



## Thrusters

### **Thrust Degradation in DP Operations** **DP Model Test of an Aframaz Shuttle Tanker – Methods** **Results, Operations**

**Reinert Nordtveit - *Teekay Corporation***

**Bjørn Nygård - *Kongsberg Maritime AS***

**Egil Jullumstrø - *MARINTEK***

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Dynamic Positioning Conference – Houston, 2007

# Thrust Degradation in DP Operations

## DP Model Test of an Aframax Shuttle Tanker

by

Reinert Nordtveit – Teekay Corporation  
Bjørn Nygård – Kongsberg Maritime  
Egil Jullumstrø - Marintek



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# Introduction

- ▶ DP model test of an IMO Class 2 Shuttle Tanker
- ▶ Focus on
  - Thrust degradation effects
  - Environmental design criteria
  - DP performance and design evaluation
- ▶ R&D project with the partners:  
Teekay, Kongsberg Maritime and Marintek



TEEKAY CORPORATION



KONGSBERG

MARINTEK

# Teekay Corporation

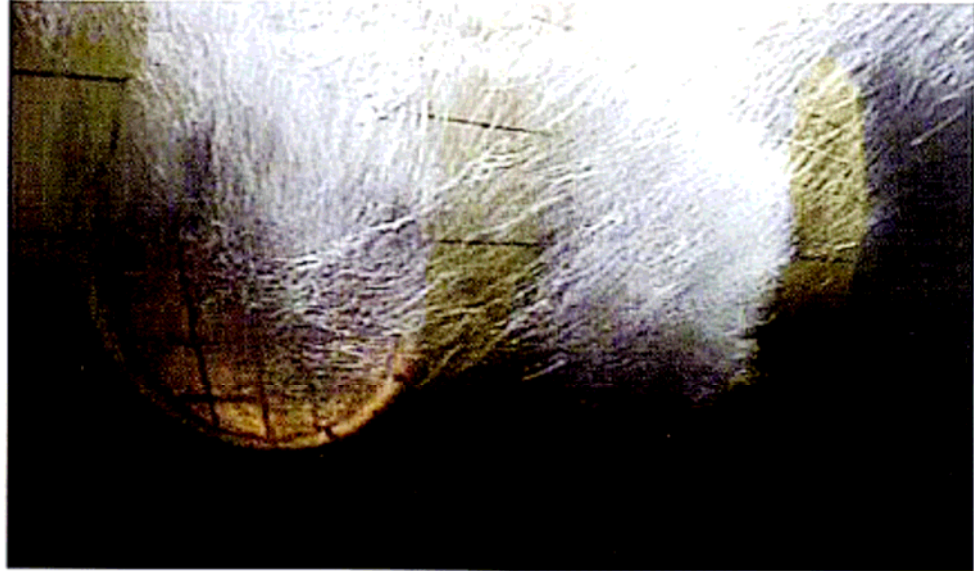
- Transports more than 10 percent of the world's seaborne oil
- Operates more than 190 vessels / 41 DP shuttle tankers
- Global organization / 17 countries / 6,300 employees
- More than 19,000 cargo lifts carried out by shuttle tankers during the past 25 years
- Offshore loading using DP control is a safe and reliable operation
- Continuous focus to improve design and operational excellence



# Project Incentive

- ▶ Experience from operations in harsh weather conditions have shown indications of lower margins on the vessel's station keeping performance than calculated by theoretical analyses such as DP capability plots
- ▶ A lack of industrial practices on how thrust degradation effects and environmental design criteria are defined and incorporated in DP capability analyses in general has been identified
- ▶ The main drivers are to further improve the safety, efficiency and regularity of offshore loading operations

