Conventional Ship Testing

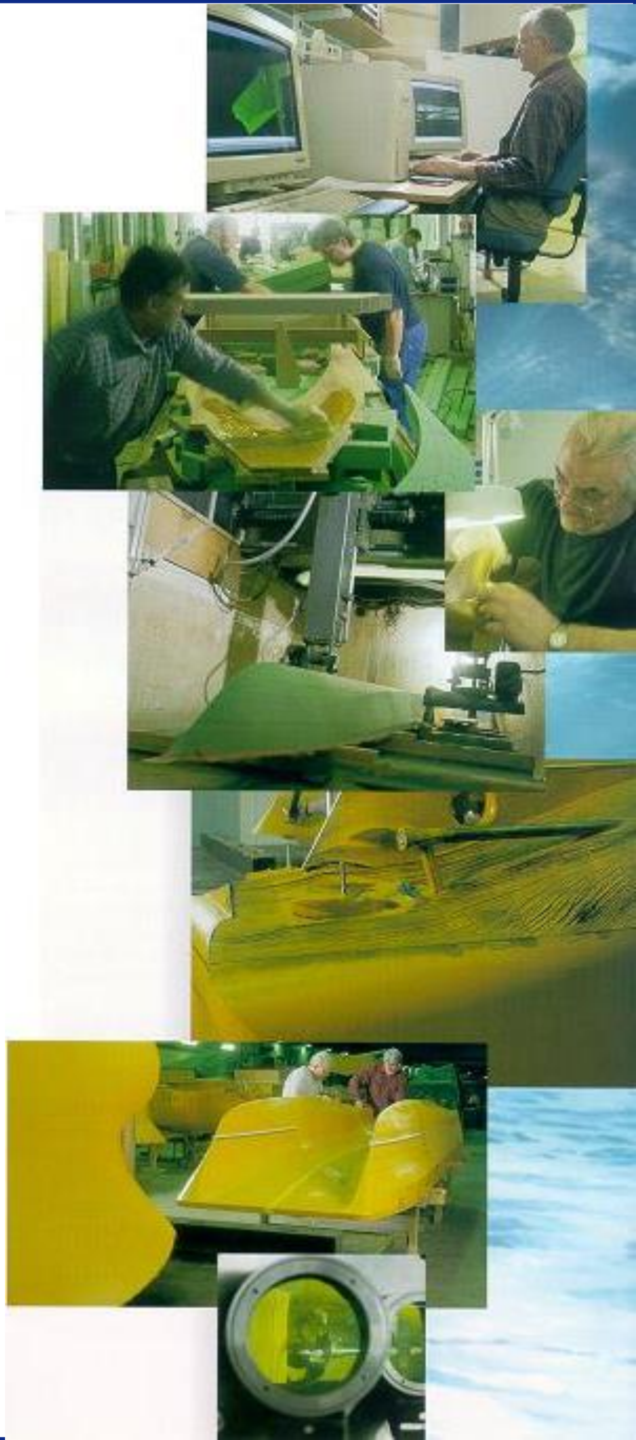
Experimental Methods in Marine Hydrodynamics

Lecture in week 34

Chapter 6 in the lecture notes

Conventional Ship Testing - Topics:

- Resistance tests
- Propeller open water tests
- Propulsion tests
- Cavitation tunnel tests
  - Cavitation observation
  - Pressure pulses
  - Noise measurements
  - Cavitation erosion
- Maneuvering tests
  - Free running maneuvering tests
  - Planar Motion Mechanism (PMM) tests

