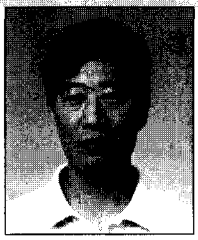
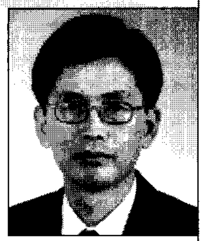
Semi-Submersible 해양시추선 상세설계

Detailed Structural Design for Thunder Horse Semi-Submersible PDQ





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1. Introduction

The Thunder Horse semi-submersible is intended for production of hydrocarbons at Thunder Horse field in the Gulf of Mexico(GOM), Mississippi Canyon Block 778. The field is located in water depth of 1850m, 240km SE of New Orleans.(ref. Fig.1)

These areas have estimated 1.5 billion barrels reported. Also there are world class subsea hardwares with 15ksi Guideline less Trees, High pressure 8-12" Flow lines, Insulated Steel Catenary Risers with Flexible Connectors, 150km of Flow lines, and 100km Control & Injection Umbilicals(ref. Fig.2).

The PDQ will be the largest Production/Drilling Semi submersible in the world. It will have Dual Hoist/2MM lb Derrick, 229 person Quarters, 455ftx330ft Deck Plan, 4 Deck Cranes for Re-supply, 40,000T Deck Payload, 10,000T Riser Payload, 130,000T Total Displacement, and 16x5 3/4" Steel mooring lines with Suction pile anchors.(ref. Fig.3)