# Dynamic Positioning - Force Balance Exercise

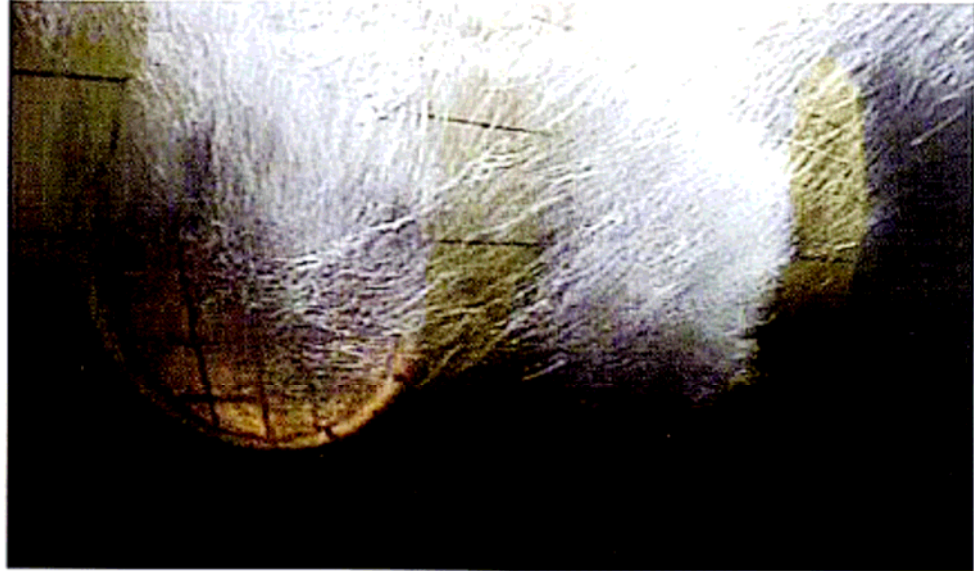


*An extreme ventilation event of tunnel thrusters in waves.*

## Propeller forces counteract drifting forces

- ▶ Propeller forces delivered by
  - ▶ Main propellers and high lift rudders
  - ▶ Tunnel and azimuth thrusters

# Dynamic Positioning - Force Balance Exercise



*An extreme ventilation event of tunnel thrusters in waves.*

## Propeller forces counteract drifting forces

- ▶ Drifting forces determined by
  - ▶ Environmental conditions
  - ▶ Vessel's main particulars

# Environmental Design Criteria

- ▶ Environmental design criteria for offshore loading
- ▶ Corresponding to Halten area – Norwegian Sea

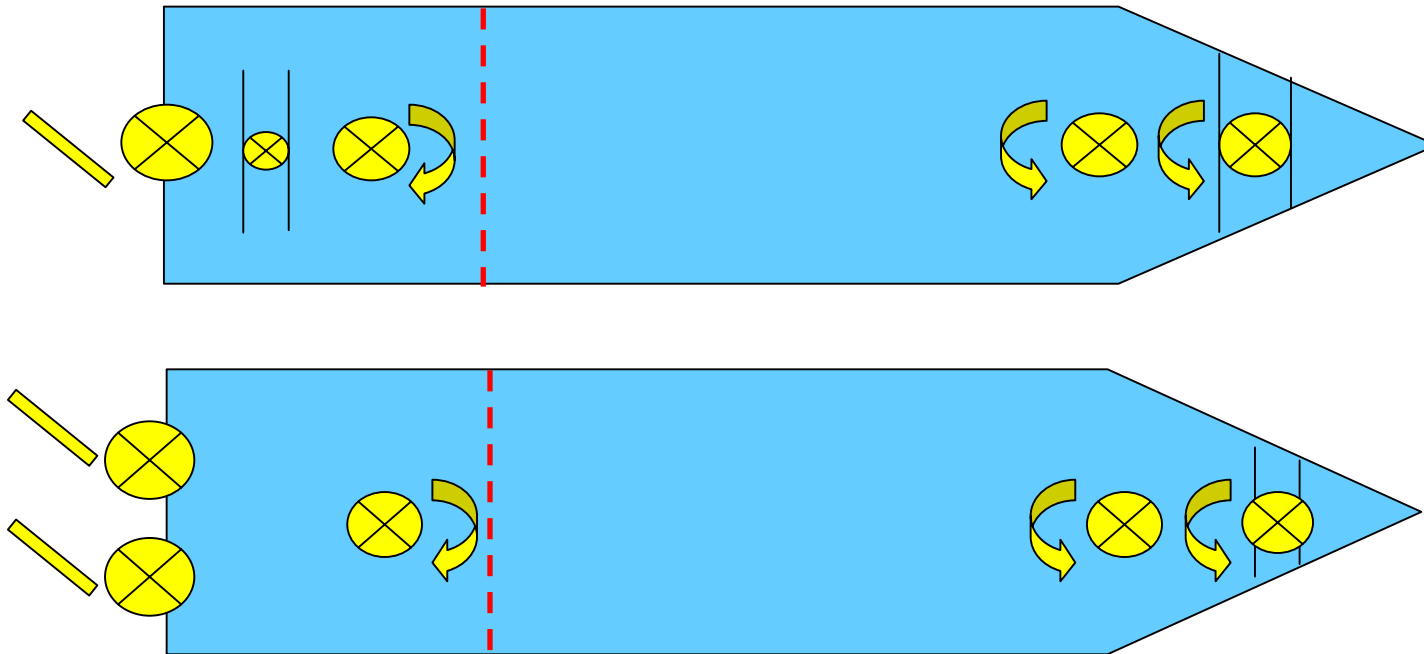
|                                      | Connection | Disconnection |
|--------------------------------------|------------|---------------|
| Significant wave height [Hs]         | 4.5 m      | 5.5 m         |
| Wind speed [U10]                     | 31 knots   | 38 knots      |
| Current speed [Cv]                   | 1 knot     | 1 knot        |
| Wave spectrum peak period [Tp]       | 11 Seconds | 12 Seconds    |
| Wave spectrum                        | JONSWAP    | JONSWAP       |
| Peak enhancement factor [ $\gamma$ ] | 1.8        | 1.8           |

