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WSI Challenges in Offshore Engineering

Lloyd's Register

Karl Mitchell
Principal Naval Architect
Marine & Offshore UK & Ireland

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for a safer world

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Why undertake hydrodynamic analysis ?

One of the main drivers for undertaking certain analysis is to satisfy National Authority Requirements.

(Compliance with the law of the country in whose waters the unit is located)

Within the UK (for offshore installations):

“Dutyholders must demonstrate that structures have a low probability of catastrophic failure when subjected to extreme environmental actions”

HSE Policy relating to extreme weather:

http://www.hse.gov.uk/offshore/extremeweather.htm#tepo

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Policy addresses issues such as:

- green water and wave slam events
- overall and local strength (in extreme waves)
- air gap
- peak responses

Performance Standards for **Safety Critical Elements** (SCEs) need to address these issues

Note the use of **bold** text – indicating legal terminology

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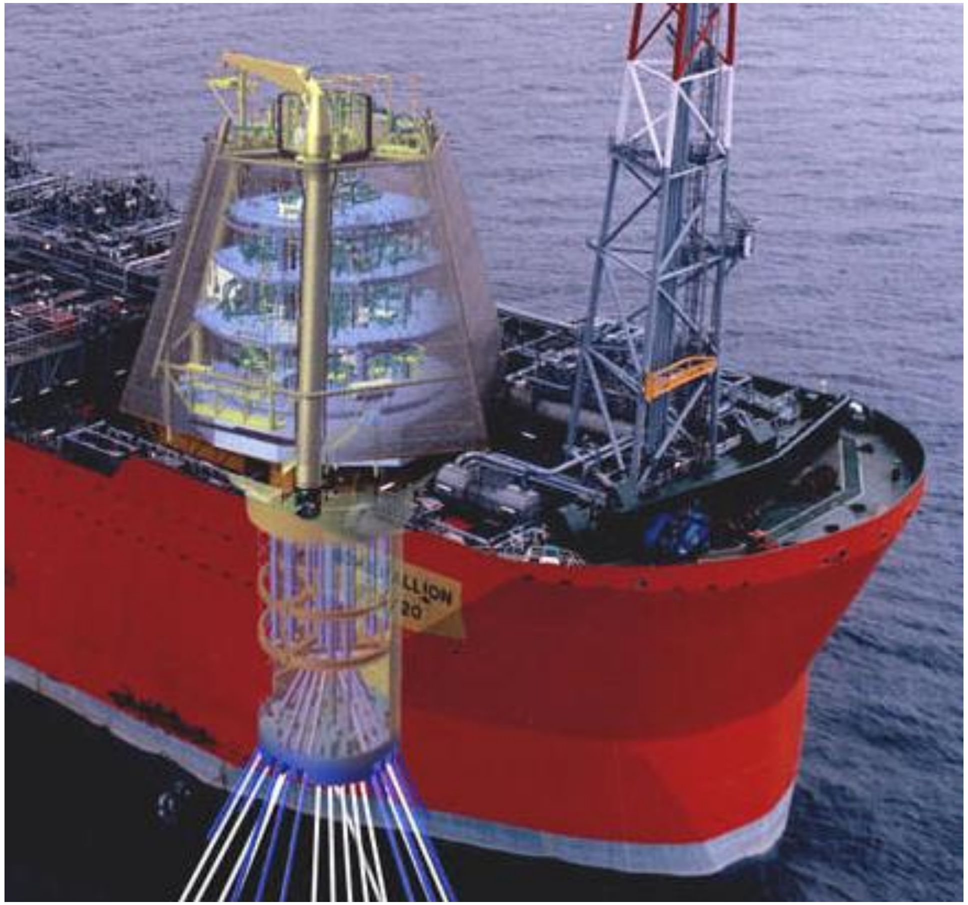
Examples of Safety Critical Elements within an FPSO unit:

- Hull
- Mooring system
- Turret structure



Hull structure – sample Performance Standard relating to harsh weather

The hull structure to be capable of avoiding progressive collapse and breach of the hydrocarbon containment system when subject to the following environmental events at a 10,000 year return period level:

- global hull loads, with particular consideration to midship bending and to shear load through hull at turret centre;
- loads due to green water in relation to head of water on deck and in support stools due to possible wave slam on topsides modules;
- localised wave slam events on hull envelope plating including and in particular on bow and bottom structures;
- sloshing impact loads within cargo tanks;

