Rev.	Issued date	Description	Made by	Chk'd by	Disc. appr.	Proj. appr.	Client appr.
A3	19.03.2007	REISSUED FOR DESIGN	JCJ	JT	AF	GB	
A2	22.02.2007	REISSUED FOR DESIGN	JCJ	JT	AF	GB	
A1	13.02.2007	ISSUED FOR DESIGN	JCJ	JT	AF	GB	
R1	23.05.2006	Issued for IDC	JT	EB	AF	GB	

vetco

Vetco Aibel AS

MAERSK CONTRACTORS

Maersk Contractors
- part of the A.P. Moller – Maersk Group

Client reference:

Project no:	Project title:
004410	VINCENT PROJECT

System:	Discipline:	Document Type:
99	S	PR

Document title:

M00 - Structural Design Brief – Topside Modules

Document no.:	Rev.:	Page:
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TABLE OF CONTENTS

1 INTRODUCTION

The Vincent oil field is located in Production Licence WA -28-L in the Exmouth Sub-basin, 43 km north of the North West Cape and 10 km north-east of the Enfield oil accumulation in Australia.

This Structural Design Brief defines the design premises for the detail structural design of pre-assembly units (PAUs) for the Vincent FPSO as listed below. The design brief includes both temporary and operational phases. Temporary phases are weighting, load-out, lift and transportation of the ship. Operational phases are in-place, fatigue and accidental conditions.

The Design Brief shall be used for the structural design for:

- M10 HP Oil Separation Module
- M11 LP Oil Separation Module
- M20 Production manifold skid
- M30 Flare skid
- M60 HP Gas Compression and Dehydration Module
- M70 LP Gas Compression And Utility Module
- M71 Closed drain
- M72 Oil desanding
- M85 Power Generation and CCR
- M99 Piperack

Strengthening of the ship and the stools are not the scope of this design brief.

The design brief does not define design and verification of PAU equipments like vessel/tanks and pipe work. Local strength to be verified in local design reports.

Rev. A2: the changes from A1 revision of this document are updated *Table 9-1* values.

Rev. A3: main changes in section 7 to 12 and appendix A.

The following table summarises the scope of work split between Vetco Aibel and Hull Conversion Contractor:

Items	Concept Design FEED PHASE	Detailed Design EPC PHASE
Class Approval / Verification		
Vessel global analyses/ Class Approval of conversion to FPSO	-	By Others
Drawings (by Contractor) for FEED Phase		
PAU main structure drawings	Drawing of main steel	
PAU lifting pad eyes location and lifting arrangement.	Drawings arrangements of lifting arrangement.	
PAU support stool global arrangement drawing	GA of stools on vessel	
PAU support stool conceptual design drawings	Concept drawing of stools	
Design		
PAU support stools, locations	To be agreed between Vecto (company) and Maersk (contractor)	To be agreed between Company and Contractor
PAU support stools, design	By Others	By Others
PAU lateral support, location of supports	By Others	By Others
PAU support stools, scantling concept	By Maersk (contractor)	By Others
PAU lateral support, design of structure at top of stools	By Maersk (contractor)	By Others
PAU vertical support, bearing details	By Maersk Contractor	By Contractor
PAU main structure, operational analysis	By Maersk Contractor	By Contractor
PAU main structure, lifting analysis	By Maersk Contractor	By Contractor

The PAUs will be transported to Singapore where the modules will be lifted onto the vessel at the Hull conversion contractor.

Verification of local strength of the ship and detail design of the support stools is not within the scope of work for VETCO.

2 STRUCTURAL PAU DESIGN

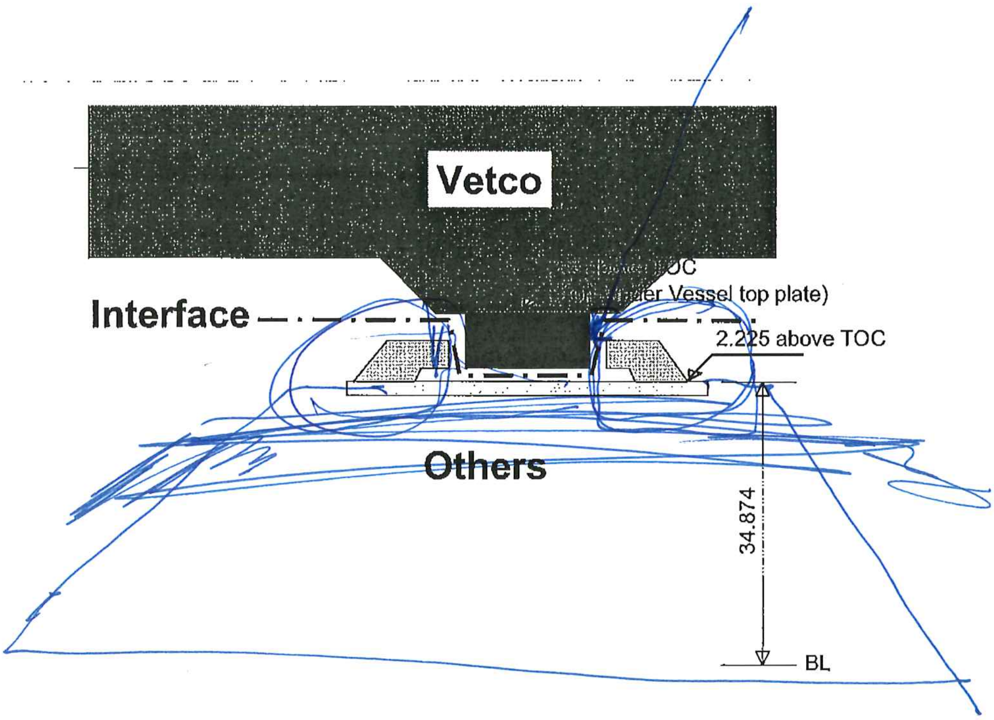


Figure 2-1 Definition of interface. Vetco is responsible for the PAUs, including the elastomerical bearings.

The primary plate girder frame will sit on footings that will be fabricated and installed by others and will form a level support arrangement with Top of Steel (T.O.S.) 2.5 m above the cargo deck at the centre line of the vessel.

The topside support arrangement will be made statically determined in order to avoid forced displacements in the topside structures due to ship deflections. The support arrangement of pancake PAUs which are less sensitive to ship deflections are statically undetermined. See Figure 6-2. The supports on the deck will be located above the existing internal transverse cargo web frames and the longitudinal bulkheads according to input given by the Vessel responsible.

T.O.S. for the topside modules primary structure ground floor shall be 4.5 m above the cargo deck at the centre line of the vessel. Contractor (Vetco) shall provide the vertical connection detail (elastomerical bearing) between the topside modules primary structure and the support on the deck. There will be a base plate at top of the support stool and below the elastomerical bearing. This plate is introduced in order to accommodate potential late adjustments due to fabrication tolerances. Plate to be part of Hull Conversion Contractor delivery. However, the nominal plate dimensions will be given by Vetco.

Vetco will provide the conceptual design of the supporting details. The final design and verification of the support stools will be by the others.

Other than the PAU support nodes, the main primary framing plate girders shall be maintained at a constant depth to simplify the connection details.

3 STRUCTURAL INTEGRATION DESIGN

The detail design and fabrication of the topside supports on deck will be by Vessel Responsible. However, it is Vetco's scope of work to make a FEM model and analyse this model of the support stools above the vessel deck on a concept level. This has been performed in the FEED phase, see doc. no. WV-P-99-S-RP-00001-001, M00 - Topside/Hull Structural Integration Report.

The support concept, with flexible bearings, is introduced in order to uncouple the topside structures from the ship and its deflections (both in overall bending and torsion). Further, this also simplifies the analyses work of both the PAU structures and the support stools as each structure can be treated separately. The topside analyses will be based on a pinned connection at top of the elastomerical bearings and the lateral restraints provided by the supports.

The FEM-model of the support stools will include the stool structure and adjacent hull structures in order to simulate the correct load transfer from the PAUs to the Vessel. A fine analyses model consisting of shell elements will be established. The FE-model will be based on received drawings of the ship. The analysis is a unit load analysis and the output from the analysis is plate stresses in stools and ship due to unit load on stools. The analysis will show ship stresses in transverse frames and longitudinal bulkheads due to unit loads on PAU support stools giving basis for verification of structures below deck and of support stool plates. Verification of these structures is not part of Vetco scope of work and will be performed by others. This has been performed in the FEED phase, see doc. no. WV-P-99-S-RP-00001-001, M00 - Topside/Hull Structural Integration Report.

4 ANALYSIS AND DESIGN

Design and fabrication of the PAUs will basically be according to NORSOK rules and regulations. Ref. /5/, volume 5.

Beam element models will be established for each PAU. The deck plating will be modelled as shear panels in order to contribute to the global stiffness of the structure. Local fine mesh finite element model of nodes or other details will not be developed unless strictly necessary in order to obtain SCF's that are not available otherwise.

As the topside modules are statically undetermined supported in the vertical plane, the out of plane deflection between the 4 support points must be included as pre-described deflections in the FE-analysis of the topside structures.

All relevant load cases will be analysed. Environmental loads are taken into account based on information given by Maersk/Woodside. Received data are summarized in the following sections.

Basically the following rules and regulations form the basis for structural design:

NORSOK	N-001: Structural Design Rev. 4, Feb.2004
NORSOK	N-003: Actions and Action Effects Rev. 1, Feb. 1999
NORSOK	N-004: Design of Steel Structures Rev. 2, Oct. 2004
NORSOK	M-001: Materials selection Rev. 4, Aug. 2004
NORSOK	M-101: Structural steel fabrication Rev. 4, Dec. 2000
NORSOK	M-120: Material data sheets for Structural steel Rev. 4, Jun. 2004
NORSOK	R-CR-002: Lifting Equipment Rev. 1, Jan. 1995
NORSOK	R-003: Lifting Equipment Operation Rev. 1, Oct. 1997
Det norske Veritas	Rules for planning and execution of marine operations, part 1. General requirements Jan. 1996
Det norske Veritas	DNV-RP-C203: Fatigue strength Analysis of offshore steel structures, Aug. 2005
Noble Denton	General Guidelines for Marine transportations

5 REFERENCES

/1/. Woodside. Vincent Development, Basis of Design. Rev. 06.12.05

/2/. CF 70-80 Environmental, metocean, geotechnical and motion data. 08-2005

/3/. Vincent Development Metocean Criteria 17. nov. 2005 j 2205.007 report R1276

/4/. Sea Keeping Analysis doc no WvT 00 G RP 00002-01

/5/. Maersk Statement of Requirements, contract document, Sections 2 and 5

/6/. 004410-VA-MAE-EM-0089: WV-MAE-VAB-EM02020 Trim and List (Heel) Data.

/7/ MC comment sheet no: WV-MAE-VAB-COM-00069.

/8/. VA, Work Instruction – Global Structural Computer Analysis, doc. no. P&F-04-02-08-06.

/9/. WV-MAE-VAB-EM-0508 - Accelerations of M85 and the Piperack, dated 29.11.06

6 GENERAL INFORMATION

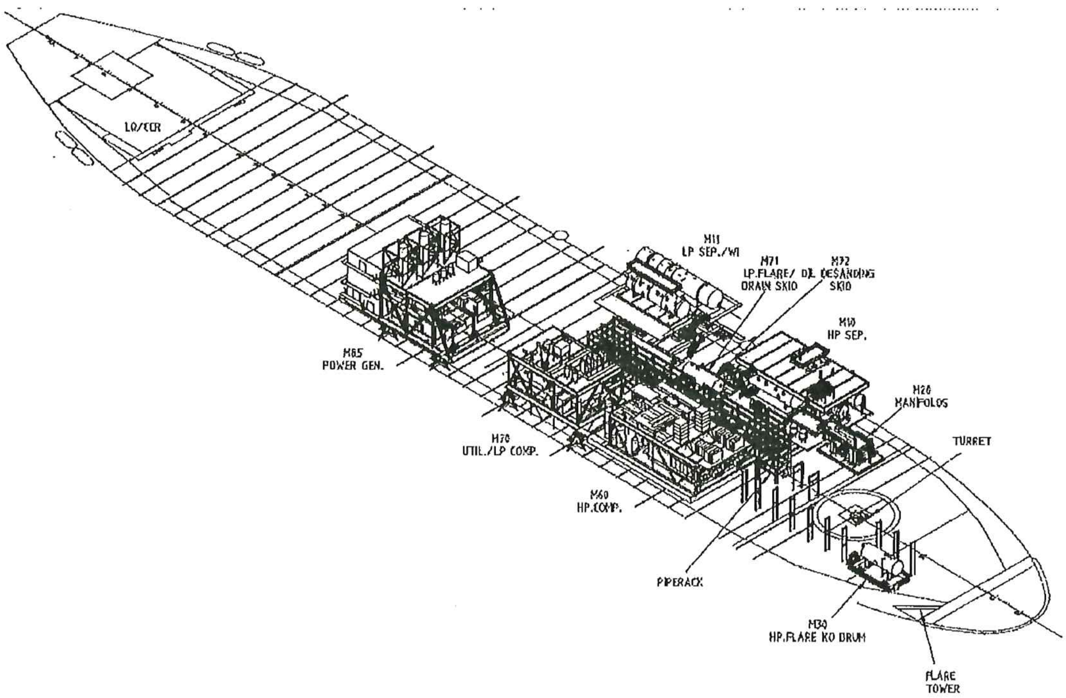


Figure 6-1 Overview Vincent topside modules

Deck elevations Top Of Steel			
	Main deck (m)	Weather deck (m)	CCR roof (m)
M10	37.15	46.65	
M11	37.15	44.15	
M20	37.15	43.55	
M30	33.29		
M60	37.15	46.65	
M70	37.15	46.15	
M71	33.49		
M85	37.15	48.65	51.00
PR01	37.15		
PR02	37.15	44.65	
PR03	37.15		

Table 6-1 Typical deck elevations

Table 6-1 lists deck elevations Top Of Steel (TOS) from vessel Base Line (BL).

