilling operations, while retaining the simplicity of the conventional semi-submersible. The only real addition is that of a large box under the water level [blister] to store oil and keep a ballast control of the structure. In some other concepts, like the FloTo concept / 4 /, this space is filled with tubular bracing trusses that then require a much larger draft. In the TLP-1000 platform, just presented by Petrobras, again there is a repetition of this same idea with four rectangular columns connected by rectangular elements, with no tanks for oil storage / 5 /.

The minimum motion drilling/ production vessel considered here is characterized by minimum motions in heave. Surge, roll and sway motions may also be kept very small in all frequencies of excitation of the Campos Basin, for example. This set allows for working to be performed in even harsh weather conditions. Both, the comparatively small water plane area and the bulbous shape of the vessel, may be tuned to the approximately 12. s period found at the considered site. Moreover, with the recent advances in mooring design, usage of permanently connected risers is clearly a possibility.

OVERALL CHARACTERISTICS

The principal dimensions of the proposed vessel are presented table 1. In synthesis the vessel possesses a main body, accommodating a main deck and three secondary decks, followed by a neck region around the moonpool, where risers may run, and a box-shaped region termed blister. In the main deck, space for crew, drilling and processing equipment as well as two cranes, is provided. The secondary decks accommodate most the equipment and furnish storage space. In the neck section some tanks for oil are installed. Finally in the blister region, completely submerged and connected to the main deck through the four columns located at the corners of the unit, most of the oil storage is done. It is on top of these columns that the mooring equipment is located. The mooring system is supposed adjustable.

The shown characteristics of the vessel were obtained after a series of requirements on mission, arrangement, safety and operation were set. Table 2 characterizes most of the requirements met. Apart from these facts, the vessel is supposed self-propelled, being equipped for that with two engines and two propellers. Mobility is ideal when strong storms, installation or end of work in a particular field occur. A minimum transit draft of 8 m is set.

LOADING

Environmental loads including waves, currents and winds combine with functional loads to subject the structure to time varying conditions.

In the design, the 100-year regular wave was specified to have a 10.80 m amplitude, wave length 225 m and a period of 12. s, which conforms basically the conditions found in the Gulf of Mexico area. In Campos, the 100-year wave amplitude is lower [around 8 m], with a frequency in the 12 to 13.5 s range. Calm water conditions are rare in Campos. Waves are constant what intensifies corrosion and fatigue demands from the structure.

Currents also change during the year, according to the predominance of the colder currents from the Malvinas, or the hotter Brazilian coast waters. Currents are quite intense in most of the year. Through depth profile is also not constant. For design purposes a constant 2 m/s amplitude 100-year current velocity, that already incorporates the tidal and wind effects, is adopted.

One-minute-sustained wind velocities of 55 m/s were accepted and critically combined with waves and currents, plus full tank loading to produce the critical loads considered in design.

The MMP response in irregular sea conditions were also used to check the behavior of the platform. Irregular Wave Loading shows acceptable heave response, as the natural period for the structure in heave is larger than 30 s. Mean surge and pitch responses to the drift and wind gusts were also shown to be well under acceptable working conditions/6/.

COMPARTMENTATION

The box shaped structure adopted for the vessel, after satisfying the hydrodynamic requirements for stability and loading. was sub-divided internally so as to accommodate the other functions established for the ship. Apart from a large main deck where the day-to-day work is supposed to take place, three secondary decks, placed right under the main one, were chosen. In the main deck, figure 3., we have a superstructural living space for a large crew [about 100 people] plus a heliport and an observing tower. In the central area of this deck, around the moonpool, the drilling equipment is placed. Additional space for people is also available in the first deck.

In the secondary decks, we have a lot of space to roof tanks for cement, mud, chemicals and cargo pumping facilities as well as all sort of equipment. The arrangement for these decks does not contemplate destination as the usage of the space generated by the framing will depend exactly on the sort of equipment to be placed on board. In figure 4 the arrangement of the neck and blister regions is presented. This part of the vessel was chosen to accommodate many oil tanks, as heavier loads located at lower levels improve the stability of the unit. The sub-division broke the space symmetrically. In being under the third deck, ventilation and access to the oil tanks. 0.6 up to 0.19, for inspection and cleaning is granted. Some of the tanks were left for oil pollution control. These slop tanks are designated with the letters from S.10 up to S.15 in the table 3. In the front and back parts of the blister area, tanks with no prior assignment, denoted as E-Tanks, or empty tanks, are left for equipment installation, such as powering equipment, for example. The access to these tanks is provided through the tubular columns at the corners of the ship. Capacities of these tanks is included in table 3.

