



OPERATIONS

The Use of Safety Moorings in DP Operations

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October 7-8, 2008

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On the use of "safety mooring" in DP applications



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Background

- Relative DP operation
 - Fixed structure
 - Floating structure
- Need to improve safety of operation
 - Blackout
 - Drive-off
 - Drift-off
- Mooring alternatives
 - To sea bed
 - Via support vessel
 - Safety hawser



Relative Positioning

Free floating vessel

- ROV vessels
- Platform Supply Vessels
- Accommodation vessels
- Diving vessels
- Construction vessels

Vessel "connected"

- Shuttle tanker loading
- Heavy lifting



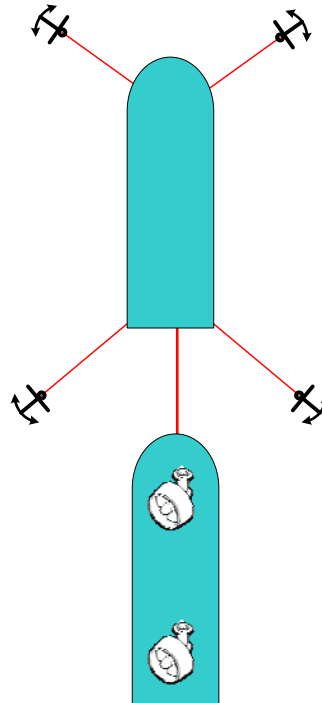
Configurations

From bad ...



Case #1

... to worse ...



Case #2

... to disaster



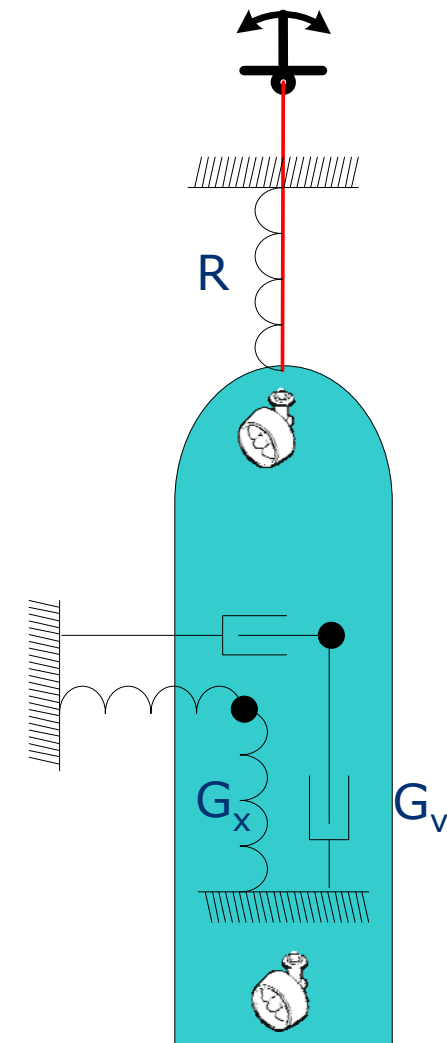
Case #3

Basic problem

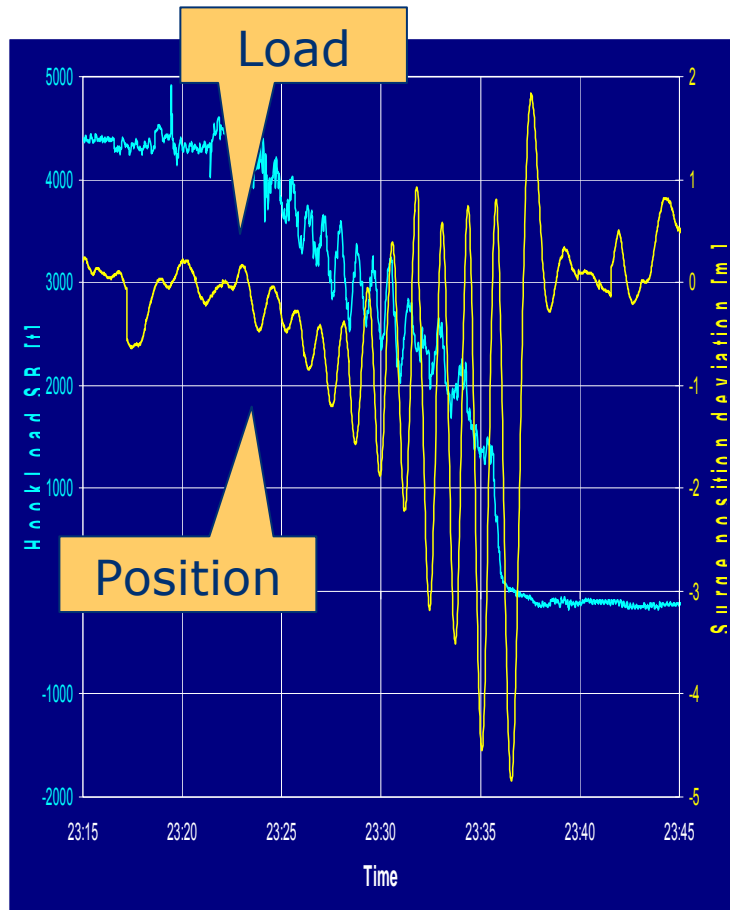
- Mooring force is unknown
- Mooring restoring stiffness unknown
 - May be high
- Relationship restoring – damping violated
 - May be fixed if mooring known

$$G_v = 2\xi\sqrt{m(R+G_x)}$$

- DP and mooring may “fight” each other
- Relative DP
 - Reference may move
- Special “anchor assist” functionality available
 - Can not change physics .