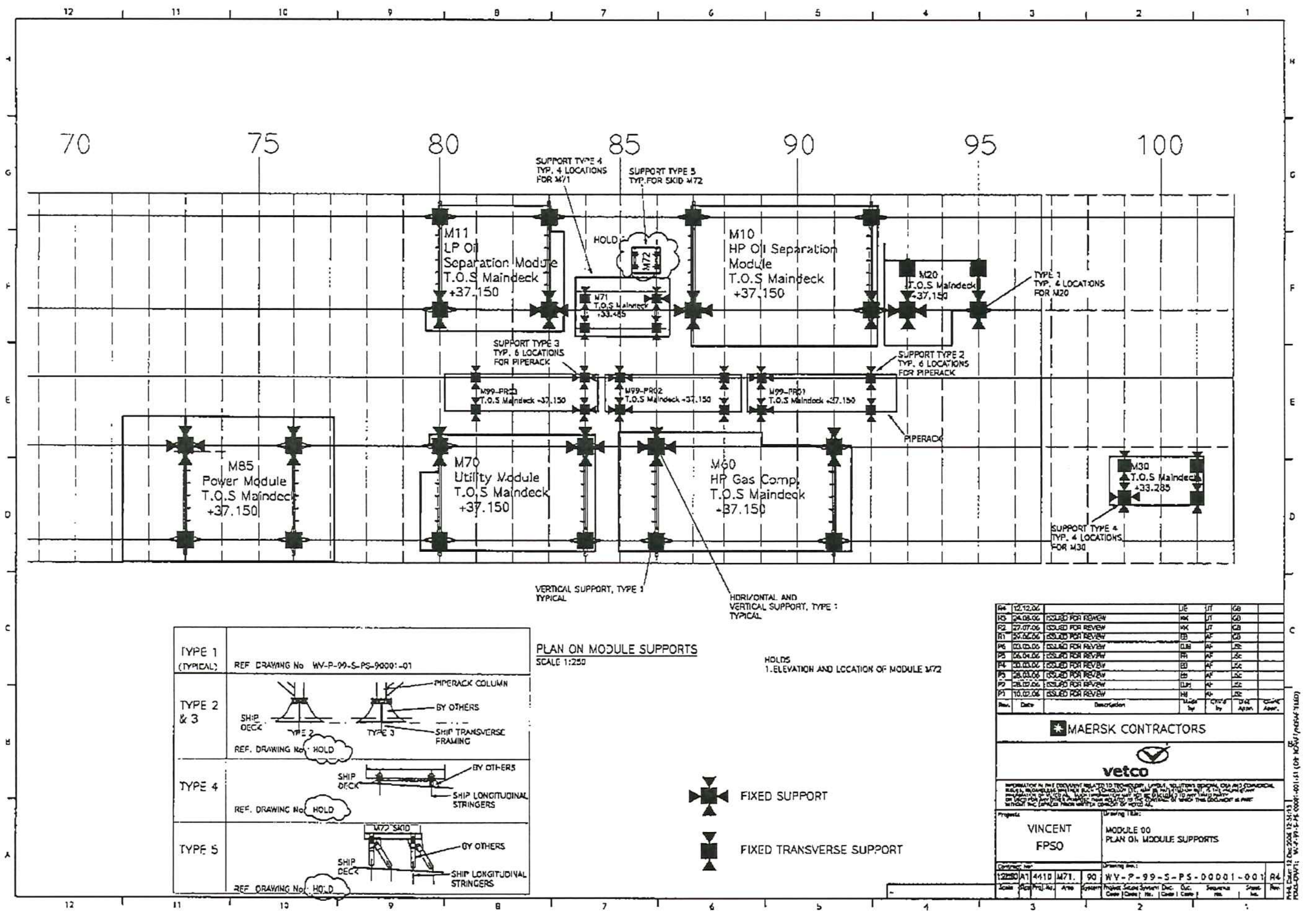


Figure 6-2 Overview Vincent topside modules, Note: M72 is likely to be relocated

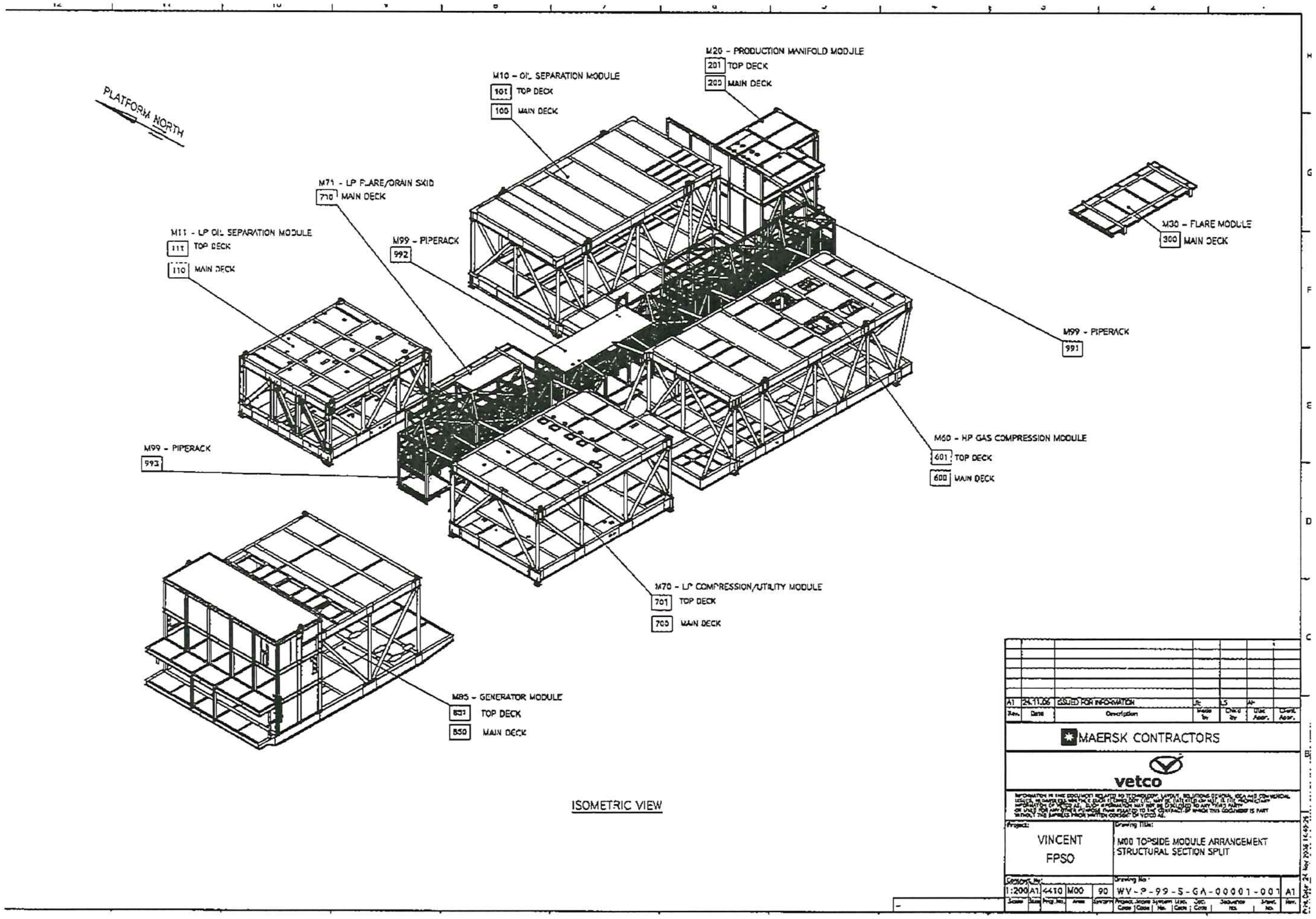


Figure 6-3 Overview and elevations Vincent topside modules Note: M72 is likely to be relocated

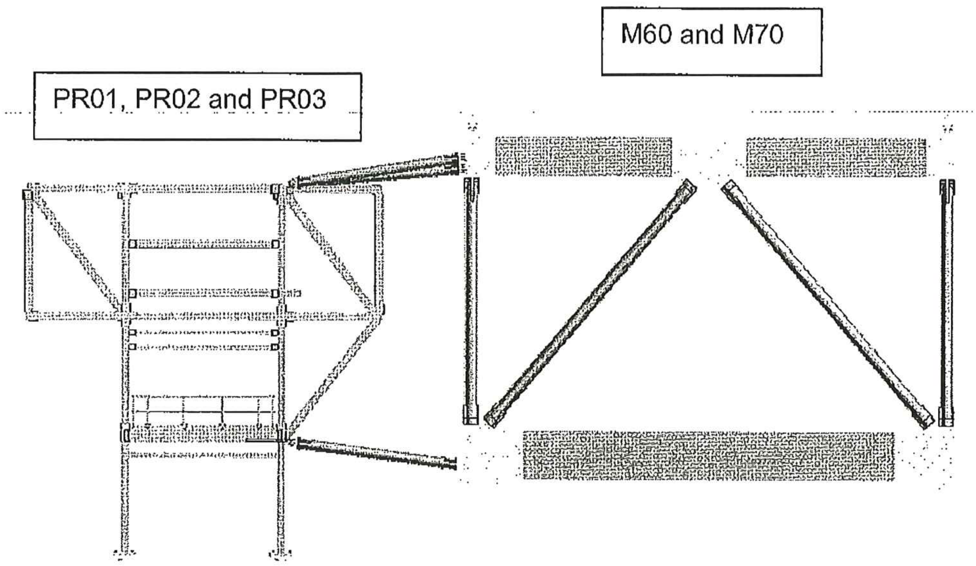


Figure 6-4 Piperacks tie-in to PAUs

PR01, PR02 and PR03 are tied back to the topside modules M60 and M70. The PRs are tied back at two levels, typical at two locations each level. Typical tie-back arrangement is shown in Figure 6-4.

6.1 Weights

The weights, CoG and CoG envelopes for all PAUs and PRs are listed in Appendix A for all conditions.

No additional weight reserve shall be added to the Not To Exceed (NTE) weights given in Appendix A.

7 MATERIAL PROPERTIES

Steel Grades:

The project philosophy with respect to the material grade is given in table below.

Steel quality levels I, II, III applies for the Topside main load bearing structures. However, the following steel qualities will be used.

	NORSOK Steel Quality Level	Material Standard [1]	Applicable Design Classes	Min Yield Strength (MPa) [4]	Thickness Range (mm)
Plates	I [2]	Y30	All [3]	420	25 < t < 150
Plates 8< t <60	I [2]	Y20	All	355 345 335	t <16 16 < t < 40 40<t< 60
Plates 8< t <60 Rolled Profiles	II III	Y25 Y26 Y05	2 – 5	355 345 335	t <16 16 < t < 40 40<t< 60
Seamless Tubular RHS/SHS	II III	Y27 Y07	2 – 5 4 – 5	355 345 335	t < 16 16 < t < 40 40 < t < 60
Plates Rolled profiles Tubulars	IV	Y04 Y01	5	355 235	

Table 7-1 Steel Grade Selection

Notes:

1) Alternative steel materials of equivalent quality may be used.
2) Structural steel plates with guaranteed through thickness properties: Z-steel.
3) Steel grade 420 may be used for nodes and lifting lugs.
4) The following material properties shall apply for the structural steel:

- Young's Modulus:	$E = 2.1 \times 105\ N/mm^2$
- Shear Module:	$G = 0.8 \times 105\ N/mm^2$
- Density:	$7{,}85\ t/m^3$
- Poisson's Ratio:	$v = 0.3$
- Thermal expansion coefficient:	$a = 12 \times 10^{-6}\ /°C$

For temperature loads the Young's Modulus (E), shear module (G) and the minimum yield strength shall be reduced according to NS3472:2001 ch. 14.

7.1 Material Factor

For the temporary conditions the material factors shall be applied as shown in Table 7-2 below:

Analysis	Material Factor (γ_m)
ULS	1,15
SLS	1,00
ALS	1,00

Table 7-2 Material factors for operational conditions

For bolt connections, fillet and partial penetration welds and the net section at boltholes a material factor of γ_m= 1.30 shall be applied.

For the temporary conditions the material factors shall be applied as shown in Table 7-3 below:

Analysis	Material Factor (γ_m)
Load Out	1,15
Barge transport	1,15
Transit	1,15
Lifting	1,15
Placement (primary guiding system)	1,00
Placement (secondary guiding system)	1,15

Table 7-3 Material factors for temporary conditions

8 ANALYSIS OVERVIEW

The global analyses are applicable for the following design checks:

- Operational conditions (SLS, ULS, FLS)
- Accidental Conditions (ALS)
- Temporary phases (ULS)

Analysis Type	ULS-a	ULS-b	SLS	FLS	ALS
Operation	x	x	x	x	
Fire					(x)*
Explosion					x
Dropped object					(x)*
Accidental heel					x
Transport from Thailand to Singapore		x		x	
Transport from Singapore to field		x		x	
Trailer transport	x				
Lifting	x				
Fabrication support	(x)*				
Weighing	(x)*				

Table 8-1 Analysis overview. (x) Not included in FEED phase.*

The following notations are used:

Global design: Design of main steel structure, such as truss members, nodes and main load bearing bulkheads.

Primary design: Design of primary deck areas, such as main girders, and equipment supports.

Local design: Design of deck plate, stiffeners and beams.

In general, the same model is used for FLS analyses as for ULS analyses. A deviation from the ULS-model is the deck plate modeling: In the FLS-model all the PAU deck plates are modeled with full plate properties (while in the ULS model, shear stiffness only are used).

8.1 Load Combinations

For each analysis performed load combinations shall be created according to NORSOK.

Combination for the different conditions to be as given below:

Condition	Dead weight	Live Load	Wave Loads			Wind Loads				Explo sion
			100-year	1-year	Trans	Squall 100 year	100-year	1-year	Trans	
Load Out	X									
Lift	X									
Trans	X				X				X	
Operation	X	X	X			X *).	X			
Test	X	X		X				X		
Accidental	X	X								X

Table 8-2 Load Combinations

Condition	Action combination	Permanent actions, P	Variable actions, L	Environmental actions, E
Load Out (ULS)	a	1.3	NA	NA
Lift (ULS)	a	1.3	NA	NA
Transport (ULS)	a	1.3	NA	0.7
	b	1.0	NA	1.3
Operation & Test (ULS)	a	1.3	1.3	0.7
	b	1.0	1.0	1.3
	b	1.0 *).	1.0	1.3 *).
Accidental damage Limit Stage (ALS)	ALS	1.0	1.0	1.0
Service Limit State (SLS)	SLS	1.0	1.0	1.0
Fatigue Limit State (FLS)	FLS	1.0	1.0	1.0

Table 8-3 Load Combination Factors.
***) Squall wind used in combine with FLS maximum accelerations, only ULS-b check.**

8.2 Transit

Under present tropical cyclone operational procedures, disconnect will occur when a tropical cyclone is a distance of greater than 400 km from an installation. As long as disconnect occurs at greater than 250 km, the distant tropical cyclone case will be less severe than the other survival conditions presented. See ref. /3/, section 7.16.

It is concluded that transit is not governing.

9 ENVIRONMENTAL LOADS (E)

The environmental loads to be considered for structural design of PAUs comprise:

- Wind
- Waves

9.1 Wind

Basis of Design ref. 1.

The wind speeds are calculated based on formula 6.4 to 6.7 in sect. 6.3 in NORSOK N-003, i.e. all winds are considered to be extreme winds. The formula requires a 10 min or a one-hour mean speed.

The elevation for Transit and Operation condition is 40 m.

The resulting wind pressure is $q_{wind}=0.5*\rho*v^2$, excluding the shape factor (C_d). The density (ρ) of air is taken as 1.225 kg/m^3.

In addition wind heel effect shall be included as correction to gravity.

Condition	Reference wind speed [m/s]	Wind speed at z=40m ASL and t=60 sec [m/s]	**Wind pressure** (excl. Drag factor) [kN/m2]
100-year Squall	40.8 *).	40.8 *).	**1.152**
100-year Wind[1)]	21.0	27.8	**0.475**
1-year Wind[1)]	17.0	22.1	**0.298**

Table 9-1 Wind pressure, exclusive drag factor *). For squall winds, the wind speed represent maximum 3-second gust. For the other reference wind speeds, U10 is the hourly duration wind speed at 10m ASL.

Note: 1) From ref./3/, Table 6.1a

9.2 Shape Factors

Shape factors shall be calculated according to DnV Classification Notes 30.5.

The wind direction will be assigned in the same direction as the horizontal accelerations for all load combinations.

The wind pressure given in *Table 9-1* and explosion load shall be combined with given drag factor.

9.3 Waves and ship motion

Accelerations on PAUs for 100 year wave, non-cyclonic condition are listed in Table 9-2, ref. /5/, volume 2 and ref. /9/.

Maximum heave, roll and pitch motions for transport from fabrication yard to Singapore are based on Noble Denton criteria.

Ship and Barge Motions

The ship movement accelerations are valid for all modules and shall be combined, as a minimum, as:

Heave (downwards) ± Surge: $a_z \pm a_y$

Heave (downwards) ± Roll: $a_z \pm a_x$

ULS

	X from AP	y from CL.	z above BL.		Vertical a (m/s²)	Transverse a (m/s²)	Longitudinal a (m/s²)
M85	142,35	18,5	37	stbd	2,63	4,41	0,58
M85	142,35	18,5	47	stbd	2,63	5,01	0,73
M70	193,35	20	37	Stbd	1,43	4,42	0,76
M70	193,35	20	47	Stbd	1,43	5,02	0,91
M60	226,35	20	37	Stbd	1,44	4,44	0,76
M60	226,35	20	47	Stbd	1,34	5,03	0,91
M11	187,65	20	37	Port	2,72	4,42	0,58
M11	187,65	20	47	Port	2,72	5,02	0,73
M10	232,05	20	37	Port	2,73	4,44	0,58
M10	232,05	20	47	Port	2,73	5,04	0,73
PR03	176,25	5	32,6	Stbd	2,73	3,56	0,37
PR03	176,25	5	43,6	Stbd	2,73	4,35	0,57
PR02	210,15	5	32,6	Stbd	2,73	3,58	0,37
PR02	210,15	5	43,6	Stbd	2,73	4,37	0,56
PR01	232,05	5	32,6	Stbd	2,73	3,59	0,37
PR01	232,05	5	43,6	Stbd	2,73	4,38	0,56

Table 9-2 Accelerations on PAUs and PRs. 100 years wave, non-cyclonic condition.

Note 1: Due to symmetry of the Vincent vessel, the vertical accelerations of M60 and M70 are expected to be at the same scale as M10 and M11. I.e. vertical acceleration of M60 and M70 is set equal to 2.73 m/s^2.
Note 2: Even though accelerations are given at two levels for each PAU, only the highest of the accelerations given for each PAU is used in analysis.

Only accelerations for the PAUs listed in Table 9-2 are given in ref. /5/ or ref. /9/. The accelerations for the remaining PAUs, as listed in Table 9-3, are assumed to be the same as for M10. M71 transverse acceleration is lowered according to elevation of COG.

	X from AP	y from CL.	z above BL.		Vertival a (m/s²)	Transverse a (m/s²)	Longitudinal a (m/s²)
M20	251.7	12.4	38.9	port	2.73	5,04	0,73
M30	286.8	-13.5	35.5	port	2.73	5,04	0,73
M71	206.2	-10.5	35.0	stbd	2.73	4,00	0,73
M72	214.0	-20.0	34.0	stbd	2.73	5,04	0,73

Table 9-3 Assumed accelerations on PAUs. 100 years wave, non-cyclonic condition.