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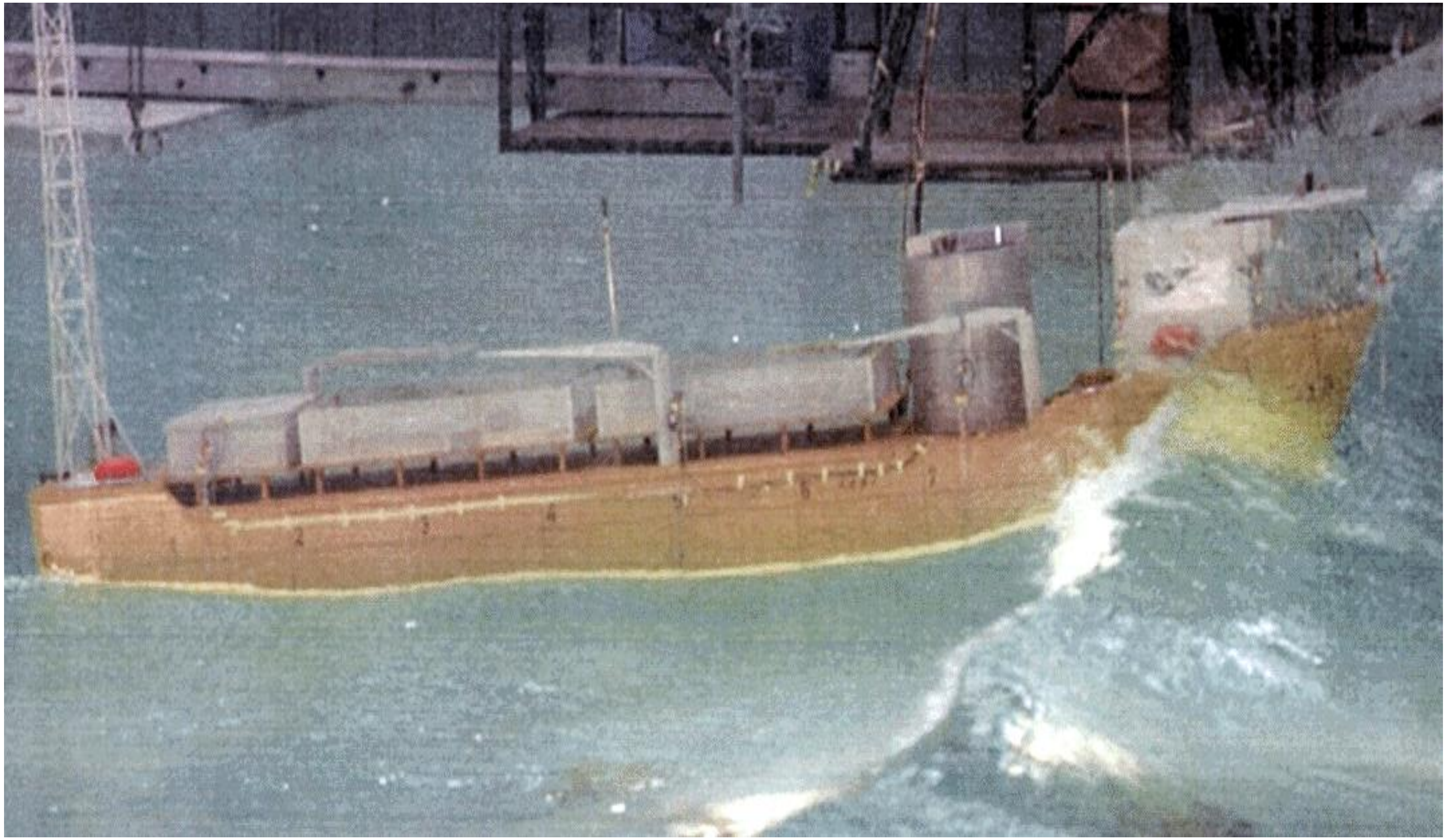