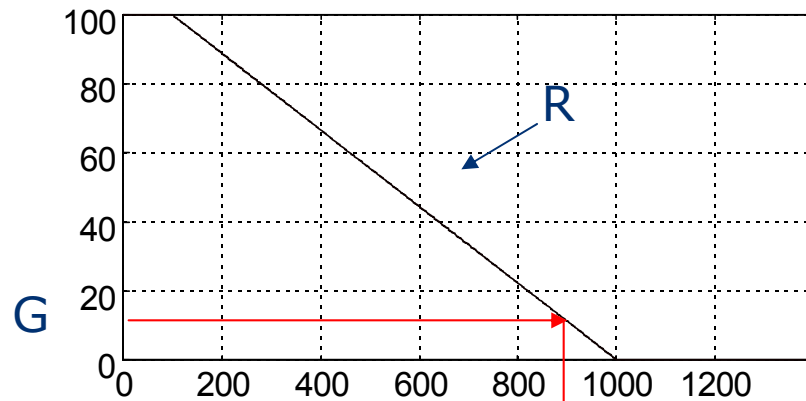
Heavy lifting



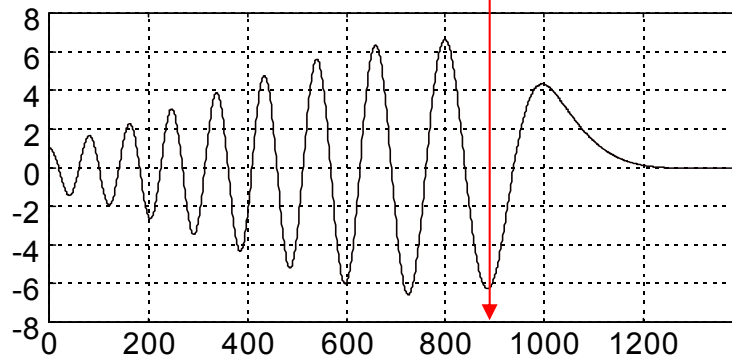
- Oscillations due to interconnection
 - Too large DP bandwidth
 - Relative position measurements do not help
 - Special severe when lifting to moored structure
- Very different from free floating bodies

Mooring and DP

Mooring stiffness

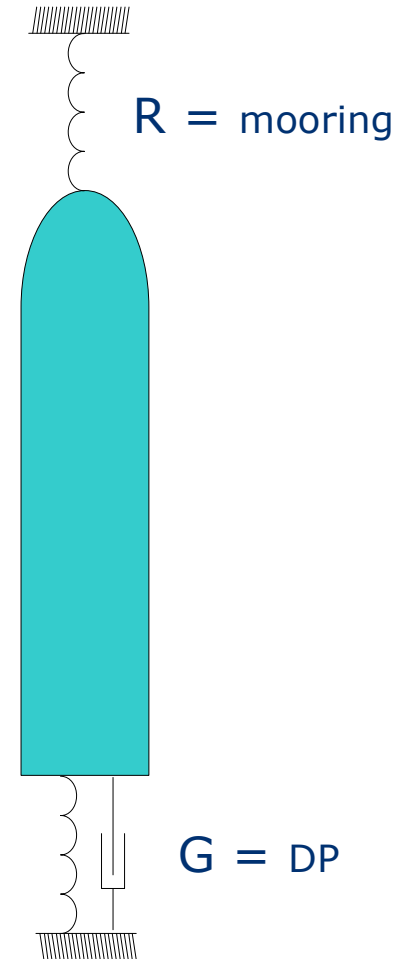


Motion



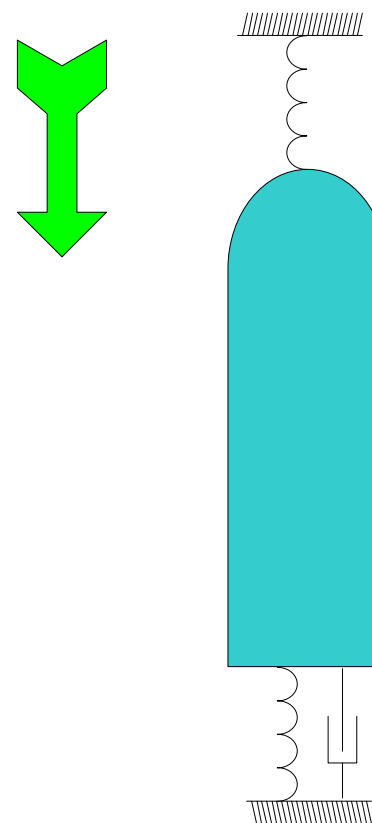
Time

OK when
 $R \leq G$



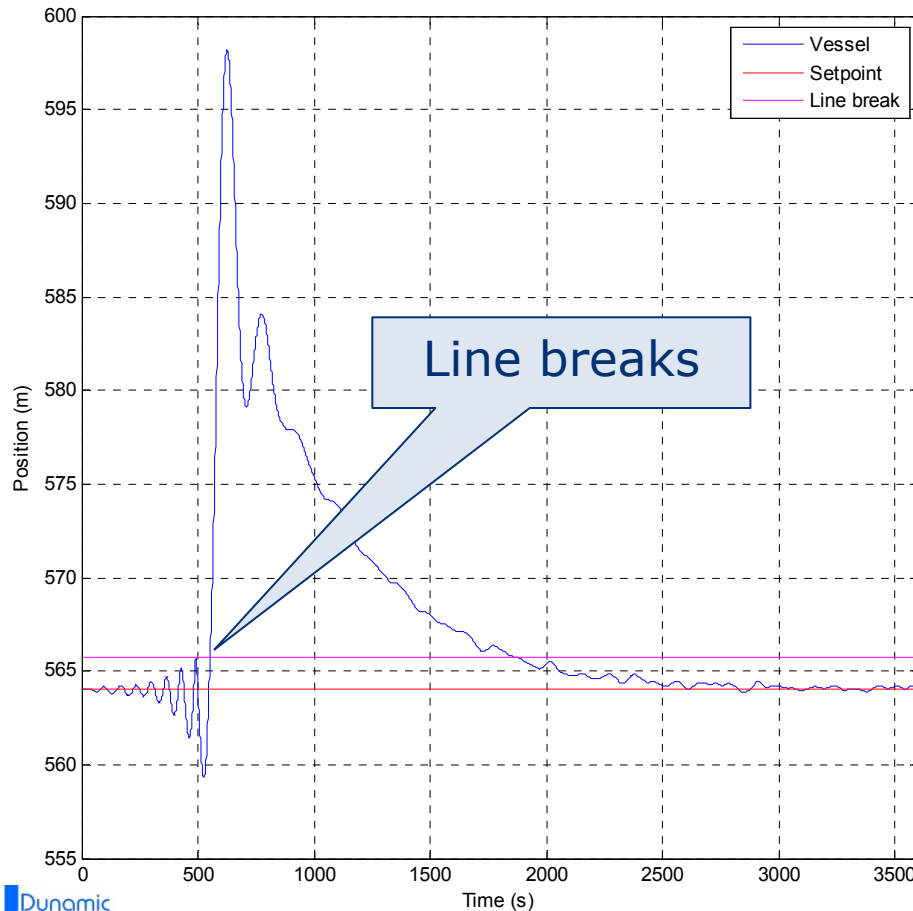
Case #1 Fixed mooring

- Mooring must be pre-tensioned to assure stability and avoid collision if blackout
 - Define minimum restoring stiffness
 - Define maximum restoring stiffness
 - Offsetting by thrusters (if needed)
 - Stiffness is generally unknown
- Stability problem if mooring stiffness exceeds DP stiffness
- Anchor dragging severe problem
- Line break disaster