# Thrust and Propeller Forces

Nominal thrust – Thrust degradation = Thrust available

- ▶ Thrust degradation  $\tau = \frac{T}{T_{nom}}$
- ▶ Thrust degradation affected by
  - thruster-hull interactions (Coanda)
  - thruster-thruster interactions
  - sea current
  - wave effects
  - ship motions
  - thruster ventilation

# Model and Thruster Configuration



- ▶ Two aft ships; single and twin screw
- ▶ Interchangeable forebody
- ▶ Model scale 1:25,  $L \approx 10$  m , Displ.  $\approx 6.9$  mt

# Model and Thruster Configuration



# Thrust Loss Model Test

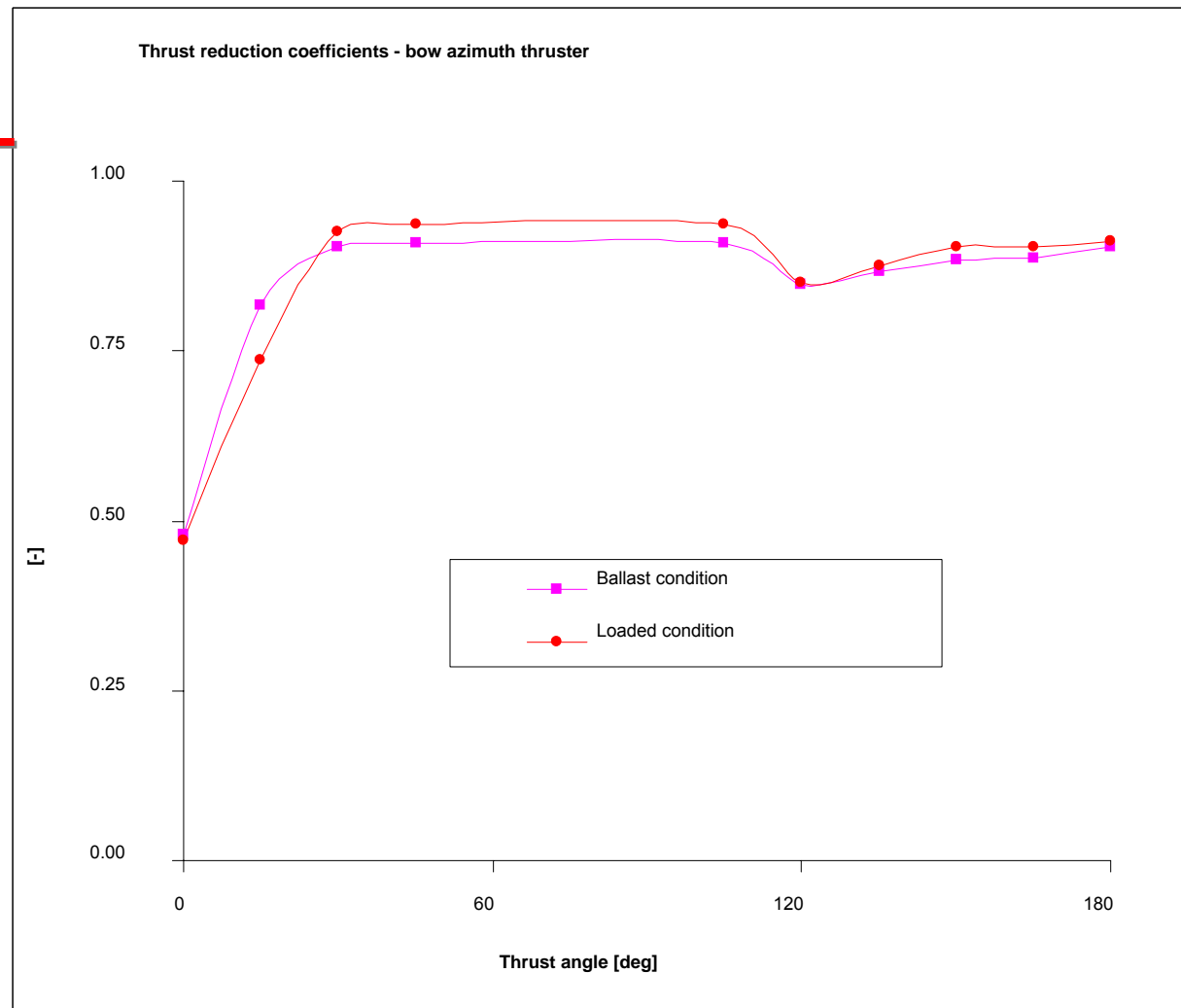
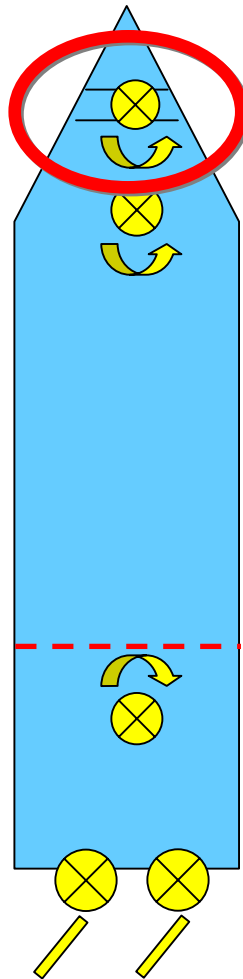
- ▶ Measurement of thrust degradation for
  - ▶ Main propellers and rudders - single and twin screw
  - ▶ Tunnel thrusters - fwd and aft
  - ▶ Azimuth thrusters – fwd and aft
- ▶ Loading conditions
  - ▶ Ballast
  - ▶ Loaded
- ▶ Environmental Conditions
  - ▶ Calm water
  - ▶ Offshore loading criteria; connection and disconnection
  - ▶ Corresponding to Halten Area in the Norwegian Sea

