FPSO Training Course

Radisson Blu Boulogne Hotel, Paris ~ October 2016

Session 2.4 – FPSO topsides layout

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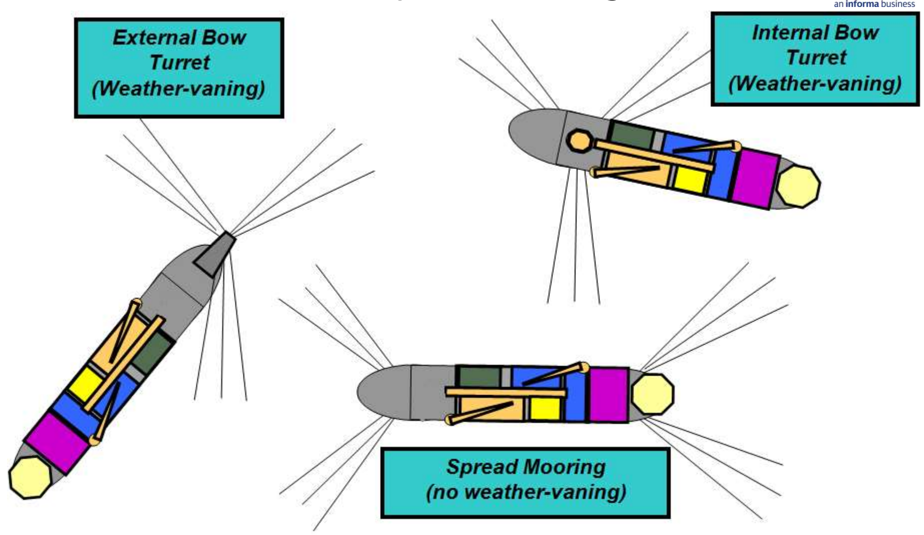
Agenda

- Context
- Temporary refuge and escape
- Modularisation
- Module and topside layout
- Equipment layout within modules
- Topsides weight and weight control

Topsides Layout: Context

Turret and Spread Mooring



Turret and Spread Mooring

- For topsides layout key differentiators are:
  - Weather vaning (turret) or fixed orientation (spread moored) and impact on:
    - Motions
    - Dispersion
  - Requirements for blast and fire walls differ. Chief difference is need for blast wall between turret and forward accommodation (external turret and forward accommodation is not used).
  - Deck area
    - Reduced by internal turret
    - Location of Risers: Along side (spread) or forward (turret) and within hull if internal

Accommodation Location

Factor:	Fwd Accommodation:	Aft Accommodation:	Comments:
Turret Fires	⚠	⚠	Greater separation with aft accomodation but accomodation is downwind. Typically install blast wall with fwd accommodation.
Major Hazards (Process / Turret / Cargo Tank – fire & smoke)	✔	✖	LQ & helideck upwind with fwd accommodation.
H_2S	✔	✖	LQ & helideck upwind with fwd accommodation.
Pump Room Hazards	✔	✖	Pump rooms located aft: physical separation and pump room access issues with aft accomodation.
Helideck	⚠	⚠	Motions better aft but helideck impairment more likely; fwd better for smoke etc. (risk can be reduced with thrusters). Aft accomodation require that Power Generation is positioned away from the accomodation & helideck (hot exhaust gases).
Greenwater	⚠	✔	Not a significant factor.
Shuttle Tanker Offloading	✔	✖	Greater physical separation between accomodation and tanker / offloading hazard with fwd accomodation.
Human Performance	✖	✔	Reduced vertical motions aft.
Swivel (HP Hazard)	✖	✔	Greater physical separation with aft accomodation.
Weathervaning	✖	✔	Aft accommodation allows internal turret to be closer to bow - hence natural weathervaning with no thruster requirement. Fwd accommodation may require safety-critical thrusters.
Escape & Evacuation:			
Primary (helicopter)	✔	✖	Fwd better as upwind of fire and smoke.
Secondary (lifeboat)	✖	✔	Aft accomodation allows quicker escape from FPSO & associated hazards.
Tertiary (liferaft, step-off)	✖	✔	Aft accomodation allows quicker escape from FPSO & associated hazards.