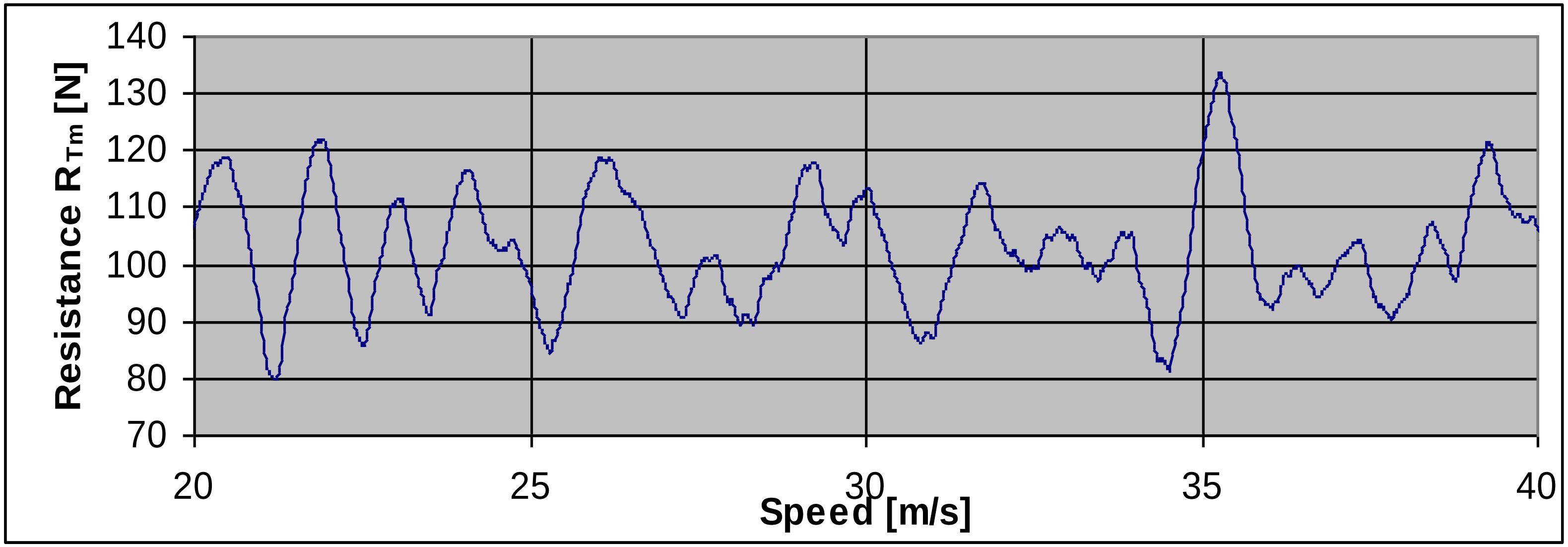


Resistance tests

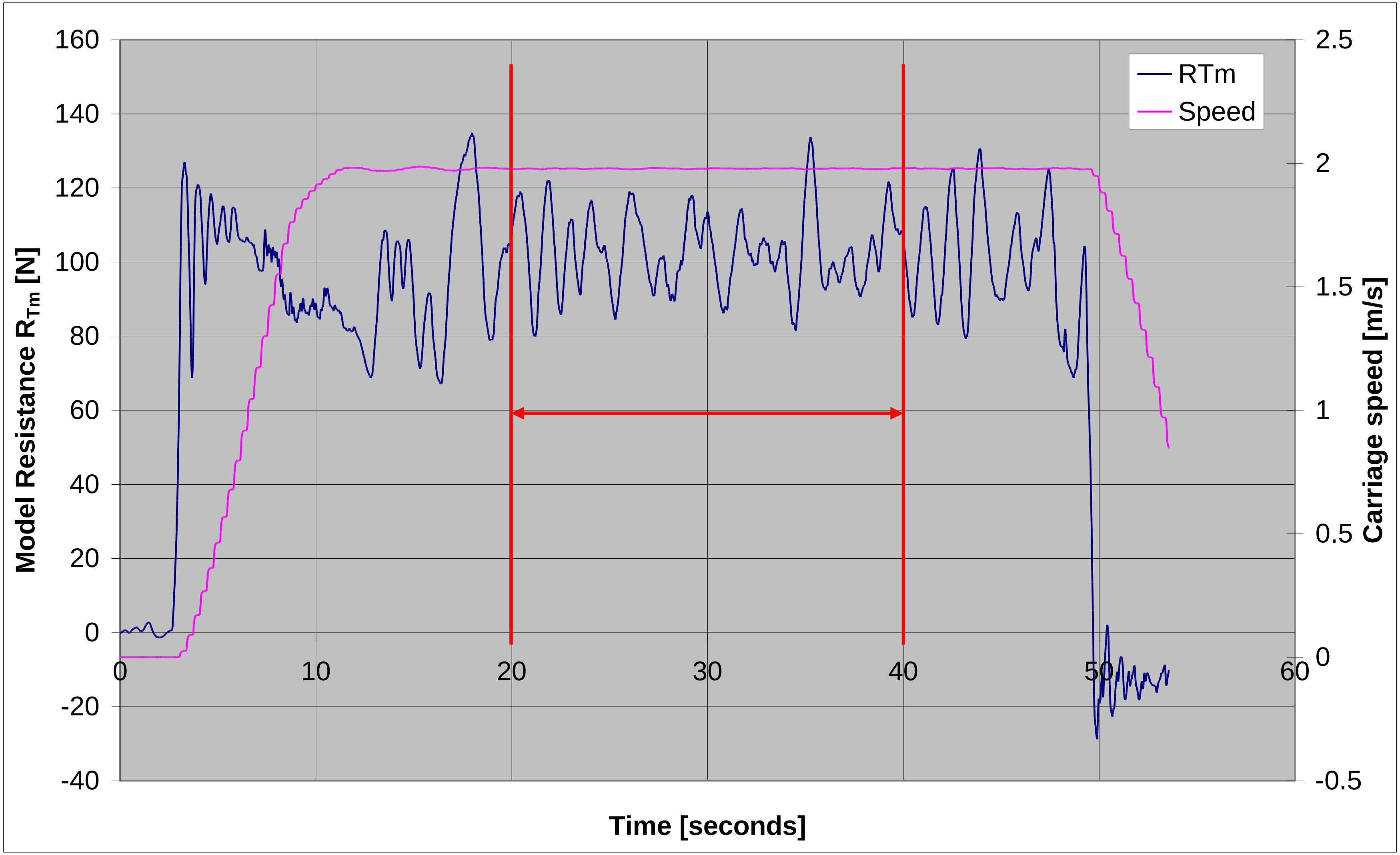
- Test procedure:
  - The model is accelerated to wanted speed
  - speed is kept constant for at least 10 seconds (or at least 10 load cycles)
  - Average values of the measurements for the period of constant speed is calculated

Required length of measurement

- The tow force might fluctuate considerably, especially for models with low Drag/Displacement ratio and large displacement
- In such cases, one needs at least ten oscillations in the time series
  - This is just a simple “rule of thumb”. We will return to this question in the lecture on uncertainty and design of experiments.
- One must make sure to leave out the transient part of the time series, which is due to the acceleration