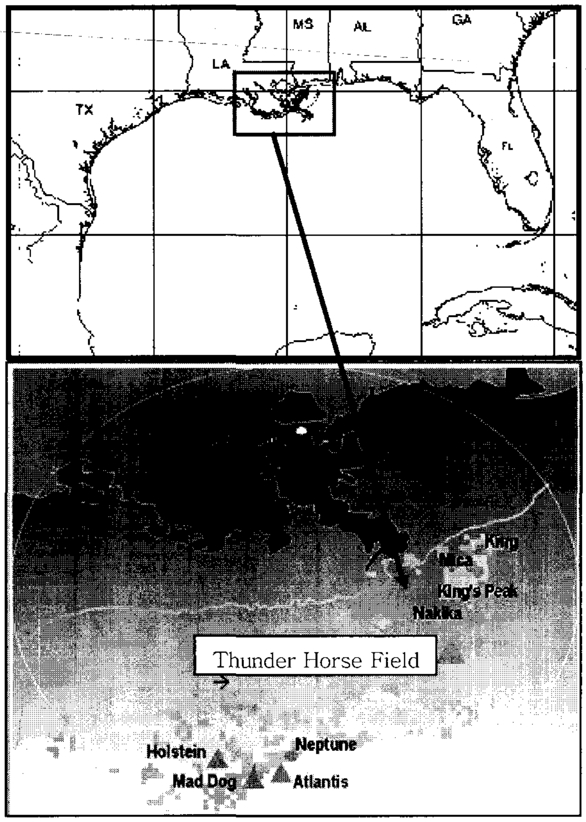


Fig. 1 Thunder Horse Field Location

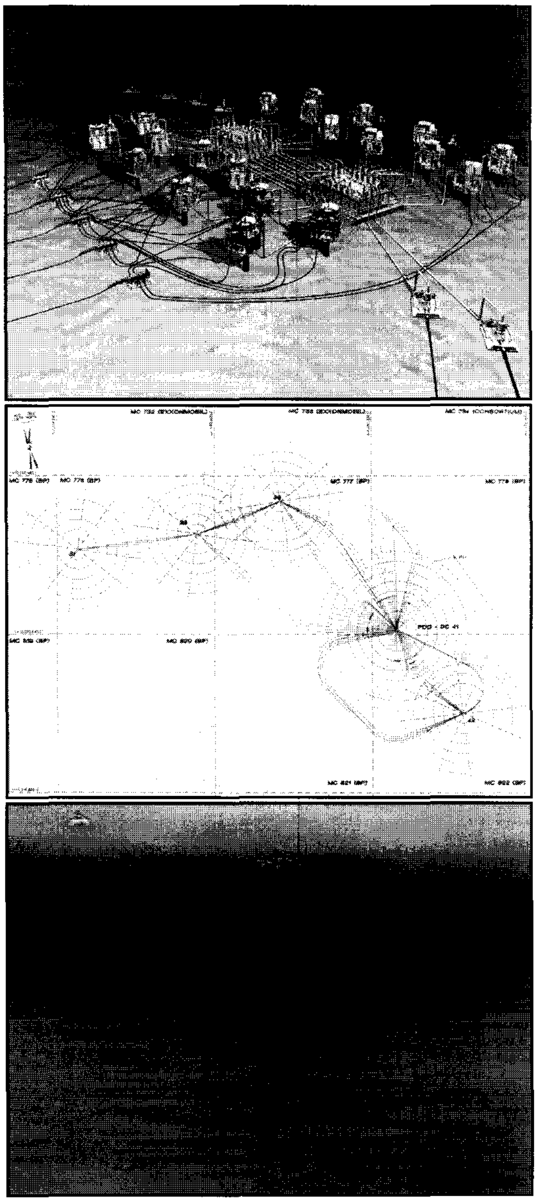


Fig.2 Thunder Horse Field Layout

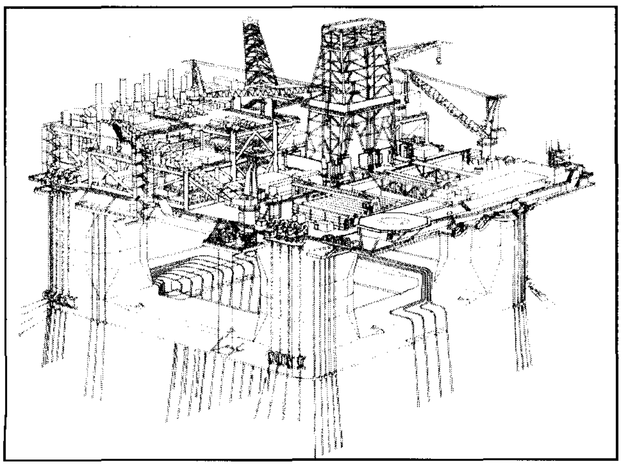


Fig.3 Thunder Horse Overview

2. Project Characteristic

2.1 Main Outline

- Owner : BP Exploration & Production Inc.
- Location : GOM (South East of New Orleans)
  - Water Depth 6,300 ft, Drilling Depth 30,000 ft
- Production
  - 250,000 BPD, Oil
  - 250 MMSCFD, Gas
  - 12,500 psi, Max. Surface Pressure
- Design Life : 25 Years
- Rules and Regulation
  - The American Bureau of Shipping(ABS)
  - The United States Coast Guard(USCG)
  - The United States Minerals Management Service (MMS)

2.2 Main Dimension

- Length over all : about 164 meter
- Pontoon
  - Length, outside pontoon 110.08 meter
  - Breadth, outside pontoon 104.96 meter
  - Height of pontoon 11.52 meter
  - Beam of aft transverse pontoon 25.60 meter
- Columns
  - Forward(two) Length, longitudinal 23.04 meter
    Breadth, 21.76 meter
    Corner radius 7.04 meter
  - Aft(two) Length, longitudinal 25.60 meter
    Breadth, transverse 21.76 meter
    Corner radius 8.32 meter
- Upper Hull
  - Length of deck-box 138.24 meter
  - Beam of deck-box 112.64 meter
  - Height of deck-box 10.00 meter
- Draughts
  - Operation draughts30.0 meter
- Drill floor
  - Drill floor to sea level(at oper. Draft) 37.0 meter
- Displacement

- Operation condition displacement 129,185 tonnes

3. Engineering

3.1 Engineering Executive scope of work

The engineering executive consists of following 3 phases.

- Phase I : FEED Support and Detailed Engineering
- Phase II : Detailed Engineering
- Phase III : Production Engineering

DSME has Engineering Center at home office to perform Detailed Engineering as well as to supply supporting staff to support FEED efforts.(ref. Fig.4)

The execution plan for detailed design and engineering of the Thunder Horse Semi-submersible PDQ floating platform facility comprises the following scope:

- The semi-submersible hull and deck structure.
- Mechanical, electrical and controls equipment and systems within the hull and deck structure.
- The accommodation and office facilities.
- The on-vessel mooring systems/equipment.
- The drilling system.
- Riser support and guide system within or externally attached to the hull.
- Equipment and systems that interface with topside facilities that is to be designed and installed by others.
- FEED stage support activities with GVA in Sweden.
- Classification support services.
- Engineering for procurement activities/Procurement.

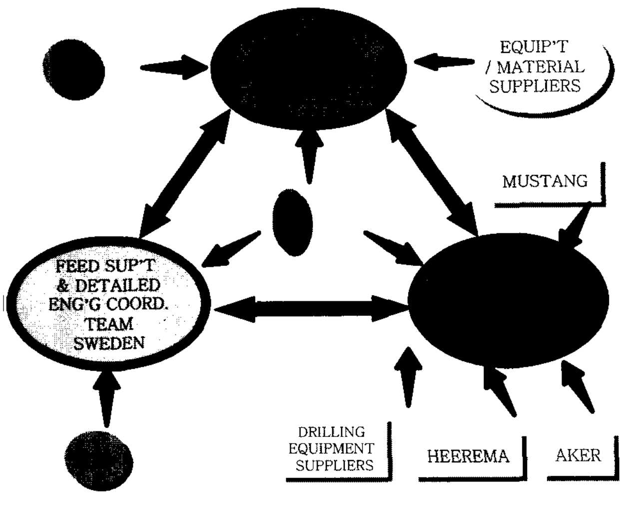


Fig.4 Interface Networ

3.2 Engineering Process

Engineering process and milestone achievement are dependent on procurement and fabrication schedules, information and activities.