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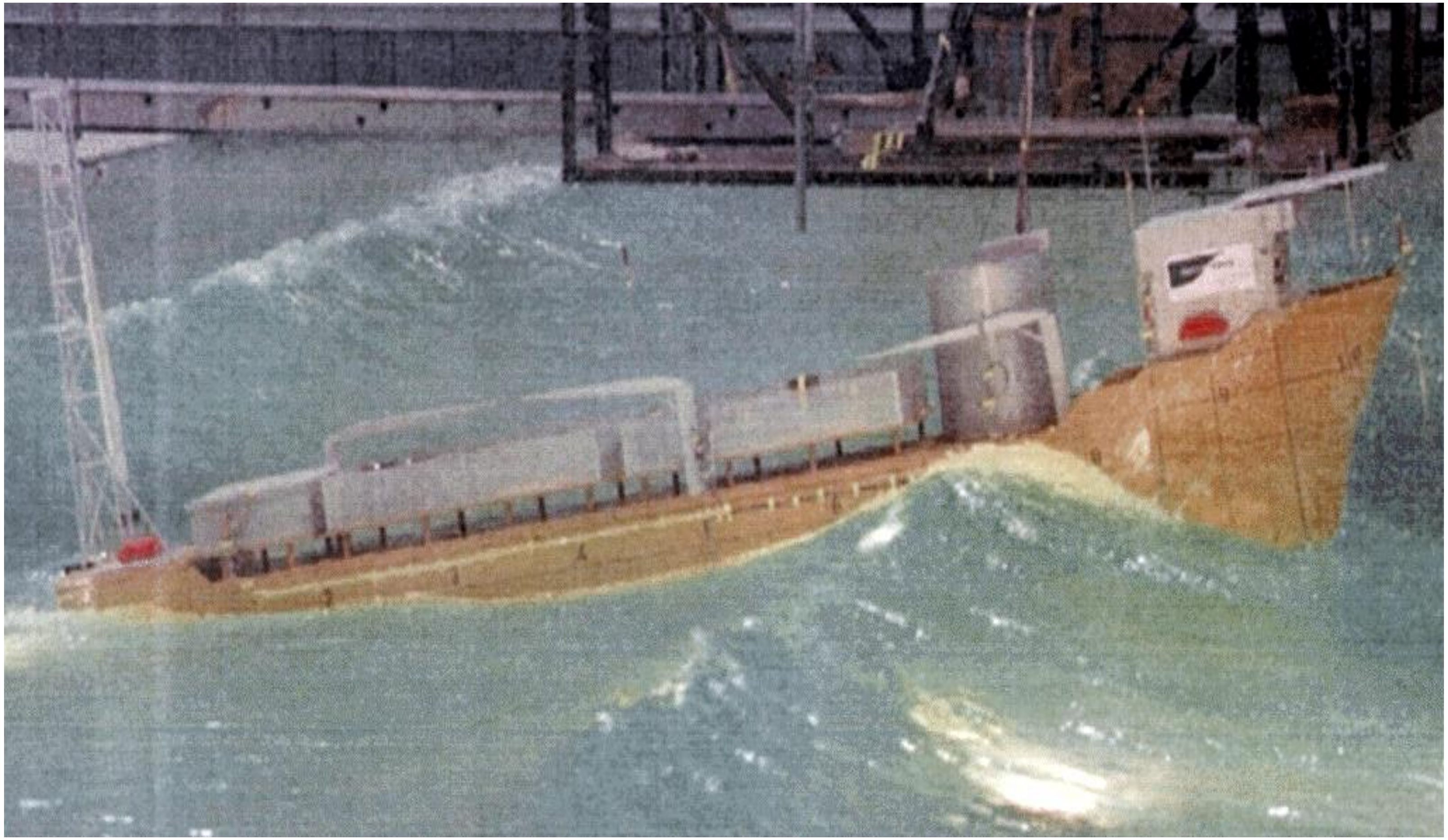

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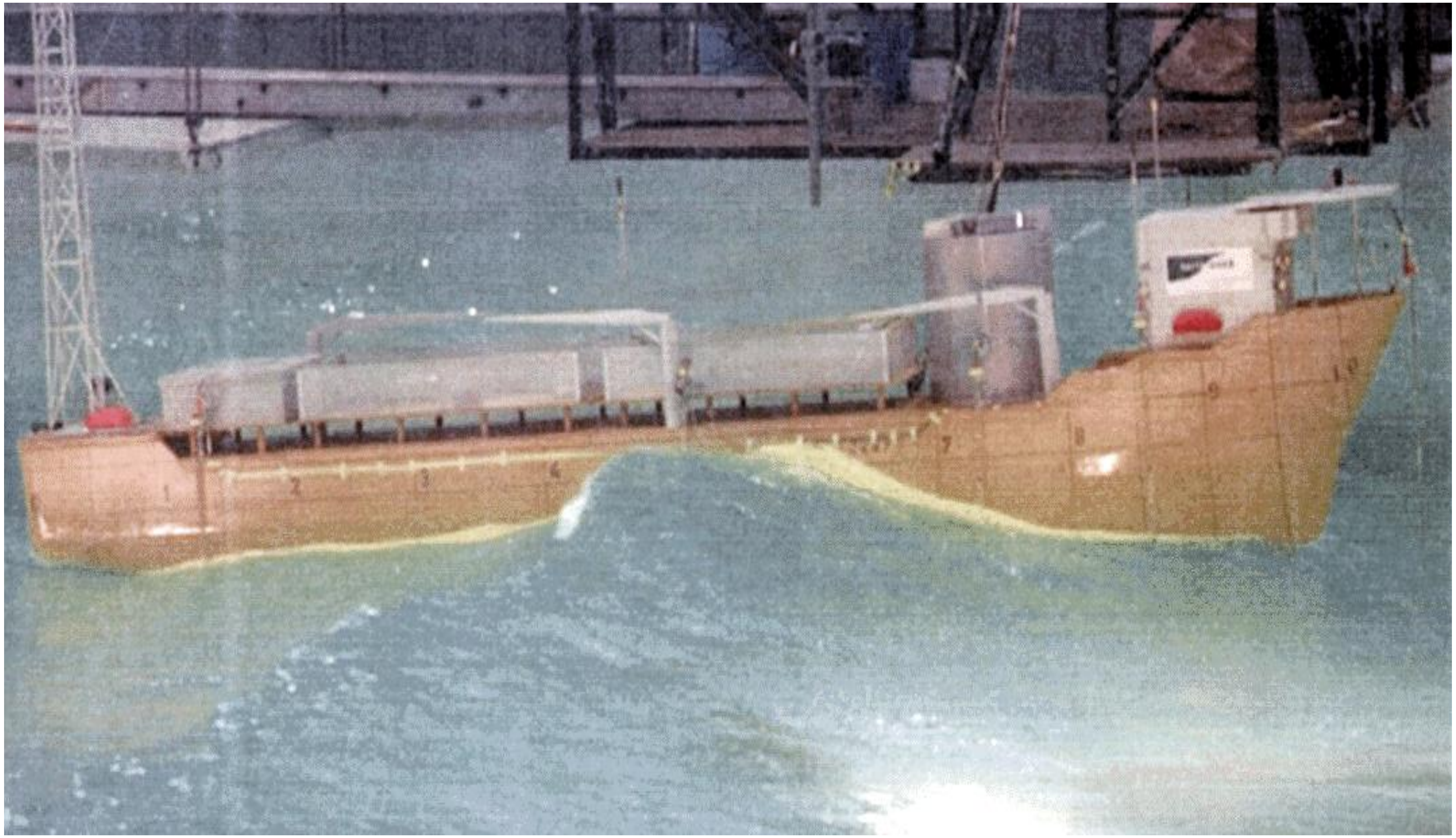