Typical deck elevations are shown in Figure 6-3 and Table 6-1. COGs are listed in Appendix A.

FLS

Figure 9-1 shows the non-cyclonic wave directional distribution, which is used for FLS operational condition.

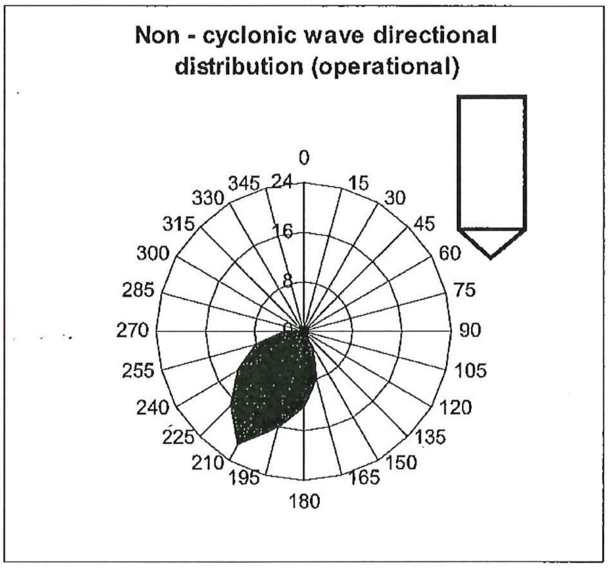


Figure 9-1. Assumed probability for distribution of non-cyclonic waves relative to the ship/vessel (set 1). Set 2 is a mirrored around the centerline. 180 degrees is waves coming towards the front of the vessel.

Figure 9-2 shows the assumed cyclonic wave directional distribution, which is used for FLS transit condition. The transit condition is twice a year for six hours, in 20 years. The cyclonic wave direction distribution is to be used with the cyclonic occurrence scatter table listed in ref. /3/.

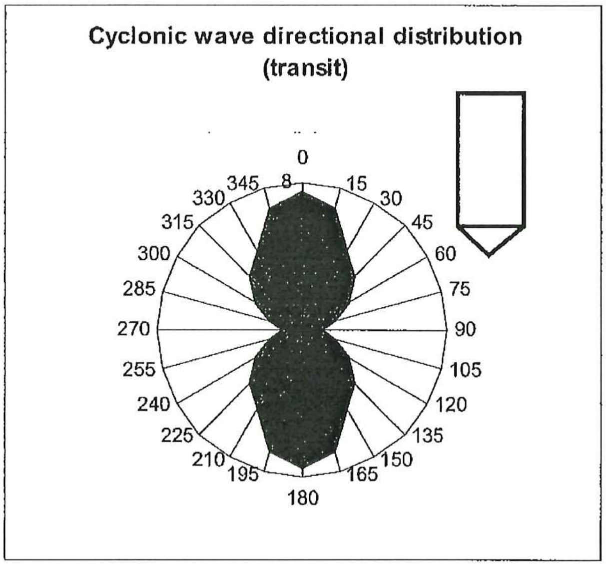


Figure 9-2. Assumed probability for distribution of cyclonic waves relative to the ship/vessel. 180 degrees is waves coming towards the front of the vessel.

	Spread	Direction (degrees)	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240	255	270	285	300	315	330	345
FLS_oper (%)	Cos^8		-	-	-	-	-	-	-	-	-	-	3	8	12	16	21	17	12	8	3	-	-	-	-	-
FLS_cyclonic (%)	Cos^8		8	7	5	4	3	2	1	2	3	4	5	7	8	7	5	4	3	2	1	2	3	4	5	7

Table 9-4 Wave directional distribution for FLS, operational and cyclonic (transit).

Draft 13.18

Module	From AP	From CL	Above BL.	Direction	h	n	a (m/s^2)
	X	y	z				
M10	230.2	18.1	41.82	X	0.88	84046.69	0.95
M10		18.1	41.82	Y	0.88	84046.69	3.71
M10		18.1	41.82	Z	0.88	84046.69	2.26

Table 9-5 Transit acceleration for M10.

Table 9-5 shows the transit accelerations for M10. The accelerations were used as input to a simplified FLS analysis of M10. The braces were selected to measure the stress level, as the braces are sensitive to SCF. The stress level for transit was then readout from the result plot as shown in Figure 9-3. The maximum FLS stress is 68 MPa. The FLS stress, the weibull factor h and the number of transit cycles n in 20 years are then used to calculate the part damage for transit, see Figure 9-4. The part damage is 0.0002 and therefore neglected for all PAUs.

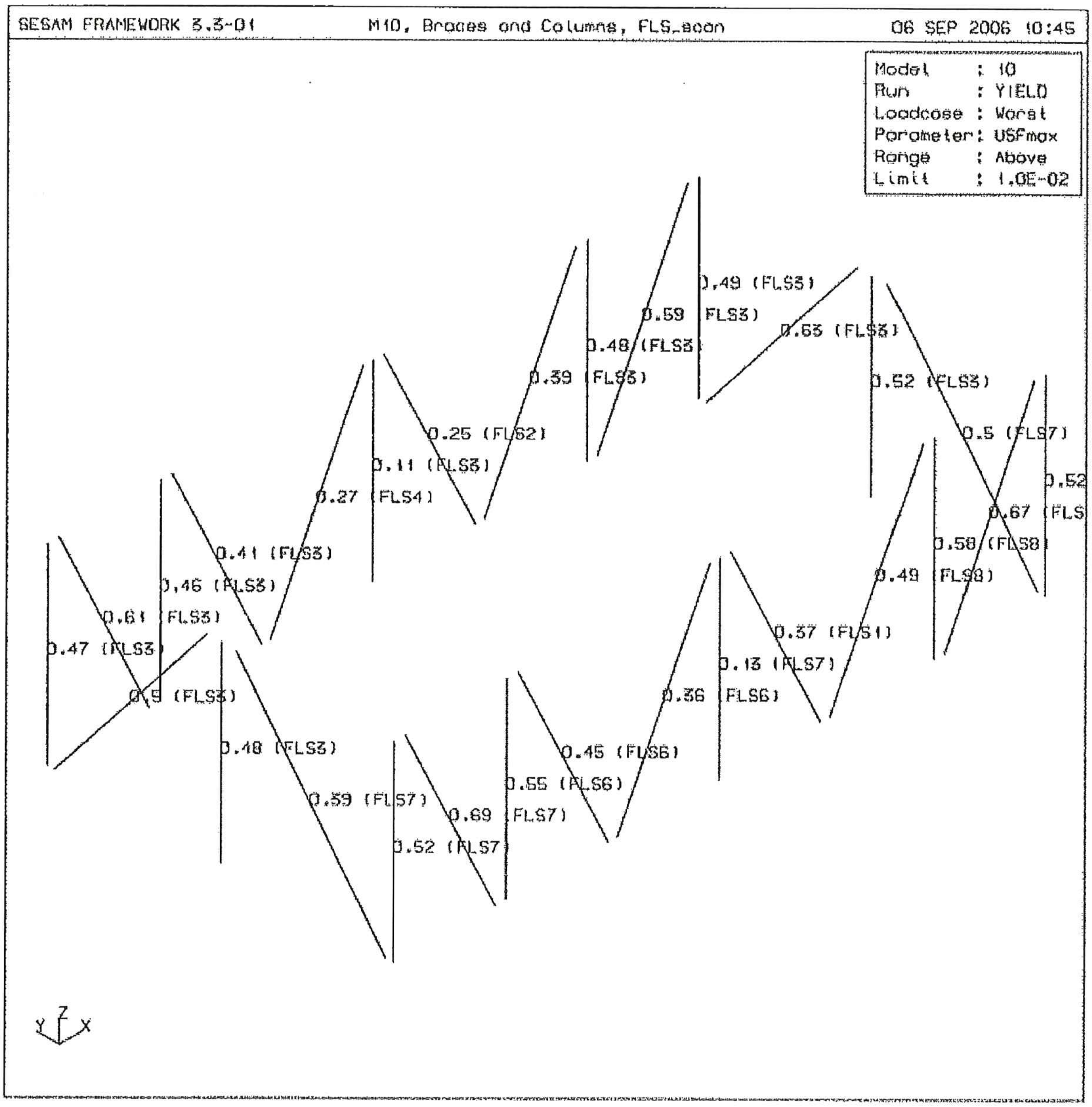
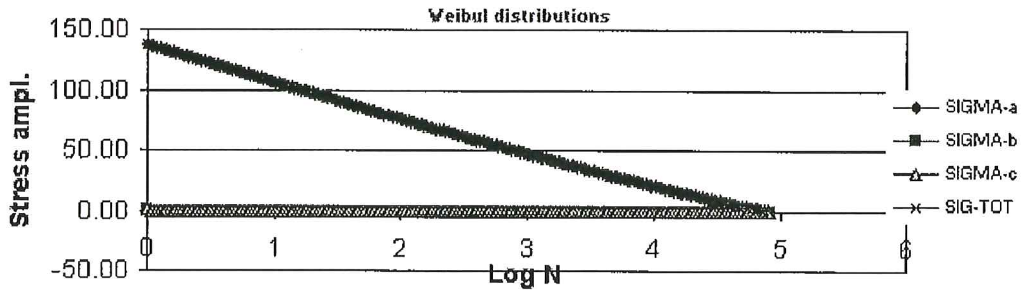


Figure 9-3 Transit FLS scan of M10, yield maximum stress level.

GENERAL FATIGUE CALCULATION

Environment(SW/AIR/L)	AIR	Blue shaded cells to be changed by user
(AIR=Bl-Linear Air, L=linear Air for comp. With closed		**Comments:**
(SW=Seawater with cathodic protection)		Project : .004410 - Vincent
SN - curve (NS/NORSOK)	D NORSOK	
(NS=NS3472 1984 , NORSOI		Location : Transit FLS scan M10
Cut-off if ENV=SW	NO	
Number of cycles	8.405E+04	Revision :...... etc.....
DFF factor	1	
Plate thickness	25	
SCF (for thick. Exp curve T)	1	

INPUT DATA	Maximum stress (Single amp)		Weibull parameter	
a) Stress distribution 1	68.80	Mpa	0.88	
b) Stress distribution 2	0.00	Mpa	0.00	Stress dist. b) and c) when
c) Stress distribution 3	0.00	Mpa	0.00	stress from different models
(Macro Ctrl+G: goal seek C31=1.0 by changing C14)				Normally not used



RESULTS

Thickness exponent	0.2	(dependent on SN-curve)
Method 1, summation of stress, from summed Weibul		(Correlation = 1.0)
Resulting maximum stress amplitude	68.80	
Damage (Target = 1.0)	0.0002	

Figure 9-4 Transit part damage calculation for M10.

Transport from Thailand to Singapore on barge, FLS

The accelerations from the barge transport from Thailand to Singapore are based on Noble Denton criteria, which is a conservative assumption. The transport is expected to last approximately four days. The maximum ULS accelerations for the transport according to Noble Denton criteria is slightly higher than the ULS operational accelerations. It is expected that the Noble Denton FLS accelerations is also slightly larger than the FLS operation acceleration. But as the transport is expected to have duration of approximately four days, the damage from the transport from Thailand to Singapore is neglected.

Transport from Singapore to field on Vincent vessel, FLS

The transport from Singapore to field is expected to last approximately 10 days. The transit duration is:
- cyclone duration of 6 hours
- cyclones twice a year
- design life 20 years

Transit duration = 6*2*20* 1/24 = 10 days.

As the transit duration is approximately as long as the transport duration from Singapore to field and the transport is not expected to be performed in cyclone condition, the damage from the transport is expected to be lower than the damage from the transit. This means that the transport damage from Singapore to field is neglected.

Operation of the Vincent vessel

Module	From AP	From CL	Above BL.	Weibull h	Cycles n	Acceleration (m/s^2)		
	X	Y	Z			X	Y	Z
M10	230.2	17.0	41.8	0.92	64435454	0.59	2.36	1.53
M11	184.9	18.1	44.0	0.92	62287182	0.61	2.38	1.47
M60	222.3	-18.1	42.0	0.92	64083885	0.73	2.35	1.18
M70	187.7	-18.1	42.0	0.92	62504460	0.76	2.32	1.02
M85	138.2	-18.1	42.0	0.91	60875021	0.78	2.30	1.07
M20	251.7	12.4	38.9	0.92	65457942	0.56	2.30	1.56
M30	286.8	-13.5	35.5	0.93	66748508	0.59	2.26	1.67
M71	206.2	10.5	35.0	0.92	63872967	0.61	2.14	1.10
M72	214.0	20.0	34.0	0.92	64326364	0.64	2.12	1.11

Note 1: z value is given for draft 10.22 m
Note 2: Weibull factor and number of cycles is given for y-direction.
Accelerations in x and z direction are scaled according to h and n in y-direction

Table 9-6 Fatigue accelerations on PAUs. 100 years wave, non-cyclonic condition based on fatigue scatter diagram given in the "Vincent Development Metocean Criteria", Report nt. R1276, combined with the "Sea Keeping Analysis" doc. WV-T-00-G-RP-00002-001 and wave probability distribution relative to the ship assumed according to figure 9-1.

The calculated fatigue accelerations are based on 15% in ballast condition (draft 10.22 m), 52% in intermediate condition (draft 15.21m, i.e. (13.18+17.25)/2)) and 33 % in full load condition (draft 22.53 m). Ref. /7/.

The accelerations are used to calculate FLS stress in the PAUs, using a simplified FLS calculation. See Table 10-4.

The accelerations listed in Table 9-6 shall be used to calculate FLS stress levels for the PAUs. The allowable stress level is calculated based on the average of the weibull factor h and the number of cycles n. I.e. average weibull factor = 0.9199 and average number of cycles = 63843531.

See section 10.4 for allowable FLS stresses.

9.4 Applied global ship Bending Moment

The hull bending moments are for reference and are normally not included in analyses for modules. Ref. /5/, volume 2.

1) S.W.B.M.

Hogging: 6,07E12 Nmm
Sagging: 6,55E12 Nmm

2) W.B.M.

Hogging/Sagging: 10,4E12 Nmm

9.5 Hull Deflection Result

Hull deflections are to be considered for structures between modules. Ref. /5/, volume 2.

1) Longitudinal deflection:

Hogging: 1 mm/m
Sagging: 1 mm/m

2) Vertical deflection:

Frame No.	x	Deflection (mm)	
	from AP	Sag.	Hog.
fr68	108,15	756,79	735,24
fr76	153,44	861,99	837,44
fr83	193,35	819,02	795,70
fr89	226,35	690,60	670,93
fr82	187,65	832,93	809,21

9.6 Heel Conditions

The following heel conditions apply, see ref. /6/:

	Operation (degrees)	Survival (degrees)
Trim	1	4
List	5	20

Note: Survival condition is to be considered as static, hence no dynamic roll or pitch should be added to the survival values.

Wind heel to be included as correction to acceleration loads and combined with E-factors.

10 OPERATIONAL CONDITIONS

10.1 General

For the in-place analyses the following limit states shall be checked:

- Ultimate Limit States (ULS)
- Serviceability Limit States (SLS)
- Accidental damage limit states (ALS)
- Fatigue Limit States (FLS)

The various basic loads are:

P - Permanent loads

L - Variable functional loads

E - Environmental loads

D - Deformation loads

Ultimate Limit States (ULS)

In-place load combinations shall consider ULS-a and ULS-b load conditions with contribution from all relevant basic load cases. Load combinations shall as a minimum be established to give maximum reactions at the interface between modules and the vessel.

LOAD COMBINATION	P	L	E	D
ULS - A	1,3	1,3	0,7	1,0
ULS – B	1,0	1,0	1,3	1,0

Table 10-1 Load coefficients for the Ultimate Limit States (ULS)

The loads to be included in the in-place condition are:

Load Type	Load Category
- Permanent Loads	P
- Variable Functional Loads	L
- General Live Loads	L
- Environmental Loads	E
- Deformation Loads	D
- Special Loads	P&L
- Weight Reserve	P

10.2 Permanent Loads (P)

The permanent loads are defined as the weight of the structure, equipment and dry weight of piping and other bulk items, which is a permanent part of the module.

The weight applied shall be taken from the project weight report, which is included in Appendix A..

Equipment items having an operating weight of 5 tons or more shall be applied to the structural FE-model. Other weights to be grouped under area loads and applied as uniformly distributed load as masses.

10.2.1 Structural Dead Loads

The weight of the primary, secondary and outfitting structures shall be included.

10.2.2 Equipment and Bulk (other than structural)

These loads contain the following:

Equipment
Electrical bulk
Fire & Safety bulk
HVAC bulk
Instrument & Telecom bulk
Architectural bulk
Piping bulk

Equipment and bulk loads shall be taken from the Master Equipment List, and the Weight Report.

Bulk loads shall be distributed in accordance with input from the Area Disciplines.