Example time series – entire run

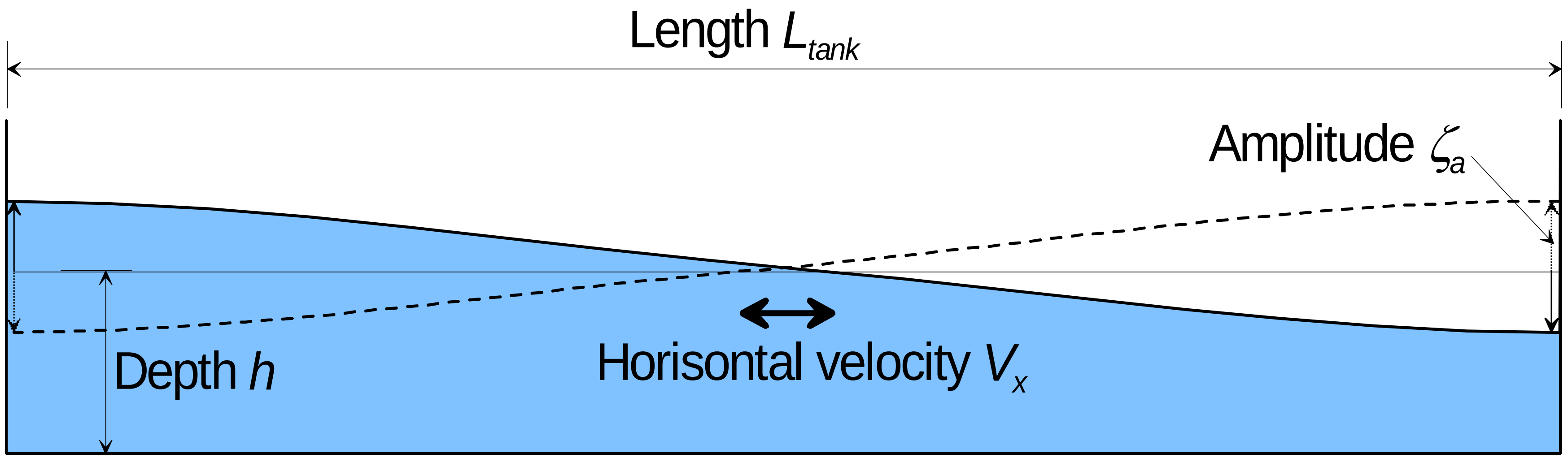


Seiching – standing waves in the tank

Wave elevation: $\zeta = \zeta_a \cdot \cos(\omega t) \cdot \sin(kx)$

Horizontal velocity: $V_x = -\dfrac{\zeta_a \cdot k \cdot g}{\omega} \cdot \sin(\omega t) \cdot \sin(kx)$

Wave period: $T \approx \dfrac{2 \cdot L_{Tank}}{\sqrt{g \cdot h}}$



Error from seishing on total resistance
- *Example from the large towing tank*

Wave amplitude $\zeta_a = 1$ cm

Horizontal max velocity $V_x = 0.03$ m/s

Carriage speed $V_m = 1.5$ m/s

Total resistance: $\propto \frac{1}{2}\rho V^2$

Induced max. error: 4%

Waiting time between runs

- Surface waves must calm down
  - Waiting time can be reduced by conventional wave dampers
  - Takes longer time in larger tanks
- Seishing must calm down
  - Might be difficult to see
  - Might be damped by special arrangements
  - Takes much longer time in larger tanks
- Waiting time will be a trade-off between:
  - Accuracy
  - Efficiency
- Typical waiting time between runs in large tanks: 15 minutes

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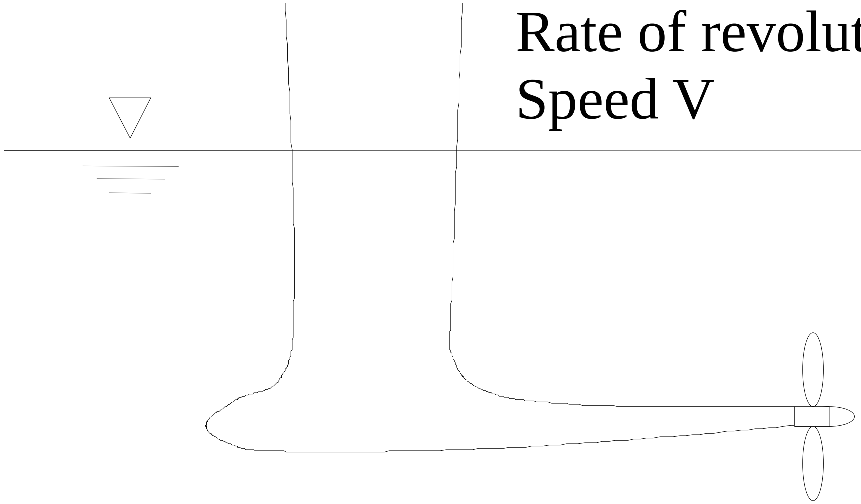
Propeller Open Water Tests
- Measurement equipment

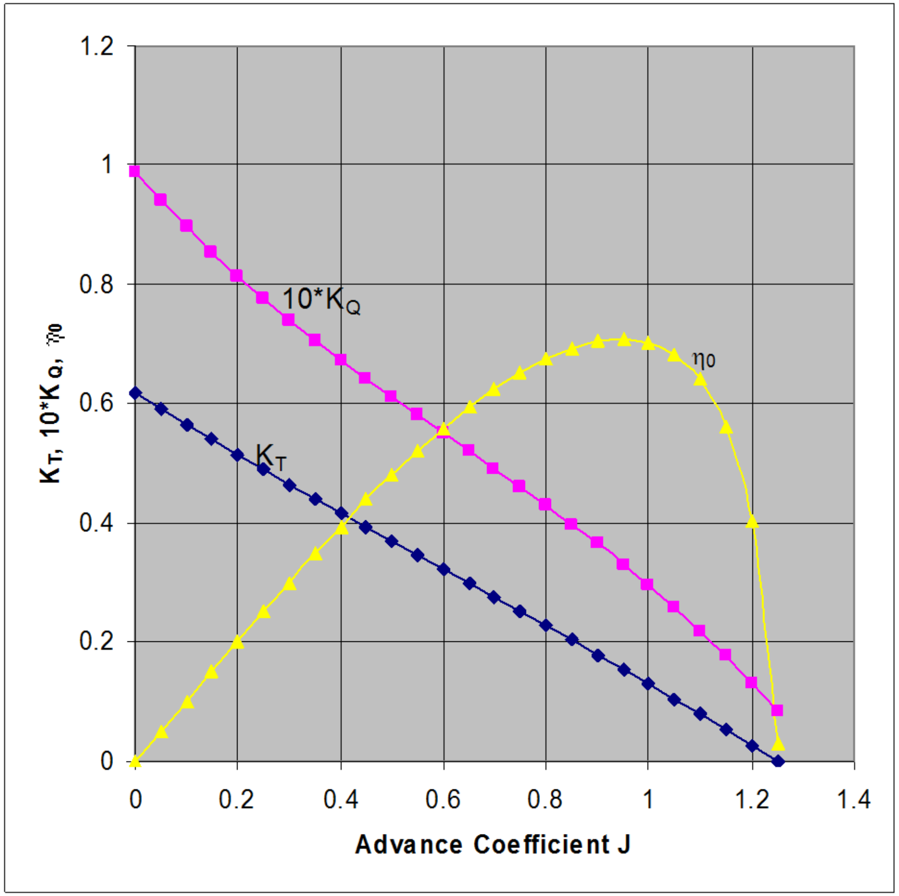
<u>Measurement of:</u>
Torque Q
Thrust T
Rate of revolutions n
Speed V