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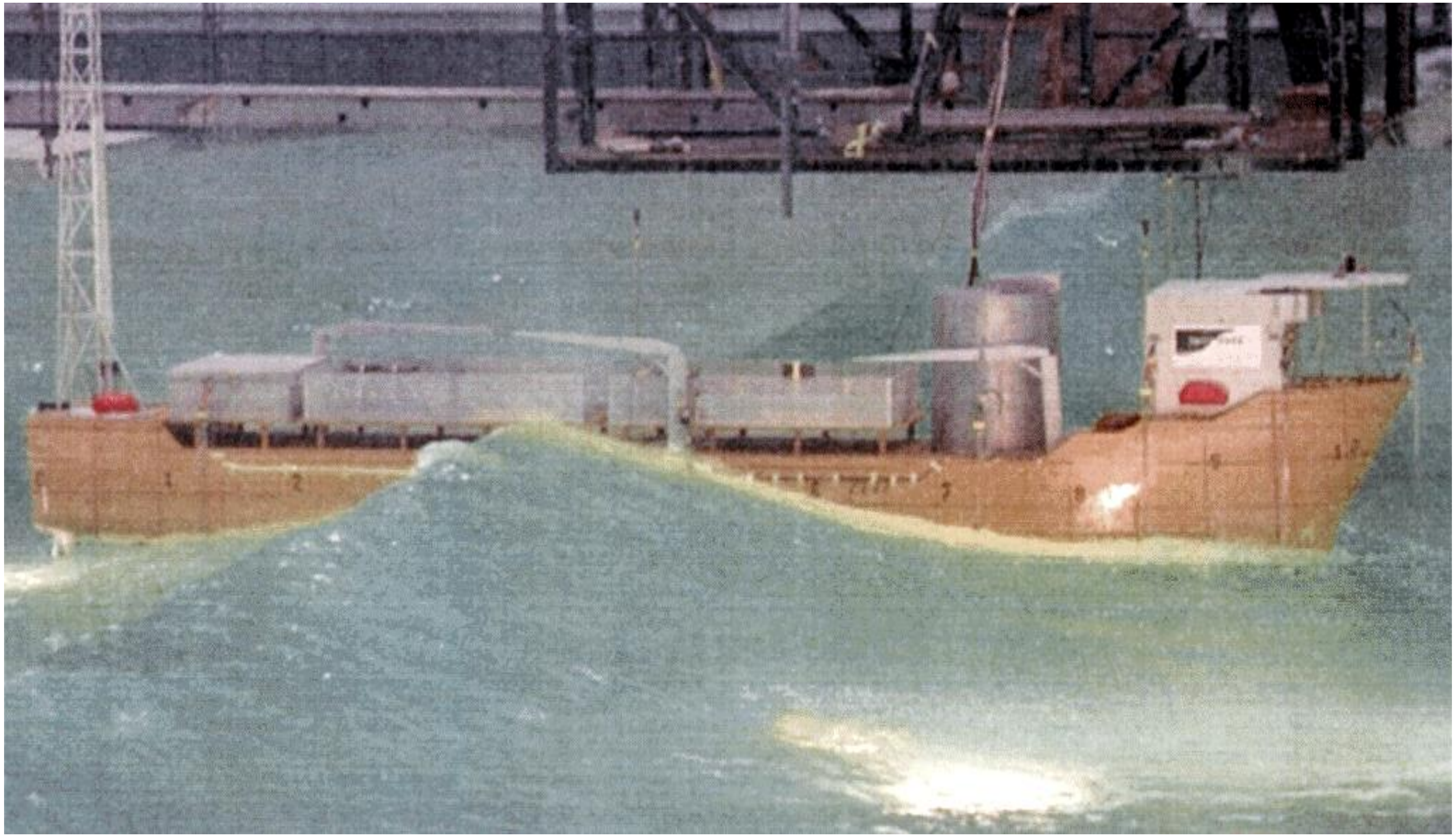

Turret structure – sample Performance Standard relating to harsh weather

The turret structure and interface to the hull (bearings and support structure) to be capable of avoiding progressive collapse and loss of weathervaning capability when subject to the following environmental events at a 10,000 year return period level:

- wave impact loads on turret underside and chain table due to bottom of vessel clearing the water surface;
- load from single mooring line;
- combined load from mooring lines acting in unison;
- inertia load due to entrained water mass within turret and around chain table, particularly when bottom of vessel clears the water surface.