STRUCTURE

In having the basic form, principal dimensions, and the loading associated with the usage of the vessel, we need to create a structural system to frame it. The framing takes into account the arrangement made above. A mixed form of framing is adopted. In figures 2, 3 and 4 the framing considered was already shown. Internally we have 6 longitudinal bulkheads. LBH1 up to 6, and transversely again 6 bulkheads, TBH1 up to 6. The bulkheads 2 and 5 are swash-type bulkheads and each one is set 9.5 m from the sides of the ship, so as to provide acceptable collision damage protection. In figure 5, the transverse bulkhead 6, TBH6, is presented. In the following table, table 4, thickness of the plating used in the element is given.

Between each pair of bulkheads we have transverse frames, twenty two in total. Not all equal however. In the central region of the ship, the transverse frames extend throughout the neck and blister regions. They are numbered from 6 up to 9, and from 12 up to 15. As an example, one such a frame is included in figure 6. In the bow and stern regions of the blister, the typical transverse frame included in figure 7 is adopted. Of this type we have a total of twelve frames, half and half, figure 4. Finally another type of framing exists around the moonpool region. the dimensions of the elements considered each of the frames are included in the tables that accompany each frame, tables 5 e 6. The material specified for design purposes has a yield stress of 220. N/mm2. Better materials would decrease the structural weight, and consequently increase the deck payload.

The four tubular columns encountered in the corners of the unit are depicted in figure 8, and the corresponding table. These columns are designed with ring and axial stiffeners as well. In the collision protection zones additional stiffening is used. Watertight compartments are not used with the columns as they are not necessary. Mooring equipment may be handled through these columns.

The structure included was designed to conform to DnV /7/ regulations. A global finite element analysis of the structure was afterwards done. With bulkheads playing the role of rigid elements, a first order finite element analysis of each of the local frames was implemented with a particular element to conform with the conditions of this type of structure /8/. It is felt that a fatigue analysis should be done, as well as a second order analysis of the structure, before any detailing be done.

CONCLUSIóN

The work developed, thought preliminary, shows that a MMP for more than a 1000 m has good chances. It clearly may suit the offshore requirements, looking very competitive. There is a cost increase comparably smaller than those aggregated to the other present concepts.

The concept can be developed to fit the very deep water conditions without large extrapolations from the present practice. There are certain unknowns to consider. Further analysis on the structural aspect, which was the prior endeavor of this work, must be done. A second order analysis and a non-linear analysis on the stress concentration spots much be done.

REFERENCES

/1/ Daube, F., "A Comparative Seakeeping Analysis of Minimum Motion Hull Shapes", M. S. Thesis, m.I.T., 1982.

/2/ **Suspended Mat Proposed to Reduce Semi Motions**. Offshore Engineer, pg. 52, April, 1991.

/3/ Murphey, C. E. and Langner, C. G., "Ultimate Pipe Strength under Bending, Collapse and Fatigue", O. M. A. E., vol. 1, pg. 467, 1985.

/4/ Kjelland-Fosterud, E. and Mowinckel, P.M., "Floto, Floating Production Platform for Deep Waters", O. M. A. E., pg. 63, 1986.

/5/ **TLP Design Ready for Brasil** Offshore Engineer, pg. 49, April, 1991.

/6/ Kriesiz, G.A., "Preliminary Design of a Minimal Wave Motion Floating Production Vessel", M. S. Thesis, M. I. T., 1986.

/7/ Det Norske Veritas, "Rules for Classification of Mobile Offshore Units", Norway, 1984.

/8/ De Aguiar, J. B., "Structural Analysis and Design of a Vessel Based on a Minimum Motion Concept", Engineer D. Thesis, M. I. T. 1986.