For modeling of heavy equipment items, reference is made to Sect. 14.5. Other equipment weights will be grouped under area loads and applied as uniformly distributed load (UDL) on the transverse deck beams.

10.3 General Live Loads (L)

General live loads are loads from:

- Stored materials and equipment
- Lay-down materials and equipment
- Personnel

10.3.1 Inventory and Equipment Live Load

Inventory loads are the weight of fluids in equipment, tanks and pipe work under normal operating condition. Loads will be applied according to weight report.

The modules shall be checked for the test condition of equipment, i.e. water filled equipment.

10.3.2 Variable Functional Load

According to NORSOK the following minimum design loads shall be used for open areas.

Area	Local design		Primary design	Global design
	Distributed action, p Point action, P		Apply factor to distributed action	Apply factor to primary design action
	p (kN/m2)	P (kN)		
Storage areas	Q	1.5 q	1.0	1.0
Lay down areas	Q	1.5 q	F	1.0
Lifeboat platforms	9.00	9.00	1.0	May be ignored
Area between equipment	5.00	5.00	F	May be ignored
Walkways, staircases and platforms	4.00	4.00	F	May be ignored
Walkways and staircases for inspection and repair only	3.00	3.00	F	May be ignored
Roofs, accessible for inspection and repair only	1.00	2.00	1.0	May be ignored

Notes:

1. Wheel actions to be added to distributed actions where relevant. (Wheel actions can normally be considered acting on an area of 300 x 300 mm.)
2. Point actions to be applied on an area 100 x 100 mm, and at the most severe position, but not added to wheel actions or distributed actions.
3. q to be evaluated for each case. Lay down areas not normally to be designed for less than 15 kN/m^2
4. f = min{1.0 ; (0.5 + 3/A$^{0.5}$)}, where A is the loaded area in m^2. f = 1,0 for Area ≤ 36m^2, f = (0,5 + 3/A ^{0,5}) for area > 36 m^2, A = total loaded area (m^2) for the PAU

Table 10-2 Variable Functional Loads

For the global structural operational analysis is an overall functional live load applied for the deck areas outside the lay-down areas. For this load it is assumed that 50% of the deck area is outside equipment and lay-down and 10% is transport routes. Hence, the applied load becomes 0.50*5.0+0.1*10.0 = 3.5 kN/m^2. No area reduction factor is used for the general functional load.

Total loads applied in the primary design FE-analysis are then:

Lay down areas: 15.0 kN/m^2

General functional load: 3.5 kN/m^2 (Over entire deck excl. lay down area)

For the locale design of deck stiffeners shall an additional load of 10 kN be considered. This load represents the maximum pipe support load on deck stiffeners.

For the fatigue damage calculations (FLS) may the variable function load be reduced by the factor f given in note 4 in Table 10-2.

10.3.3 Center of Gravity (CoG) Shift

CoG shift for ULS:

Possible COG shift according to the COG design envelope as defined in Appendix A shall be accounted for. This shall be done by means of introducing a force couple about both the global x- and y-axis. No COG shift factor will be applied in Z-direction.

The COG as derived from the computer analyses shall be moved to the most critical corner of the COG envelope for each load combination.

The following two basic load cases to be included:

Basic Load Case "1"

A vertical load of +/-1000 kN to be applied at each of the longitudinal truss lines.

Basic Load Case "2"

A vertical load of +/-1000 kN to be applied at each of the transverse truss lines.

The loads shall be applied with 50% at each deck level for the applicable PAUs.

A new structural verification analysis is only required if COG given in the weight report lies outside the envelope defined, or if the reported weights exceed the design weights.

CoG shift for FLS:

Possible COG shift according to the COG design envelope as defined in Appendix A shall be considered. The CoG shift is covered by applying a CoG shift factor. The factor used in the analysis shall be verified towards the CoG and envelope given in the project weight report.

The principle for calculation of the CoG factor, α_{CoG} is given in formula below.

$$\text{CoG factor, } \alpha_{CoG} = \frac{DX + a}{a} \times \frac{DY + b}{b}$$

The unshifted CoG shall be the computer analysis CoG.

a = distance in x-dir. between analysis CoG and the closest support point.

b = distance in y-dir. between analysis CoG and the closest support point.

DX = distance in x-dir. between analysis CoG and max shifted CoG

DY = distance in y-dir. between analysis CoG and max shifted CoG

The above CoG shift factor will be correct for one corner of the CoG envelope and conservative for the other three corners. If required the correct factor can be calculated for the remaining corners and incorporated in the analysis.

10.3.4 Dynamic Equipment loads

Dynamic loads from rotating equipment such as generators and compressors will be analysed in order to confirm that the code requirements are met with respect to;

- fatigue of deck structure
- fatigue of attached piping
- structure borne vibrations for noise and human comfort
- airborne noise

The design basis for these analyses will be described and documented in separate reports and are not covered by this design brief.

10.4 Fatigue

The fatigue limit state (FLS) shall be considered based on a 20 years design life.

	Miner's No	Fatigue life	DFF
Non-redundant, uninspectable components (incl. primary structure)	0.1	200	10
Non-redundant, inspectable components (incl. primary structure)	0.33	60	3
All other structures	0.5	40	2

Table 10-3 Fatigue life. Based on ref. /1/. and conversation with Maersk.

In general, all structures are regarded as redundant. There are some exceptions to this, namely:

- Primary support nodes of modules
- Some isolated structural members carrying cantilevered structures by a single feature.

Such structures shall be designed for fatigue life in accordance with the statements in Table 10-3.

The NTE operating weight of the PAUs, shall be used for the FLS analysis.

Only 50% of the general live load shall be applied for global FLS analysis.

For primary main steel members of the PAUs, the maximum allowable damage is 0,5 according to Table 10-3.

The SN-curves used in the FLS code check is based on NORSOK N004. The design fatigue factor (DFF) used is depending on the access to the actual detail.

The structures shall be verified with accelerations taken from the long-term analysis of the ship motions. The acceleration shall be combined according to Table 10-4.

Load combination	Factor for x-acc a)	Factor for y-acc b)	Factor for z-acc c)
1	1.0	0.0	-1.0
2	1/√2	1/√2	-1.0
3	0.0	1.0	-1.0
4	-1/√2	1/√2	-1.0
5	-1.0	0.0	-1.0
6	-1/√2	-1/√2	-1.0
7	0.0	-1.0	-1.0
8	1/√2	-1/√2	-1.0

Table 10-4 FLS load combinations

At each possible fatigue location, the maximum principal stress from the eight load combinations shall be checked against the allowable stresses in Table 10-5.

As all damages from transport and transit are neglected, the allowable damage during the operation condition is 1.0.

Detail category	DFF=2	DFF=3	DFF=10
B1	250	224	165
B2	219	196	145
C	195	175	129
C1	175	157	116
C2	156	140	103
D	141	126	93
E	125	112	83
F	111	99	73
F1	99	88	65
F3	88	78	58
G	78	70	52
W1	70	63	46
W2	63	56	41
W3	56	50	37

Table 10-5 Allowable fatigue single amplitude stresses [MPa], weibull factor = 0.92 and 6.384E7 cycles in 20 years.

The allowable stresses are for plate thickness 25 mm or less. The allowable stress must be adjusted with (t/25)k, where k=thickness exponent from DnV RP-C203, ref./6/.

The structural detail categorization with respect to SN-curves shall be according to DNV RP-C203, Fatigue check Analysis of offshore steel structures.

The nominal stress or the hotspot stress method may be used. If the hot spot stress method is used, the stress concentration factors used must be documented.

Design factors for fatigue (DFF) shall be according to NORSOK N-004,

10.4.1 Fatigue SCF

The fatigue Stress Concentration Factors (SCFs) presented in this section are to be used in lieu of more refined analysis. Such analyses may give basis for improved values which can be adopted provided sufficient documentation is available.
Models, analysis methods, and results for the Vincent project will be documented in the operational report.

Typical tubular to gusset plate connection

SCF for the detail gusset plate and brace connections are extracted from local FEM analysis.

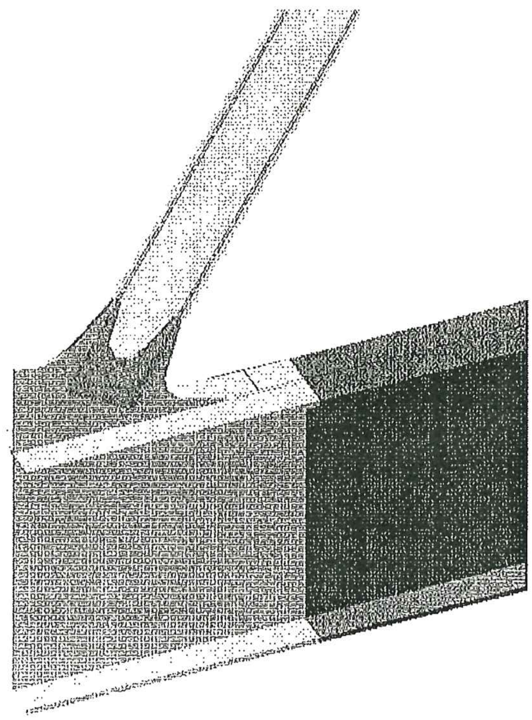


Figure 10-1 Tubular brace connected to gusset plate, brace shown transparent.

Both shell element models and solid element models were used in the investigation of the gusset plate details. Series of models were analyzed to cover the different combinations of tubular dimensions and gusset plate thickness.

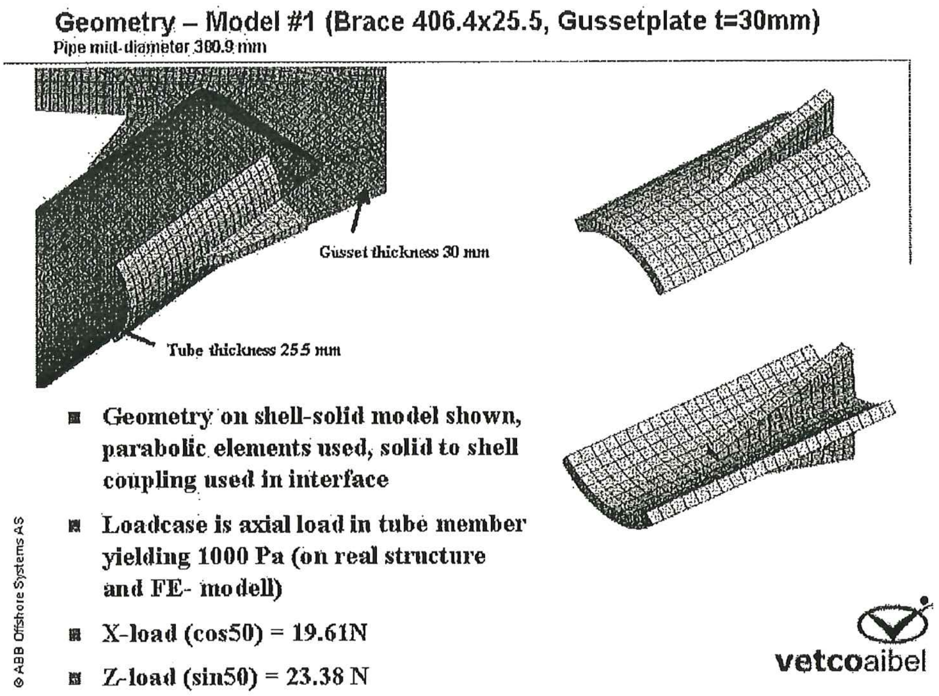


Figure 10-2 Example of FEM model used in the SCF analysis

	Brace		
Gusset plate wt	OD 406.4, WT15.9	OD 406.4, WT 25.4	OD 323.9, WT 12.7
20	X		X
25	X	X	
30	X	X	
50		X	
60		X	

Table 10-6 Combinations of gusset plate wt and brace wt.

		Tubular axial force		Tubular bending moment	
WT Tubular	WT Gusset plate	Inside	Outside	Inside	Outside
15,9	20	3,50	3,14	1,92	2,80
Max SCF		3,50		2,80	
15,9	25	3,53	2,85	1,89	2,56
Max SCF		3,53		2,56	
15,9	30	3,41	2,65	1,79	2,37
Max SCF		3,41		2,37	
25,4	25	2,31	3,52	1,46	2,89
Max SCF		3,52		2,89	
25,4	30	2,43	3,35	1,50	2,73
Max SCF		3,35		2,73	
25,4	50	2,60	3,16	1,50	2,58
Max SCF		3,16		2,58	
25,4	60	2,84	3,15	1,60	2,71
Max SCF		3,15		2,71	

Table 10-7 Typical SCFs for gusset to tubular connections, from recent projects.

The inside detail is a SN F curve, but the values are scaled to a D curve. The outside is a D curve.

Typical deck girder connection

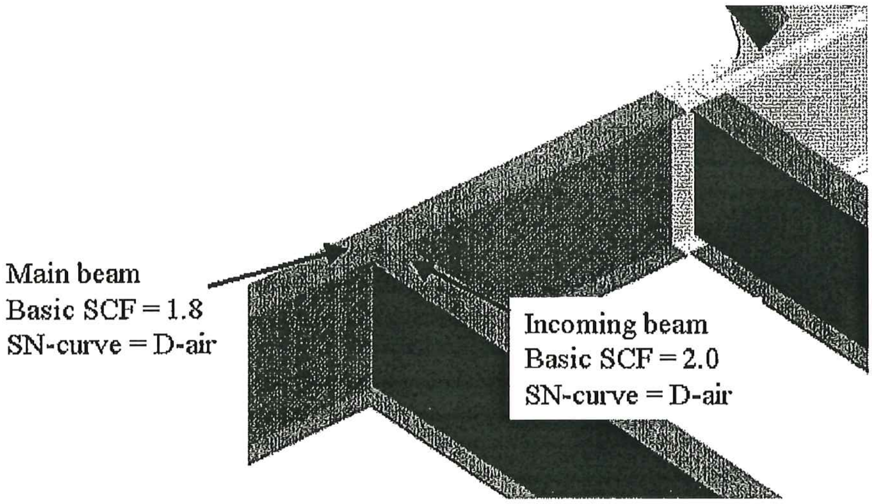


Figure 10-3 Stress Concentration Factors (SCFs) used for typical deck girder connections, from recent projects.

The figure above shows Stress Concentration Factors (SCFs) used in the Framework input for typical girder connections.

11 SERVICEABILITY LIMIT STATES (SLS)

Maximum main structure (trusses) and deck girder deflections shall be analysed combining all permanent loads, variable functional loads, general live loads, special loads and environmental loads.

LOAD COMBINATION	P	L	E	D
SLS	1,0	1,0	1,0	1,0

Table 11-1 Load coefficients for the Serviceability Limit States (SLS)

A force couple shall be applied to simulate CoG shift, see section 10.3.3.

The deflections of the structural items shall be within the requirements in DNV-OS-C101, Section 8. See Table 11-2 and Figure 11-1. The requirements are summarised:

Condition	**Limit for maximum deformation (δ_{max})**
Deck beams	L/200
Deck beams supporting plaster or other brittle finish or non-flexible partitions	L/250

Table 11-2 Deflection criteria from DNV-OS-C101

Note: L is span of the beam. For cantilever L is twice the projected length.

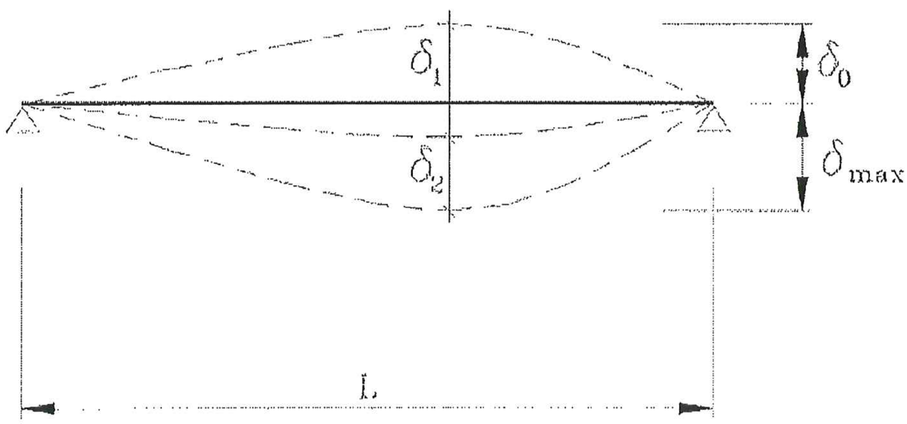


Figure 11-1 Definition of vertical deflection

11.1 Vortex Shedding

Long slender elements shall be screened for vortex shedding.

11.2 Structural Dynamic Response

The structural dynamic response from rotating equipment shall be considered. Where excitation frequencies are in the area of the natural frequencies for the structural steel, further investigations are required.