Mooring System – sample Performance Standard relating to harsh weather

- The mooring system to be capable of maintaining the 10,000 year return period unit’s excursions within the riser design limits (with these limits determined by the ability of the risers to prevent release of hydrocarbons to the environment).
- Individual mooring lines to be capable of withstanding extreme 10,000 year return period loads with no line breakage and no loss of anchor holding capacity.

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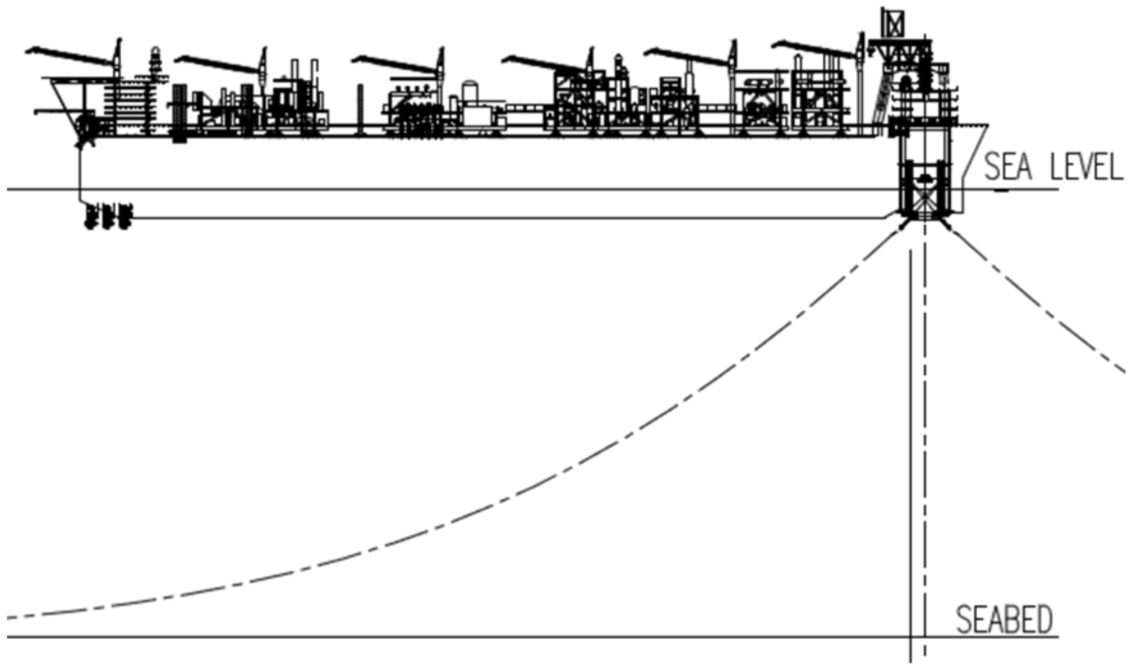
Designers need to satisfy the stated criteria within Performance Standards.

Tools need to be available to allow them to do this.

It is recommended the future direction of research should be aimed at providing these.