Water speed V

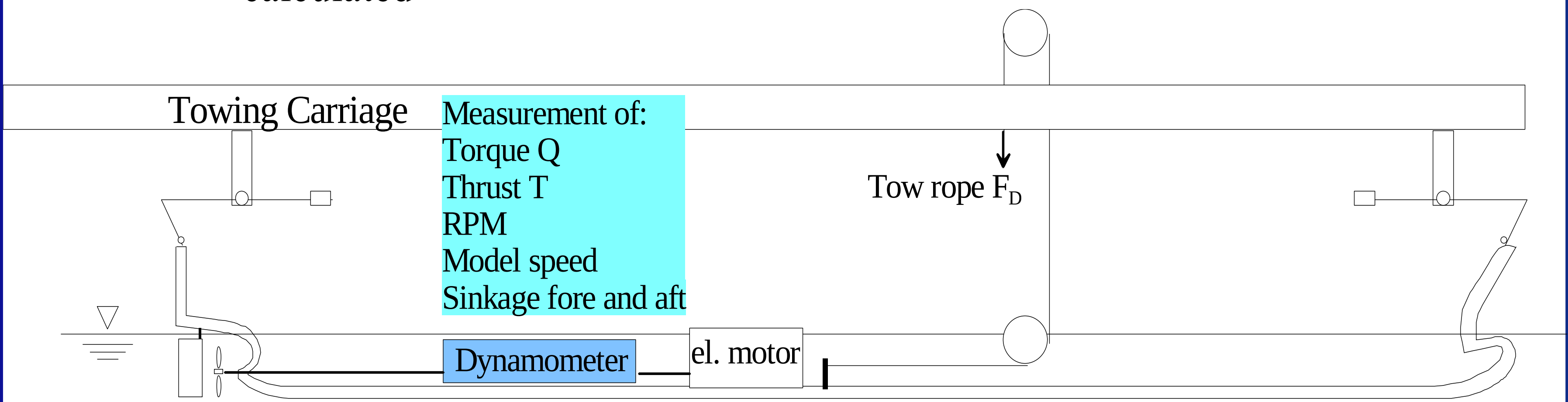
Propeller Open Water Tests - Measurement procedure

- Propeller revs are kept constant
- Carriage speed is varied in steps from zero speed to zero propeller thrust
- Tests are performed at same revs as expected for design speed in propulsion tests
- Tests might be repeated at higher propeller revs (attempted full scale condition)
- Results are presented in non-dimensional form



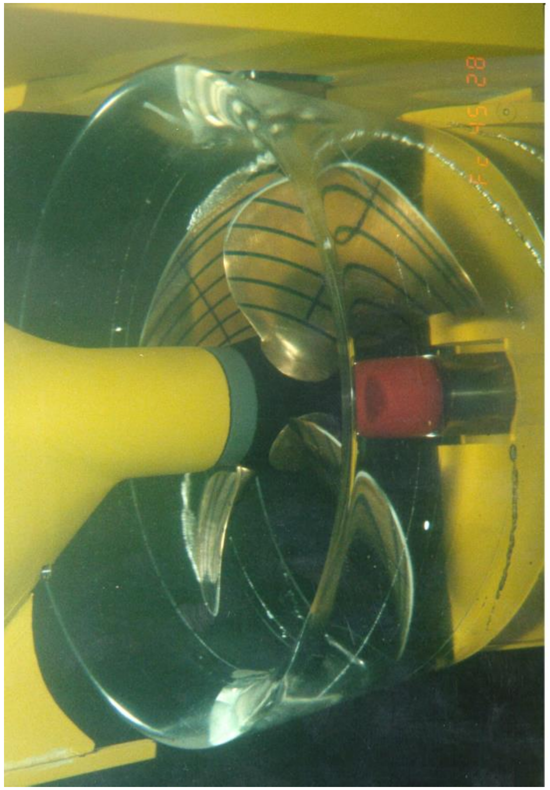
Propulsion tests

- Test procedure (Continental Method):
  - The model is accelerated to wanted speed
  - Propeller revs are adjusted so that the model is getting the same speed as the carriage, and then the model is released
  - Measurement is made with found revs for at least 10 seconds
  - Average values of the measurements for the period of constant speed is calculated



Cavitation testing of propellers

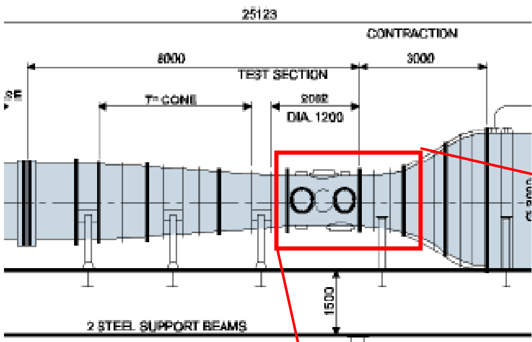
- Purpose: investigation of:
  - Cavitation induced erosion of propeller blades
  - Effect of cavitation on propulsion efficiency
  - Vibrations and noise
- Test types:
  - Cavitation observation
  - Pressure pulses
  - Noise measurements
  - Cavitation erosion