# Thrust Loss Model Test

- ▶ Thrust degradation measurement program comprised the following
  - ▶ Open water characteristics for all propeller and thruster units
  - ▶ Thruster – thruster interactions
  - ▶ Thruster – hull interactions
  - ▶ Thruster – rudder interactions
  - ▶ Tunnel thruster losses
  - ▶ Thrust degradation due to current
  - ▶ Thrust degradation due to waves
  - ▶ Thrust degradation due to ventilation

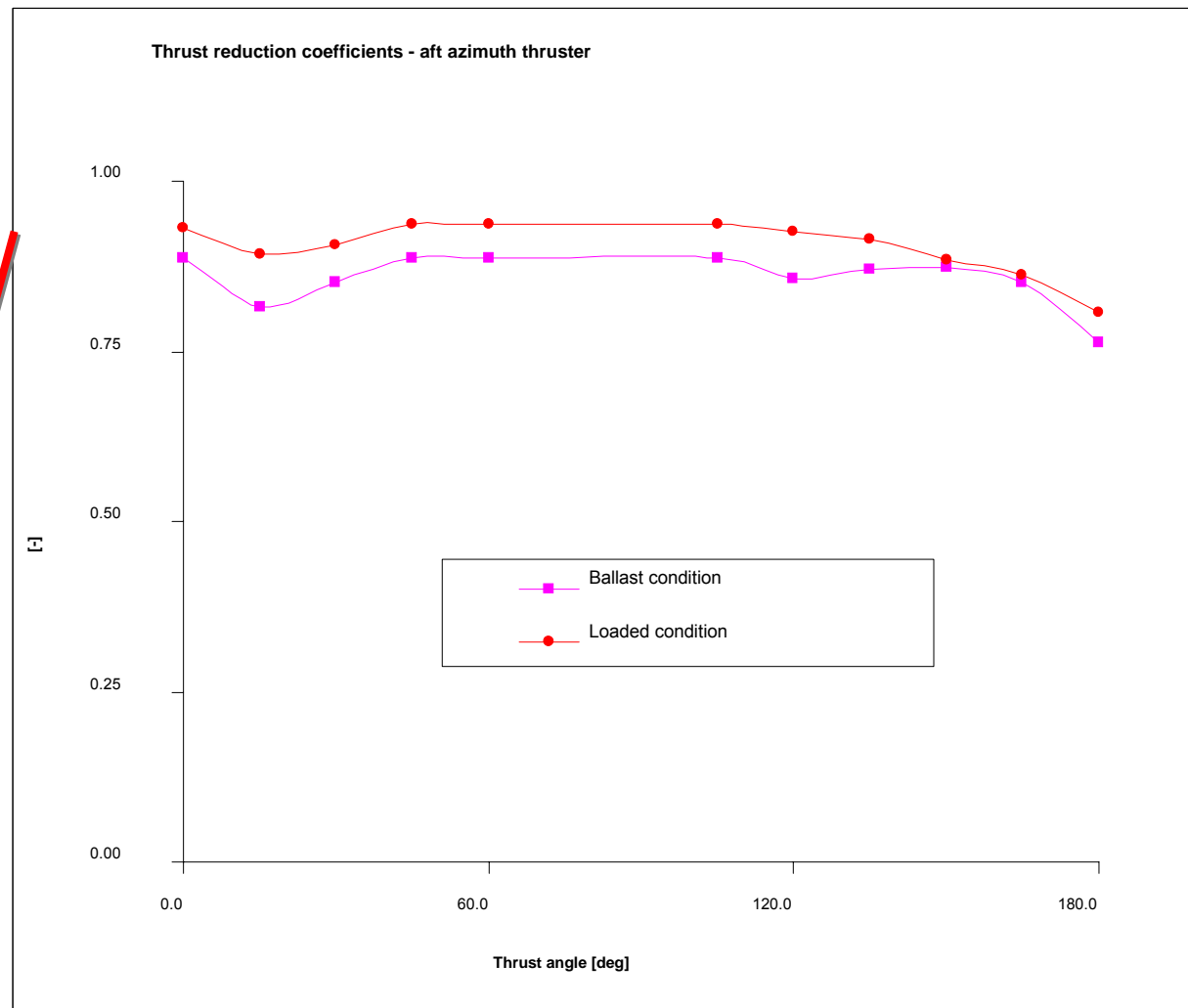
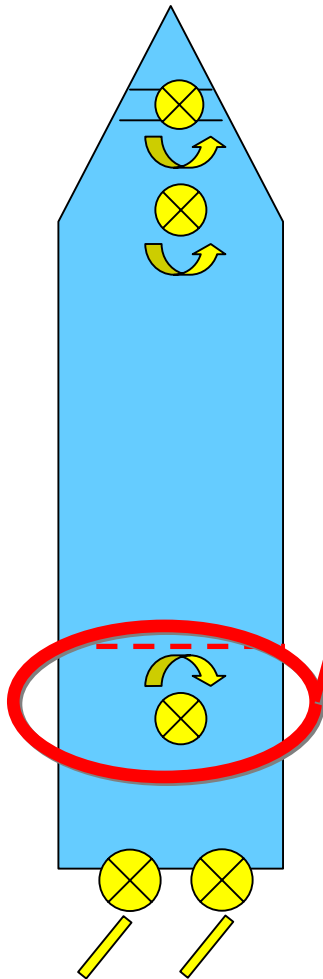
# Thrust Loss Model Test - Results