Lets look now at some problems more closely…

Large floating unit – showing mooring and turret

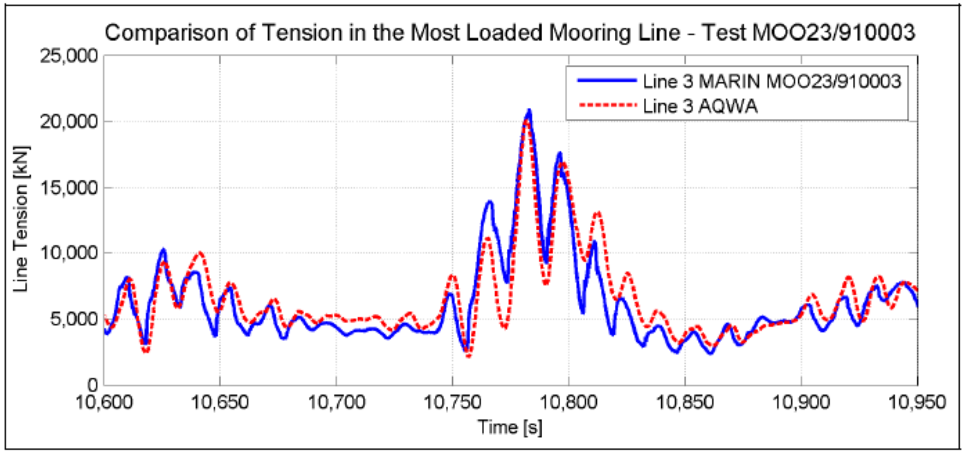


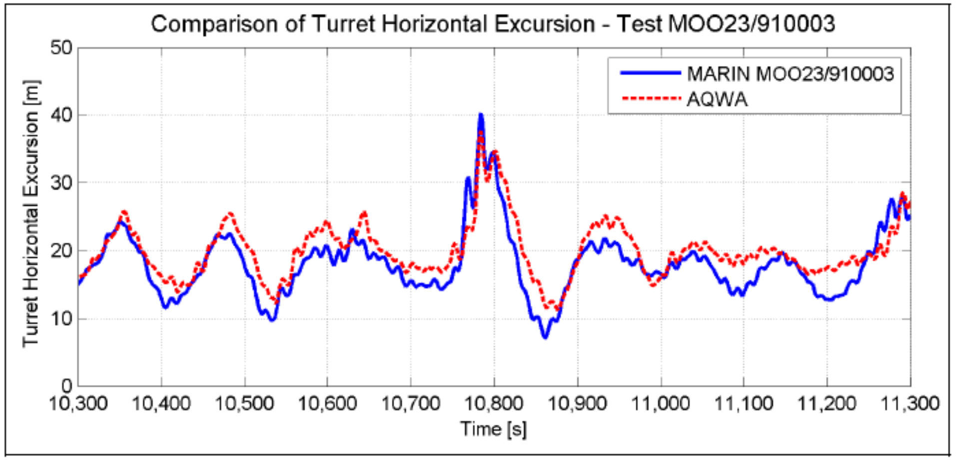
- Large with respect to the waves
- Wall sided
- Motions are "small"

Linear diffraction analysis very applicable

Extreme responses and global loads can be modelled reasonably for such units with linear diffraction analysis techniques: 100 year, 10,000 year RP.

Large FLNG unit – mooring response and hull loads





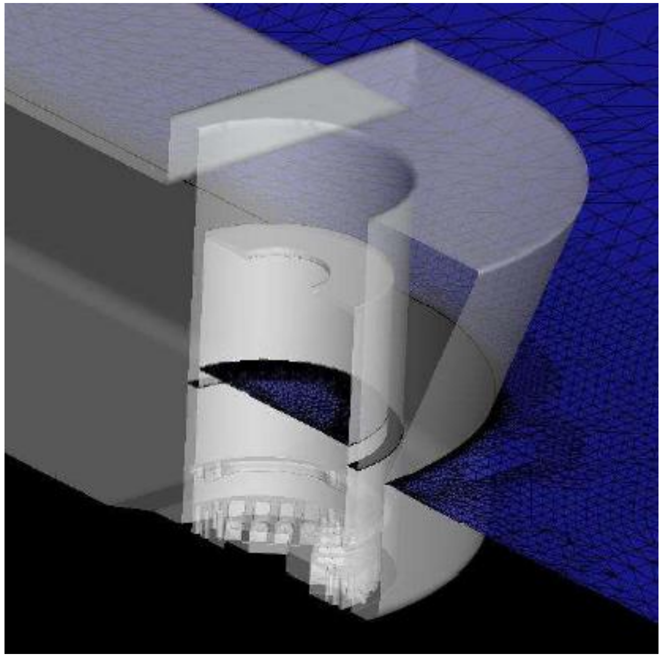
Model test results undertaken at scale 1:60

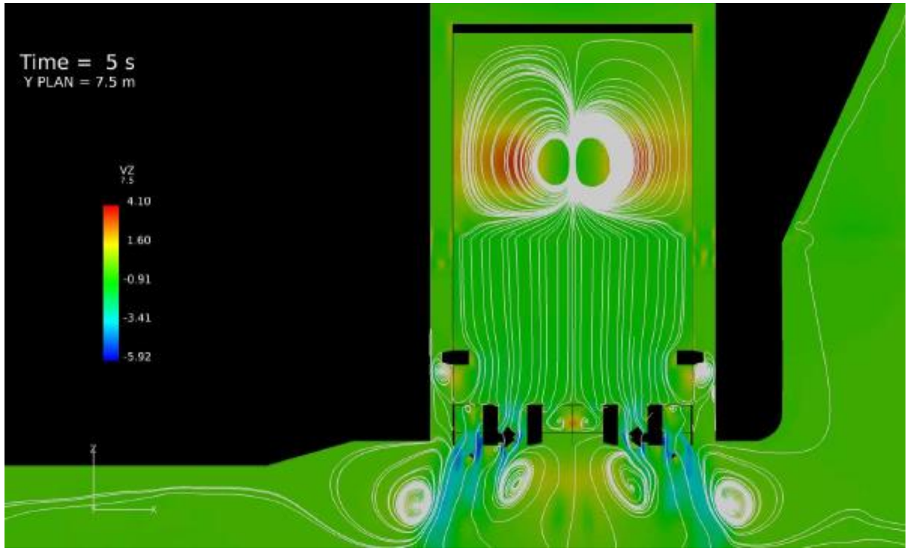
- Global loads on hull: modelled in frequency domain with many thousands of 3hr sea states;
- Mooring loads: modelled in time domain with many hundreds of 3hr sea states;
- Class Rules normally require analysis is verified by model tests – see above;