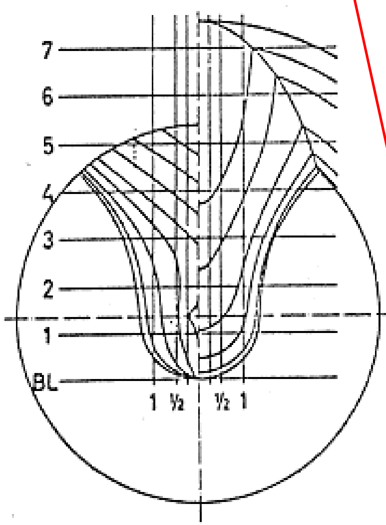


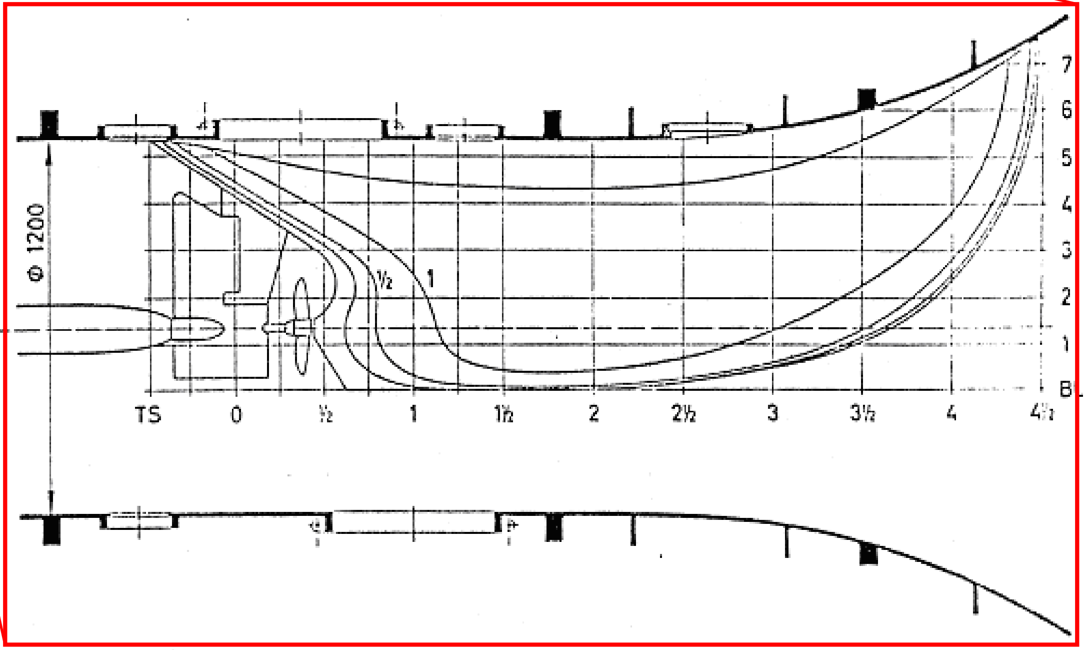
Cavitation test procedure

1. Choose flow velocity in test section based on actual advance ratio, J.
2. Install aft-body model and adjust wake field by mesh screens
3. Install propeller model
4. With atmospheric pressure in the tunnel, adjust propeller rate of revolution (and/or flow velocity) until the propeller torque is correct according to the propulsion test in the towing tank (equal K_Q). This is called the **"torque identity"** principle.
5. Keeping flow velocity and rate of revolutions constant, reduce the tunnel pressure until the specified cavitation number is achieved.
6. Do necessary cavitation observation and measurements.