N.B. This discussion assumes a weathervaning FPSO. As a whole, it does not apply to spread-moored FPSOs.

Temporary refuge & escape

Temporary Refuge

- The Temporary Refuge (TR) is a safe area on the FPSO that is designed to resist the effects of fire & explosion for a period of time long enough for the crew to evacuate.
- Layout studies & the outcomes of incident studies will determine the best location for the TR. The most common location has tended to be in the living quarters.
- Provision must be made for the FPSO crew to quickly access evacuation means from the TR.
- During FPSO layout development, the location of the main escape routes from the main & production decks to the living quarters & TR have a major influence on the overall layout.
- Consider second TR at other end of the vessel.
- Provide means of escape at TR (primary by helicopter, secondary by lifeboat).

Escape Routes (1)

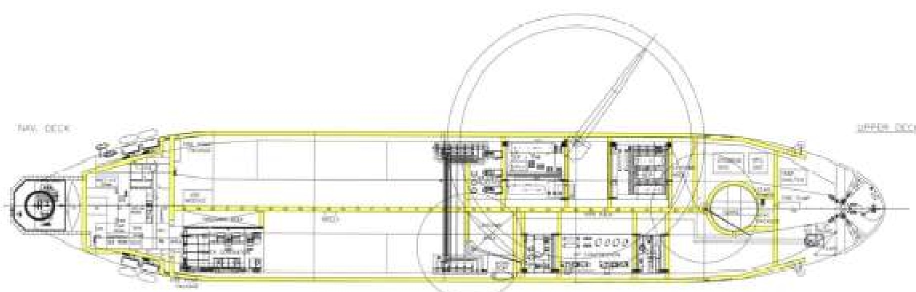
- Good practice to assess escape route requirements at an early stage of the project to ensure that rapid escape from congested areas is not compromised.

- Provide at least two longitudinal oriented escape routes running along the port and starboard sides of the vessel.
  - Also consider a central route.
  - Integration with piperack (more later).

- Protection of the escape routes.
  - 'Bus shelter' steel sides (towards the process) and roofs.
  - Pressurised escape tunnel.

- Establish transverse escape routes between the logitudinal escape routes allowing personnel to get out of harms way by shifting side.
  - Establish access and escape routes from both longitudinal escape routes to the modules.

Escape Routes (2)



Modularisation

Module choices

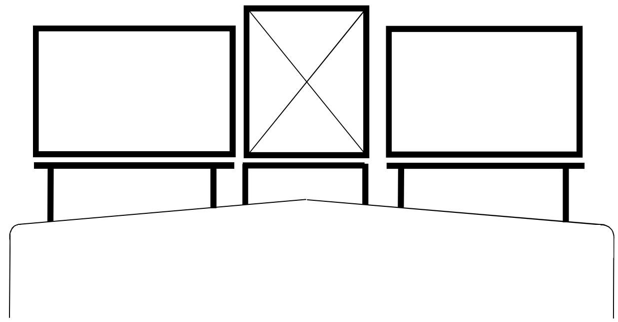
Jargon warning: module, pallet etc. may mean different things to different people on different projects

- ❑ Module lay-out, size and lift weight are key considerations in developing the overall construction strategy
- ❑ Needs to be agreed at an early stage – and take account of the large cost drivers and availability/mobilisation associated with heavy lift facilities
- ❑ Need to retain flexibility of options where possible and where appropriate, i.e. future expansion
- ❑ Module width, type & weight and pipe rack design are major choices.