Large FLNG unit – use of CFD

CFD is used to evaluate local non-linear effects

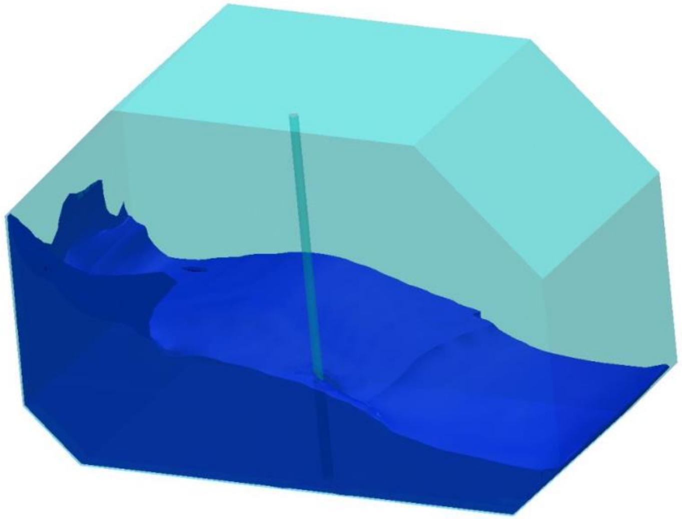
…such as impact loads on turret underside:





Large FLNG unit – use of CFD

CFD used to analyse sloshing within cargo tanks: -



Issues:

- How are critical instances determined – what moment (instant) in hundreds of sea states ?
  (can be guided by analysis based on linear diffraction theory)

- How are results verified ?   How can we be sure of results without model tests ?

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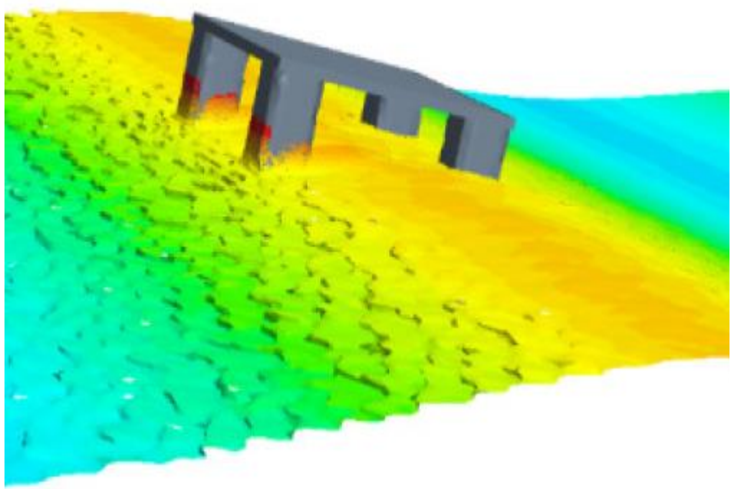
Diffraction analysis can give poor results for the types of units here – particularly at shallow draught and for “small” units;