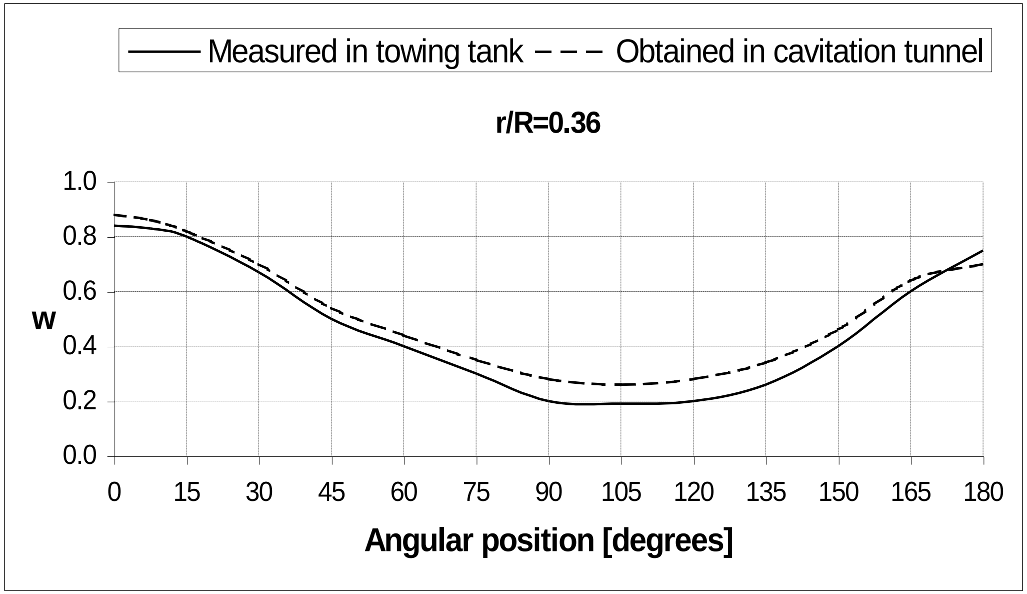
Afterbody model

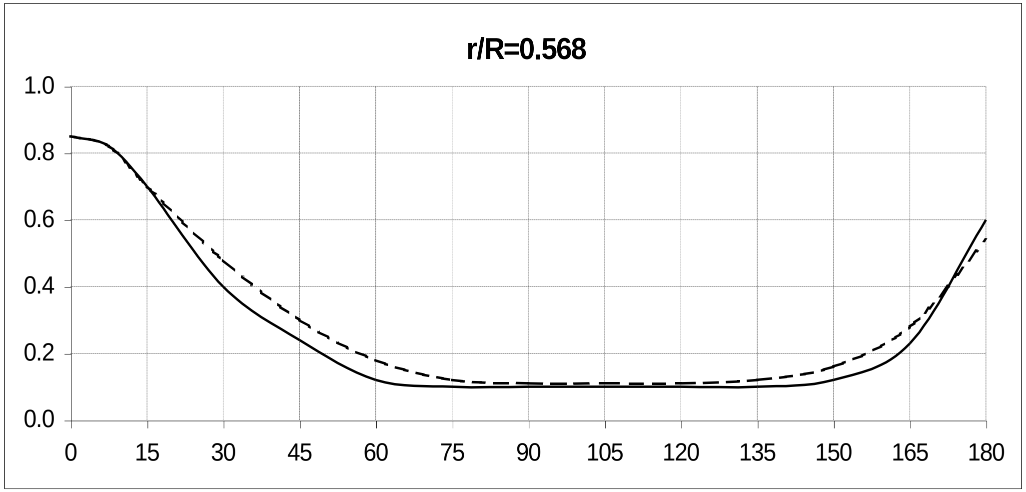






Mesh screen


Measured in towing tank
Obtained in cavitation tunnel
r/R=0.36
w
1.0
0.8
0.6
0.4
0.2
0.0
0 15 30 45 60 75 90 105 120 135 150 165 180
Angular position [degrees]


r/R=0.568
1.0
0.8
0.6
0.4
0.2
0.0
0 15 30 45 60 75 90 105 120 135 150 165 180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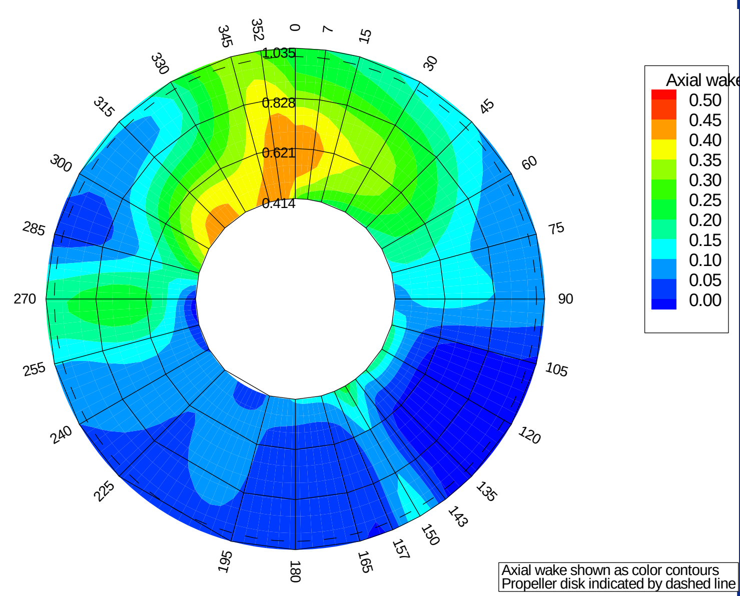

Axial wake
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1.035
0.828
0.621
0.414
Axial wake shown as color contours
Propeller disk indicated by dashed line