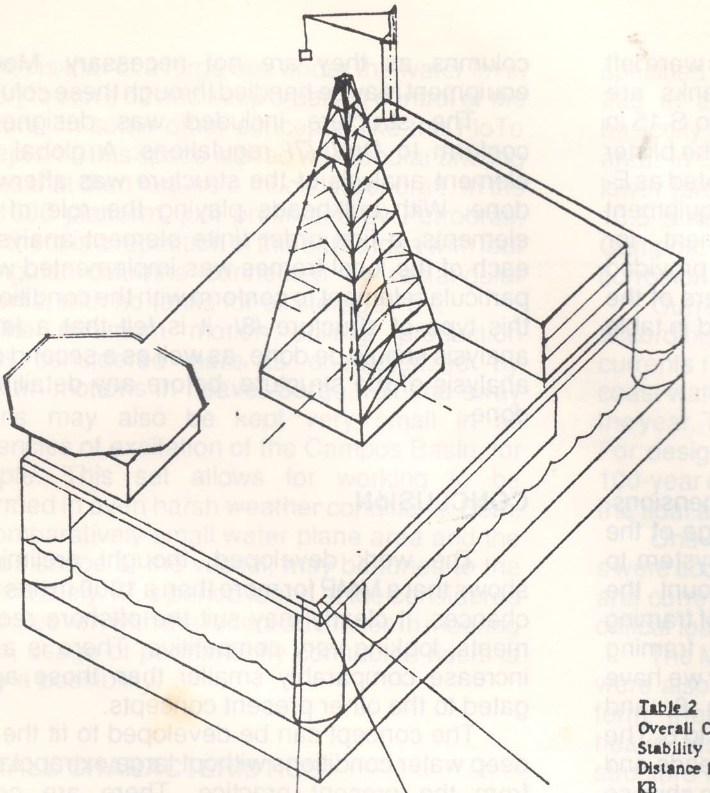


Fig.

A view of the MMP without the bow stern sections

Table 1
Principal Dimensions of the Vessel

Length between Perpendiculars, Lpp	105 m
Beam, B	70 m
Length at the Neck, Ln	60 m
Beam at the Neck, Bn	50 m
Diameter of the Columns, D	10 m
Depth to Main Deck, Dmd	23 m
Depth of Blister, Db	10 m
Depth of the Columns, Dc	13 m
Design and Drilling Draft, H	18 m
Design Freeboard, Dfb	15 m
Moonpool Length, Lmp	12 m
Moonpool Width, Bmp	12 m
Third Deck High, Tdd	4 m
Second Deck Height, Sdh	3 m
First Deck Height, Fdh	3 m
Midship Sectional Area, Ams	1100 m2
Waterplane Area, Awp	3170 m2

Table 2
Overall Characteristics of the Vessel

Stability

Distance between baseline and Center of Buoyancy KB	7.34 m
Distance between Center of Buoyancy and Transverse Metacenter. BMt	9.31 m
Distance between Center of Buoyancy and Transverse Metacenter. GMt	2.84 m
Distance between Center of Gravity and Longitudinal Metacenter. GML	10.03 m
Transverse Metacentric Height KMt	16.65 m
Longitudinal Metacentric Height KML	23.83 m

Mooring System
Number of Mooring Points - 4 [The corners at the deck]
Number of Lines per Mooring Point - 3
Angle Between Lines - 30
Length of each Line - 2500 m
Diameter of the Cables - 10.16 cm [4 "]

Weight
Light Ship

Basic Hull Steel and Superstructure	16.000 Ton
Drilling and Production Equipment	8.500 Ton
Production Riser Tension	1.000 Ton
Mooring System Tension	1.500 Ton
Payload [including drilling material]	13.000 Ton
Ballast/Oil	60.000 Ton

Table 3.
Tank Volumes and Usage
O - Oil Tank
S - Slop Tank
E - Empty or not Assigned Usage Space

Tanks	#	Volume
O.6 - O.8 - O.9 - O.11 - O.12 - O.13 - O.14 - O.17 - O.19	10	6,444
O.7 - O.18	2	3,312
S.10 - S.15	2	3,312
E.1 - E.5	2	2,250
E.2 - E.4 - E.21 - E.23	4	4,275
E.3 - E.22	2	2,700
E.20 - E.24	2	2,250

Total Volume for Slop Tanks - 6,292.8 m3 m - 0.95
Total Volume in Oil Tanks - 67,510.8 m - 0.95
Total Volume of not Assigned Space - 31,500 m3