The Area design (Structural, Piping/Layout and E&I layout) will be developed as follows.(ref. Fig.5)

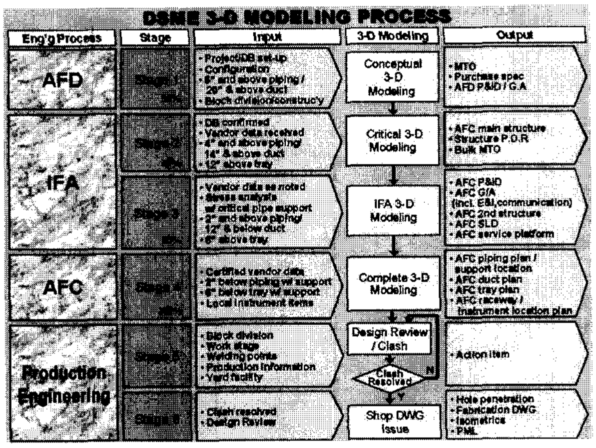


Fig.5 Engineering Process

Stage I(AFD)

- P&IDs are produced where all process and utility support equipment are shown and tagged.
- The level gives input to Conceptual 3-D modeling in area engineering.
- The 3-D model is established with project and database set-up.
- The stage comprises all preparatory design/modeling activities, that is, design based on layout studies and equipment modeling based on catalogue and/or bid information, for selected vendor.

Stage 2(IFA)

- This stage includes frozen Vital Interface Information from Vendors.
- The level gives input to Critical 3-D modeling in area engineering.
- At this stage 1st Vendor information for defined equipment and relevant information from "IDC"

(Inter Discipline Check) is incorporated in the 3-D CAD Model.
- Major Penetrations are frozen and all lines down to 6" are incorporated.

Stage 3(IFA)
- This level includes approved vendor information for all packages, instruments (Control valves etc.,) and nozzle numbers and sizes.
- All comments from the HAZOP have been included in the design.
- The level gives input to IFA 3-D modeling in area engineering.
- Accepted Vendor interface information for all defined equipment, as well as relevant information from "AFC" (where issued) drawings are incorporated in the 3-D CAD Model.
- This status is the basis for issue of Layout drawings.

Stage 4(AFC)
- This level is based on a clash free 3-D model. 3-D Model Complete (AFC).
- The Walk-Through design review shall be conducted in terms of operability, maintainability and safety.
- All defined Engineering Isometric drawings have been issued.

Stage 5(Production Engineering)
- Documentation updated according to fabrication sequence.
- The 3-D modeling will be utilized to perform fabrication dynamic simulation according to fabrication sequence and product split. This will allow preparation of shop drawings.

3.3 Structural Analysis of Riser Hard Piping and Support

The purpose is to provide a basis for structural analysis of piping, supports, and main structure with focus on foundations and main structures including the clamping of the pipes.(ref. Fig.6)

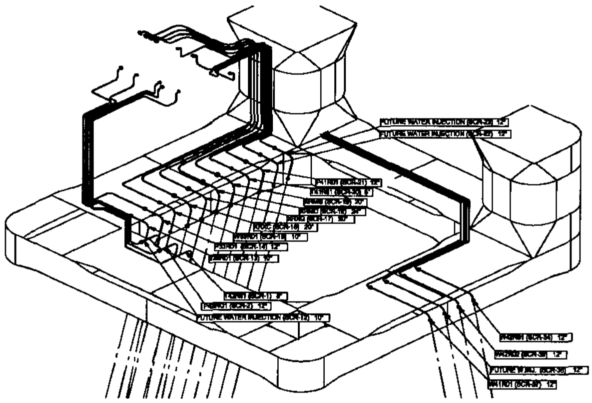


Fig.6 Arrangement of Riser Hard Piping on Hull

The hard piping and support will be exposed to loading due to waves/motions, temperature, slugging, and global displacements of the hull structure. The factor of safety of 10 shall be used on both the pipe and pipe support fatigue design. The fluid in the hard pipes for production, test, and oil/gas export has temperatures that are significantly higher than the environment. Especially along the columns the resulting thermal elongation will imply specific requirements for the supports. The pipes can be attached to the hull using rigid, flexible, or guiding support(i.e. the pipe is "free" in one or two directions"). Rigid supports shall be used for locations where small displacements due to thermal expansion are desired.(ref. Fig.7) These support structure is checked against ultimate and fatigue strength with local scantling evaluation of clamping design.