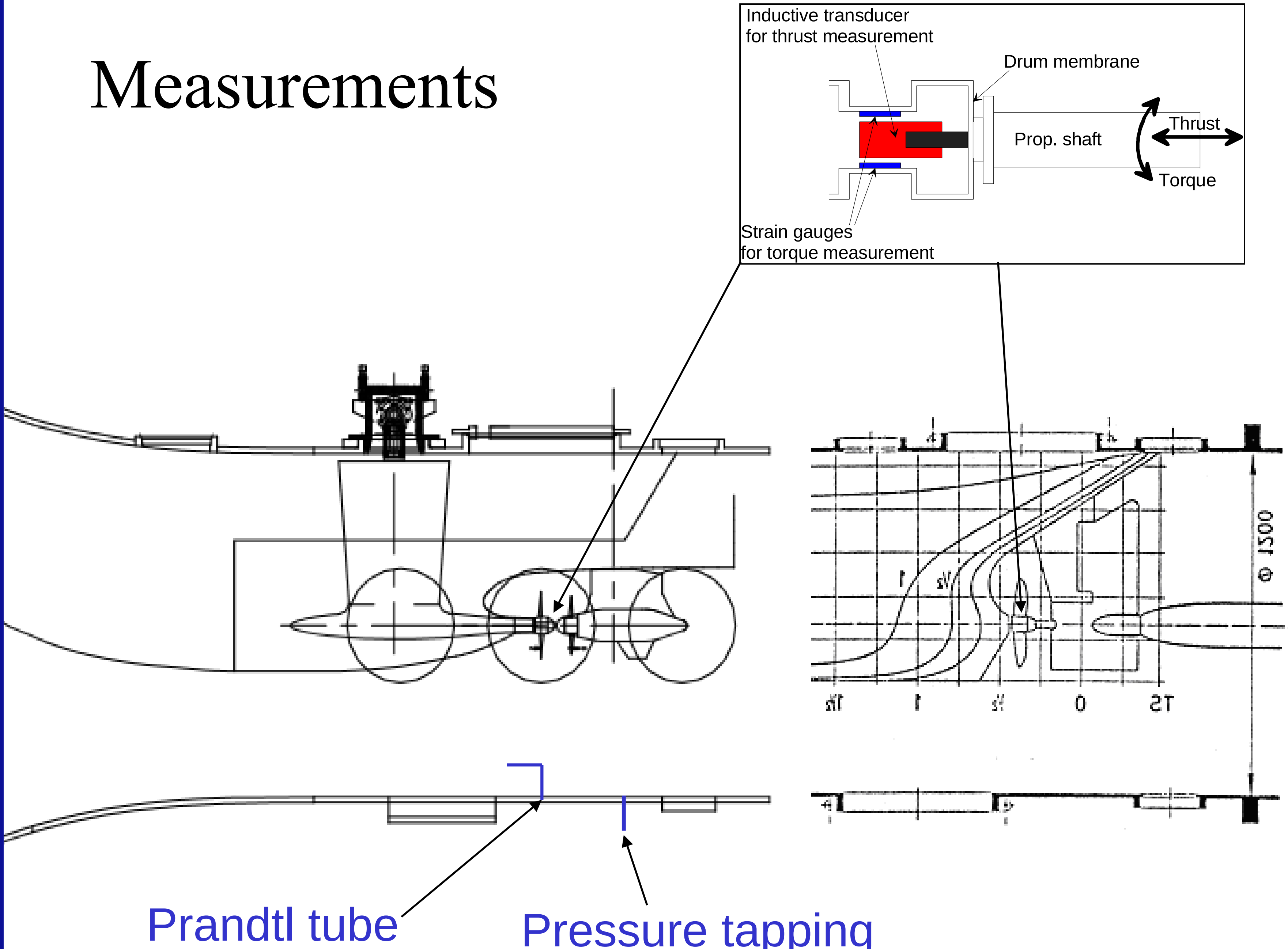
Cavitation tests - Measurements

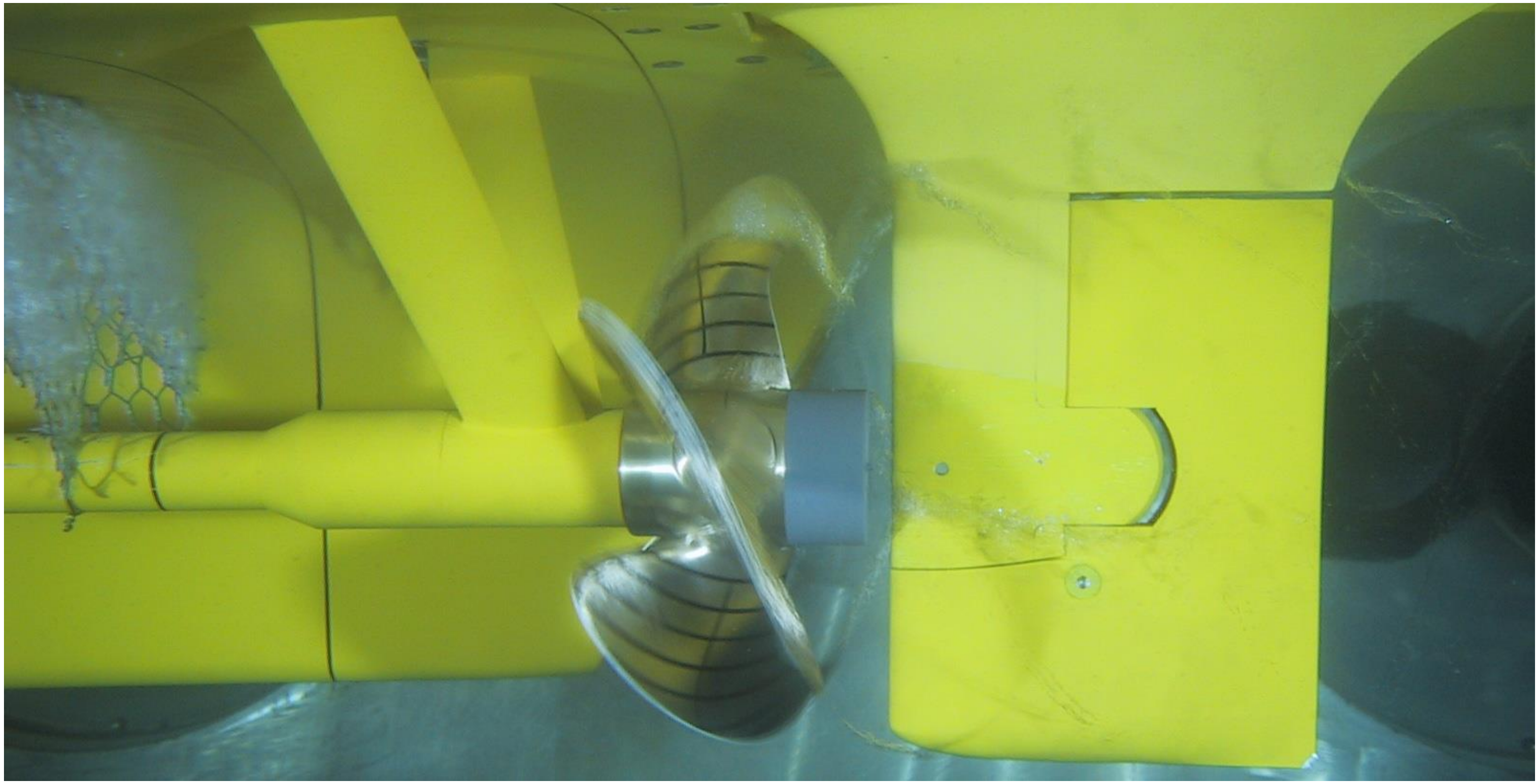
- Propeller rate of revolution
  - tachometer
- Thrust
- Torque
- Static tunnel pressure
  - Pressure tapping in tunnel wall
- Tunnel water speed
  - Prandtl tube 5 cm from tunnel wall in test section

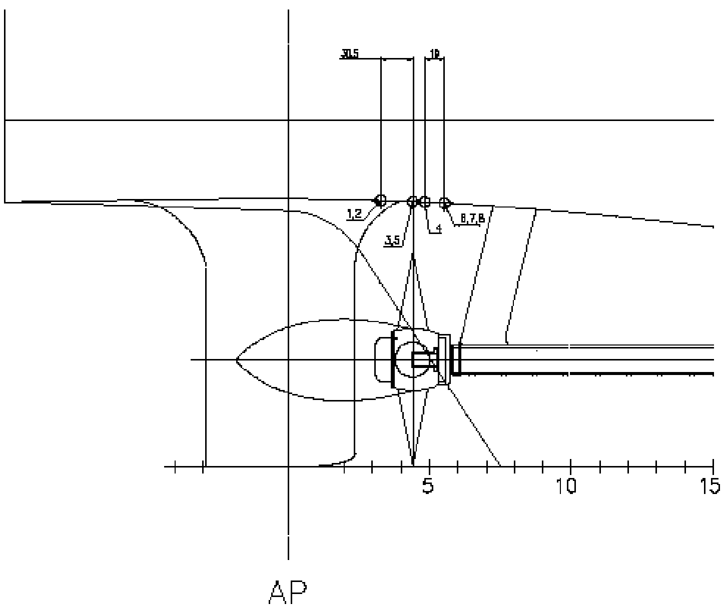
- For measurement of pressure pulses:
  - Pressure on the aft body hull surface at a number of locations (typically 6-18 positions)