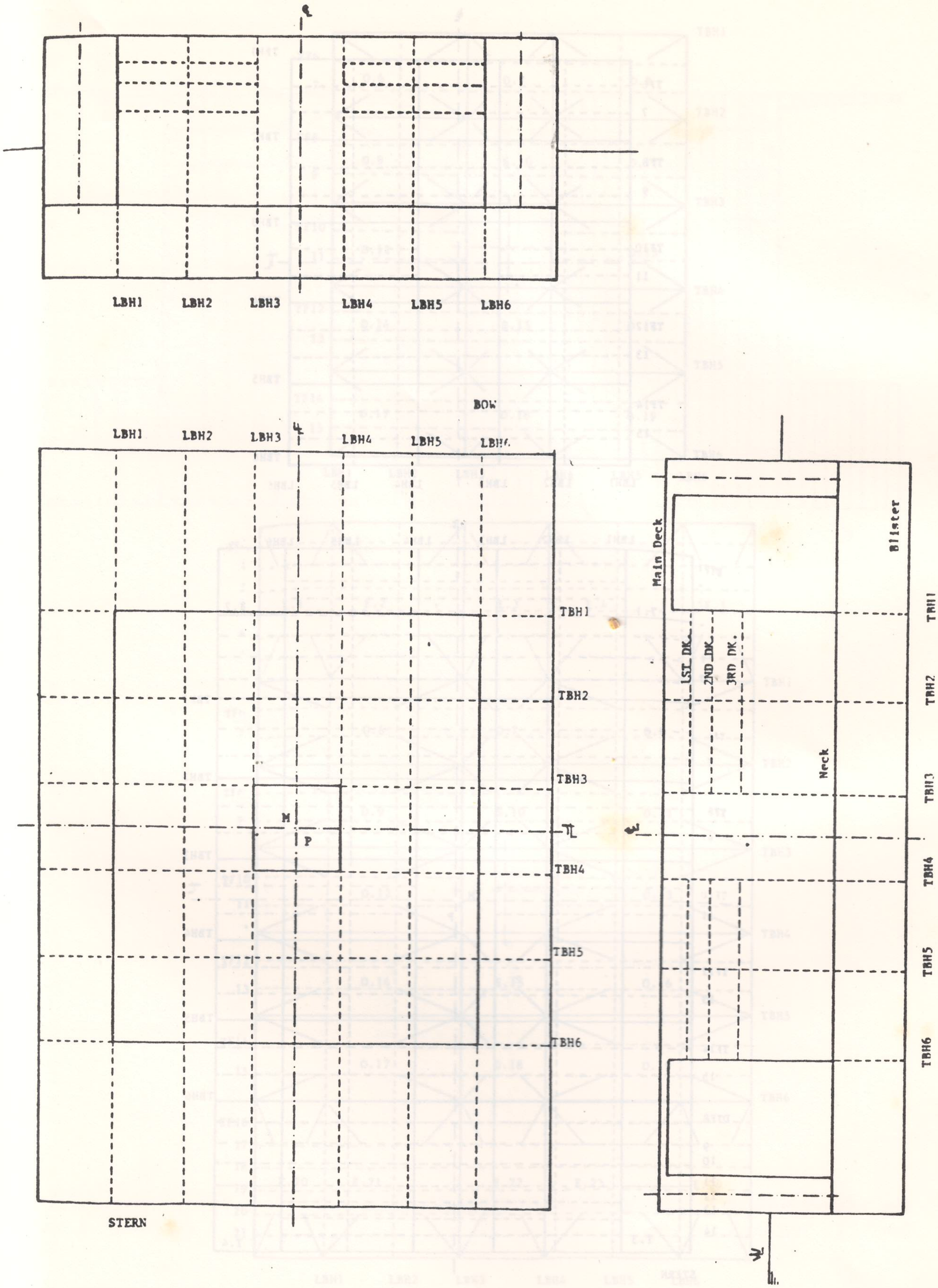


Fig. 2 Different views of the vessel with the main framing adopted
Escale 1 :500/0.65