- ❑ Vessel deflection (hog and sag / lifting cases)
  - ➢ Design of topsides primary framing arrangements
  - ➢ Limits modules to 25 to 30 m in length

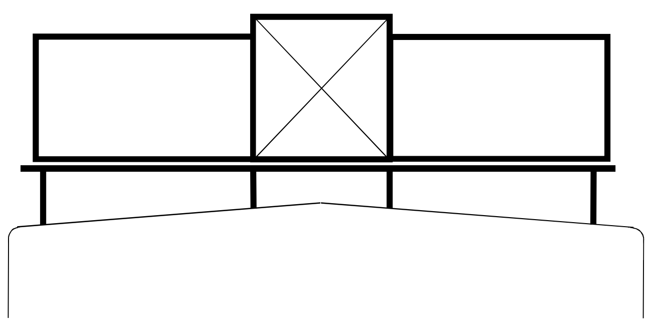
Module types (1)

- Discrete / Side by Side
  - Central pipe rack and modules port and starboard
  - Module weight ~ 1,250 te
  - e.g. White Rose, Alvheim



Module types (2)

- Full Width
  - With integral pipe-rack
  - Module weight ~ 2,500 te
  - With Central pipe rack e.g. Terra Nova
  - With Side pipe rack e.g. Triton

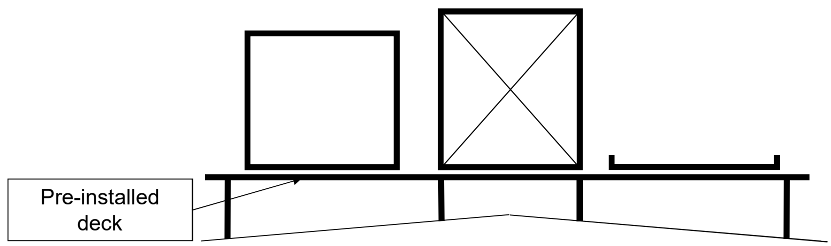


Module types (3)

- Alternatives to ‘Module’ Approach;
  - Stick-built

    Stick-built: process equipment is assembled & connected on a deck / pallet: reduces structural weight (‘lifting steel’), increases interfaces, takes longer, needs a more experienced yard.
  - Pallet
  - Pancake

    Topsides equipment added onto pre-installed deck (pallet) as equipment skids or PAUs (pre-assembled units) or pancakes (pancakes may include deck and be installed directly onto supports).



Module types (4)

- Alternatives to ‘Module’ Approach;

Gryphon

(pre-installed deck)

Chingueitti

(pallet)

Impact of Construction: lifts & cranes

~ 1600t modules

e.g.

- Taklift-4 Sheerleg Crane
- Mammoet PTC Land Based Ring Crane
- Asian Hercules / Sheerleg Crane

~ 2500 t modules

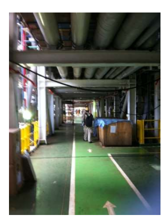
e.g.

- Asian Hercules II Sheerleg Crane (3200 t lift capacity)
- Lampson Transi-Lift LTL -2600 Land Based Crawler Crane

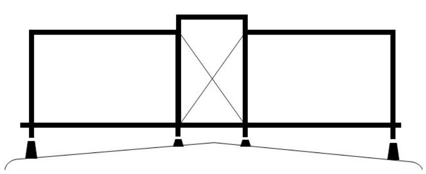
- Cranes generally in Europe, May – September & Far East, November – March

Pipe Rack Options; Access & Full Width Modules

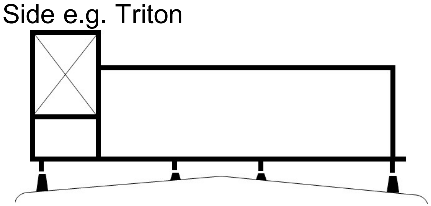
- Pipe rack area can also form walkway / transport route



- Pipe rack is integral with modules (impacts number of tie in points)
- Central e.g. Terra Nova