- ▶ Thrust degradation measurements for bow azimuth thruster



# Thrust Loss Model Test - Results

- ▶ Thrust degradation measurement for aft azimuth thruster



# Thrust Loss Model Test - Results

- ▶ Thrust degradation measurement for main propeller and tunnel thrusters

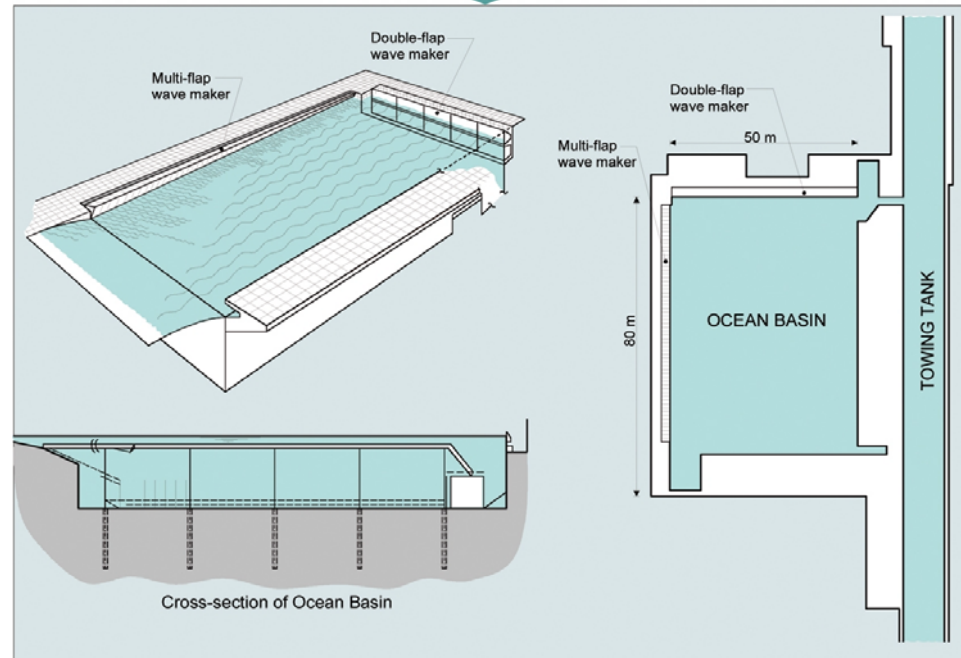
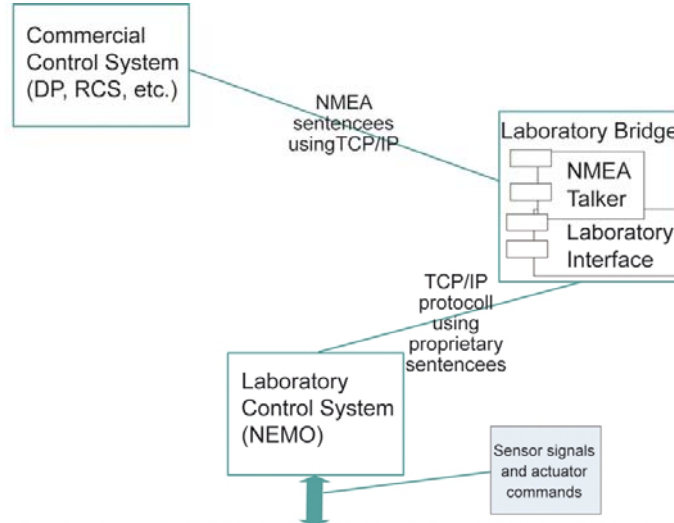
| <i>Thrust degradation coefficients –<br/>Main propeller and tunnel thrusters</i> |                          |                         |
|--|--------------------------|-------------------------|
|  | <i>Ballast condition</i> | <i>Loaded condition</i> |
| <b>Main propeller<br/>single-screw</b>   | <b>0.75</b>              | <b>0.85</b>             |
| <b>Main propeller<br/>twin-screw</b>   | <b>0.75</b>              | <b>0.87</b>             |
| <b>Tunnel thruster – bow</b>   | <b>0.65</b>              | <b>0.80</b>             |
| <b>Tunnel thruster - aft</b>   | <b>0.65</b>              | <b>0.80</b>             |