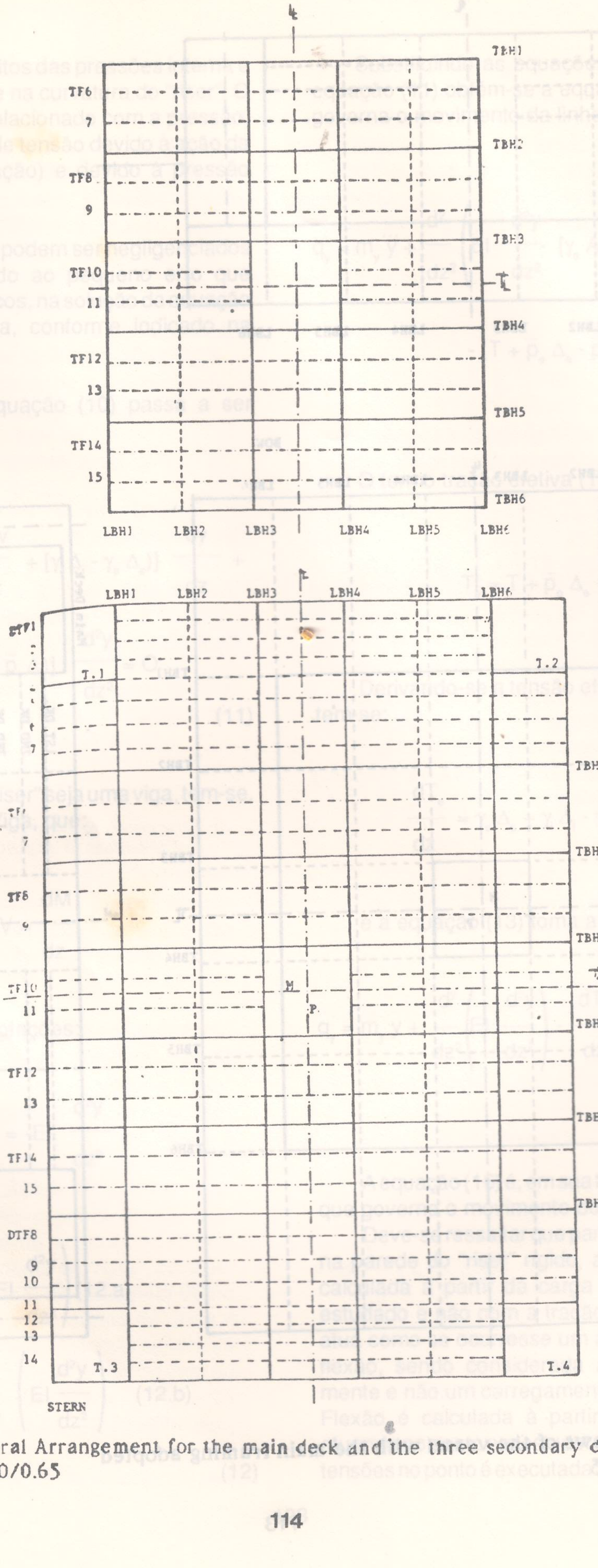


Fig. 3 Structural Arrangement for the main deck and the three secondary decks
Escale 1 : 500/0.65