For modules including rotating equipment (i.e. compressor skids at M60) an eigenfrequency analysis shall be performed and if the eigenfrequency are close to the excitation frequency a dynamic response analysis shall be performed.

12 ACCIDENTAL DAMAGE LIMIT STATES (ALS)

12.1 General

The accidental analyses shall cover the following accidental actions:

- Explosion (blast loads)
- (Fire)
- Dropped objects
- Accidental heel

12.2 Loads and Load Factors

The permanent and variable functional loads for the accidental analyses are as defined for the in-place analysis. The load factors are set to 1.0.

The accidental loads shall be combined with 75% of storage loads. No environmental loads shall be used in fire, blast or dropped object analyses.

12.3 Blast/Explosion

Structural columns, braces and deck girders exposed to drag loads due to blast shall be checked. No blast pressure to be applied to freestanding members.

The blast load is a high pressure build up over a short period of time due to explosion. The load will act on the plated decks and blast walls and will be assumed uniformly distributed within the blast area. The secondary and primary structures should be checked using non-linear dynamic analyses if needed.

For simplified analyses the dynamic amplification factor (DAF) shall be calculated for the impulse loading.

The modules shall be design for the following explosion pressure (ref. doc. WV-P-99-X-SP-00006-001 and M00 Explosion Analyses, doc. WV-P-88-X-SY-00001-001):

- Static panel pressure of 0.3 barg and drag pressure of 0.15 barg for modules M10, M11, M20, M60, M70, M71, M72 and M99.
- Static panel pressure of 0.2 barg and drag pressure of 0.1 barg for modules M30 and M85.

The explosion load shall be applied over 25% of plated deck area for the deck design. The drag loads shall be used for free-standing structural members, piping, vessels, equipments (incl. supports), etc.

12.4 Structural protection

Ref. (ref. doc. Technical safety specifications, WV-P-99-X-SP-00006-001):

Primary steel inside module M60 and M70 shall be fire protected (or have redundancy) to withstand a fire of 300 kW/m2 for 30 minutes. This fire is a jet fire and as a design case a medium leakage of 5 kg/s resulting in a jet of 35 m length and an average diameter of 4 m (maximum diameter of 10 m) is defined.

Based upon the fire defined above an evaluation of redundancy of steel in order to limit amount of passive fire protection has been performed. The result is that all exposed main steel nodes, braces, columns, trusses and top deck ring beam need passive fire protection.

12.5 Accidental Heel

This ALS-condition shall be combined with static 100 year wind, i.e. no extra heel effect due to the wind actions shall be included.

12.6 Fire Walls

Ref. (ref. doc. WV-P-99-X-SP-00006-001):

Fire walls shall provide to meet all applicable regulatory requirements.

A fire wall rated for a hydrocarbon fire of 300kW/m2 for 30 minutes shall be installed at wall of M20 facing M10 to separate fire zones B and C.

A-0 fire rated enclosures and walls shall be installed for the main generator and high pressure gas compression turbine enclosures.

Electrical/instrument rooms in M85 as a minimum be fire rated A-0 while rooms containing equipment to be operative during emergency situation shall be fire rated A-60. This means that level 1 (high voltage area) and level 2 (low voltage area) shall be a A-0 cells, while level 3 (UPS, switch rooms, battery rooms etc.) and level 4 (LIR) shall be two separate A-60 cells. HVAC rooms at level 4 and 5 shall be separate A-0 cells.

12.7 Beams Supporting Critical Process Equipment

Ref. (ref. doc. WV-P-99-N-RP-00002-001):

Structures supporting critical process equipment, where failure will have substantial consequences shall be separately evaluated in each case in order to ensure that structural redundancy is present. The evaluation shall aim at, through design and selection of inspection level of welds, sufficient redundancy is established.

Critical process equipment in this context is equipment where leak would lead to substantial process leak. Equipment and tanks with large hydrocarbon contents, or heavy rotating machinery containing hydrocarbons.

13 NON-OPERATIONAL CONDITIONS

13.1 Weighing Condition

The not to exceed dry weight and the CoG envelope in accordance with the weight report shall be used.

No environmental loads are applicable.

If found necessary local checks for the support points must be performed. The verification can probably be done by use of manual calculations.

13.2 Load-out/trailer transport

The load-out and the site-move shall be performed by use of multi-wheel trailers rolled under the modules. The hydraulic operated trailers will lift the modules clear of the construction supports.

The gravity loads of the modules shall be balanced by positive vertical forces on the modules at the trailer locations, in the load-out analyses. Three independent hydraulic systems shall be arranged and provide a stable system.

The modules shall be supported on the trailers directly at the primary structure members in lower deck. Maximum distance between transverse deck girders (supports for trailers) is 8,4 m.

Horizontal forces in both longitudinal and transversal direction of 4,5 % of deck weight (i.e. 2 % for heel and 2,5 % acceleration or braking) shall be applied at COG of topside and at the trailer interface points, hence the horizontal forces to be transferred through the support members/points to the load out frames/load out beams. To give zero horizontal reactions at computer model supports, the forces simulating the hydraulic trailer groups shall counterbalance the turnover moment.

Load out will have a limiting wind of BF 6, equal to maximum 13.8 m/s.

The arrangement of supports at the yard and module support dimensions shall be developed during the detailed design.

They shall consider trailer positions for load in and load out and access for driving trailers into position.

Capacity of site ground

The ground capacity of the site ground shall be investigated, and necessary strengthening carried out. Reinforced concrete slabs will be positioned directly below each module support.

The trailer transport analyses shall simulate the effect of the trailers by applying positive vertical forces balancing the weight of the topside.

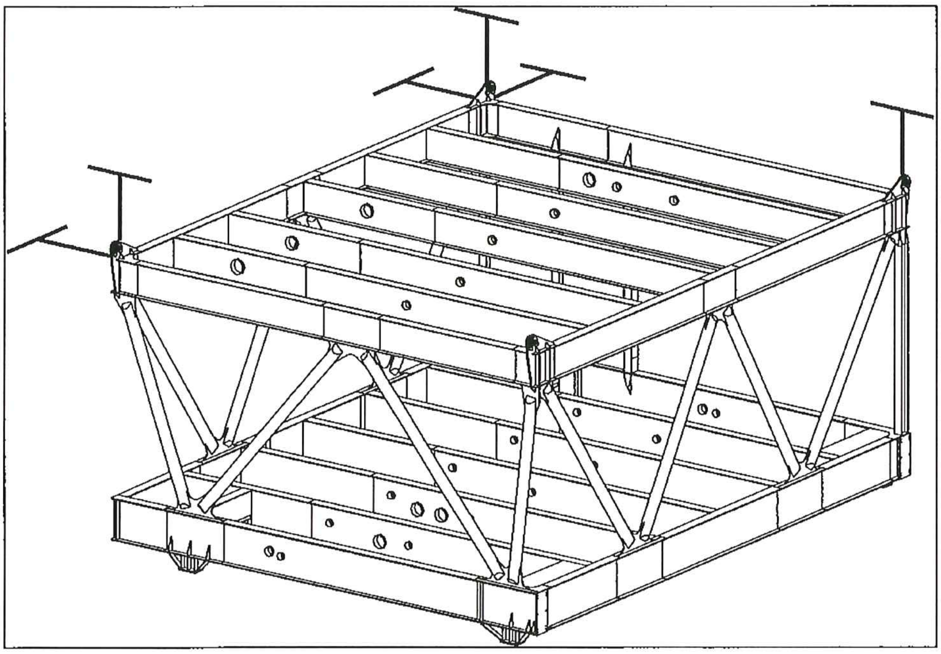
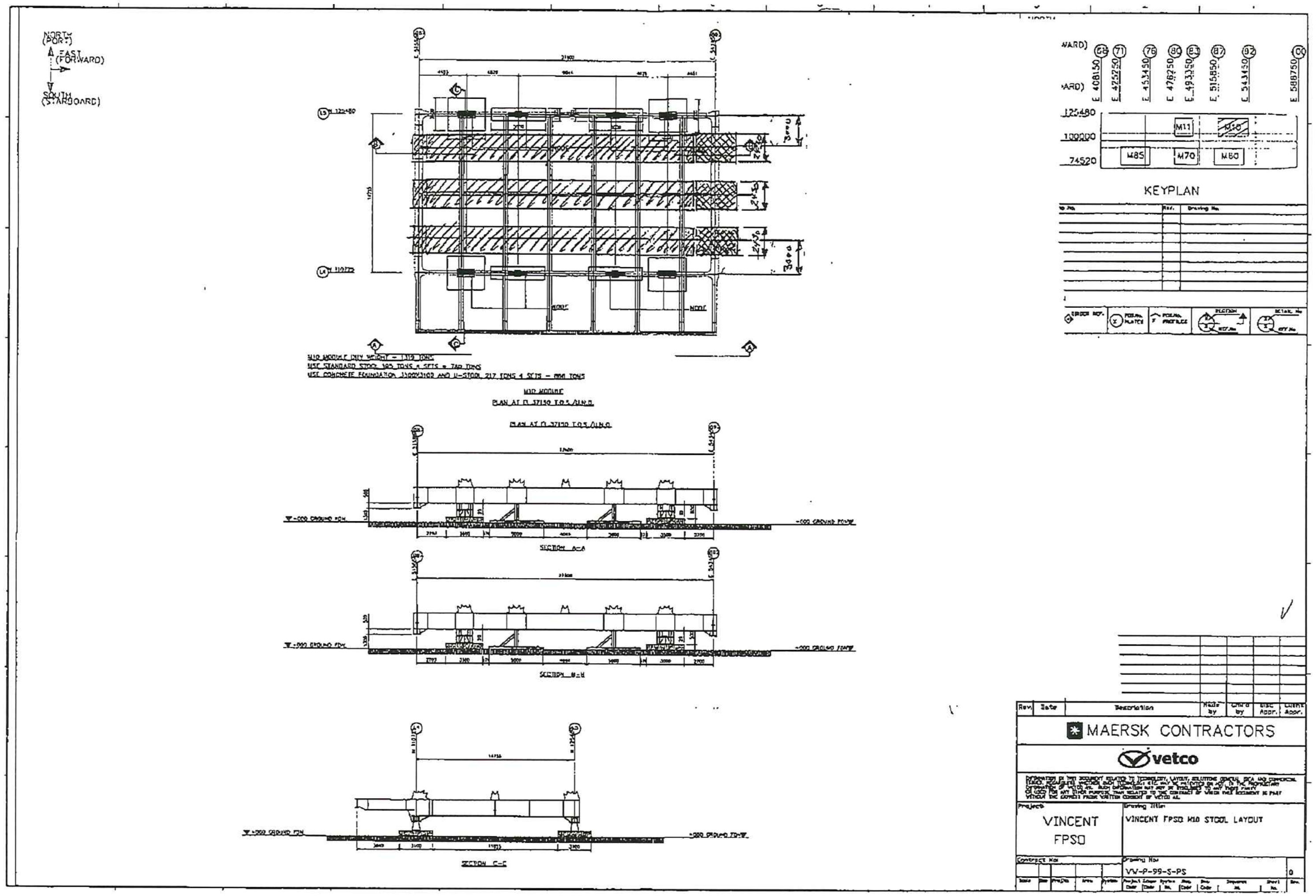


Figure 13-1 Figure Support arrangement during load-out to prevent rigid-body motion

Preliminary load out arrangements are shown below.

