Marine activities in deep water and harsh weather conditions

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Objective of presentation

- Of particular concern is the difference between short-term activities, which can be conducted within a good weather forecast period, and activities that take longer time, or may be regarded as a permanent activity.
- First, a discussion of short-term marine activities will be given, emphasizing aspects specifically related to deep water, such as the positioning and the effects of resonant motions of vessels in waves.
- After that, deep-water marine technology will be discussed in case of harsh weather. Reference will be made to typhoons, with emphasis on the possibility of aborting operations.
- For permanent activities, the need for robust design is emphasized to ensure that the facilities can withstand the strongest typhoon situations.
- The presentation will be finalized with a discussion of the selection of safety level (return period for extreme weather events), with a challenge to consider the effect of climate change and the possibility of more frequent extreme Typhoons.

Key considerations

- The large variety in meteorological and oceanographic conditions offshore China calls for thorough considerations when carrying out marine activities offshore China.
- Of key importance is the collection of appropriate data on meteorological and oceanographic conditions needed to establish statistical estimates of extreme design criteria.
- These meteorological and oceanographic criteria are required to establish the strategy for how to carry out marine operations offshore

1. Short term marine activities

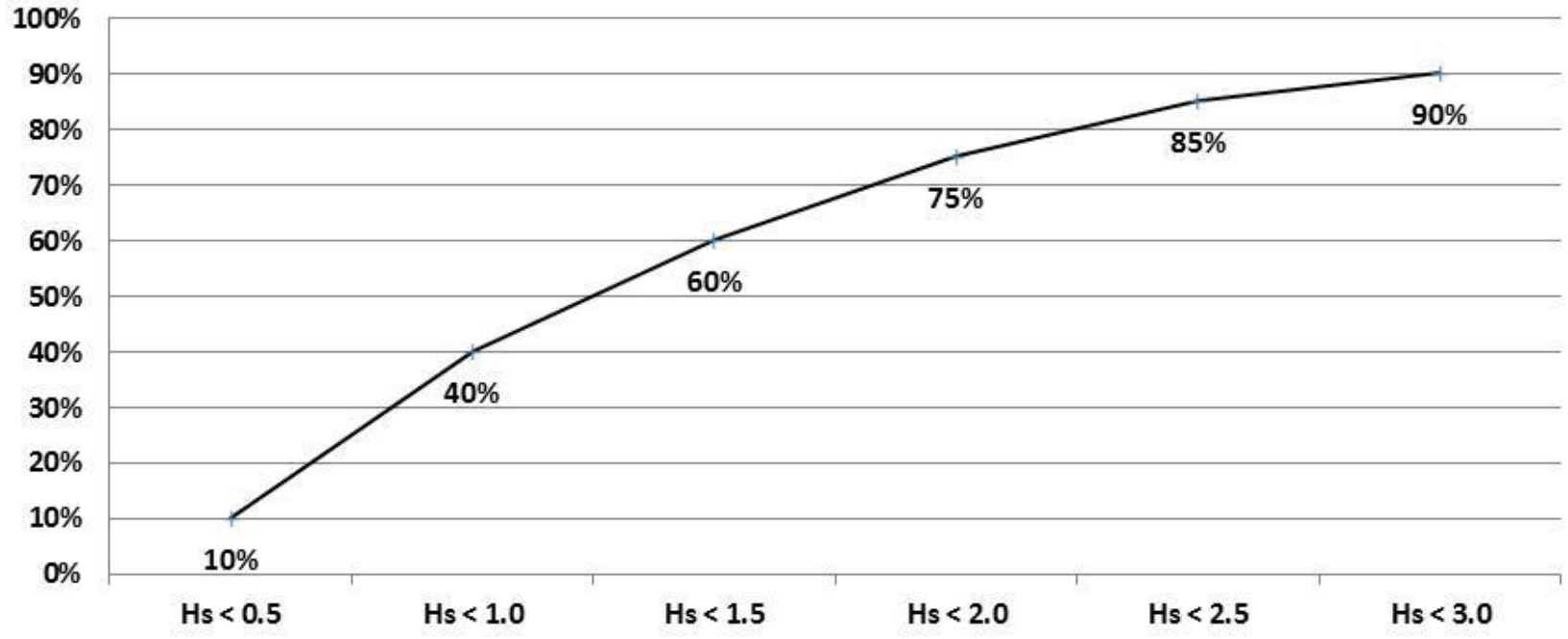
- Short-term marine activities require special weather conditions
  - Wave heights (normally considered)
  - Wave periods (often not considered)
- Notice the vessel's Response Amplitude Operator
- Amplification of the motion at the eigenfrequencies of the vessel
  - We often use a linear relationship between the response and the wave (height) multiplied by the RAO value
  - The vessel's eigenfrequencies change with the vessel's speed (encounter frequency)