3.4 Work Process Design(WPD)

The Work Process Design (WPD) is to pursue the most efficient fabrication sequence by maintaining the

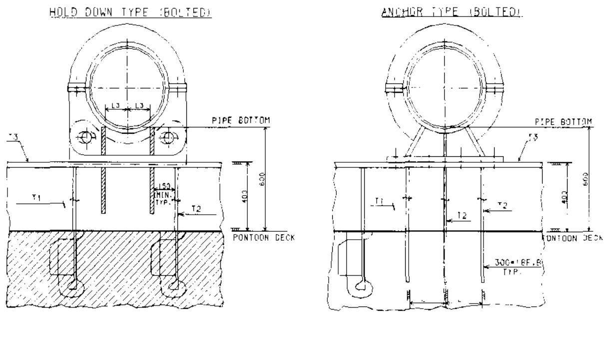


Fig.7 Support detail of Riser Hard Piping with clamping

load-even in 3M (Man/Machine/Material) to achieve the project objectives associated with quality, cost and delivery.

This WPD can be made workable or developed by DAP (Detailed Assembly Procedure) which is to be prepared by production department.(ref. Fig. 8)

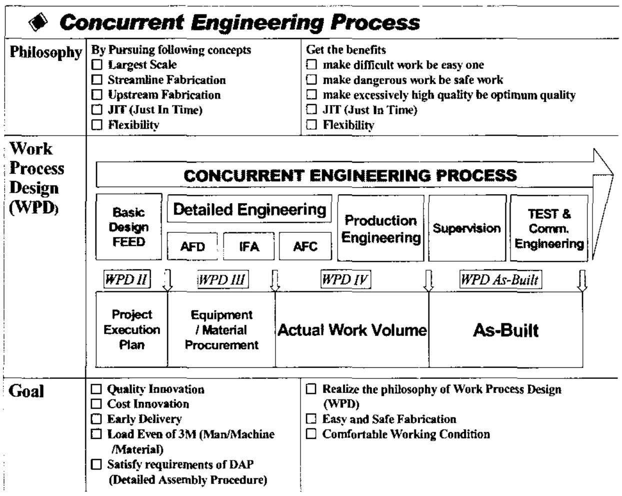


Fig.8 Concurrent Engineering Process

4. Detailed Structural Engineering

4.1 Design Area

- During FEED it is the leading criteria with regard to material selection, weld design, NDT requirements and focus for strength analysis.
- During detailed design and fabrication it forms a set of criteria for quality planning, choice of detail standards, penetrations, permanent attachments and temporary provisions for fabrication purposes.
- The steel structure of the unit is classified into three main design areas. The purpose of this is to classify the structure into parts of different importance with regard to the total structural strength and safety of the unit.(ref. Fig.9)

4.2 The design areas are classified based on:

- Consequence of failure
- Structural complexity
- Stress levels
- Stress concentrations
- Accessibility for inspection and repair

4.3 The design area classification has influence on:

- The detail design
- Type of weld joints
- The choice of steel grade, as specified in the owner specification
- The extent and methods for non-destructive testing (NDT) of welds as specified
- The requirements for penetrations in and attachments to the structure.
- The location of openings, penetrations and attachments

4.4 The design areas are based on the structural normal categories

- Special Application Structures (Most critical)
- Primary Application Structures (Intermediate)
- Secondary Application Structures (Least critical)
- Others

A summary table of Design Area versus Inspection Categories is presented in Table 1.

Inspections and examinations of the welds during

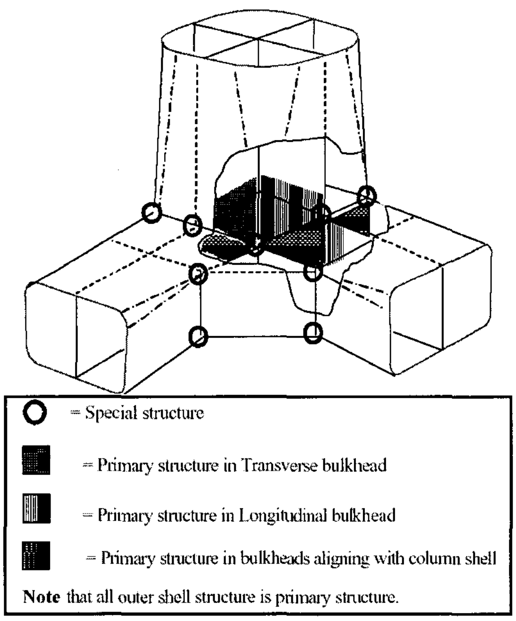


Fig.9 Special and Primary Structures in way of pontoon/column

fabrication shall be performed in accordance to the inspection program for the unit and shall be documented. Inspection and NDE(non-destructive testing) procedures shall be submitted to the classification society for approval.

Welds shall have WPS(Welding Procedure Specification) and weld list. The weld list shall be signed by qualified personnel prior to the final inspection of each weld.

Table 1. Matrix of Design Areas and Inspection Categories within these areas.