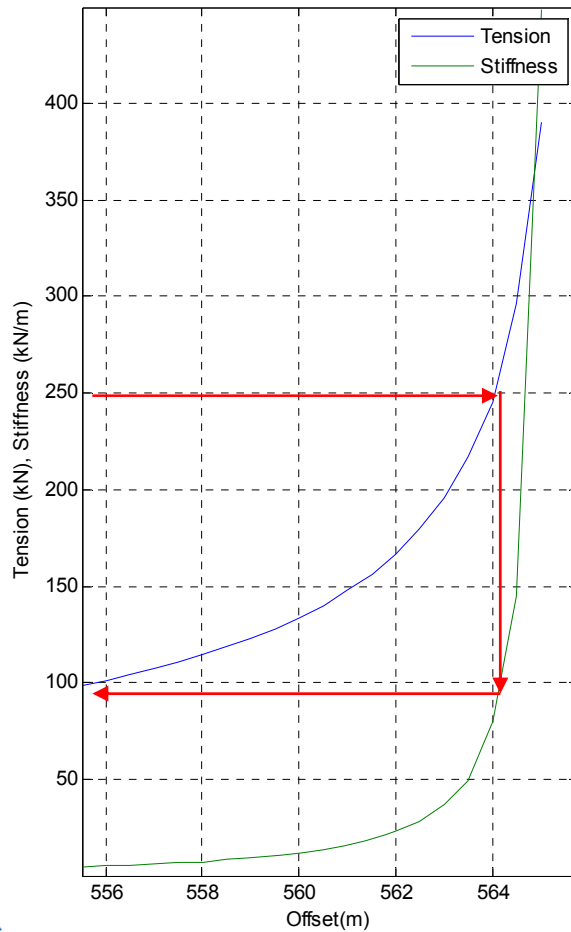
Case #1

Single anchor moored - Disaster



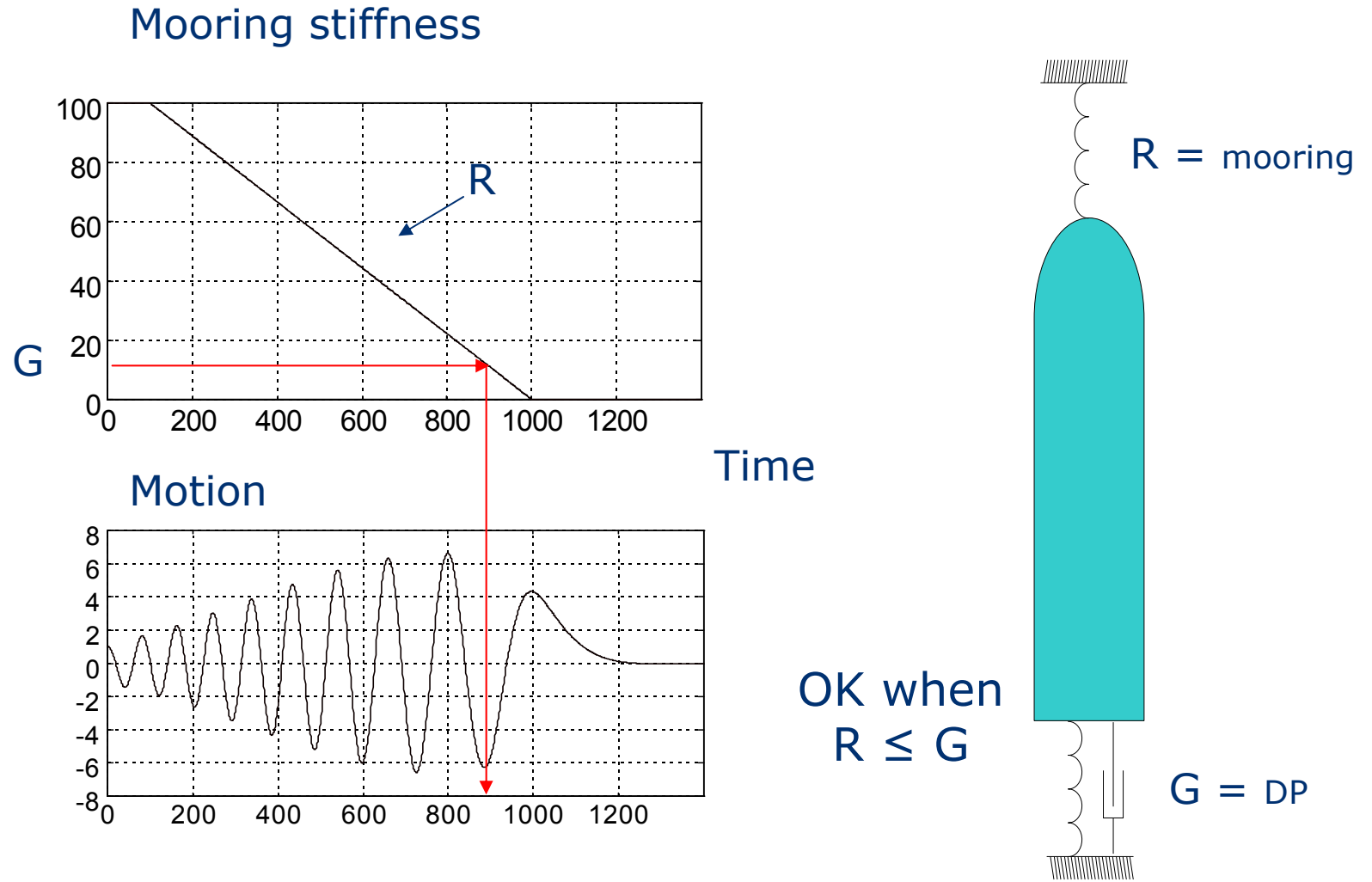
- Wire mooring
 - Diameter 66 mm
 - Length 600 m
 - Depth 200m
- Environmental forces 250 kN
- DP set-point at equilibrium
- Explanation:
 - Disturbance excite mooring
 - DP pumps energy into the system
 - Mooring stiffness too high, or needs much quicker DP control and thruster response