Weather forecast

- Marine activities require special weather conditions
  - Wave heights (normally considered)
  - Wave periods (often not considered)
- We must wait for appropriate weather conditions which will last for the duration of the activity
  - Waiting on the weather is an important issue
  - Note that the uncertainty in the weather forecast will increase with time from the issue of the forecast
- Weather statistics will be used to estimate the best time for the activity (summer season weather)
- Weather forecasts are used to decide when to start the activity
- For activities, exceeding 3 days, seasonal statistics are used
- Also, the “survival weather condition” must be assessed.

Weather window, typical distribution from the North Sea

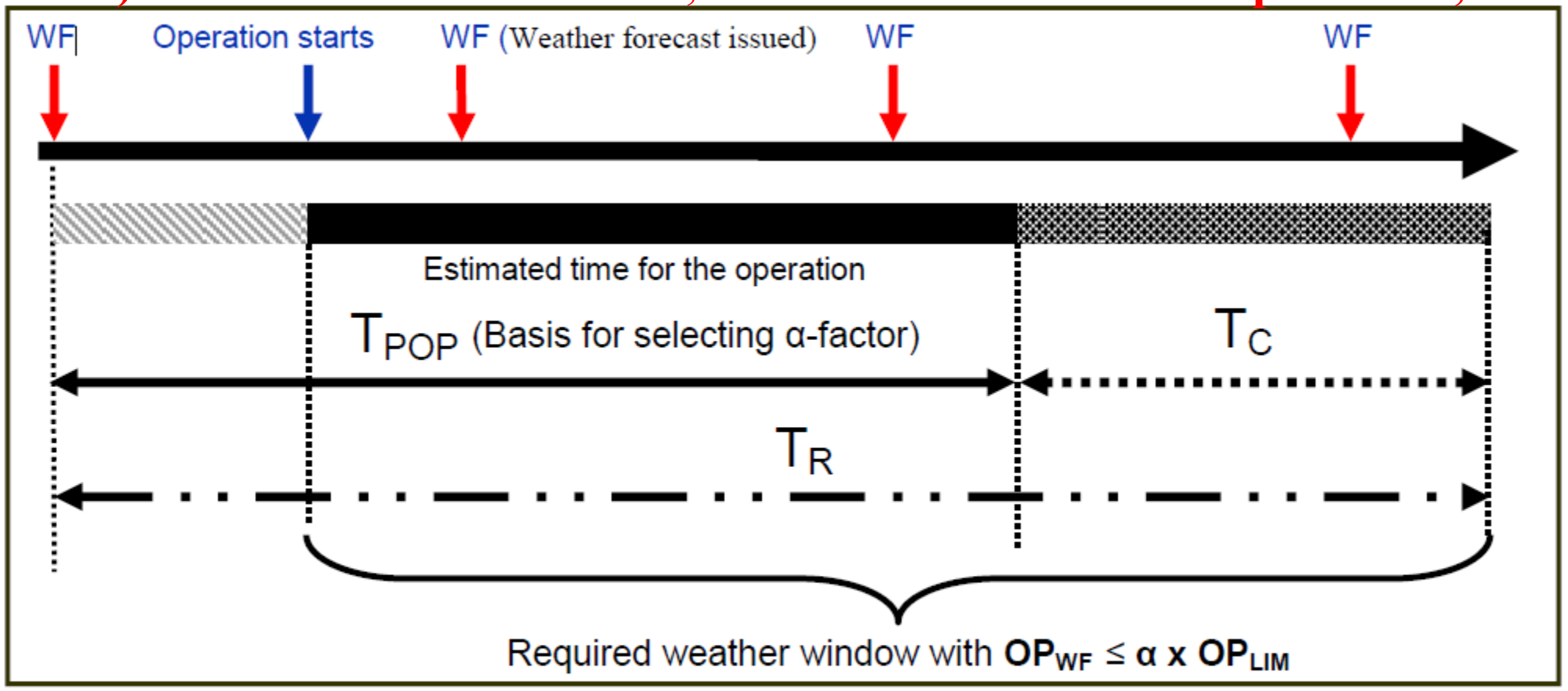
- Large wastage of offshore work time is reported just by waiting for the weather window during the installation phase.