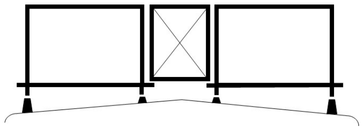


Side e.g. Triton



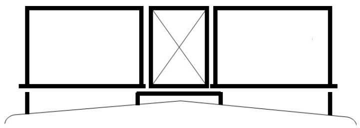
Pipe Rack Options; Side by Side Modules

- Separate - supported by modules

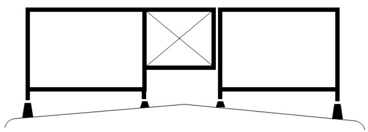


e.g. White Rose – has particular implications for installation order and safety (non-level deck)

- Separate - on main deck e.g. Alvheim



- Integral - cantilevered from module e.g. Norne



Module & Topsides Layout

Module Layout: principles

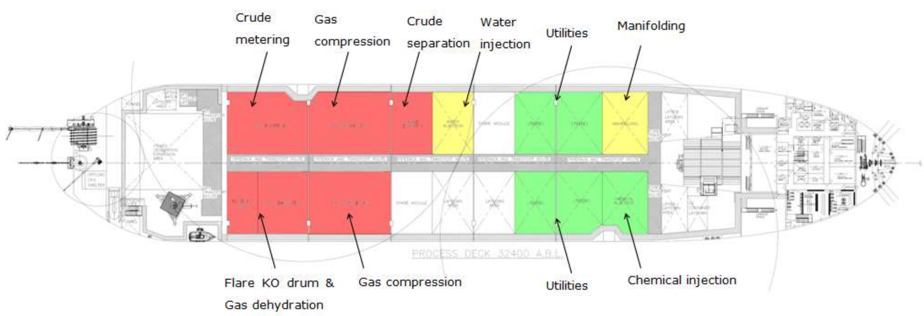
- Three main factors to consider:
  - Safety - separation distance;
  - Operability – natural flow and cost;
  - Constructability – cost and schedule.
- This discussion focuses on safety considerations.
- Compromises will be necessary.

Module Layout: safety principles

- Maximise separation of people and hazardous equipment, particularly high pressure flammable gas, fire & smoke, & potentially H_2S.
- Place highest risk items away from accommodation
  - HP hydrocarbons area furthest from accommodation
  - MP and LP hydrocarbons next furthest from accommodation
  - Less distance between utility area and accommodation
  - Gas turbines as far away from accommodation as practical within utilities area
- Power generation and gas turbine exhausts away from helideck and downwind of facilities
- Flare away from accommodation

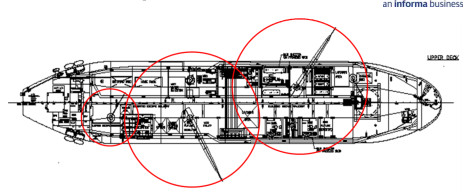
Module Layout: example

- An example.... Turret moored, forward accommodation
- Modules are scored for pressure hazard, hydrocarbon inventory, exhausts, manning levels and colour coded accordingly (red = most hazardous, green = least hazardous). White module areas are laydown / future expansion areas.
- Some compromises have been made!



Module Layout: cranes and laydown

- Cranes:
  - Located on both sides?
  - Number?
  - Type?
  - It is not always practical or possible to cover the entire deck within the crane lifting radius.