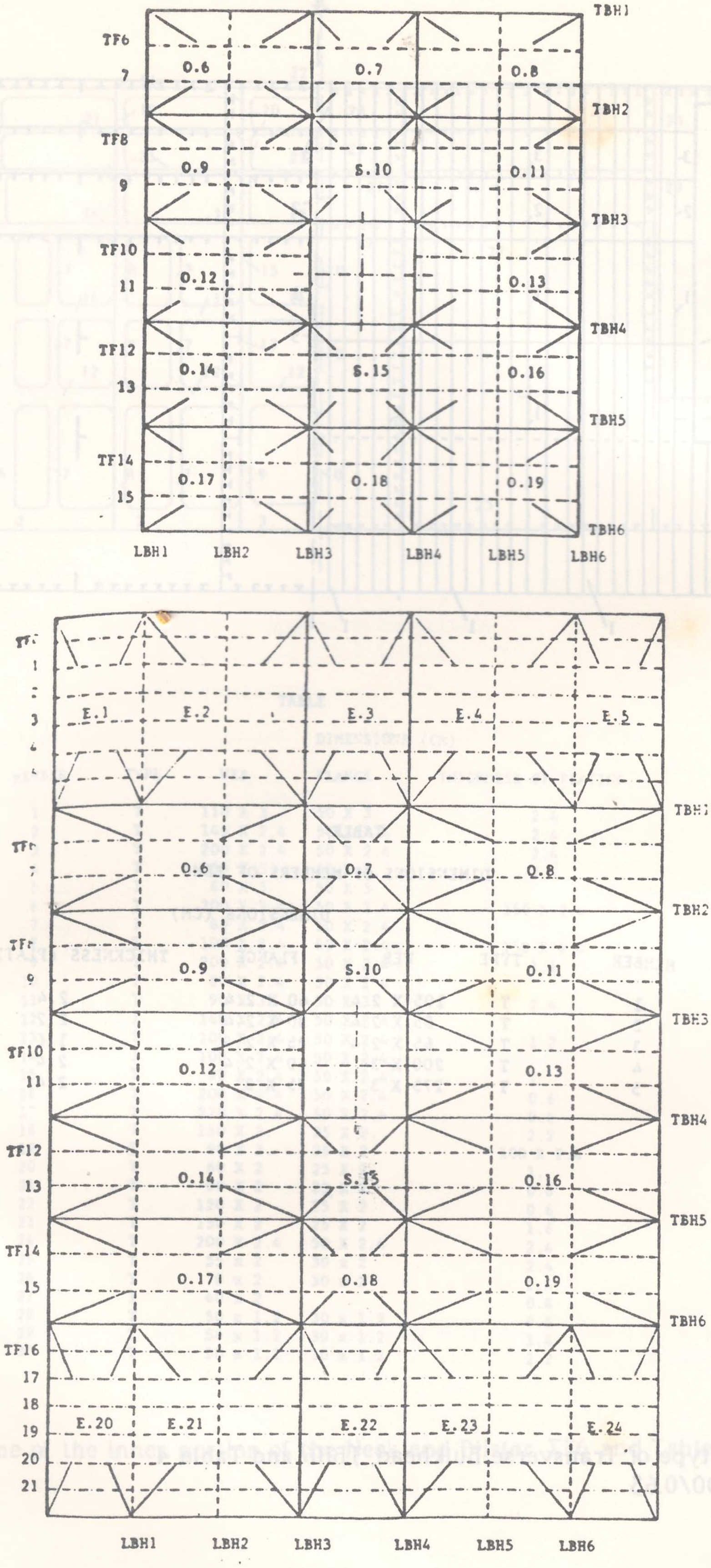
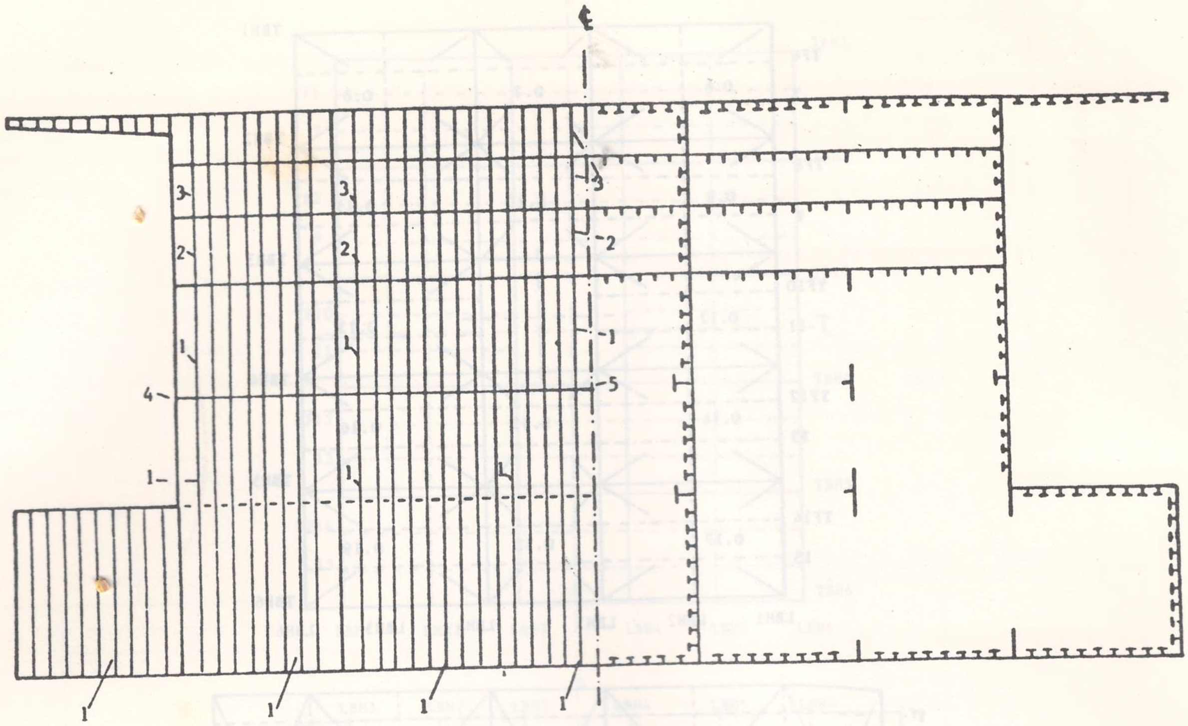


Fig. 4 Compartmentation of the neck and blister regions of the vessel
Escale 1: 500/0.65