Inspection Category	Type of Weld	Design Area	Remark
A	Weld in high stressed area	Special	Welds are assigned to inspection category on main structural drawings.
B	Welds in less stressed area		
	Transverse and shear loaded butt welds	Primary	Welds are assigned to inspection category in detail design.
C	Longitudinally loaded butt and shear loaded fillet welds		
	Load carrying welds	Secondary	Secondary structures. Welds are assigned to inspection category in detail design
D	Non load carrying welds		
E	All welds		Non main structural steel

4.5 Weight Control

The weight control summarizes and presents weight, center of gravity (COG) and allowances for the DSME delivery that consists of lower hull and upper hull including MEI's items in DSME's work scope.

The input and resulting summary data are presented in accordance with DSME's weight control procedure approved by Company. This report shall be issued on a monthly basis following the philosophy:

- Weight is most critical for a Floater Project.
- The weight control process is transferring weight data from unknown to known.

4.6 Selection of Material

All materials shall be produced to meet the requirement of ABS Rule for material and welding for the appropriate grades.

The selection of all steel shall be in accordance with the requirement of ABS Rules for Building and Classing Mobile Offshore Drilling Units and the following.

For plates:

- Main structure: DH36, DH36Z, EH36, EH36Z, EQ51Z
- Deck houses, other non-main structure: AH36

For rolled section:

- Main structure: DH36
- Deck houses, Equipment seating, pipe supports, access platforms, and other non-main structures: AH36

4.7 The connection of Casting

Casting where indicated on the drawings shall be fabricated to the requirements for carbon with the following requirement.(ref. Fig.10)

- Tensile strength: 500Mpa
- Yield strength: 355Mpa
- Charpy test: Average/single 31/23 Joule at -40C

The difficulty of fabrication for welding was found during the block stage because there are many test requirement and complicated bevel joints. Also these joints are very important connections in a special design area with high stress and must exactly meet the procedure for working progress according to the specification.

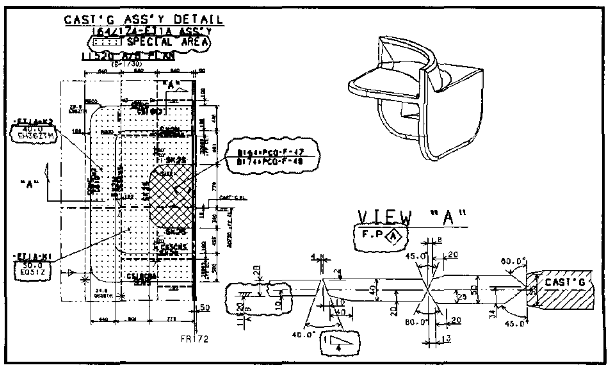


Fig.10 Casting in way of pontoon/column

4.8 Tapering of Plate & Bulb

The tapering of plate & bulb for the special areas will be applied as below details in consideration of smoothly relieving stress.(ref. Fig.11)

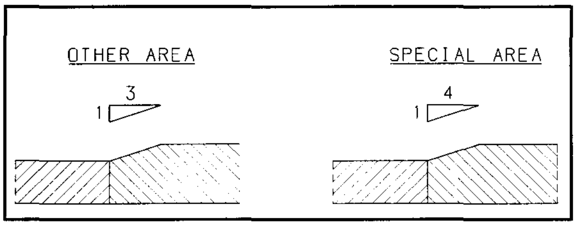


Fig.11 Tapering of Special Area

4.9 Chamfering Details for corner joints

The chamfer details in way of Fillet/F.P/P.P welding are as following Fig.12. to keep the criteria in the welding procedure.