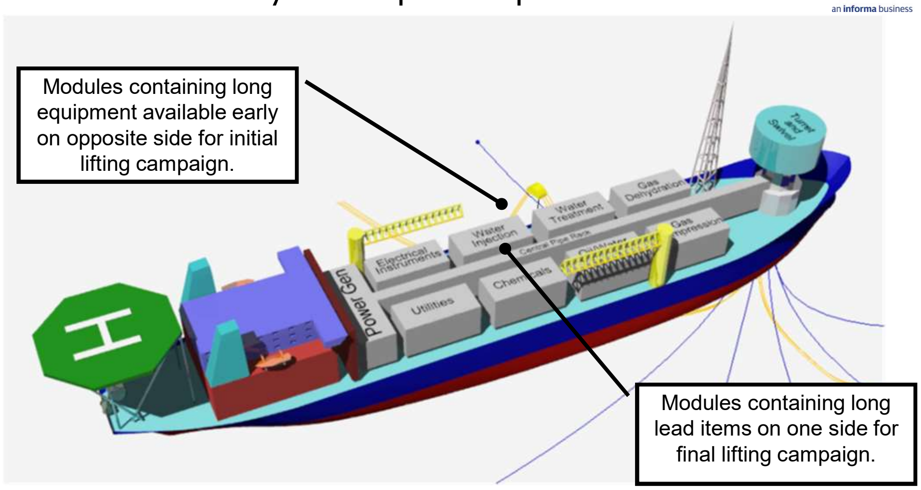
- Laydown areas:
  - Crane crossover at laydown areas is ideal;
  - Consideration should be given to providing adequate laydown areas during preliminary layout development;
  - Where possible areas should be positioned to reduce the amount of secondary lifting;
  - CAUTION - laydown areas are often reduced or taken over to provide space for additional equipment or late design changes; leaves the operator with inadequate space for storage, handling etc. It may then become necessary to provide smaller elevated laydown areas on top of modules (with increased risk of impact from swinging loads). Mitigations include:
    - Reserve given proportions (10%?) of the deck area for laydown & future expansion;
    - Develop robust topsides weight / space requirements early where these drive hull size.
  - Laydown areas can be a good means of providing separation distance between hazardous process modules;
  - Need lay down close to accommodation.

Module Layout: fire and blast walls

- Fire and blast walls are typically provided to:
  - Protect personnel;
  - Ensure the integrity of safety critical areas.

- Fire and blast walls are typically located:
  - Process/topsides end bulkhead of the accommodation;
  - Extension of bulkhead to protect the lifeboat embarking area;
  - Primary TR (part of accommodation and includes CCR);
  - Secondary TR (if provided);
  - Emergency generator enclosure (likely to be located in the hull, under the accommodation);
  - Firewater pump enclosures (likely to be located in the hull);
  - Turret area (dependant on turret type and proximity of other facilities).

Module Layout: impact of procurement



- Ship is turned between lifting campaigns
- Long leads will likely comprise rotating machinery & equipment made of exotic materials

Equipment layout within modules

Equipment layout: factors

- Safety
  - Dispersion
  - Blast overpressure
  - Separation distances

  Discussed earlier
- Functional
  - Length of pipe runs & pressure drops
  - Relative elevations
  - Motions
- Structural
- Access & Escape
- Maintenance and mechanical handling

Equipment layout: motions

- Certain equipment types are more sensitive than others to vessel motions and accelerations:
  - Equipment where motions will likely have a significant effect:
    - Equipment with LIQUID/LIQUID and/or LIQUID/VAPOUR interfaces e.g. separators, towers and columns, boilers;
    - High speed rotating machinery (thrust loads on bearings) e.g. compressors, turbines.
  - Equipment where motions have little effect:
    - Equipment with single phase or homogeneous two-phase contents e.g. heat exchangers.
    - Equipment with no moving parts.

- Equipment should of course be designed & configured to accommodate vessel motions.
  Design example: structural design of separator internals (baffles etc.)
  Configuration example: level instruments trip points & alarm delays/lags/deadbands.

- Mitigation for equipment types that are more sensitive to motions and accelerations can be:
  - LOCATION (within modules):
    - Lower down (Closer to deck level);
    - Closer to the middle of the vessel (both transversely and longitudinally).
  - ORIENTATION
    - Align equipment longitudinally with the vessel.

  Other factors (e.g. module location) may prevent these mitigations being applied.