DNV-OS-H101 - Operation Periods

MANAGING RISK

2) From: DNV Presentation, DNV-OS-H101 Marine Operations, General



T_R = Operation reference period

T_{POP} = Planned operation period

T_C = Estimated maximum contingency time

Operational Limiting Criteria

- **The OP_{LIM} (Limiting operational environmental criteria) shall never be taken greater than the minimum of:**
  - The environmental **design criteria**.
  - Maximum wind and waves for **safe working- or transfer conditions for personnel**.
  - Equipment (e.g. ROV and cranes) specified weather restrictions.
  - Limiting weather conditions of diving system (if any).
  - Limiting conditions for position keeping systems.
  - Any limitations identified, e.g. in HAZID/HAZOP, based on **operational experience** with involved vessel(s) etc.
- **The forecasted (monitored) operational criteria - OP_{WF} - is defined as $OP_{WF} = \alpha \times OP_{LIM}$.**

DNV-OS-H101 - Alpha Factors

MANAGING RISK

The alpha factor for waves is defined by 5 Tables, below "Base Case":

Operational Period [h]	Design Wave Height [m]						
	$H_s = 1$	$1 < H_s < 2$	$H_s = 2 = 2$	$2 < H_s < 4$	$H_s = 4$	$4 < H_s < 6$	$H_s \geq 6$
$T_{POP} \leq 12$	0.65	Linear Interpolation	0.76	Linear Interpolation	0.79	Linear Interpolation	0.80
$T_{POP} \leq 24$	0.63		0.73		0.76		0.78
$T_{POP} \leq 36$	0.62		0.71		0.73		0.76
$T_{POP} \leq 48$	0.60		0.68		0.71		0.74
$T_{POP} \leq 72$	0.55		0.63		0.68		0.72

The other tables take into account combinations of

- Wave monitoring
- Weather forecast level
- Meteorologist at site

Example: Installation activities

- Installation is normally carried out by lifting
  - Weather-critical activity
    - Weather forecast necessary
    - Weather-restricted activity
    - Concern when the load is lifted off, beware that lifting is rapid to avoid the barge hitting the load from below
    - Subsea lifting:
      - Concern when equipment goes through the waterline (when buoyancy comes into force, the wire could go slack and there could be a snap load in the wire
      - Concern that the equipment is stable when approaching seafloor
    - Lifting just in the air
      - When lifting onto a fixed or floating structure, impact load must be avoided
  - Simulation is often used to study the lifting

Lifting at the Hai Long wind project

2. Deep water concerns

- In deep water, anchoring is challenging due to the required length of anchor systems.
  - Use of dynamic position is required
  - The dynamic positioning system must be redundant to ensure safe activities
  - A traditional anchor system will not allow for disconnection, reference typhoon situation
- In deep water, resonances occur during lifting operations:
  - There is the transfer of the heave/ pitch motions of the ship to the crane equipment used for lifting.
  - When the eigen-period of the wire matches with the period of the motion of the vessel, energy is transferred from the vertical ship motions to a pendulum motion of the equipment being lifted.
  - This so-called “Mathieu instability” requires special attention.
- In deep water, ocean currents could cause more concern than in shallower water due to the long vertical distance the load is acting on.
- Of concern is also the potential for internal waves due to stratification caused by water of different densities