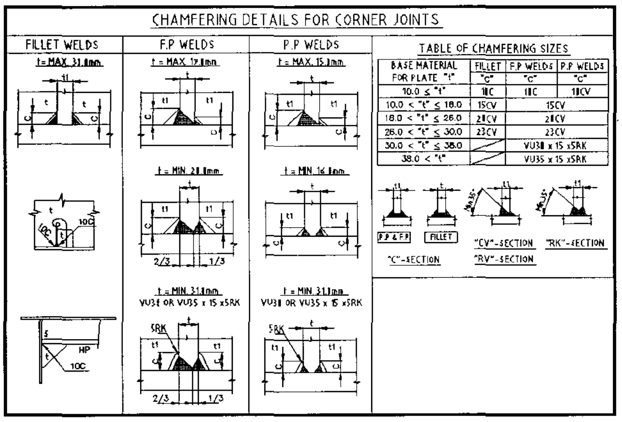


Fig.12 Chamfering details for corner joints

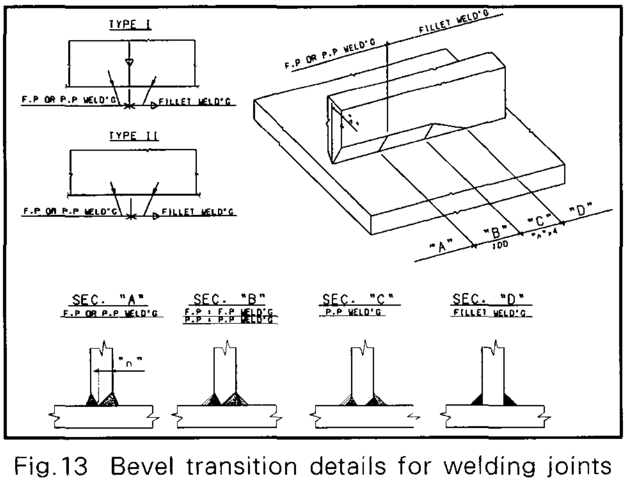


Fig.13 Bevel transition details for welding joints

4.10 Bevel Transition Detail-(From FP or PP to Fillet Weld)

When transferring the connection from F.P & P.P welding to Fillet welding, the following bevels will be prepared with adjusting joints.

4.11 End Connection of Bulb Flat

There are many difficulties in preparing the details of bulb end connections. These affect the schedule of the cutting shop which requires a standard procedure for production.(ref. Fig. 14) Also before the fabrication, the difference in bulb size will be examined and knuckles are added for simple production.(ref. Fig.15)

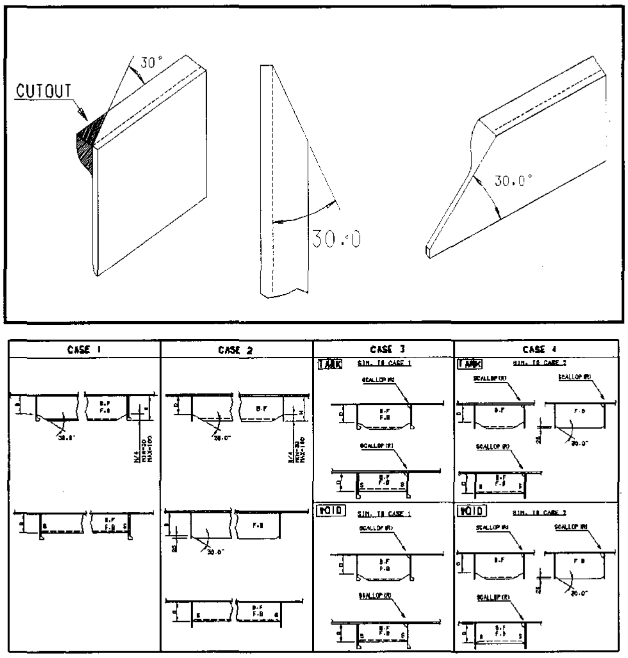
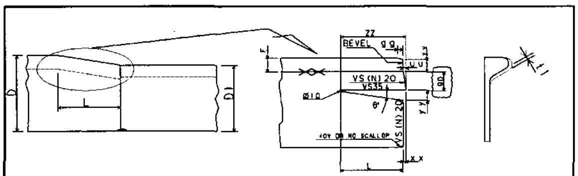


Fig. 14 Bulb End Connection



BULB SIZE D	BULB SIZE D1	FLG B D	FLG B D1	ll	θ	L	ZZ	XX	uu	yy	vv	gg	EXC	FLG BEVEL
320	300	58	55	3	3.8	300	309	9	6	20	55	9	9	VS19 OR VN11
340	300	61	55	6	7.6	300	311	11	12	41	55	18	11	VS24CN6 OR VN7CN6
370	240	66.5	46	19	18.4	390	419	29	30	135	46	62	29	VS33CN19 OR CN19
370	300	66.5	55	10.5	13.1	300	316	16	21	72	55	35	16	VS28CN11 OR VN2CN11
370	320	66.5	58	8	9.5	300	312	12	15	51	58	26	12	VS25CN8 OR VN11CN8
400	300	72	55	15	18.4	300	324	24	30	105	55	51	24	VS33CN15 OR CN15
400	370	72	66.5	5	5.7	300	309	9	9	30	66.5	17	9	VS21CN5 OR VN9CN5
430	340	77.5	61	14	16.7	300	321	21	27	94	61	50	21	VS32CN14 OR CN14

Fig.15 Bulb Flat Depth for Knuckle

5.12 Scallop and Slot with Collar Plate

It is very important to control the welding quality for fatigue and corrosion, especially the scallops and slots for construction of block joints.(ref. Fig.16)