Equipment layout: elevation and deck levels

- Whatever modular approach is adopted there will usually be some form of "mezzanine deck" – by which we mean a highest level, partial coverage deck. There will also be a main deck at the lowest level. With 'full' modules there may also be a second 'full' deck (or more than one, possibly with further internmediate mezzanine levels).

- The lower or main deck level will be used for:
  - Heavier items of equipment (structural reasons);
  - Rotating machinery (access for maintenance);
  - Motion sensitive equipment.
- Higher levels will be used for:
  - Heat exchangers (lighter, need deck area for cleaning e.g. pulling bundles).
- The highest level (Mezzanine deck) will be used for:
  - PSVs (safety valves)and BDVs (blowdown valves) - no pockets in tail pipes, keep liquids out of flare and valves higher than flare header;
  - Make-up / expansion / header tanks;
  - Small laydown areas e.g. drums of lube oil.
- Compromises will be required!

Equipment layout: considerations

- Vessels & columns:
  - Hull motions and accelerations;
  - Head considerations (incl. gravity drainage);
  - Structural support locations.
- Coalescers:
  - As vessels plus;
  - Access to transformer.
- Heat exchangers:
  - Cleaning (pulling/handling bundle, cleaning plates etc.)
  - Structural support locations.
- Rotating Machinery:
  - Hull motion and accelerations;
  - Pumps – NPSH (Net positive suction head) – can change pump design, lower pump, raise feed.
- General:
  - Minimum separation between two items is usually walkway width (maybe some 1000 mm);
  - Crane access (load vs radius) or alternative handling method;
  - Deck penetrations (e.g. columns, access).

Water Injection Module

Equipment & module layout: escape & access

- Ensure adequate personnel escape routes from module (a walkway junction every 5 meters?)
- Modules must be adequately spacious & easy to operate, maintain etc:
  - Easy access to operational equipment and anything that might need maintenance (incl. cleaning). Particularly:
    - Instruments;
    - Local control panels;
    - Relief valves;
    - Control valves;
    - Check valves;
    - Filter elements;
    - Heat exchanger tube bundles / plates;
    - Rotating equipment.
  - Easy access to ALL manways, handholes, cabinets, valves, spectacle blinds/spades, spool pieces etc.
    - Pay particular attention to critical valves needed during routine operation or for isolation (don't forget : drain and vent valves, control valve blocks and bypass);
    - Ladders & platforms.
  - Easy access to and sight of instrumentation (for operation, maintenance & testing).
  - Minimise tripping hazards, do not obstruct walkways or escape routes which should be clearly marked.

Mechanical Handling: Options by weight & handling frequency

	daily	weekly	annually	periodic maintenance (2 to 4 years)	occasionally (> 4 years)
greater than 15 te	Permanently installed powered lifting arrangements (runway beams or crane) suitable for transferring equipment to a location for crane pick-up.				
5 te to 15 te	Permanently installed powered lifting arrangements (runway beams or crane) suitable for transferring equipment to a mechanical handling trolley with a max carrying capacity of 15 te.				
3 te to 5 te	Transfer using mechanical handling trolley with a manipulator arm that has a max lifting capacity of 5 te. Or, permanently installed lifting arrangements suitable for transferring equipment to mechanical handling trolley.				
200 kg to 3 te	Transfer using mechanical handling trolley with a manipulator arm that has a max lifting capacity of 5 te. Or, permanently installed lifting arrangements suitable for transferring equipment to mechanical handling trolley.			Documented mechanical handling report detailing handling of materials with temporary lifting equipment. The report shall include documentation of the structural capacity of all lifting points of more than 200 kg.	
25 to 200 kg	Permanently installed lifting arrangements or suitable direct access for a portable lifting appliance.			Documented mechanical handling report detailing handling of materials with temporary lifting equipment. The report shall include documentation of the structural capacity of all lifting points of more than 200 kg.	
less than 25 kg	Manual handling				

frequency of handling operation

- ❑ Mechanical handling does not just apply to topsides – needs to be considered for the whole facility (garbage, supply boat....);
- ❑ Cranes discussed above.