3. Harsh weather conditions; typhoons

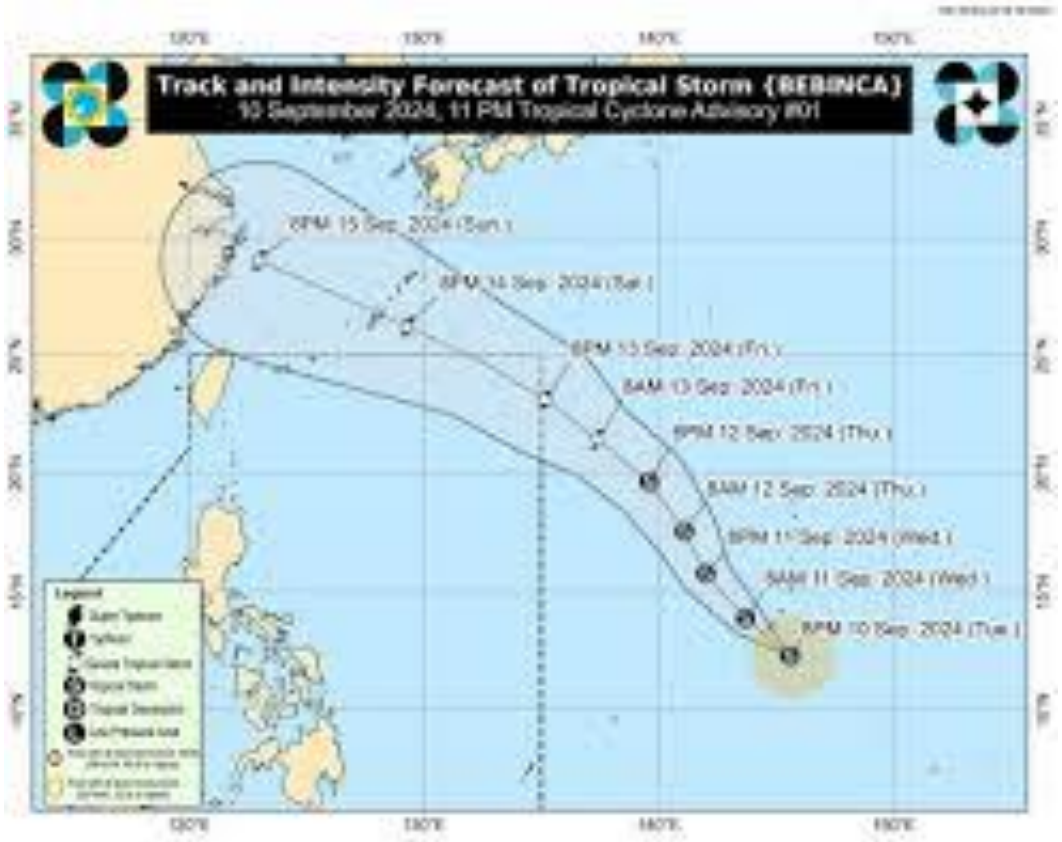
- In The South China Sea the strongest winds are experienced during typhoons
- The selection of extreme wind speed for permanent marine activity at a selected location is difficult due to limited measurements of wind speeds in a typhoon.
- It could be considered to select the highest value ever recorded
- The possibility of more frequent extreme typhoons due to climate change should not be underestimated.
- The design wind conditions for permanently anchored facilities like wind turbines is critical.
- An option for some facilities is to disconnect them and tow them out of the probable path of the typhoon.
- Note: A typhoon has a wind speed of 64–79 knots (118–149 km/h), a severe typhoon has winds of at least 80 knots (150 km/h), and a super typhoon has winds of at least 100 knots (190 km/h, i.e.: 53m/s).