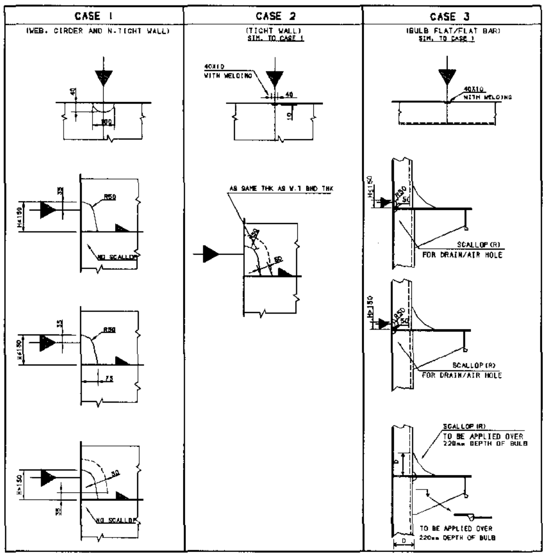


Fig.16 Scallop details in way of the joint of blocks

Also the tightness of watertight bulkheads for slot holes will be insured with collar plates, which have an overlapped beveled configuration of the welding joint using both FP and PP. The welding problem for these connections will be increased in consideration of corrosion and leakage experienced.(ref. Fig.17)

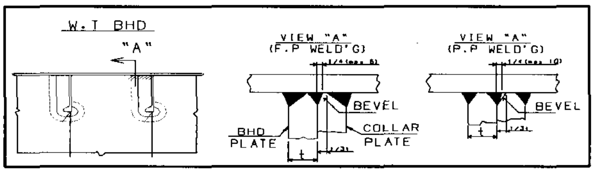


Fig.17 Slot with Collar Plate in way of FP and PP

4.13 The Support of Riser Hard Piping and Umbilical I-Tube

The hard piping is attached to the hull on pontoon decks, plan sides of the aft columns, and underneath box bottom. Descriptive views showing the basic arrangement are shown on Fig.18 below. Different sizes of pipe diameter are used and attached on the hull withclamping and foundation. So, there are lots of various details of support.(ref. Fig.18). Dynamic umbilicals are guided in I-tubes from bend stiffeners near base line to balconies outside the hull above box bottom. The I-tube cylinders are welded to flexible individual brackets that are welded to rigid foundations connecting to the columns in stringer plans.

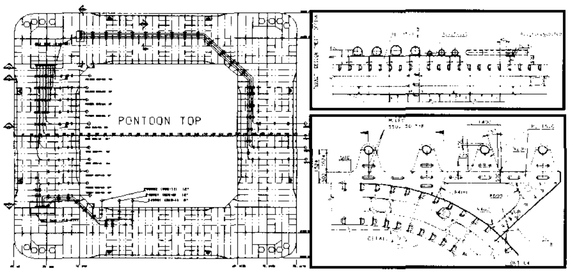


Fig.18 Support of Riser Hard Piping and Umbilical I-Tube

5. Fabrication Process And Sequence

5.1 Block Division and Yard Layout

The product is divided in pursuit of largest scale and streamline fabrication, considering the structure fabrication process, outfitting fabrication process, theyard road width limit, heavy lift equipment capacity and other restraints. The details are shown on Block Assembly Analysis and Yard Layout. (ref. Fig.19 and Fig.20)

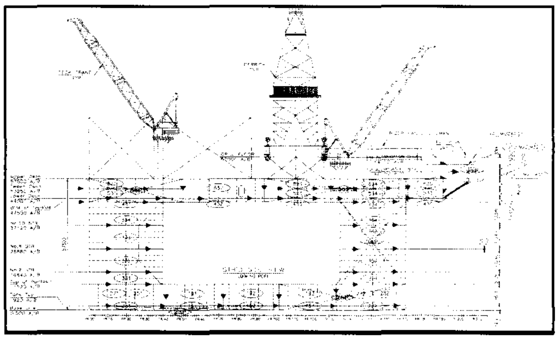


Fig.19 Block Divisio

Fabrication Sequence Diagram

The Fabrication Sequence Diagram is designed to depict every milestone fabrication phase from Steel Cutting up to Hand-Over to the customer.

Every phase requires its own design considerations

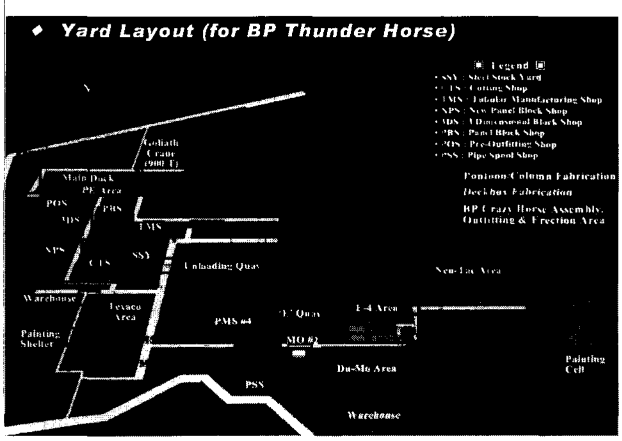


Fig.20 Yard Layout

so as to ensure the project execution according to DSME's fabrication process.(ref. Fig.21)