Case #1 Stiffness



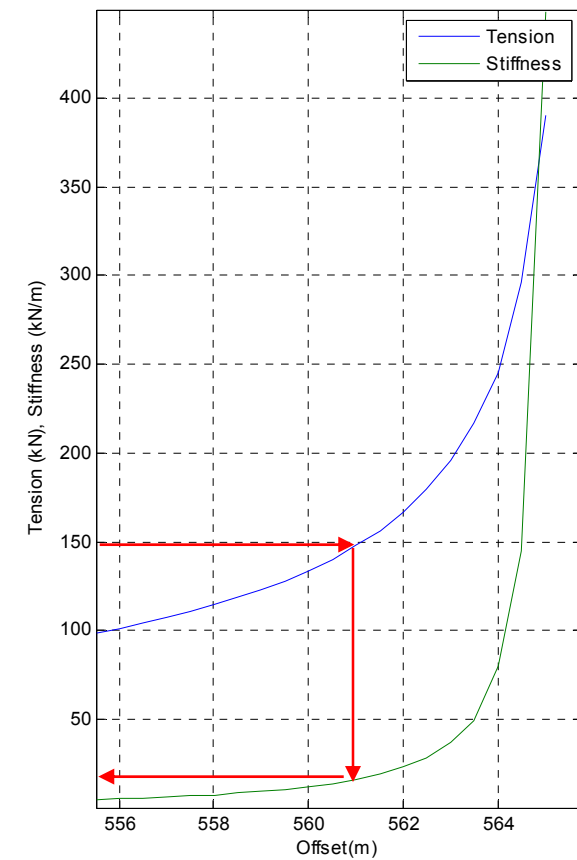
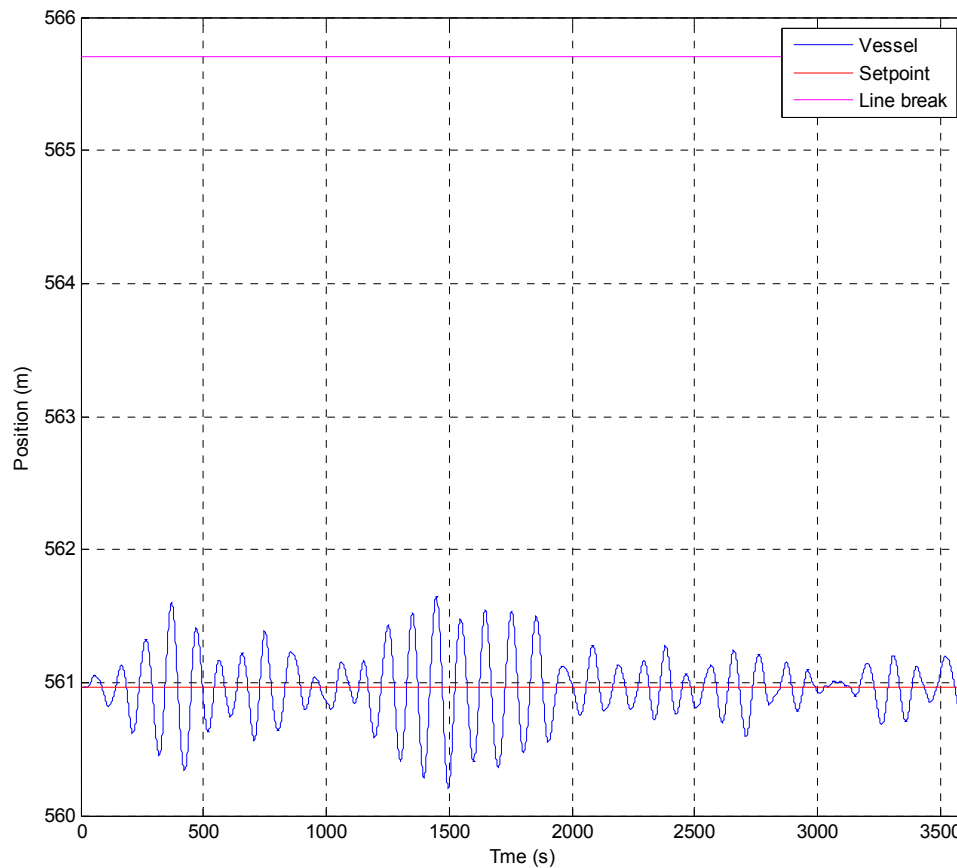
- Mooring stiffness 100kN/m
- DP stiffness 30 kN/m