# DP Model Test

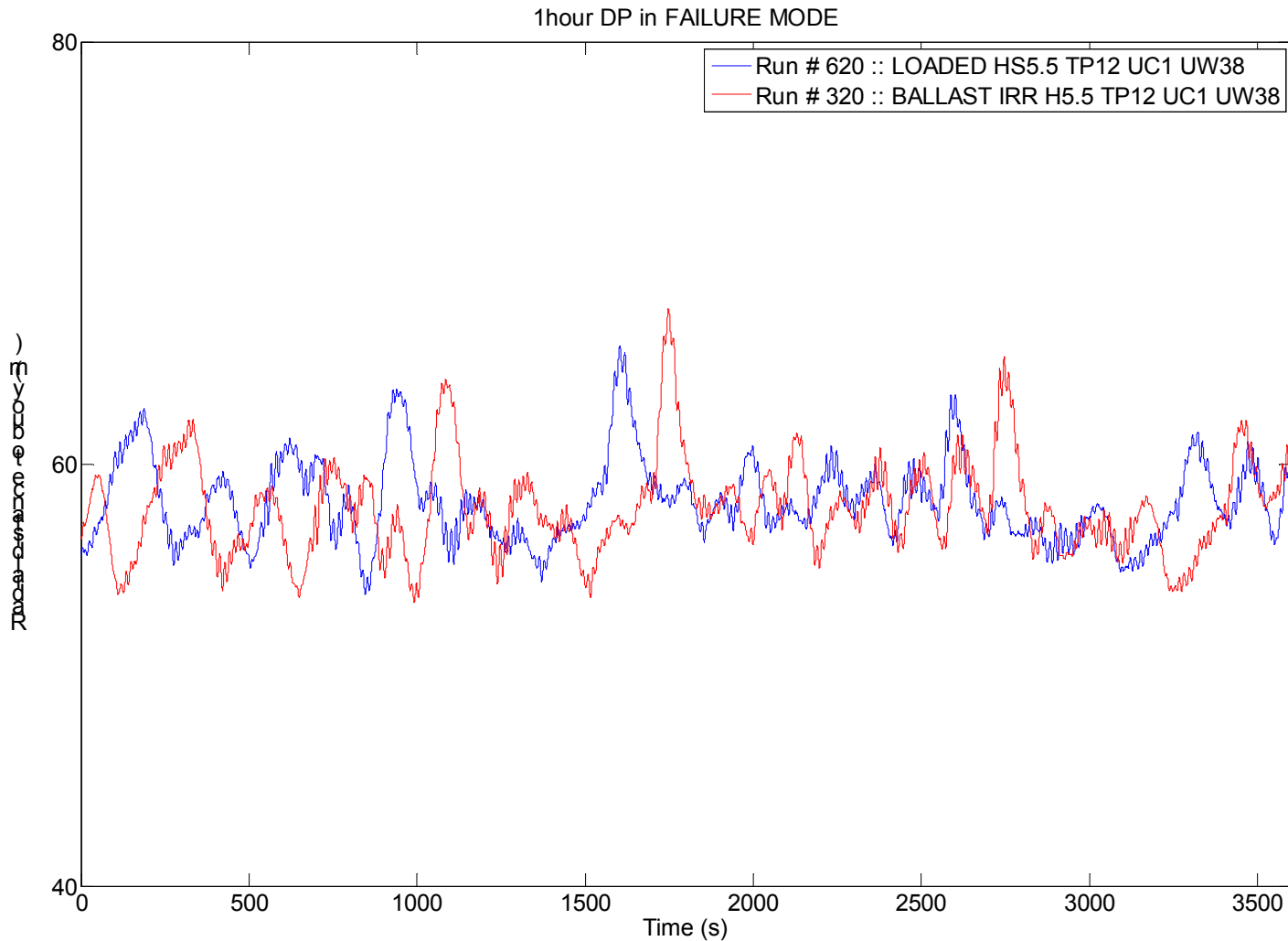
- ▶ Marintek Ocean Basin, 80m x 50m x 10m
- ▶ “Off-the-shelf” DP software
- ▶ North Sea environmental conditions
- ▶ Ballast and loaded conditions
- ▶ Intact and failure mode
- ▶ Various power settings for thrusters
- ▶ Test duration; 1 hour full scale time / 12 minutes model scale time