Note: Building support configuration not shown correctly



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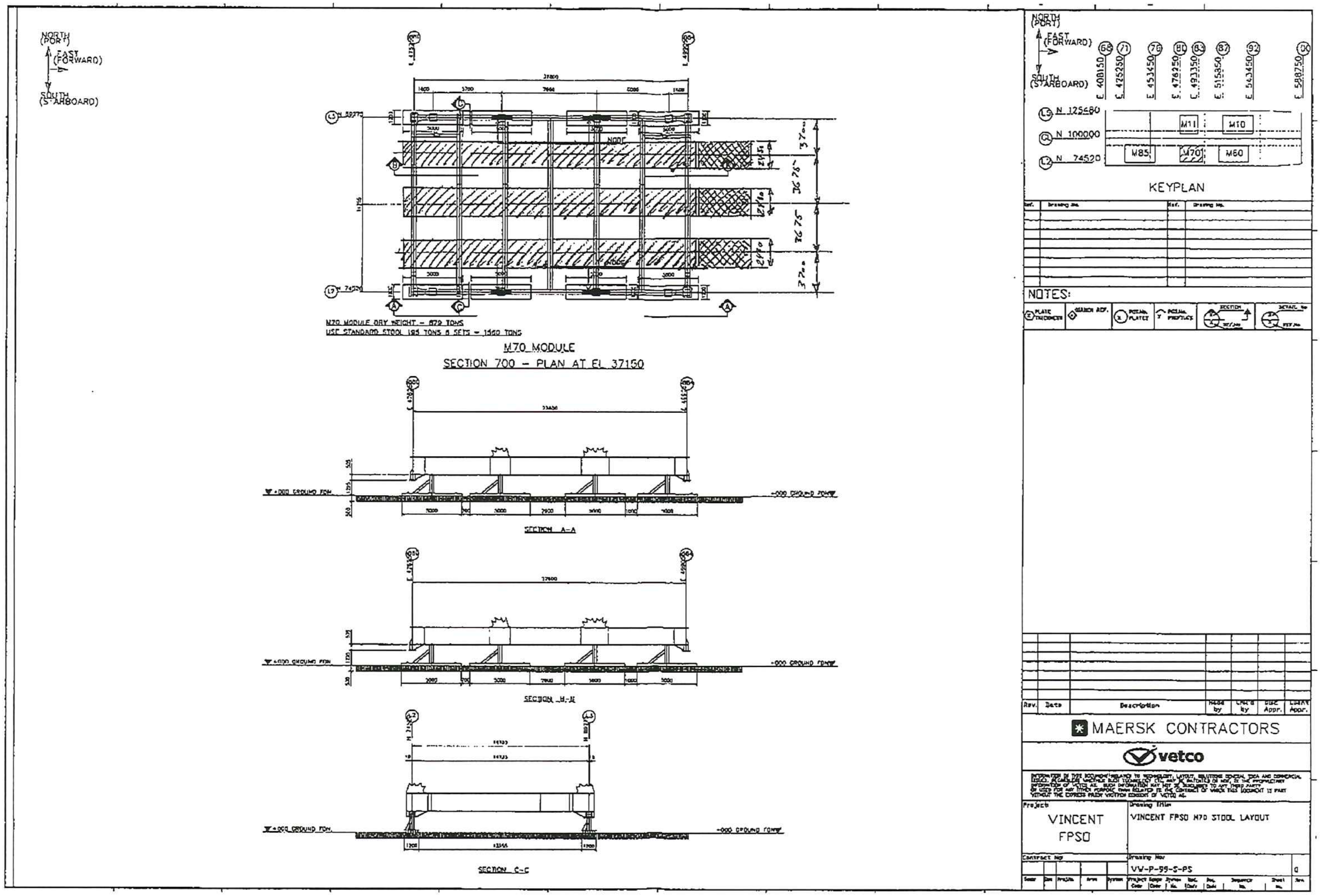
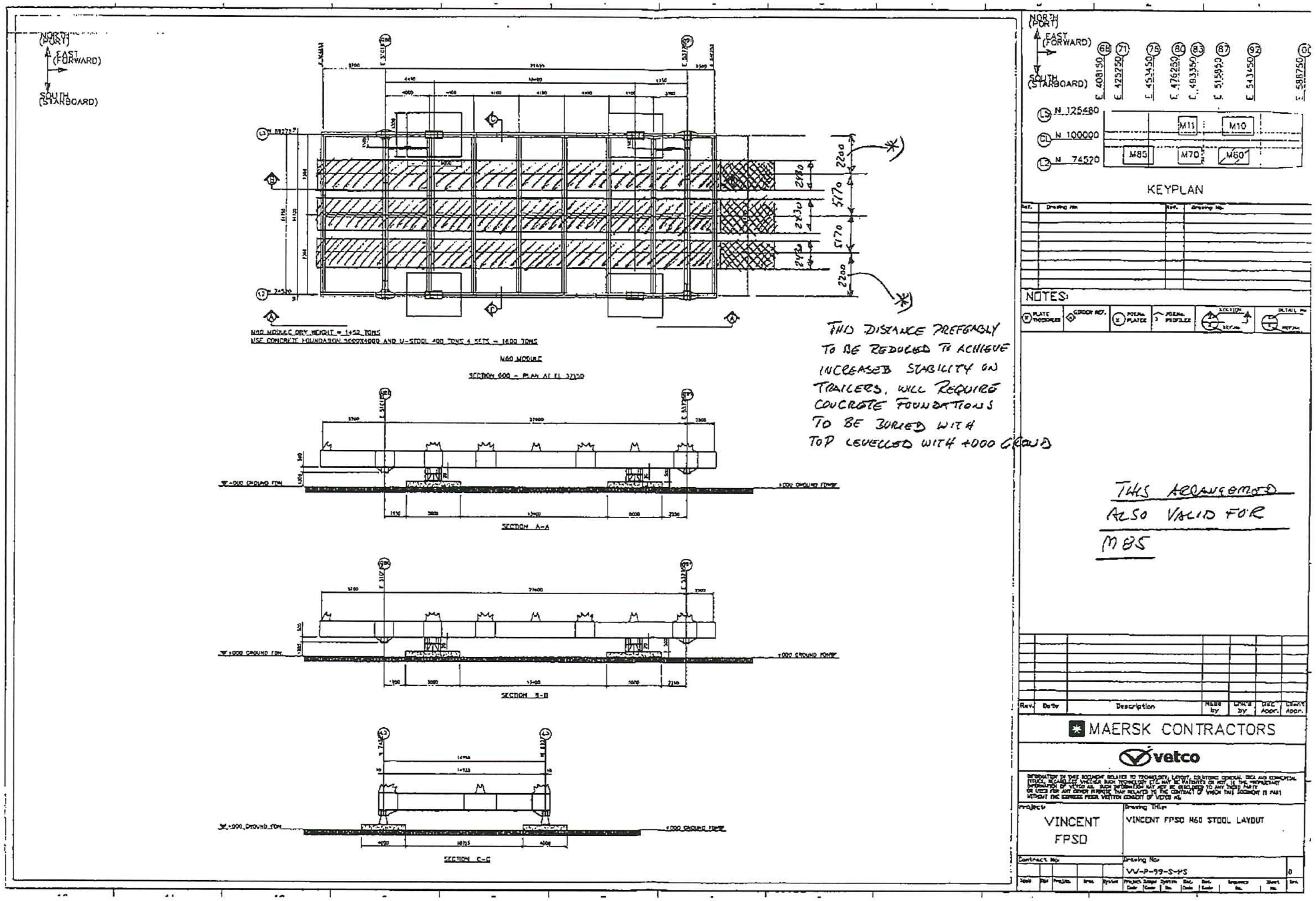
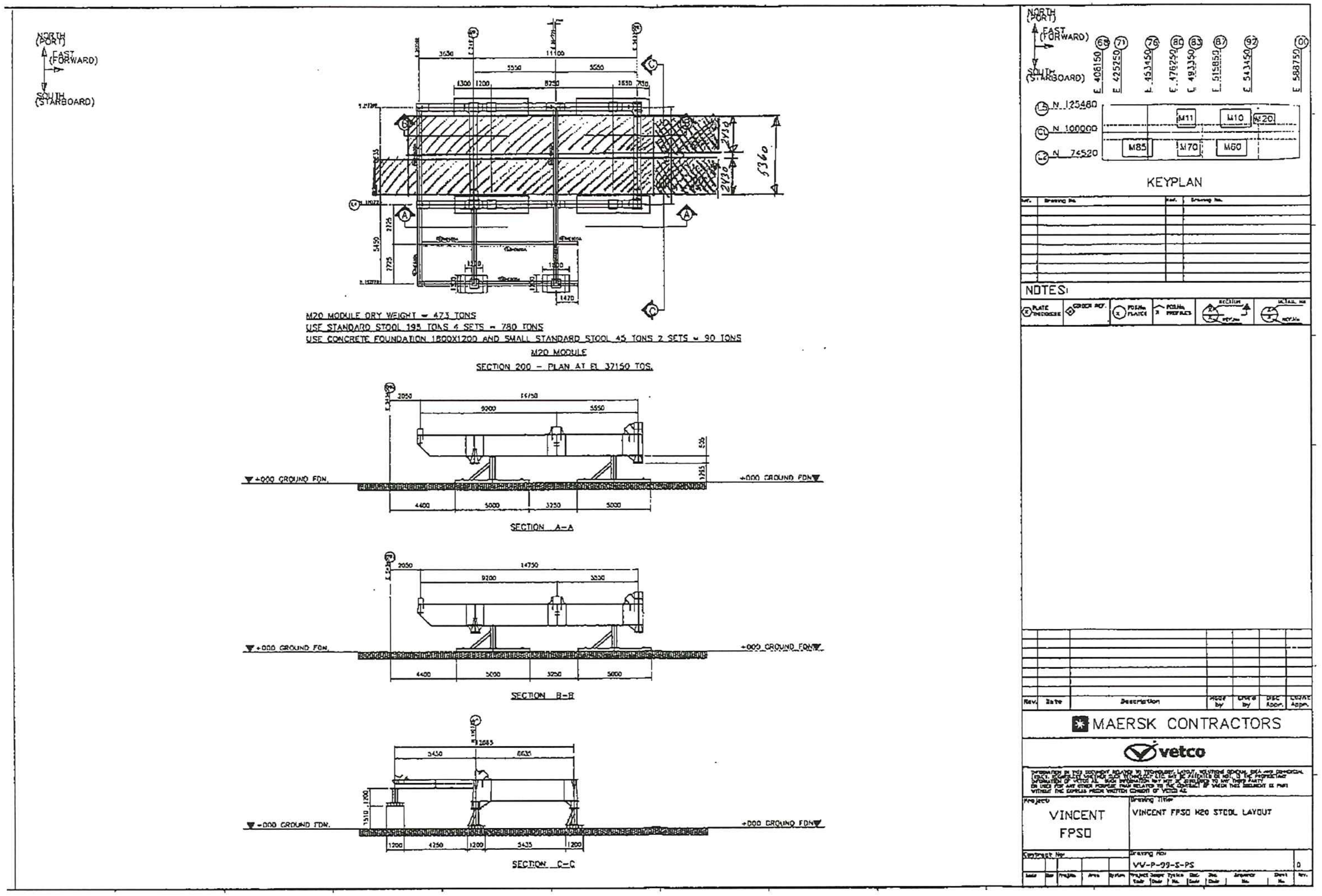


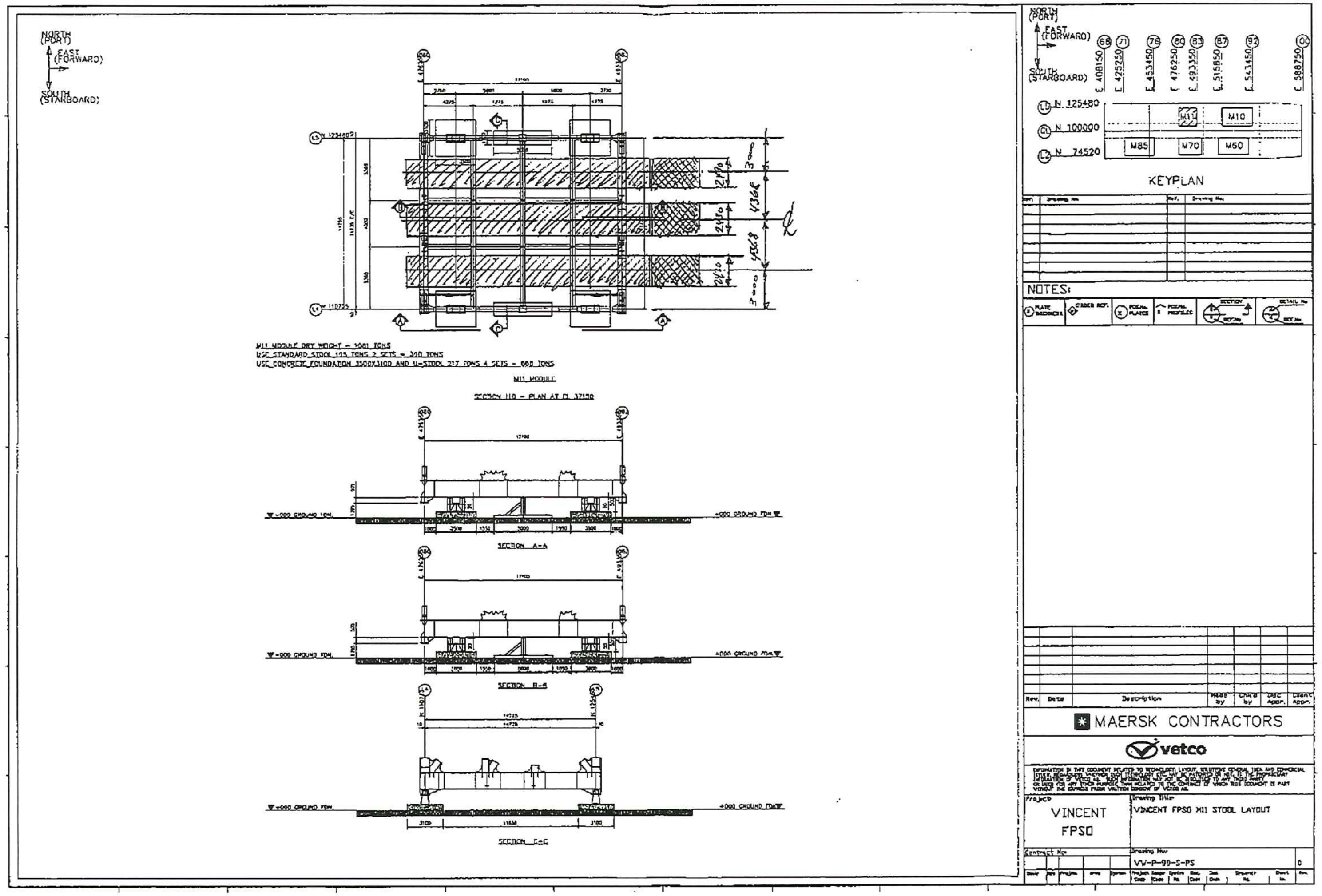
Note: Building support configuration not shown correctly



Note: Building support configuration not shown correctly



Note: Building support configuration not shown correctly



13.2.1 Centre of Gravity (COG) Shift

The effect of a shift in the COG shall be considered for the load-out conditions. Establishing load combinations for each corner of the COG envelope shall simulate the COG shift in the horizontal plane.

13.2.2 Horizontal Loads

For the construction phase the yard the design of the supports shall allow for a horizontal wind load according to local regulations and relevant conditions and rules in accordance with project requirements.

13.3 Transport

The modules shall be transported from the fabrication site to the assembly site in Singapore.

The following loads/load effects are to be used for the barge transport and for the transit to field condition:

- Gravity loads
- Centre of gravity shift
- Wind loads
- Vessel motions
- Differential settlement/Vessel deflection

13.3.1 Support Condition

During sea transport to the assembly site the modules shall be supported vertically at 4 or more support points. Horizontal roll stops shall be provided at each of the support nodes, these stoppers shall act in both compression and tension. Pitch stops shall be provided at the forward supports and sliding supports at the other supports. The roll and pitch stops may be welded shear plates to the underside of the module. Eccentricities to the support nodes shall be considered in the analyses.

The analyses should be carried out in two steps and merged as described below.

1. The modules are resting on vertical supports; pitch-stops and roll-stops on one side. Simulating situation prior to completion of welding out of the sea fastening. Dead load only shall be applied in this condition.

2. Include the roll stops on opposite side. Environmental loads (vessel motion including deck deflections and wind) are applicable for this condition.

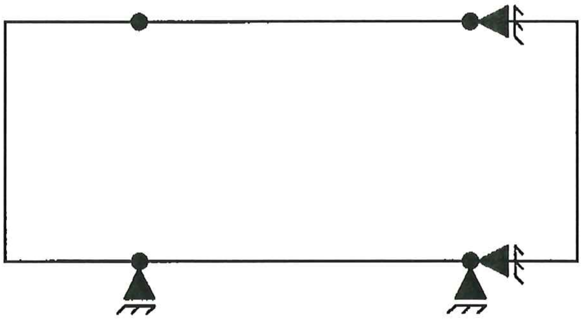


Figure 13-2 Figure Support arrangement during transport.

13.3.2 Transport from fabrication yard to Singapore

In case a Topsides module is transported on a cargo barge for a transoceanic voyage between the fabrication yard and the integration yard, a specific structural analysis has to be carried out.

Unless a specific motion study is carried out and results in lesser values, Noble Denton default motion criteria shall be used. They are recalled in the table herebelow.

Cargo barge category	Full cycle period	Single amplitude		Heave
		Roll	Pitch	
Small cargo barge Length < 76m and Width < 23 m	10 s	25°	15°	0.2 g
Large cargo barge Length ≥ 76m or Width ≥ 23 m	10 s	20°	12.5°	0.2g

13.4 Lift

To avoid stiffness matrix singularity in the structural analysis, the topside shall be supported as shown in Figure 13-3 below.

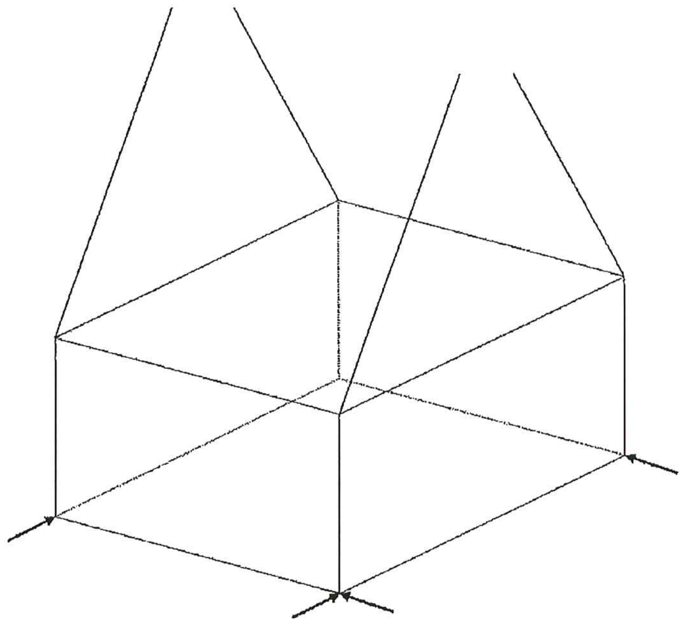


Figure 13-3 Possible support arrangement for lift

Factors to be used for the PAUs:

ULS-a load factor	:	1.3
Yaw factor	:	1.05
Tilt factor	:	1.03
DAF – weight > 1000T	:	1.05
DAF – weight < 1000T	:	1.1
Skew load factor	:	1.0
Weighing inaccuracy factor	:	1.03
Consequence factor	:	see below
CoG shift factor	:	see below

Consequence factors:

Lift points and critical elements supporting the points	:	1.3
Main elements supporting the lift points	:	1.15
Other elements	:	1.0

Factor for lateral load:

For lift points design : 0.05 (of maximum sling load)

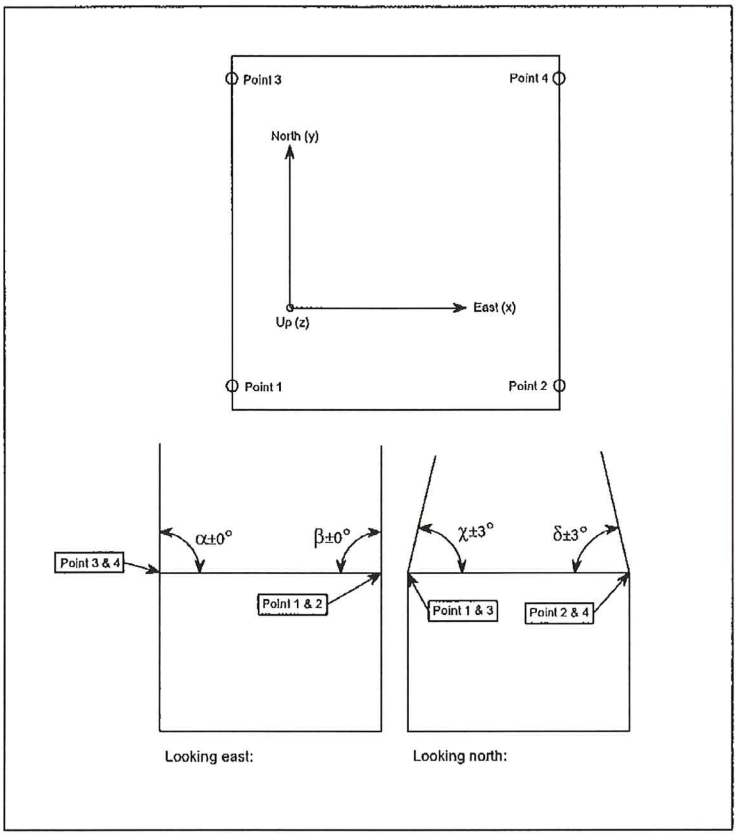


Figure 5.2 Definition of lifting points and sling angles for PAUs

Load to be applied at the point of action, e.g. at the inside of the shackle bow.

Conceptual lift arrangement is shown in Figure 13-4 below.