Mooring and DP



Case #1

Single anchor mooring – On the limit

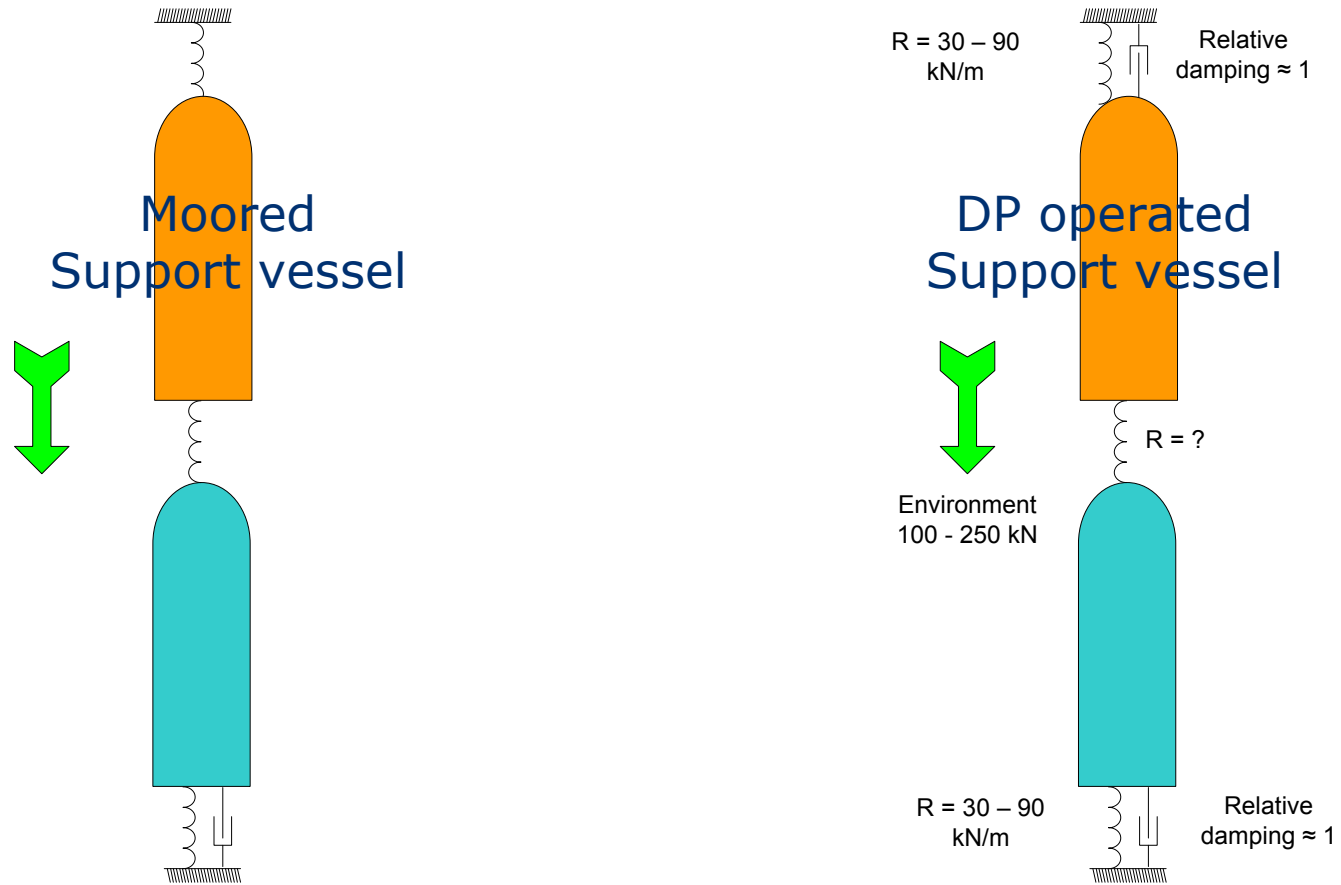


- Environment 150 kN

- Mooring stiffness
- DP stiffness

20 kN/m
30 kN/m

Vessel to vessel mooring



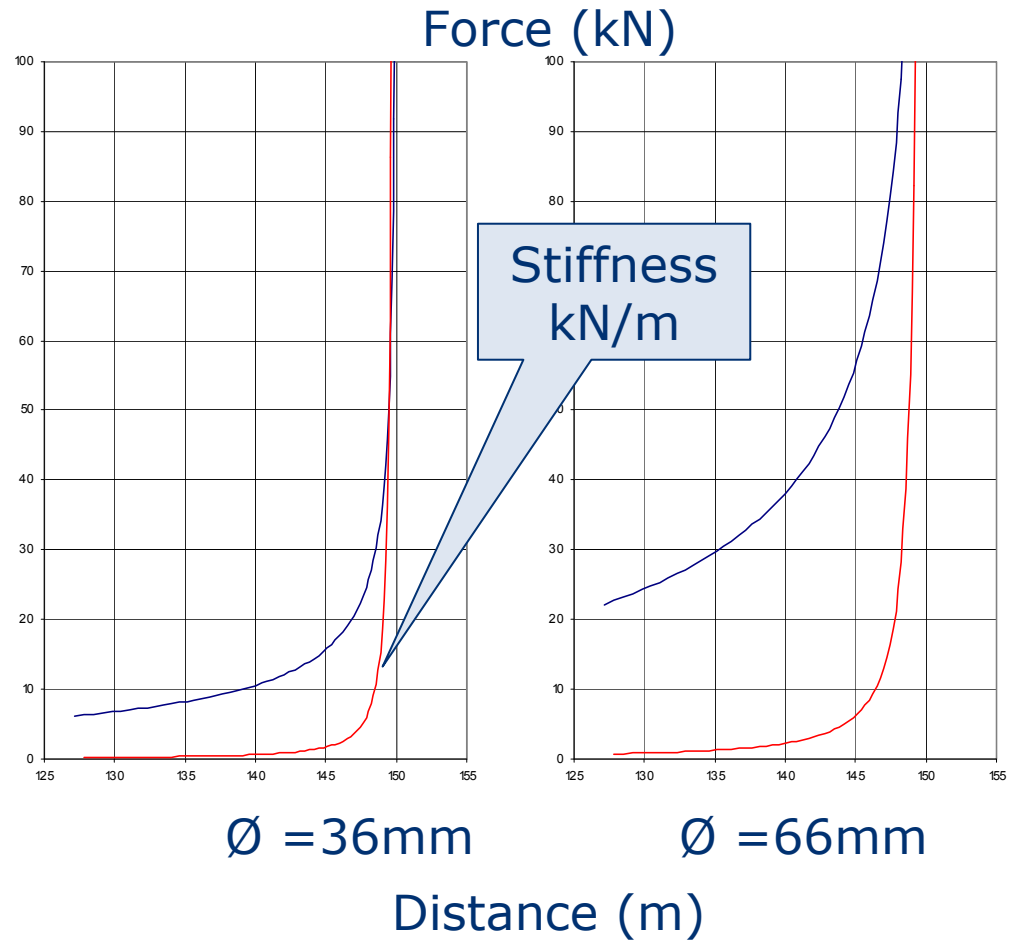
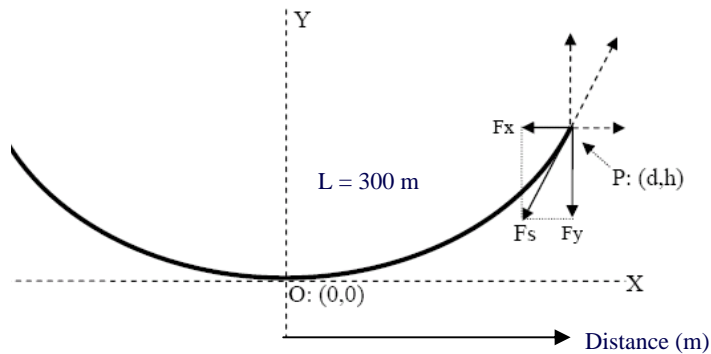
$R = 500 - 1000$
 kN/m