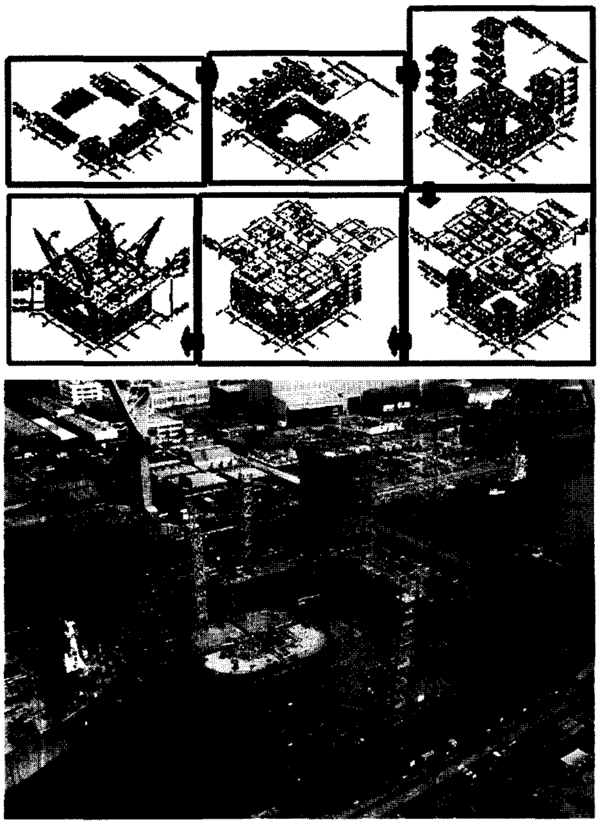


Fig.21 Fabrication Sequence Diagram

5.2 Dry-tow and Transportations for GOM

The transportation of PDQ is shown on Fig.22 and Fig.23.

- Hull, Deck Box, Drilling Rig, and Quarters built in Korea
- Dry Transport from Korea to US Gulf of Mexico (~13,000 miles in 2-3 months)
- 20,000T (3 large modules) built at McDermott (Morgan City, LA)
- Modules lifted aboard Hull at Kiewit Offshore (Ingleside, TX).
- Inshore Integration at Ingleside, TX, on the Gulf Coast

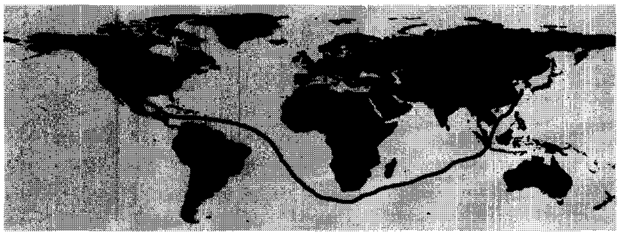


Fig.22 Routine of PDQ

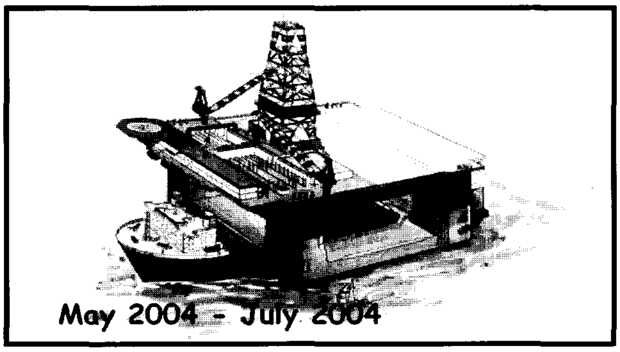


Fig.23 Dry tow for PDQ

6. Conclusions

It was a big challenge to build the Thunder Horse Floating Drilling & Production Platform, and the followings were accomplished during the successful detailed engineering and fabrication:

- Verification of Safety, System Operation, Structural Strength & Stability.
- Kept the schedule and facilitated communication between relevant disciplines.
- Implemented concurrent engineering.
- FEED and Detailed Engineering were concurrently established.
- Kept a strong focus on interface management and

control.

- Kept a strong focus on procurement engineering.
- Kept a strong focus on fabrication requirements input.

References

1. 1410-50-ST-RP-110-0001. "Design Brief Main Structure" *Technical Report*, GVAC, Project Order No.1005.
2. 1410-50-ST-RP-110-0002. "Main Structure Design Area" *Technical Report*, GVAC, Project Order No.1005.
3. 1410-50-ST-RP-110-0004. "Main Structure NDE Booklet" *Technical Report*, GVAC, Project Order No.1005.
4. 1410-50-ST-SP-110-0005. "Main Structure Fabrication Specification" *Technical Report*, GVAC, Project Order No.1005.
5. 1410-50-ST-DB-118-1001. Structural Analysis of Riser Hard piping and Support" *Technical Report*, GVAC, Project Order No.1005.

Acronyms

PDQ	Production, Drilling and living Quarters
GOM	Golf of Mexico
FEED	Front End Engineering Design
AFD	Approved for Detail Engineering
IFA	Issued for Approval
AFC	Approval for Construction
FP	Full Penetration
PP	Partial Penetration