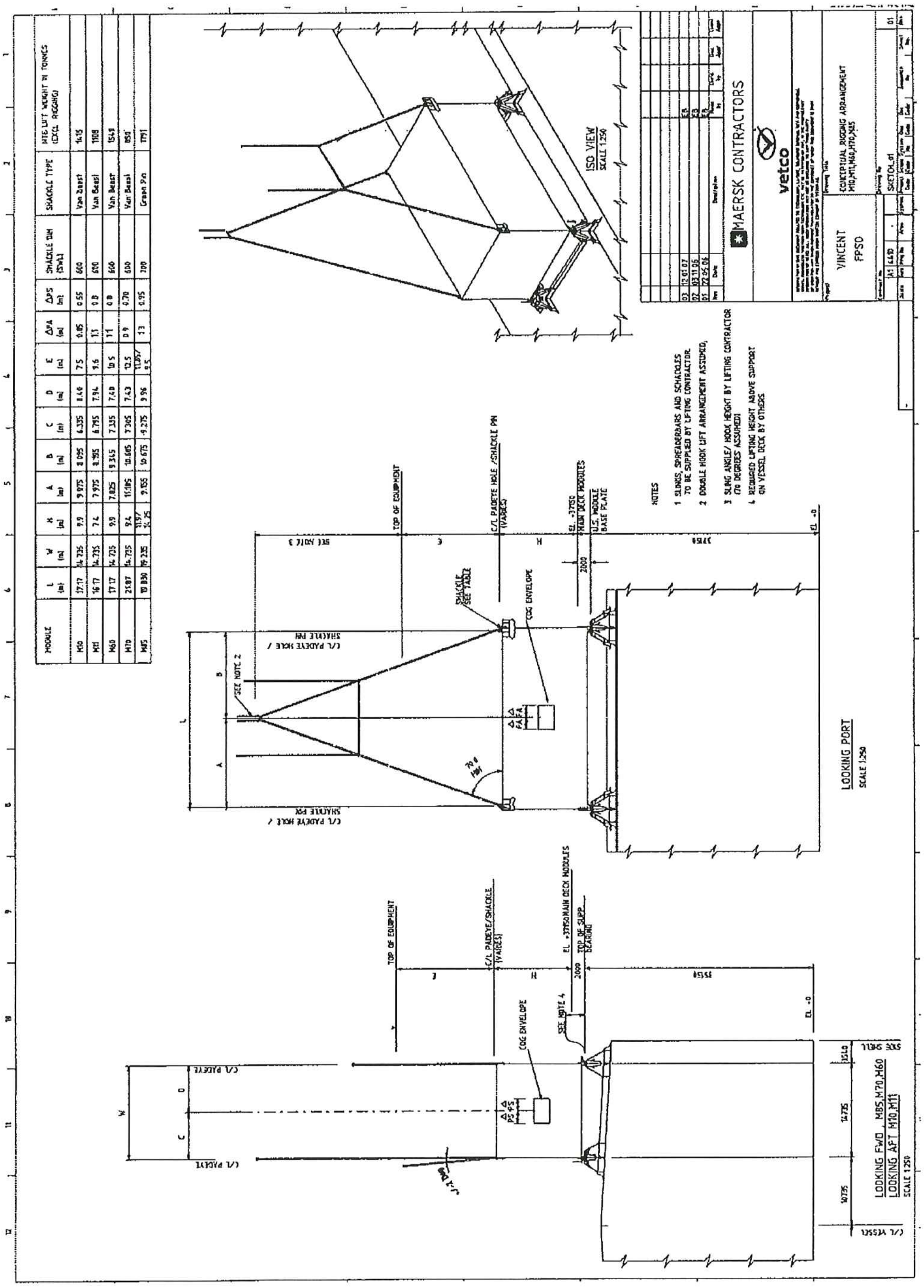


Figure 13-4 Conceptual rigging arrangement

Preliminary lift study of M60 is shown in Figure 13-5.

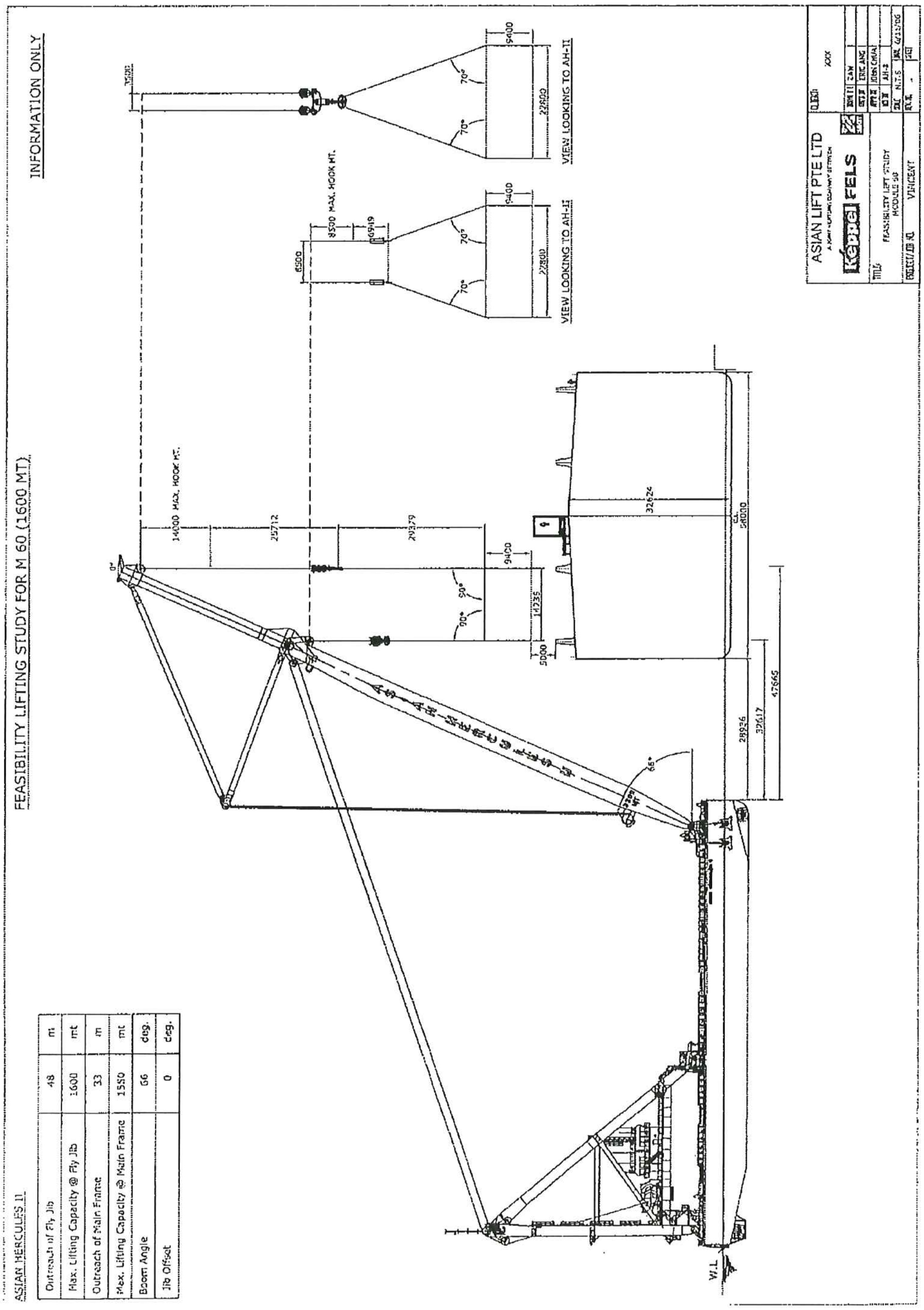


Figure 13-5 Preliminary lift study M60

13.4.1 Center of Gravity (CoG) Shift

The effect of a shift in the COG shall be considered for the lift conditions. Establishing load combinations for each corner of the COG envelope shall simulate the COG shift in the horizontal plane.

Sling angle tolerance

For the PAUs a sling angle tolerance of ± 3° in one direction shall be incorporated in the lift point design.

13.4.2 Lifting Lugs

Lifting lugs shall be documented and standardised. For design of standard lifting lugs NORSOK standard R-CR-002, shall be used. In Annex A, A9 - "Lifting lugs data sheet", the following is specified:

- Design factor: 1.3
- Dynamic factor (DAF): 2.0
- Material factor: 1.15
- Lateral load: maximum 10 % (of SWL) *

*Lateral load is considered acting at the bottom of the shackle bow, transverse to the pad-eye.

In addition, the maximum allowable out swing in line with lug shall be 45 °.

13.4.3 Lifting Lugs for Material Handling

For design of standard lifting lugs within the module NORSOK standard R-CD-002, shall be used.

<u>Design parameters:</u>

Design factor	1.3
Dynamic factor (DAF)	2.0
Material factor	1.15
Lateral load	10% (of SWL)

14 GLOBAL FEM-ANALYSIS

14.1 General

The SESAM system is used for the computer global analyses of the structure.
The global computer model shall comprise the global stiffness of the Hull and the PAUs. All main structural components such as main trusses, deck girders and deck plates should be modelled. Secondary structures such as mezzanine decks may be modelled in order to account for local stiffness and load transfer to the main structure.

14.2 Member Modelling

The computer model shall include all primary members, i. e. all members that contribute to the main structural strength. These will consist of truss chords, columns and braces, deck girders and bulkheads.

Secondary steelwork is included when important for the loading and load transfer of the main steel. Bracing effect of secondary members can be included by appropriate use of buckling length factors.

Effect of column/brace to chord eccentricities should be accounted for when greater than or equal to 100 mm. Member offset (eccentricity) command may be used when actual eccentricities are less than 100 mm. Increased member stiffness in areas of major nodes can be included as separate elements with increased stiffness.

Member end stiffness shall be in accordance with Table 9.2-1. The table shows how the member moment of inertias may be modified to give a better simulation of the node stiffness. The member end properties given are based on common practice in the offshore industry.

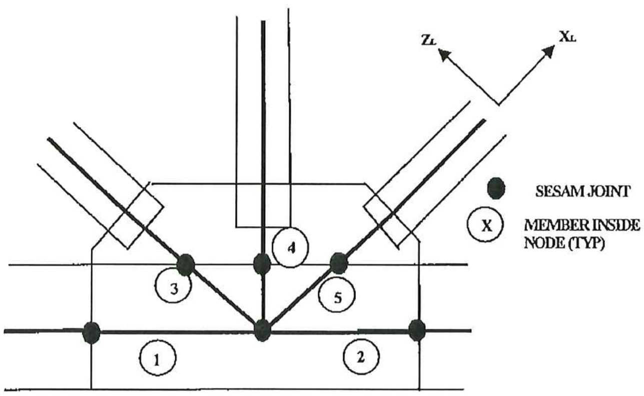


Figure 9.2-1 Main structural node simulation.

"I" - Nodes				
Member No.	Incoming I –section (deck girder)		Member inside node	
1 – 5	Ax	IX IY IZ	Ax • 1.1	IX IY IZ

Table 9.2-1. Increased Member End Stiffness

14.3 Bulkheads

The blast walls bulkheads are modelled with 4 noded shell elements representing the plate and beam elements representing the boundary girders and columns. The shell elements shall have anisotropic properties, i.e. no stiffness transverse of the stringer direction. The stiffeners in the bulkheads may be included in the computer analysis.

14.4 Deck Plates

For the ULS conditions, the stressed-skin philosophy applies for the Deck Plates. The stress skin elements shall be modelled with shear stiffness only, using 3 or 4 noded shell elements. This means that all normal stresses from membrane action, including tensile stresses, are ignored in the panels. Stiffeners in these decks are ignored in the global model. The deck plating elements are connected to the frame structure without accounting for eccentricities, i.e. plate-elements to be at centreline of the main steel girders. Thus minimising the effect of increased bending stiffness of the girders. The element thickness to be used should be equal the plate thickness. See ref. /8/.

For the FLS condition, full plate properties shall be used.

14.5 Modelling of Heavy Equipment

Equipment items with an operating weight of 5 tons or more shall be applied to the structural model through a dummy structure with node mass and correct CoG. Releases and member properties shall be evaluated to avoid contribution to main structure strength.

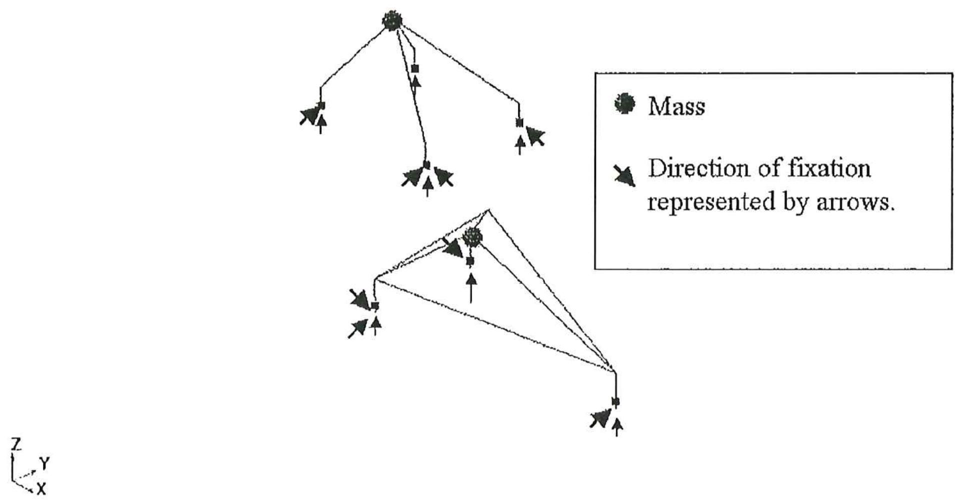


Figure 9.5-14-1 Modelling of heavy equipment

14.6 Modelling of Bulk and Live Loads

All bulk loads shall be modelled as masses in the analyses model. 50% of the general live load shall be included as masses, to get correct fatigue loading. In addition, 50% of the general live load shall be included in the static analyses models as forces, to get correct total vertical live load for ULS structural design.

In order to get analysis results to the safe side and include robustness in the design, the loads should generally be applied on to the transverse deck girders and at the centre half of the span.

The loads of the analysis shall be built upon a set of basic load cases. Most of these loads are unit loads which will be factorised to the actual value for each of the conditions investigated.

The structural calculation report shall contain a description and the total load sum for each BLC.

The basic load cases will not necessary be exact as indicated above for all modules. Some modules will experience different conditions as described and some needs to increase the number of basic load cases. The definition of the basic load case shall be clearly described in the respective module report.

15 DEFINITIONS AND ABBREVIATIONS

15.1 Definitions

15.1.1 Glossary

The following words shall in this specification have the described meaning:

Shall - indicates a mandatory requirement

Should - indicates a preferred course of action

May - indicates one acceptable course of action

15.1.2 Structural category

15.1.2.1 Primary Structure

- Main trusses - longitudinal & transverse
- Main columns & braces
- Main beams in decks
- Main bulkheads / blast walls
- Deck nodes
- Lifting nodes
- Conductor guides & supports
- Module support structure

15.1.2.2 Secondary Structure

- Deck plate, incl. deck stiffeners / stringers
- Plated room structure, incl. stiffeners / stringers

NOTE! Secondary Structure is not the same as secondary category, ref. ch. 15.1.2.

15.1.2.3 Outfitting Structure

- Mezzanine decks
- Lay down areas
- External areas
- Pipe racks
- Access platforms with pipe- / equipment- support

- Minor access platforms
- Equipment supports
- Special pipe supports
- Integrated tanks
- Walkways
- Stair tower
- Stairs & ladders
- Handrails & flexi barriers
- Drain gullies & drain boxes
- Hatches
- Monorails
- Lifting lugs
- Scaffolding lugs

15.2 Abbreviations

a	Acceleration
h	Weibull parameter
n	Cycles
ALS	Accidental damage limit states
AP	Aft Perpendicular
API	American Petroleum Institute
BOS	Bottom of Steel
CL	Centre Line
COG	Centre of Gravity
DAF	Dynamic Amplification Factor
DFF	Design Fatigue Factor
DnV	Det norske Veritas
FEM	Finite Element Method
FLS	Fatigue Limit States
GM	Metacentric Height
GML	Longitudinal Metacentric Height
GMT	Transverse Metacentric Height
HLV	Heavy Lift Vessel
LAT	Lowest Astronomical Tide

LC	Lift Contractor
Lpp	Length between perpendiculars
MSL	Mean Sea Level
NDE	Non Destructive Testing
NPD	Norwegian Petroleum Directorate
NS	Norsk Standard
NTE	Not To Exceed
PFP	Passive Fire Protection
PSA	Petroleum safety Authority Norway
SCF	Stress Concentration Factor
SKL	Skew Load Factor
SLS	Serviceability Limit States
SPMT	Self Propelled Modular Transporters
TCF	Thickness Correction Factor
TOS	Top of Steel
ULS	Ultimate Limit States
VA	Vetco Aibel

15.3 Definitions and Symbols for Non-operational Phases

The following terms are used extensively to describe various conditions, loads and operations for the non-operational phases:

Structural Design Weight:	Structural Design Weight (SDW). Weights established for the load-out, transport, skidding, lifting and transit conditions. Included are weights of bumpers, guides, pins, sheaves and rigging platforms. Sling Weights are included in the load-out and transportation conditions where applicable.
Not to exceed weight:	Not to exceed weight (NEW). The maximum weight of all items in a certain condition.
Calculated weight:	Weight (W) as given in the weight control report. Temporary weights and rigging weights are normally included. Weight contingencies are included according to the weight control procedures.
Rigging weights:	Weight of slings and lifting appurtenances (RW).