Reference: Gulf of Mexico platforms were damaged in hurricanes in 2005

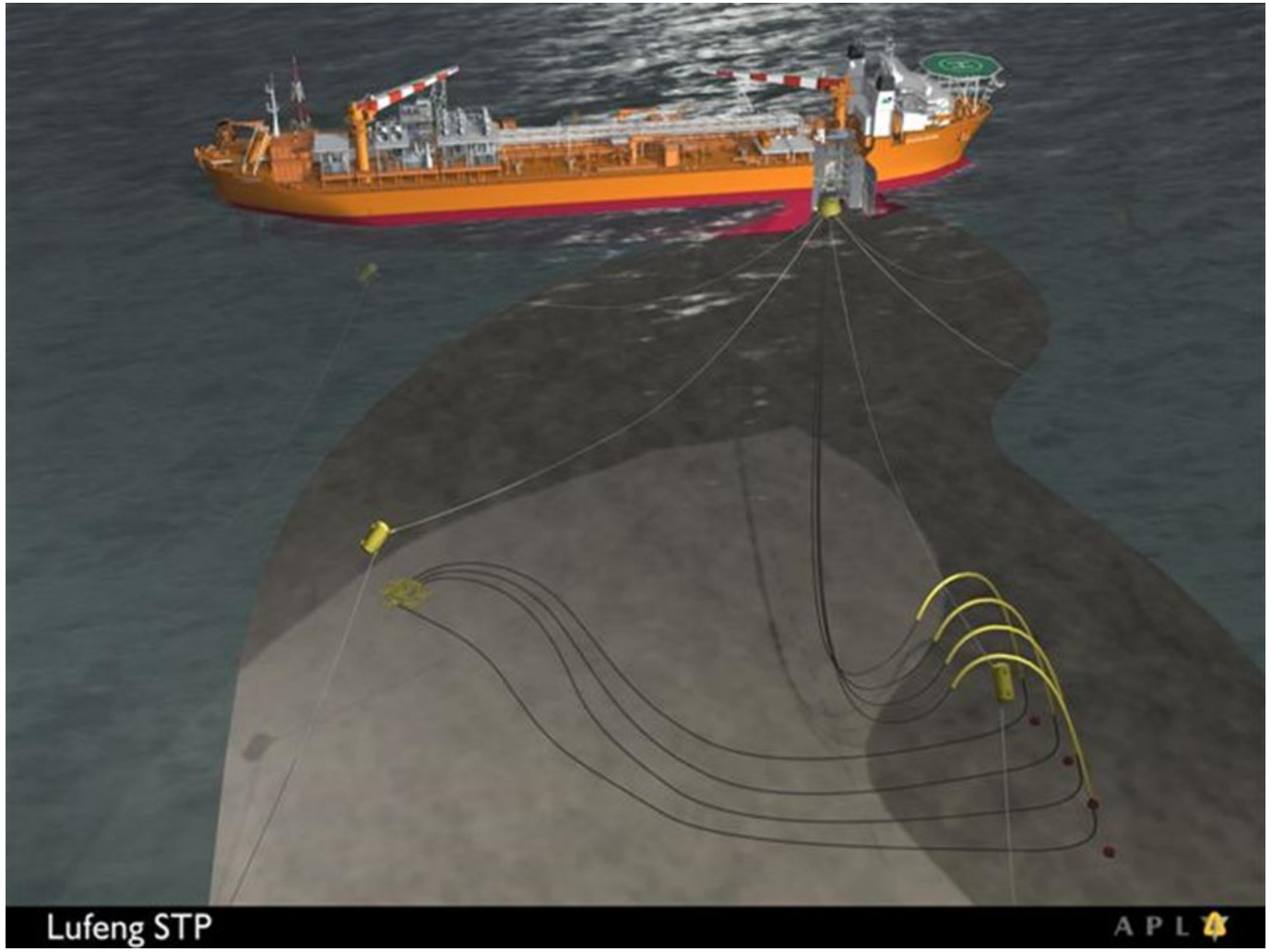
- Pictures show Mars and Typhoon platforms in GOM that were damaged in 2005
- Possible causes:
  - Large wind forces
  - Wave in deck loads
  - Very high waves
  - Storm surge
  - Seabed slides

Typhoons

- The Typhoon Bebinca made landfall on 16th September 2024 near Shanghai.
- The China Meteorological Administration recorded wind speeds of 151 km/h (42m/s) near the typhoon's eye when it made landfall, and state media described it as the strongest storm to hit Shanghai since 1949.
- The path of a typhoon is difficult to predict accurately



Example of a dis-connectable facility: The Lufeng turret production system. Dec 1997 – June 2008. 330 m water depth.