Vessel to vessel mooring

- Catenary

$$d = \frac{L^2 - h^2}{2h} \ln\left(\frac{L+h}{L-h}\right)$$

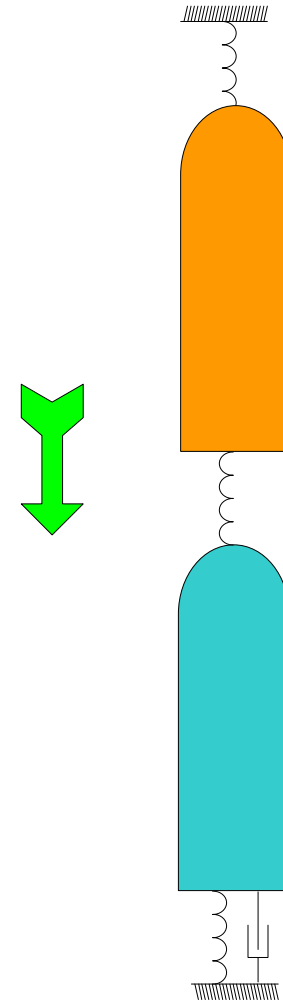
$$F_x = \frac{w(L^2 - h^2)}{2h}$$



Case #2

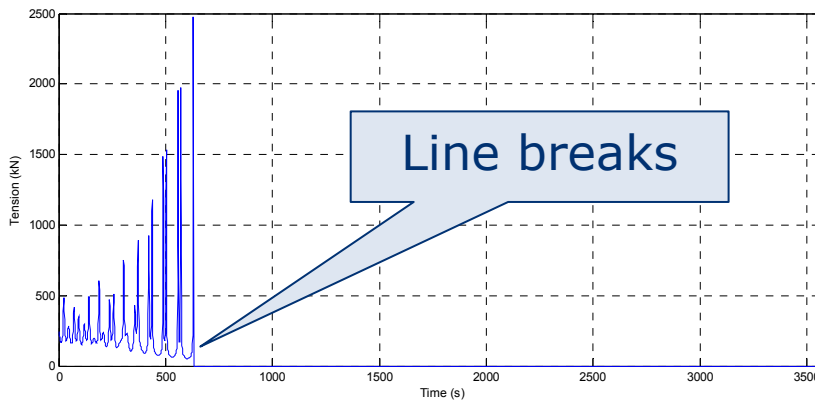
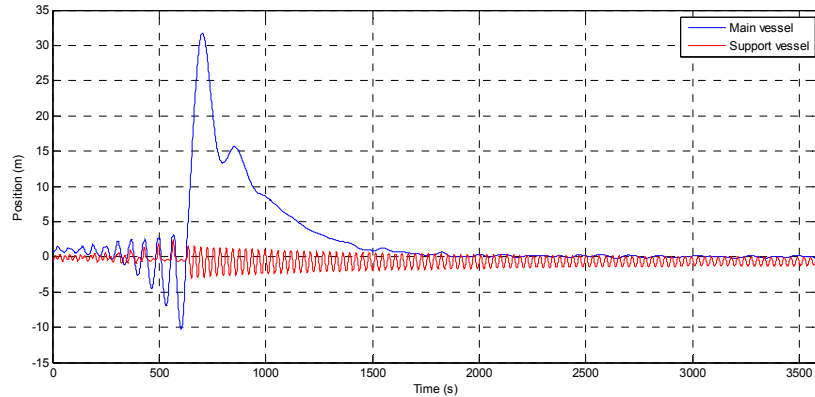
Moored to moored support vessel

- Mooring must be pre-tensioned to assure stability and avoid collision if blackout
 - Define minimum restoring stiffness
 - Define maximum restoring stiffness
 - Offsetting by thrusters (if needed)
 - Stiffness is generally unknown, but high
- Stability problem
- Anchor dragging severe problem
- Anchor line break disaster



Case #2

Moored to moored support vessel - Disaster

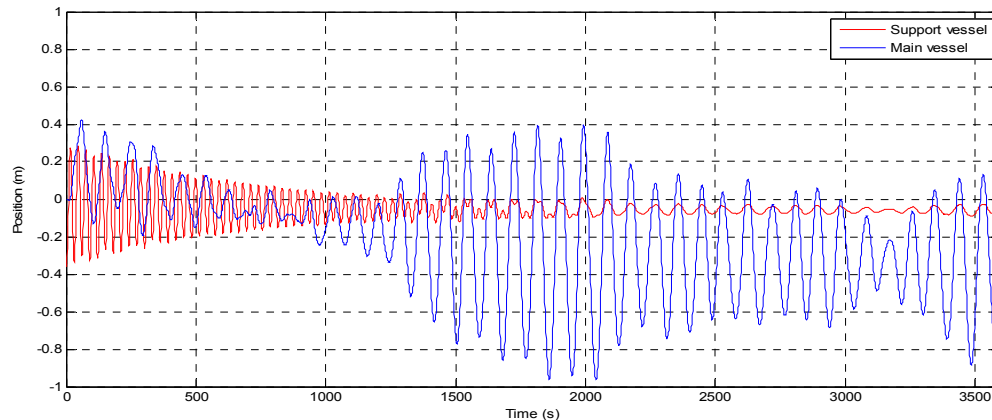


- Wire mooring between vessels
 - Diameter 66 mm
 - Length 300 m
- Environmental forces 250 kN
- Support vessel in equilibrium
 - Four point mooring (symmetric)
 - Diameter 66 mm
 - Length 800 m
 - Depth 200 m
- DP set-point at equilibrium

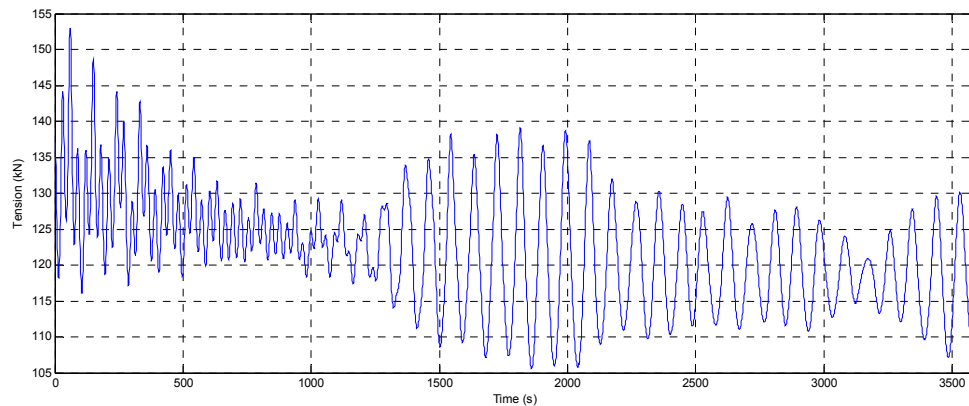
- Explanation:
 - Same story

Case #2

Moored to moored support vessel – On the limit



- Wire mooring
 - As before
- Environmental forces 140 kN
- Support vessel in equilibrium
 - Mooring as before
- DP set-points at equilibrium

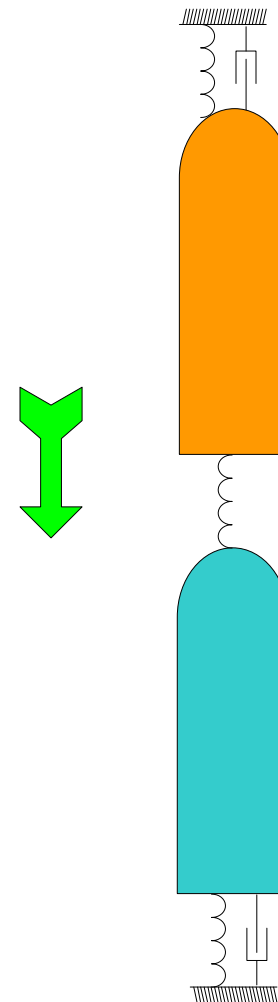


- Explanation:
 - Same story
 - Mooring stiffness matches DP
 - DP 30 kN/m
 - Vessel-vessel mooring 25 kN/m
 - Additional body