Calculated COG:	Calculated centre of gravity given in actual weight report.
COG-shift factor:	Factor to cover variations in COG location (f_{cog}), due to uncertainties in calculated COG, live load variations not otherwise catered for and late design development.
Temporary weights:	Weights included in analyses to simulate weights of temporary installation aids (TW). (Typically: bumper/guide/rigging platforms etc.)
Dynamic Amplification Factor:	Factor to cover dynamic effects in quasi-static analyses (DAF).
Skew load factor:	Factor to cover the effect of inaccurate sling lengths and other uncertainties in force distribution between slings (SKL)
Consequence factor:	Design factor to account for severe consequences of single element failure (f_c)
Yaw factor:	Factor to cover out of balance yaw (rotation about global vertical Z-axis) moment at the time of lift-off from barge resulting in redistribution of sling forces and torsion in module
Tilt factor:	Factor to cover effect of tilt of structure about global horizontal X- or Y- axes compared to theoretical horizontal position.
Crane offset factor:	Factor to cover effect of crane boom misalignment at time of lift off
Bumper:	Dedicated structure attached to lifted object or other structure, designed to resist and spread loads caused by impacts from guides during installation.
Primary guide:	Stationary structural items to arrest and stop initial object motion.
Secondary guide:	Stationary structural item to arrest and stop secondary object motion, and to position modules within lateral tolerances.

16 SYSTEM OF UNITS

The system of units shall in general comply with the SI- standard for all structural design.

For global computer analyses the following units apply:

Length:	Meters (m)
Force:	kilo Newton (kN)
Mass:	tonnes (metric) (t = 10^3 kg =1000 kg)
Acceleration:	m/s^2 (g= 9.810 m/s^2)
Density:	t/m^3
Moment of Inertia:	m^4
Section Modules:	m^3
Stresses:	kN/m^2 (= kPa)

For calculations:

Length:	mm
Force:	Newton (N)
Mass:	kilogram (kg)
Stresses:	N/ mm^2 (= MPa)
Time:	s (seconds)
Temperature:	°C deg. (degrees Celsius)
Energy/Work:	J, Joule (Nm)
Pressure:	1 barg (= 0.1 N/mm^2 = 100 kN/m^2)

APPENDIX A DESIGN WEIGHTS AND COG ENVELOPES

Appendix A1.

The design weights and CoG envelopes are in accordance with M00 – Topside Weight Budget Report, rev. A1.

Exceptions are:

- M10, for which the weight and CoG envelope has been updated for operation condition, after the issue of the Topside Weight Budget Report.

- M30, for which the extreme operating content is reduced from 80 to 39.5 tonnes.

- M71, LP Flare / Closed Drain KO Drum on M71 may under special circumstances increase its operational weight by 39.5 tonnes. This is not included in Topside Weight Budget Report

Load Out

Weight Budget Report, rev. A1

Load Out		Budget	Not to Exceed Weight and CoG				Envelope		
		Dry Weight	Dry Weight	x	y	z	x	y	z
M10	HP Oil Separation	1 343	1 430	530,14	117,07	42,30	± 1,20	± 0,85	± 0,65
M11	LP Oil Separation	1 027	1 094	484,69	117,53	42,11	± 1,15	± 0,85	± 0,80
M20	Production Manifold Skid	399	425	552,17	112,67	40,64	± 0,75	± 0,65	± 0,70
M30	Flare Module	128	137	588,45	84,97	36,82	± 0,65	± 0,45	± 0,45
M60	Gas Compression	1 434	1 528	523,19	81,93	42,06	± 1,20	± 0,85	± 0,70
M70	LP Compression / Utility Module	790	841	487,90	81,96	41,86	± 1,00	± 0,75	± 0,80
M71	LP Flare / Closed Drain	134	142	504,63	110,09	36,36	± 0,70	± 0,50	± 0,45
M72	Oil Desanding	32	34	505,92	112,97	35,53	± 0,55	± 0,35	± 0,40
M85	Power Generation	1 661	1 769	442,31	82,24	42,19	± 1,35	± 1,00	± 0,70
M99	Pipe racks	601	640	511,07	96,41	40,88	± 2,85	± 0,40	± 0,60
		7 549	8 040						

Transport

Weight Budget Report, rev. A1

Transport		Budget	Not to Exceed Weight and CoG				Envelope		
		Dry Weight	Dry Weight	x	y	z	x	y	z
M10	HP Oil Separation	1 363	1 452	530,14	117,08	42,30	± 1,20	± 0,80	± 0,70
M11	LP Oil Separation	1 041	1 109	484,69	117,53	42,11	± 1,15	± 0,85	± 0,80
M20	Production Manifold Skid	405	432	552,20	112,69	40,65	± 0,70	± 0,65	± 0,65
M30	Flare Module	129	137	588,46	85,01	36,85	± 0,65	± 0,50	± 0,45
M60	Gas Compression	1 455	1 549	523,20	81,93	42,05	± 1,20	± 0,85	± 0,65
M70	LP Compression / Utility Module	798	850	487,97	81,96	41,85	± 1,00	± 0,75	± 0,85
M71	LP Flare / Closed Drain	134	143	504,63	110,10	36,40	± 0,70	± 0,50	± 0,40
M72	Oil Desanding	32	34	505,96	113,03	35,53	± 0,55	± 0,35	± 0,35
M85	Power Generation	1 682	1 791	442,29	82,24	42,20	± 1,35	± 1,00	± 0,70
M99	Pipe racks	608	647	510,94	96,39	40,88	± 2,85	± 0,40	± 0,60
		7 647	8 144						

Lift

Weight Budget Report, rev. A1

Lift		Budget	Not to Exceed Weight and CoG				Envelope		
		Dry Weight	Dry Weight	x	y	z	x	y	z
M10	HP Oil Separation	1 350	1 451	530,14	117,07	42,30	± 1,15	± 0,75	± 0,60
M11	LP Oil Separation	1 031	1 108	484,69	117,53	42,11	± 1,10	± 0,80	± 0,70
M20	Production Manifold Skid	401	431	552,17	112,67	40,64	± 0,70	± 0,65	± 0,65
M30	Flare Module	128	137	588,45	84,97	36,82	± 0,65	± 0,45	± 0,45
M60	Gas Compression	1 441	1 549	523,19	81,93	42,06	± 1,10	± 0,80	± 0,65
M70	LP Compression / Utility Module	790	850	487,90	81,96	41,86	± 0,90	± 0,70	± 0,75
M71	LP Flare / Closed Drain	133	143	504,63	110,09	36,36	± 0,65	± 0,50	± 0,45
M72	Oil Desanding	32	34	505,92	112,97	35,53	± 0,50	± 0,35	± 0,35
M85	Power Generation	1 666	1 791	442,31	82,24	42,19	± 1,30	± 0,95	± 0,70
M99	Pipe racks	602	647	511,07	96,41	40,88	± 2,65	± 0,40	± 0,55
		7 573	8 141						

Normal Operating

Weight Budget Report, rev. A1

HP Flare KO Drum on M30 may under special circumstances increase its operational weight by 39.5 tonnes. This is not included in the Budget and NTE weight.

LP Flare / Closed Drain KO Drum on M71 may under special circumstances increase its operational weight by 39.5 tonnes. This is not included in the Budget and NTE weight.

Normal Operating		Budget	Not to Exceed Weight and CoG				Envelope		
		Operation Weight	Operation Weight	x	y	z	x	y	z
~~M10~~	~~HP Oil Separation~~	~~1 792~~	~~1 926~~	~~529,78~~	~~117,32~~	~~42,15~~	~~± 1,00~~	~~± 0,70~~	~~± 0,55~~
M11	LP Oil Separation	1 552	1 668	484,55	118,42	43,88	± 0,95	± 0,70	± 0,65
M20	Production Manifold Skid	410	441	552,05	112,54	40,66	± 0,65	± 0,55	± 0,55
M30	Flare Module	139	149	588,47	84,84	36,85	± 0,60	± 0,45	± 0,40
M60	Gas Compression	1 475	1 586	523,12	81,92	42,06	± 1,00	± 0,70	± 0,60
M70	LP Compression / Utility Module	838	901	487,93	81,84	42,11	± 0,85	± 0,65	± 0,70
M71	LP Flare / Closed Drain	189	203	504,87	110,16	36,28	± 0,60	± 0,45	± 0,40
M72	Oil Desanding	36	39	505,87	112,96	35,45	± 0,45	± 0,35	± 0,35
M85	Power Generation	1 659	1 783	442,52	82,38	42,19	± 1,10	± 0,80	± 0,60
M99	Pipe racks	595	640	511,10	96,41	40,88	± 2,20	± 0,40	± 0,50
		8 685	9 336						

M10 fra WB01	1792	1926	529,78	117,32	42,15	±1,00	±0,70	±0,55
M10 Ny	**1792**	**1891**	**530,13**	**117,48**	**42,42**	**±0,70**	**±0,50**	**±0,45**
Endring	-	-36	0,35	0,16	0,27	-0,30	-0,20	-0,10

M10 updated weight and CoG envelope, according to e-mail, 15/12-2006, from Kjell-Ola Sveinhaug. The reduction in mass and CoG envelope also applies for the other conditions for M10.

Appendix A2.

The design weights and CoG envelopes are in accordance with M00 – Topside Weight Budget Report, rev. A2.

Load Out

Weight Budget Report, rev. A2

Load Out		Budget	Not to Exceed Weight and CoG				Envelope		
		Dry Weight	Dry Weight	x	y	z	x	y	z
M10	HP Oil Separation	1 343	1 394	530,40	117,00	42,50	± 0,80	± 0,60	± 0,50
M11	LP Oil Separation	1 027	1 066	484,75	117,30	42,40	± 0,75	± 0,60	± 0,60
M20	Production Manifold Skid	416	432	552,05	112,45	40,90	± 0,55	± 0,45	± 0,50
M30	Flare Module	127	132	588,30	84,85	36,75	± 0,50	± 0,35	± 0,35
M60	Gas Compression	1 375	1 428	523,30	82,00	42,45	± 0,80	± 0,60	± 0,45
M70	LP Compression / Utility Module	787	817	488,15	82,05	42,25	± 0,65	± 0,55	± 0,55
M71	LP Flare / Closed Drain	133	138	504,50	109,90	36,15	± 0,50	± 0,30	± 0,15
M72	Oil Desanding	32	33	-	-	-	-	-	-
M85	Power Generation	1 677	1 740	442,30	82,30	42,60	± 0,90	± 0,70	± 0,40
M99	Pipe racks	555	576	-	-	-	-	-	-
		7 472	7 756						

Transport

Weight Budget Report, rev. A2

Transport		Budget	Not to Exceed Weight and CoG				Envelope		
		Dry Weight	Dry Weight	x	y	z	x	y	z
M10	HP Oil Separation	1 363	1 416	530,40	117,00	42,40	± 0,80	± 0,60	± 0,50
M11	LP Oil Separation	1 036	1 076	484,75	117,30	42,30	± 0,75	± 0,60	± 0,60
M20	Production Manifold Skid	420	436	552,05	112,45	40,80	± 0,55	± 0,45	± 0,50
M30	Flare Module	129	134	588,30	84,90	36,75	± 0,50	± 0,40	± 0,35
M60	Gas Compression	1 395	1 460	523,30	82,00	42,30	± 0,80	± 0,60	± 0,40
M70	LP Compression / Utility Module	795	826	488,15	82,05	42,10	± 0,65	± 0,55	± 0,60
M71	LP Flare / Closed Drain	134	139	504,45	109,90	36,15	± 0,55	± 0,30	± 0,15
M72	Oil Desanding	32	33	-	-	-	-	-	-
M85	Power Generation	1 698	1 764	442,25	82,30	42,50	± 0,95	± 0,70	± 0,40
M99	Pipe racks	561	583	-	-	-	-	-	-
		7 564	7 859						

Lift

Weight Budget Report, rev. A2

Lift		Budget	Not to Exceed Weight and CoG				Envelope		
		Dry Weight	Dry Weight	x	y	z	x	y	z
M10	HP Oil Separation	1 350	1 415	530,40	116,95	42,45	± 0,80	± 0,55	± 0,45
M11	LP Oil Separation	1 026	1 075	484,75	117,30	42,25	± 0,75	± 0,60	± 0,55
M20	Production Manifold Skid	416	436	552,05	112,45	40,80	± 0,55	± 0,45	± 0,50
M30	Flare Module	128	134	588,30	84,85	36,75	± 0,50	± 0,35	± 0,35
M60	Gas Compression	1 382	1 448	523,30	82,00	42,30	± 0,80	± 0,60	± 0,40
M70	LP Compression / Utility Module	787	825	488,15	82,05	42,05	± 0,65	± 0,55	± 0,55
M71	LP Flare / Closed Drain	133	139	504,50	109,90	36,10	± 0,50	± 0,30	± 0,20
M72	Oil Desanding	32	33	-	-	-	-	-	-
M85	Power Generation	1 681	1 762	442,25	82,30	42,50	± 0,85	± 0,70	± 0,40
M99	Pipe racks	554	580	-	-	-	-	-	-
		7 489	7 847						

Normal Operating

Weight Budget Report, rev. A2

Flare KO HP Drum on M30 may under special circumstances increase its operational weight by 39,5 tonnes, likewise Flare KO LP Drum on M71 may under special circumstances increase its operational weight by 39,5 tonnes . This is not included in the Budget and NTE weight.

Normal Operating		Budget	Not to Exceed Weight and CoG				Envelope		
		Operation Weight	Operation Weight	x	y	z	x	y	z
M10	HP Oil Separation	1 792	1 891	530,23	117,38	42,45	± 0,60	± 0,40	± 0,40
M11	LP Oil Separation	1 552	1 637	484,60	118,25	44,10	± 0,70	± 0,50	± 0,40
M20	Production Manifold Skid	430	454	552,05	112,35	40,75	± 0,55	± 0,35	± 0,45
M30	Flare Module	139	147	588,35	84,75	36,80	± 0,45	± 0,35	± 0,30
M60	Gas Compression	1 418	1 496	523,05	81,90	42,20	± 0,75	± 0,60	± 0,50
M70	LP Compression / Utility Module	835	881	487,65	81,90	42,30	± 0,55	± 0,50	± 0,50
M71	LP Flare / Closed Drain	189	199	504,75	110,25	36,10	± 0,45	± 0,35	± 0,20
M72	Oil Desanding	36	38	-	-	-	-	-	-
M85	Power Generation	1 674	1 766	442,65	82,45	42,45	± 0,85	± 0,65	± 0,35
M99	Pipe racks	770	812	-	-	-	-	-	-
		8 835	9 321						

Helge-Hjalmar Olsen/NO/AIBEL
29.10.2009 15:28

To Colin Blackburn/NO/AIBEL@AIBEL
cc Trond Pedersen/NO/AIBEL@AIBEL
bcc
Subject Re: OSD Project 1030 VMP

Hei,

done. (WBG15-M56 has been inserted from other projects.)

Here is an updated list of not defined stockno's that need to be verified:

STOCKNO

G109CSHSM10x035
G109HLNM10
G46HNM10
G46HNM12
G46LSBM10x055
G46LSBM10x090
G46LSBM12x0130
G46WM10
G46WM12
G88HBM24x260
G88IWM20
G88M24x230
GA4CSHSM10x030
GA4CSHSM12x040
GA4HAMBM20x120
GA4IWM16
M04TB133.0x08.0
PLYWOOD20x260
S01RB30
WOOD200x300
Y01FB050x25
Y01PL001
Y01PL080
Y05PL045
Y20PL06
Y26UPE160
Y26UPE180
Y27TB219.1x8.2
Y27TB244.5x12.5
Y30PL20x600

Helge

Colin Blackburn/NO/AIBEL

Colin Blackburn /NO/AIBEL
29.10.2009 15:07

To Helge-Hjalmar Olsen/NO/AIBEL@AIBEL
cc Trond Pedersen/NO/AIBEL@AIBEL
Subject Re: OSD Project 1030 VMP