# DP Model Test



# DP Model Test - Results

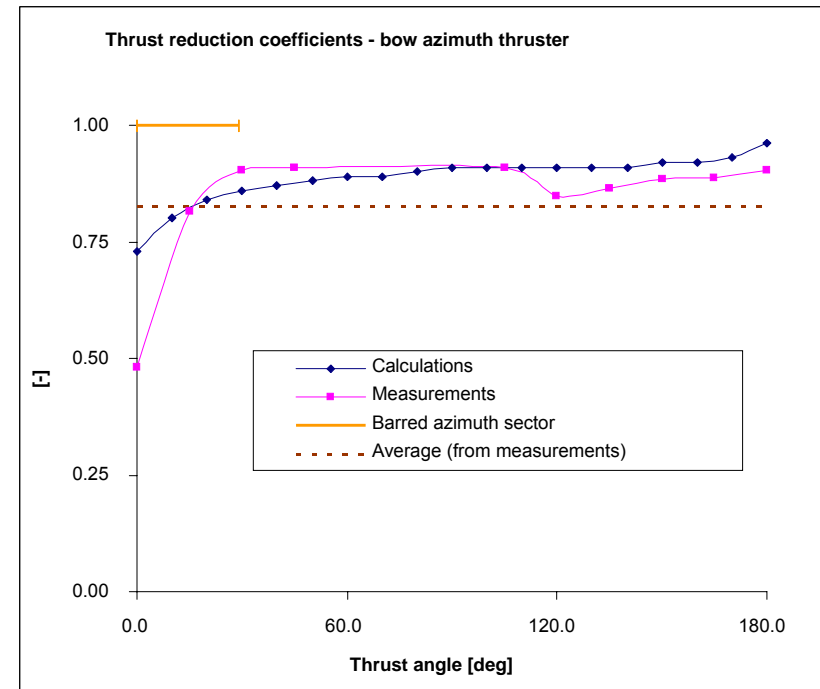
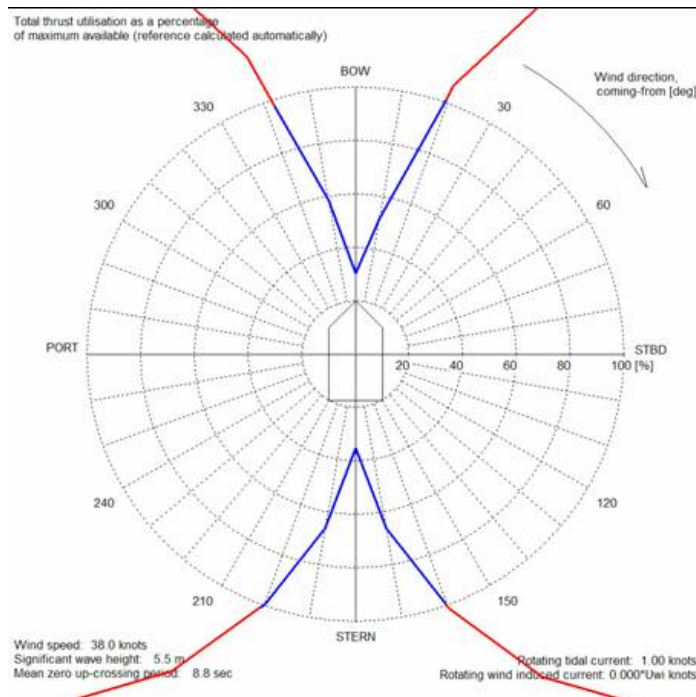