Case #3

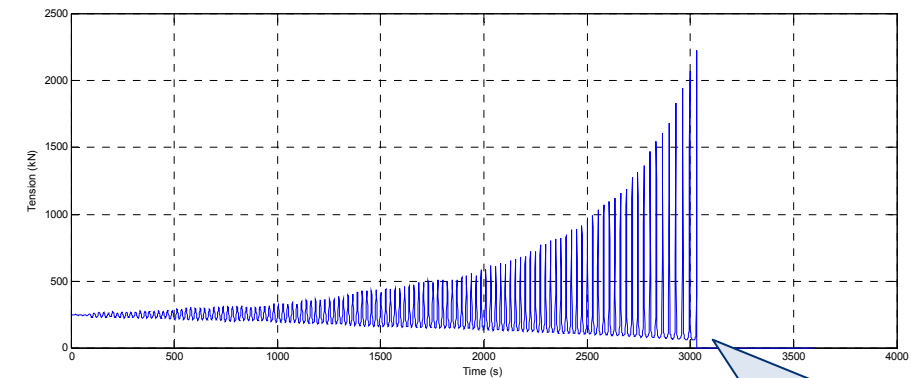
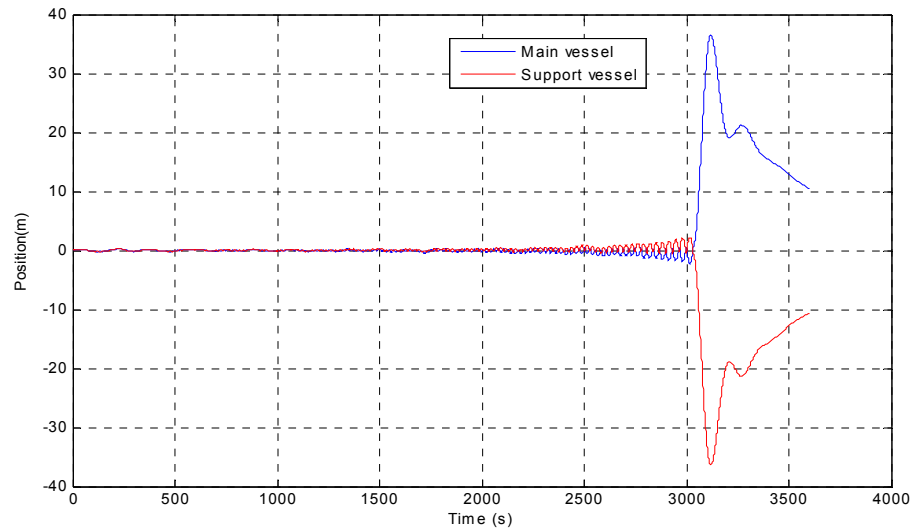
Moored to DP support vessel

- Mooring must be pre-tensioned to assure stability and avoid collision if blackout
 - Define minimum restoring stiffness
 - Define maximum restoring stiffness
 - Offsetting by thrusters (if needed)
 - Stiffness is generally unknown, but high
- Stability problem
- DP failure support vessel sever problem



Case #3

Moored to DP support vessel - Disaster

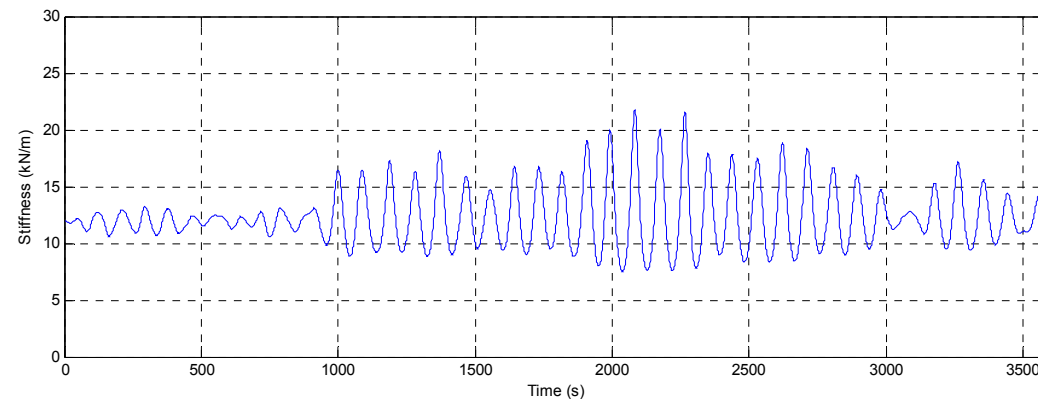
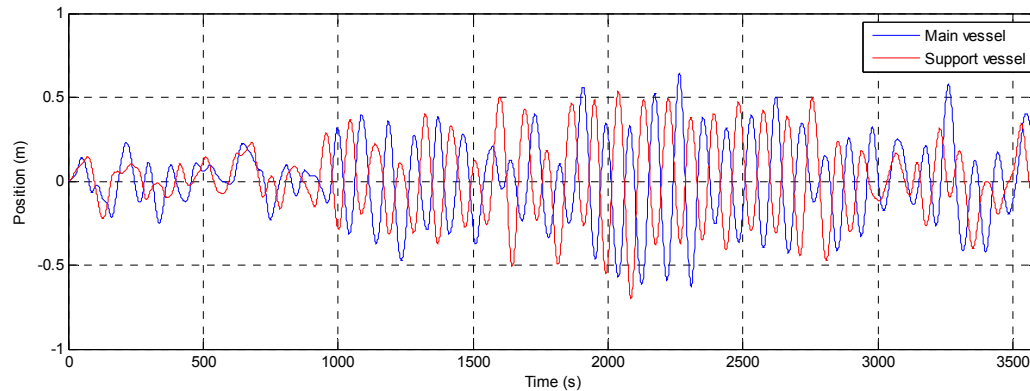


- Wire mooring
 - Diameter 66 mm
 - Length 300 m
- Environmental forces 250 kN
- DP set-points at equilibrium
- Explanation:
 - Same story

Line breaks

Case #3

Moored to DP support vessel – On the limit



- Wire mooring
 - Diameter 66 mm
 - Length 300 m
- Environmental forces 70 kN
- DP set-points at equilibrium

- Explanation:
 - Same story
 - Mooring stiffness matches DP
 - DP 30 kN/m
 - Mooring 15 kN/m
 - Additional body

Configurations Summary

From bad ...

... to worse ...