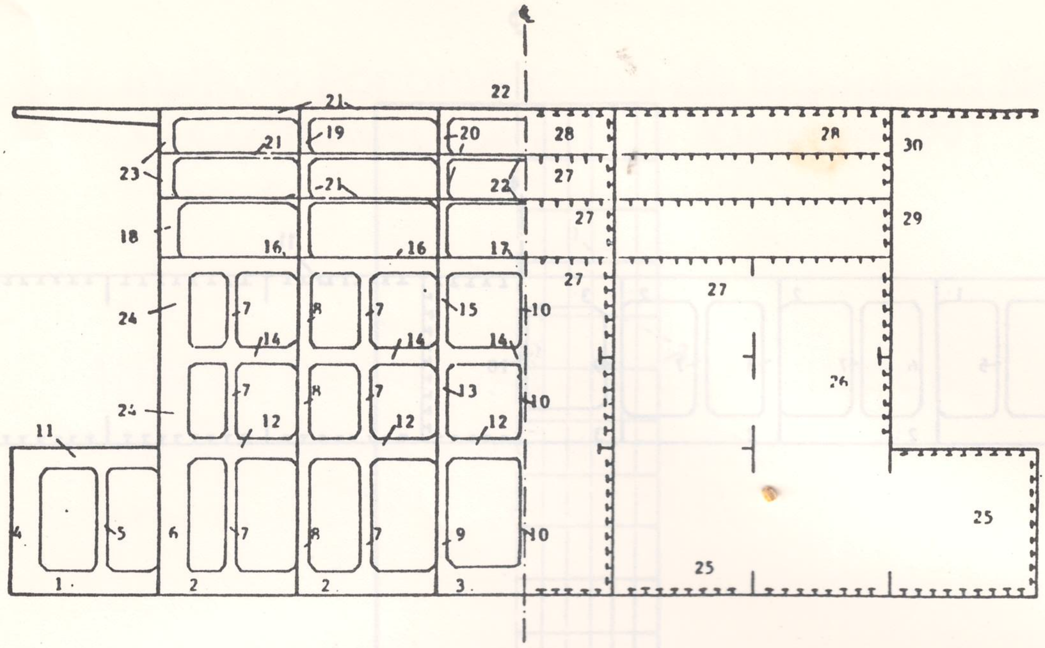


TABLE

DIMENSIONS OF MEMBERS OF TBH6

MEMBER	TYPE	DIMENSIONS (CM) WEB	FLANGE	THICKNESS (PLATING)
1	T	105 X 2.4	40 X 2.4	2.4
2	T	85 X 2.4	30 X 2.4	2.2
3	T	65 X 2.4	25 X 2.4	1.6
4	T	200 X 3.	60 X 2.4	2.4
5	T	275 X 3.	75 X 3	2.4

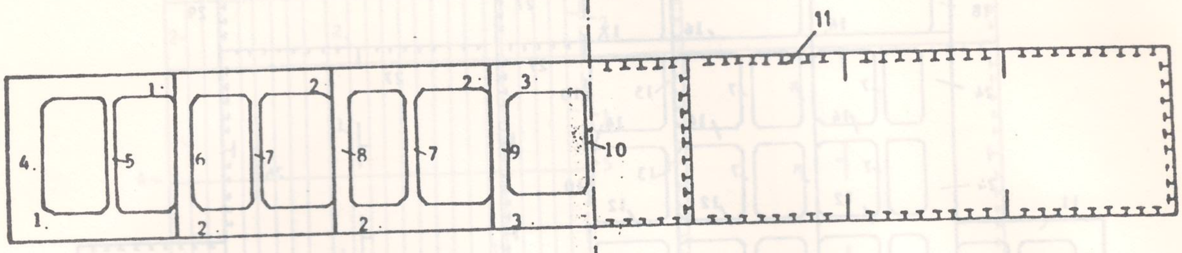
Fig. 5 Outer-type of Transverse Bulkhead, TBH6 and Table 4
Escale 1 : 500/0.65