The Lufeng oil field location

- Lufeng 22-1 oil field was located 250km southeast of Hong Kong in the South China Sea, in 330m of water. Recoverable reserves were estimated at 30 million bbls, representing a recovery factor of approximately 25% of oil-in-place.
- Lufeng 22-1 area was prone to tropical cyclones with an average passing speed of 18-22km/h, (50km/h max) and an average duration of 26 hours, which generate waves up to 8m high.
- The South China Sea is also subject to a cold wave from Siberia, causing force-six winds and correspondingly, very rough seas.

Production turret

Anchor system (Suction anchors) for the STL anchor system

Lufeng operations, dis-connections 1998 - 2006

- During the operations of the Lufeng oil production vessel, the STL was dropped 9 times and the vessel sailed away
- 10 times, preparations were made for **dis-connection,** but the buoy was not dropped

Typhoon name	Shutdown period	Description
Unknown	Oct 23rd to 30th, 1998	STL dropped
Maggie	June 5th to 8th, 1999	STL dropped
SAM	Aug 20th to 24th, 1999	STL dropped
Dan	Oct 5th to 9th, 1999	STL dropped
Utor	July 4th to 7th, 2001	STL dropped
Imbudo	July 22nd to 25th, 2003	STL dropped
Sunvo	September 1st to 3rd, 2003	STL dropped
Damrey	Sept. 22nd to 25th, 2005	STL dropped
Chanchu	May 15th to 20th, 2006	STL dropped

Dis-connectable oil and gas production systems

- The possibility of transferring present design and operational experience applying existing development solutions in Chinese waters into deeper waters is regarded to be promising
- The dis-connectable Lufeng development operated by Statoil in the South China Sea is thought to provide maximum safety as the FPSO can leave the location in case of most severe weather
- The solution, furthermore, incorporated the use of a sub-sea solution and points towards limited offshore processing with multiphase transfer of hydrocarbons to shallow water units and possibly to shore facilities

4. Permanent marine activities

- Notice that the criteria for permanent marine activities (design analysis) are the metocean criteria with a small probability of annual exceedance
- Normally an exceedance probability of 0.01 per year, “the 100-year criteria” is selected for elastic analysis
- In the future, the probability that extreme weather may occur more frequently should be considered. The requirement is caused by global warming and increased weather uncertainty
- Furthermore, a non-collapse scenario is implemented

5. Safety level for marine activities

- Sunmmary regarding criteria for marine activities
  - Notice that limiting **criteria for short-term marine activities** are determined by the behavior of the equipment in a storm and that limiting wave conditions are found by simulating the equipment's behavior in the storm
    - The criteria will be the allowable maximum wave height where equipment can be safe during the period of the storm
    - Normally we will refer to significant wave height and peak period in the storm
    - Simulations using any realizations (time histories) of wave data from former storms are normally used and the extreme response values are calculated
  - Notice that the criteria for **permanent marine activities** (design analysis) are the metocean criteria with a small probability of annual exceedance
    - Normally an exceedance probability of 0.01 per year, the 100-year criteria is selected for elastic analysis
    - In the future, the probability that extreme weather may occur more frequently should be considered. The requirement is caused by global warming and increased weather uncertainty
    - Furthermore, a non-collapse scenario is implemented

Risk evaluations, Redundancy

- A marine activity should be redundant (like a parallel electric system compared with a series system) so one failure does not lead to collapse
- The point of “no return” of starting an activity is important as it will be an important point when decisions to continue must be made
- Redundancy can be obtained in several ways, for example by
  - Providing more anchor lines than strictly necessary, requiring safe mooring should one (or more) line break
  - Using a completely redundant DP system on the vessel carrying out the activity
  - Ensuring that single failures do not escalate to multiple failures and potential collapse

6. Conclusions

- Short-term marine activities are carried out when a suitable weather forecast is made
  - The uncertainty in the weather forecast must be taken into account
- Deepwater marine activities lead to specific challenges as discussed
- If an activity can be aborted or the facility can be disconnected, the safety of the activity is much improved
- Permanent marine activities must take extreme weather conditions into account
- The selection of extreme values for wind and waves is uncertain due to climate change
  - The selected extreme values should take into account the most extreme values ever recorded.
- The safety level of an activity must be closely selected. Intranational standards give guidance.

Questions?

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