... to disaster

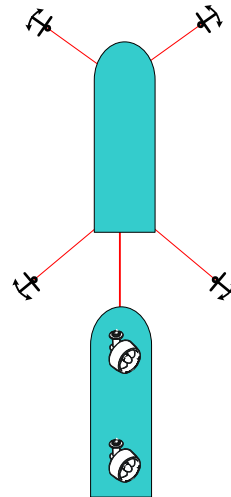
**Environment
150 kN**

**Environment
140 kN**

**Environment
70 kN**



Case #1



Case #2



Case #3

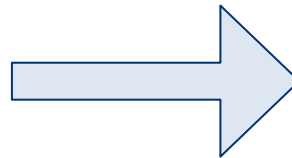
Additional hazards

Moored to moored support vessel



Hold-back vessel

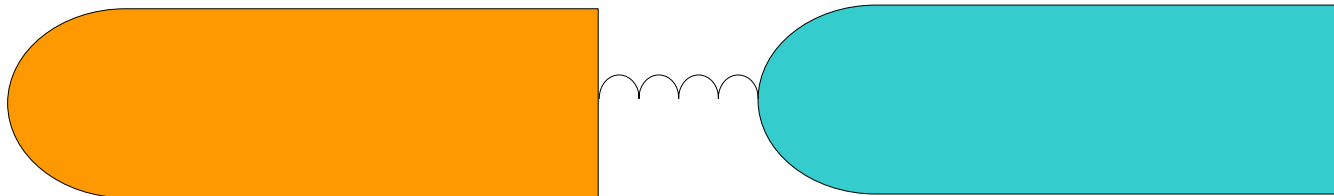
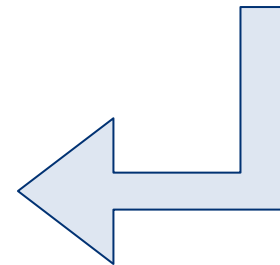
- Drive-off
- Black out
- Positioning instability



Main vessel

- Positioning instability

- Positioning instability



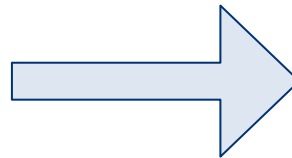
Additional hazards

Moored to moored support vessel



Hold-back vessel

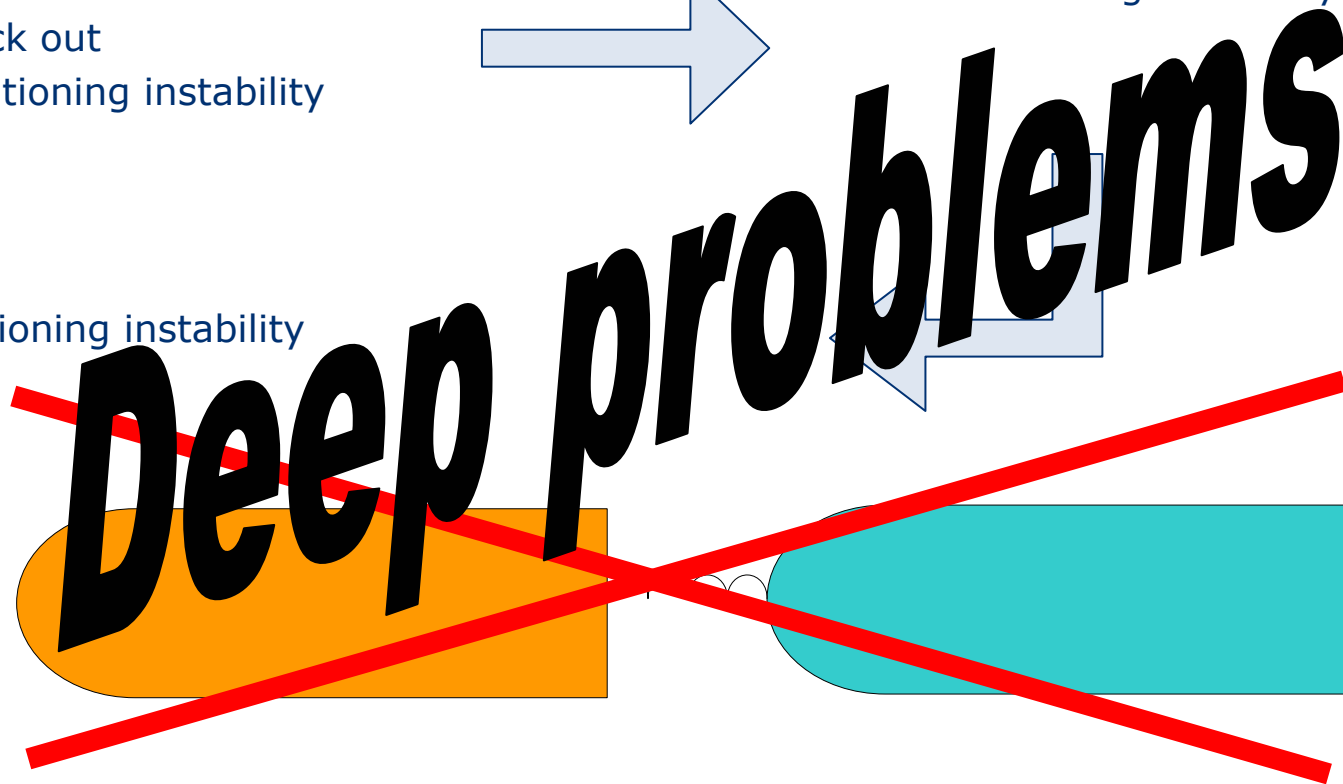
- Drive-off
- Black out
- Positioning instability



Main vessel

- Positioning instability

- Positioning instability



Alternative risk control measures IMCA M 185 (2007)

Before considering attaching a hold-back vessel:

- Reschedule operation to a time when principal hazard does not exist
- Wait for environmental conditions
- Use sea bed anchor
- Connect to another moored vessel
- Moor to a fixed facility

Good enough?

Considerations About the Use of Hold-Back Vessels
During DP Diving Operations



Alternative risk control measures

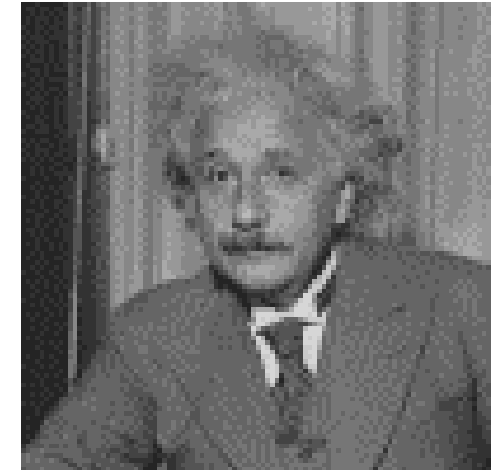
Good enough advice?

Before considering attaching a hold-back vessel:

- Reschedule operation to a time when principal hazard does not exist
- Wait for environmental conditions

YOU CAN'T BEAT THE PHYSICS

KNOW WHAT YOU ARE DOING



Considerations About the Use of Hold-Back Vessels
During DP Diving Operations

Thank you for the attention
Questions?



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