Mechanical Handling: Lifting Beams

- ❑ Lifting beams can be used to move equipment to within crane lifting radius.
- ❑ Beams should be rated to support all equipment that may require lifting.

Mechanical Handling: Skid-ways

- ❑ Skid-ways can be used to pull equipment from its location to the workshop / supply boat area.
- ❑ Skids can be greased & pulled along deck or equipment transported on trolleys.

Mechanical Handling: Lessons Learned

- ❑ The choice of solid boom cranes for 4 of 5 FPSOs was not optimum. These heavily built booms are strongly affected by the wind and due to their weight respond slowly for offloading.
- ❑ As built handling systems for equipment in the hull are often inadequate.
- ❑ In general the vessel layouts are poorly optimised for equipment handling and storage.
- ❑ One option is to require package bidders to provide for equipment removal - a solution for each maintainable item.
- ❑ Means to get material to crane and workshop can be via central walkway and forklift.
- ❑ Studies must be completed at the design stage and concepts not retrofitted.
- ❑ Make provision for loading hose maintenance and section change-out on board.
- ❑ A number of hydraulic arm "mini cranes" has proven successful and more precise for control.
- ❑ The lay-down area was not large enough for the offshore and subsea installation equipment (chemicals, Nitrogen units, test pumps etc.)
- ❑ See http://fpso.olf.no/lesson/overview/

Topsides weight and weight control

Topsides Weights & Weight Control

- Topsides weight is not a main contributor to overall ship weight/displacement - topsides weigh only 5-7%
- Topsides center of gravity (CoG) can have a major impact on stability.
- Understanding & controlling topsides weights is critical to:
  - The process/ package support structures
  - Deck reinforcement requirements
- Weight control report & declaration of topsides "not to exceed weight" critical:
  - Management of stability
  - Structural design interface between hull and topsides
- Correlation between topsides scope/ weight growth & the potential for overall project cost growth and schedule slippage.
- Topsides weight growth typically results from a combination of:
  - Ineffective FEED causing late design changes
  - Failure to fully define scope
  - Lack of robust weight estimating norms/ process
  - Poor weight control processes

Analogue Topsides Area & Plot Density

- ***North Sea (turret-moored)***
  - *Average topside plot density 0.8 te/m^2 (1.2 m^2/te).*

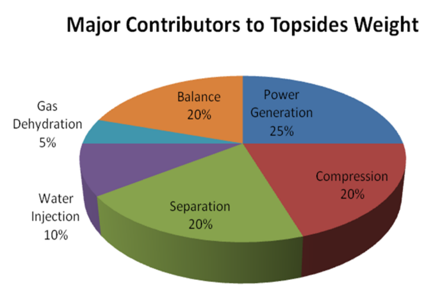
	process area	dry process weight (incl. utils & power gen)	density
	m2	te	te/m2
Haewene Brim	6000	5000	0.83
Petrojarl Varg	4700	4300	0.91
Aoka Mizu	6000	4600	0.77
Glas Dowr	6000	4500	0.75
Petrojarl Foinaven	4600	4000	0.87

- ***West Africa (large, spread-moored units) (plus a large Chinese, yoke moored unit)***
  - *Average topside plot density 2.1 te/m^2 (0.5 m^2/te).*

	process area	dry process weight (incl. utils & power gen)	density
	m2	te	te/m2
Dalia	15400	30000	1.95
Bonga	14500	34000	2.34
Bohai Bay Phase 2	16000	38000	2.38
Greater Plutonio	15200	27000	1.78

- *Impact of multi level decks - motions*
- *Establish norms for your project as a **rough** check*

"Typical" Weight Breakdown



- *Total dry weight approximately 3 x equipment weight*
- *Operating weight typically about 15% more than total dry weight*

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- Any questions?