TABLE

MEMBER	TYPE	DIMENSIONS (CM) WEB	FLANGE	THICKNESS OF PLATING
1	T	110 X 3	50 X 3	2.4
2	T	145 X 2.4	50 X 2.4	2.4
3	T	200 X 2.4	50 X 2.4	2.4
4	T	250 X 3.	50 X 3.	2.4
5	I	60 X 3	50 X 3	
6	I	200 X 2.4	50 X 2.4	150 X 2.4
7	I	60 X 2.4	50 X 2.4	
8	I	100 X 2.4	50 X 2.4	150 X 2.4
9	T	200 X 2.4	50 X 2.4	1.6
10	I	80 X 2.4	50 X 2.4	
11	T	90 X 3	50 X 3	2.4
12	I	140 X 2.4	50 X 2.4	
13	T	100 X 2.4	50 X 2.4	1.2
14	I	100 X 2.4	50 X 2.4	
15	T	90 X 2.4	50 X 2.4	1.
16	T	200 X 2.4	50 X 2.4	0.6
17	T	220 X 2.4	50 X 2.4	0.6
18	T	150 X 2.	25 X 2.	2.2
19	I	90 X 2.	25 X 2	100 X 2.4
20	T	60 X 2	25 X 2	1.
21	T	90 X 2	25 X 2	0.6
22	T	120 X 2	25 X 2	0.6
23	T	150 X 2	25 X 2	1.6
24	T	200 X 2.4	50 X 2.4	2.4
25	T	55 x 2	30 x 2	2.4
26	T	70 x 2	30 x 2	2.4
27	1	40 x 2		0.6
28	T	50 x 1.2	30 x 1.2	0.6
29	T	50 x 1.2	30 x 1.2	1.6
30	T	50 x 1.2	30 x 1.2	2.2

Fig. 6 Transverse frame of the inner portion of the Neck and Blister, TF6 and Table 5
Escale 1 : 500/0.65

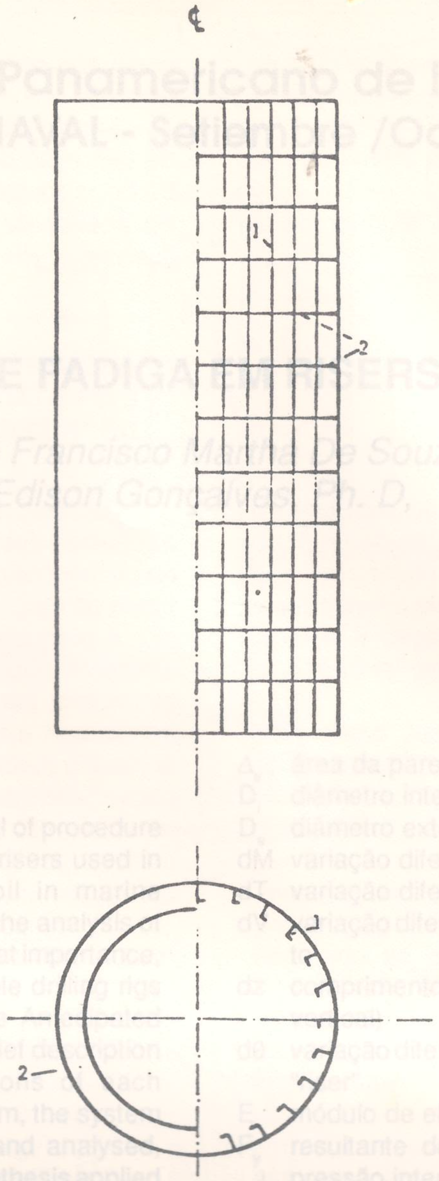


TABLE

DIMENSIONS OF MEMBERS OF TF3 OR TF18

MEMBER	TYPE	DIMENSIONS (CM) WEB	FLANGE	THICKNESS (PLATING)
1	T	200 X 3	50 X 3	3.
2	T	180 X 3	50 X 3	3.
3	T	230 X 3	50 X 3	3.
4	T	275 X 3	50 X 3	3.
5	I	70 X 3	50 X 3	
6	T	100 X 3	50 X 3	2.4
7	I	60 X 3	50 X 3	
8	I	100 X 3	50 X 3	150 X 2.4
9	T	100 X 2.4	50 X 2.4	3.
10	I	80 X 2.4	50 X 2.4	
11	T	55 x 3	30 x 3	3.

Fig. 7 Transverse frame of the bow and stern regions of the blister, TF18, and Table 6
Escale 1 : 500/0.65



TABLE

DIMENSION OF MEMBERS OF TC1

MEMBER	TYPE	WEB	FLANGE	THICKNESS (PLATING)
		DIMENSIONS (CM)		
1	L	70 X 2	20 X 2	2.4
2			WIDTH = 1.M	3

Fig. 8 Tubular column, TC1, and corresponding Table 7
Escale 1 : 500/0.65