MARINTEK, 18:00 26-Sep-2007

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# DP Capability Plot

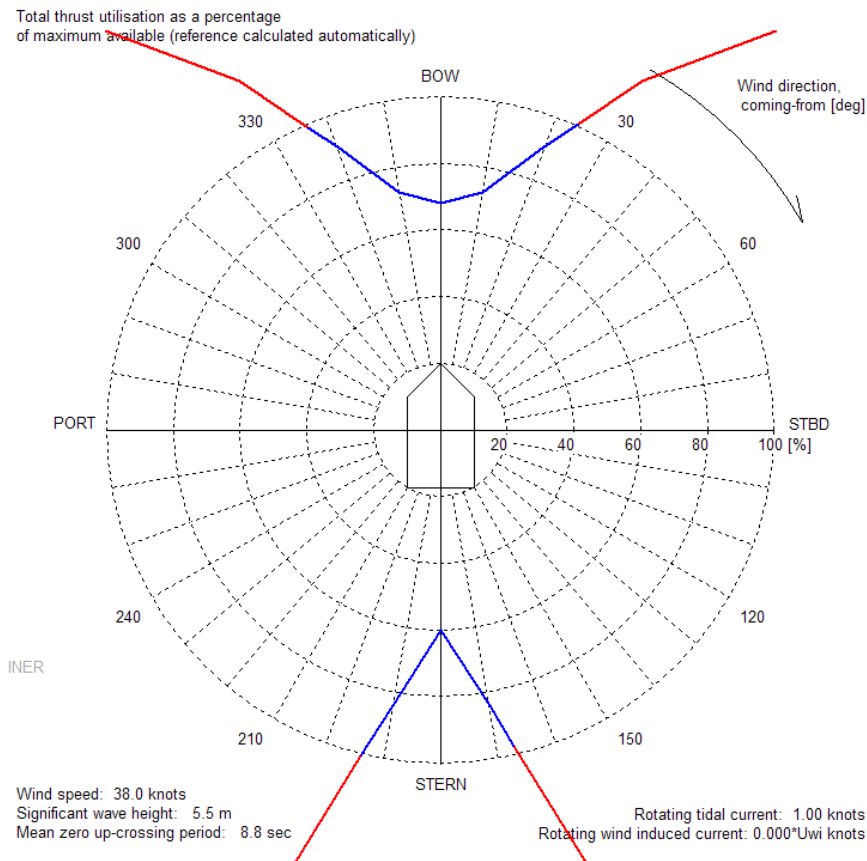
- ▶ Static force balance
- ▶ Auto position mode is assumed
- ▶ Tandem offshore loading is a “weather vane” operation
- ▶ Sector around the bow of relevance for shuttle tankers
- ▶ Thrust degradation calculation included in StatCap



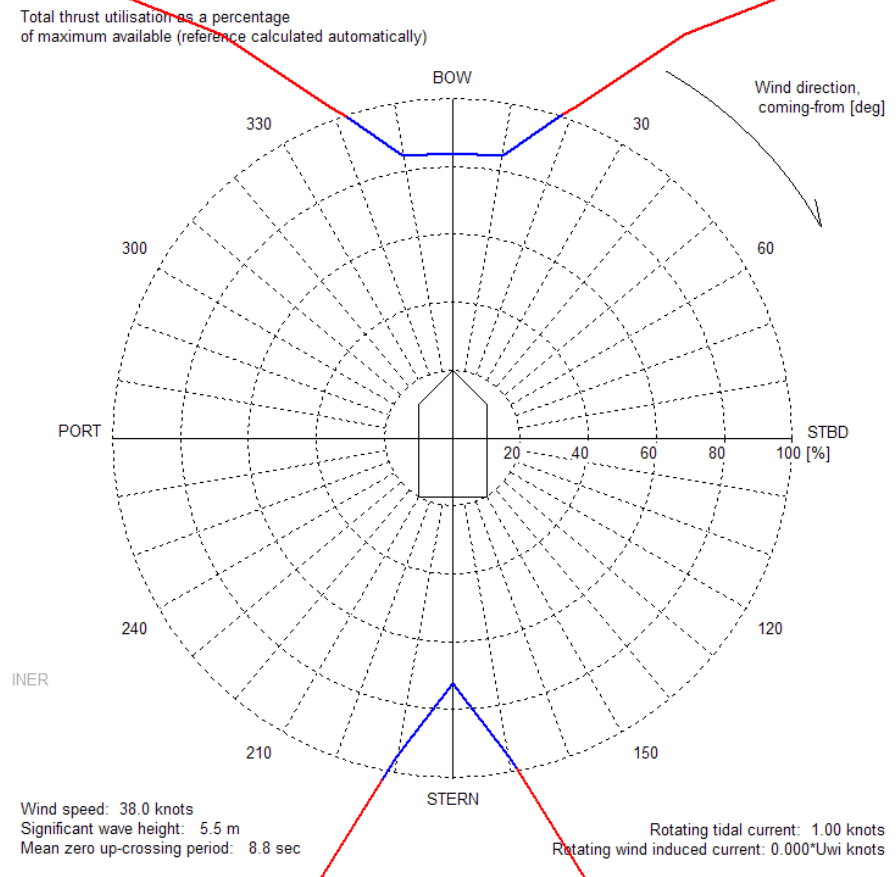
# DP Capability Plot - Example

- ▶ Worst case single failure for a DP2 single screw shuttle tanker
- ▶ North sea environmental design conditions - ballast

Plot 1: Thrust degradation not included



Plot 2: Thrust degradation included



## Conclusions

- ▶ Thrust degradation effects are of significant importance for all types of DP vessels
- ▶ Thrust degradation effects should be accounted for in design and operation of DP vessels
- ▶ Magnitude depends on vessel design, operation and environmental conditions
- ▶ Thrust degradation calculations have been included in software for DP capability analysis; KM StatCap
- ▶ Calculations correspond reasonably well with model test measurements for a shuttle tanker
- ▶ Results from DP capability analysis (capability plot) correspond well with shuttle tanker operational experience

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Questions ?

Thank you!