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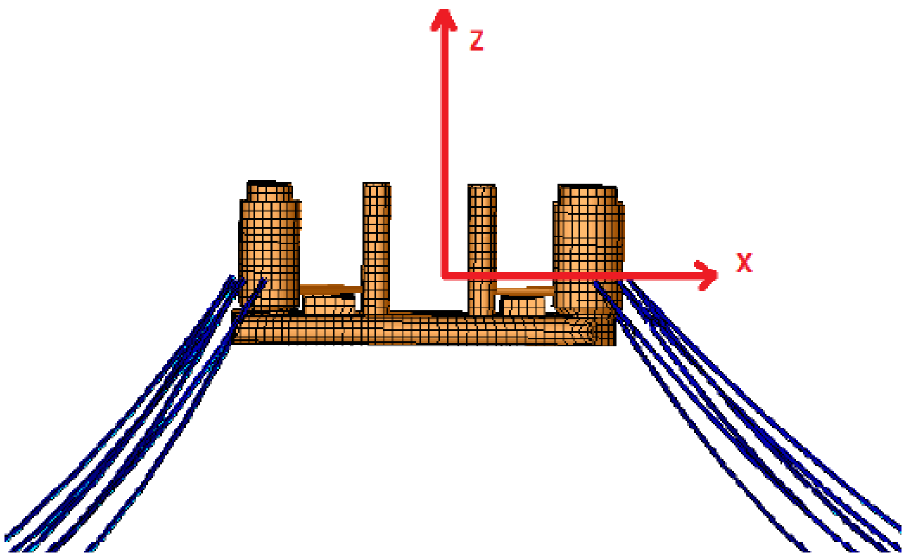
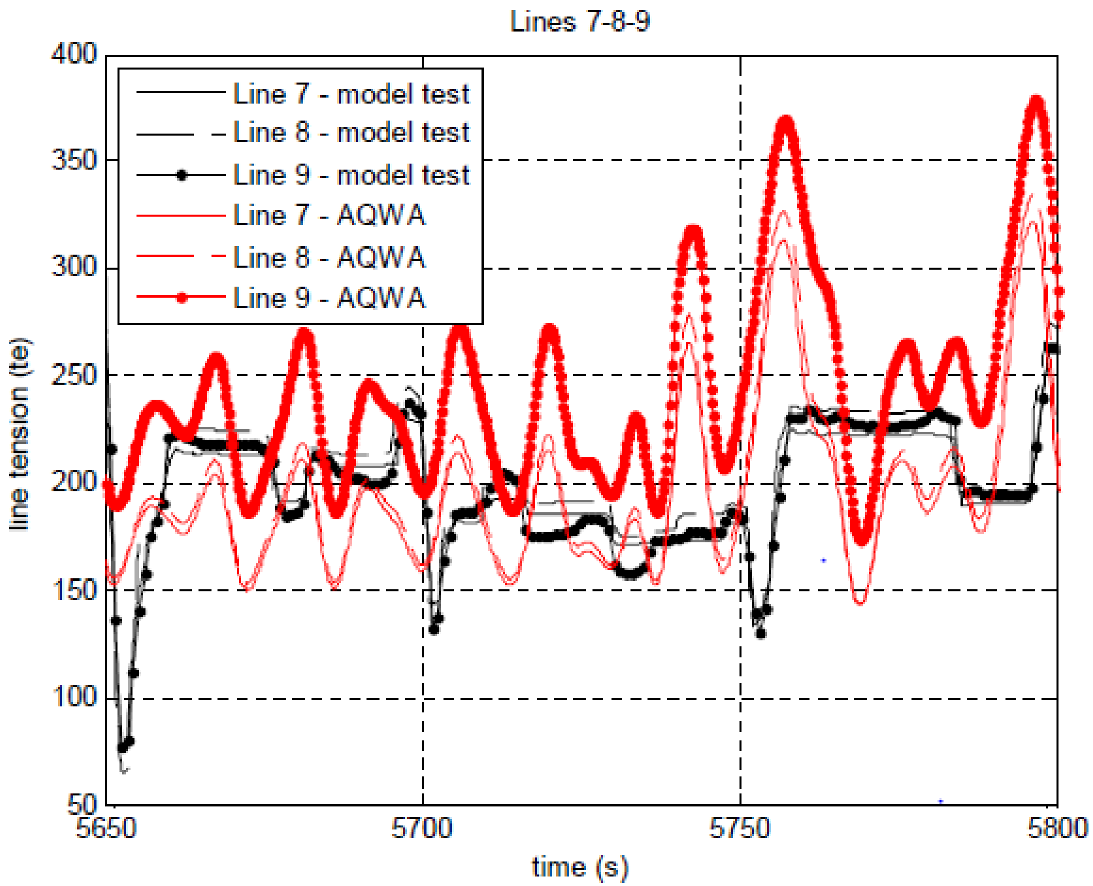
An example of poor comparison of mooring loads:

(Model test results undertaken at scale 1:85)





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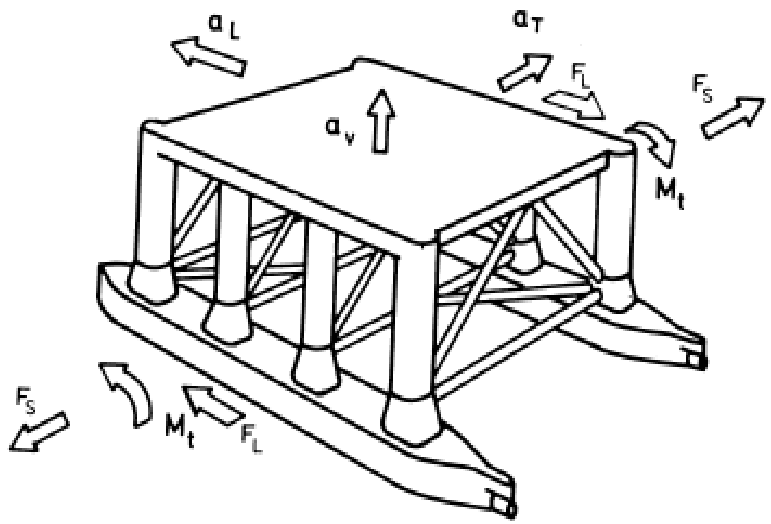
- Challenge to determine:
  - internal loads: twisting / splitting – vital for structural designers to know this;
  - mooring loads (previous slide)
  - air gap
  - wave impact loads on deck

- Wind loads can play major role:
  - heading for turret moored units
  - loads on wind turbines

- Peak response may not occur in “large” waves (splitting);



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- Ideally loads should be determined by CFD – but at what instant in time ?
- Metocean data provided for 25 years at 3hr intervals;
  How are critical instances determined (particularly when diffraction analysis results are poor) ?
- How can CFD be mapped on FEA model for structural analysis ?
- Can length of CFD simulation be "suitable for daily design work" ?

  ideal situation: run 10,000 years of sea state with structural response with CFD in seconds ?
  …including wind ?
- How are results from CFD verified ?

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Specific challenge from Marine colleagues:

To develop a reliable and practical CFD methodology for the prediction of added resistance in waves that is backed up with full-scale validation and can be used for irregular sea states.

Questions & Answers