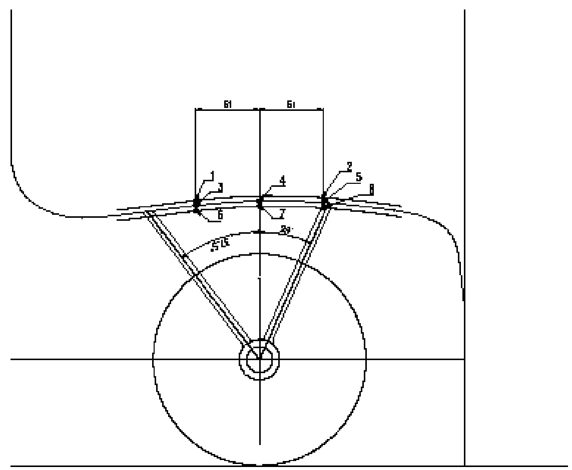
- For measurement of propeller noise:
  - One or two hydrophones

Measurements






30,5
19
1,2
3,5
4
6,7,8
5
10
15
AP



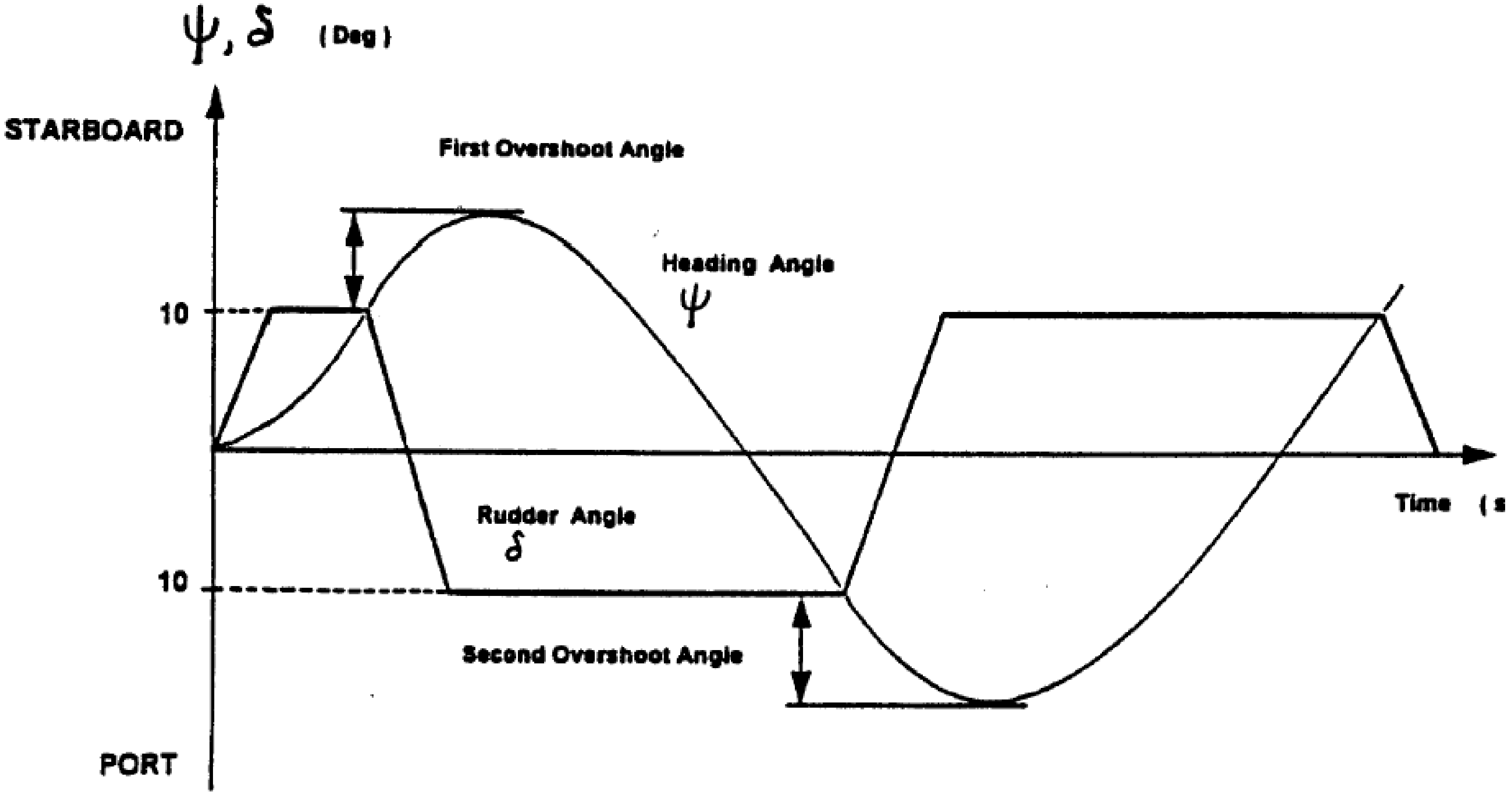
Maneuvering tests

- Two alternative purposes:
  1. Direct verification of maneuverability – fulfillment of IMO criteria
  2. Establishment of hydrodynamic coefficients for the maneuvering equations
     - Usually followed by calculation of maneuverability in a maneuvering prediction program
- Two alternative test schemes:
  1. Testing of free-running model
     - Gives direct assessment of maneuverability
     - Hydrodynamic coefficients for maneuvering equations can be derived
  2. Testing of captive model
     - Measurement of forces for establishment of hydrodynamic coefficients for the maneuvering equations

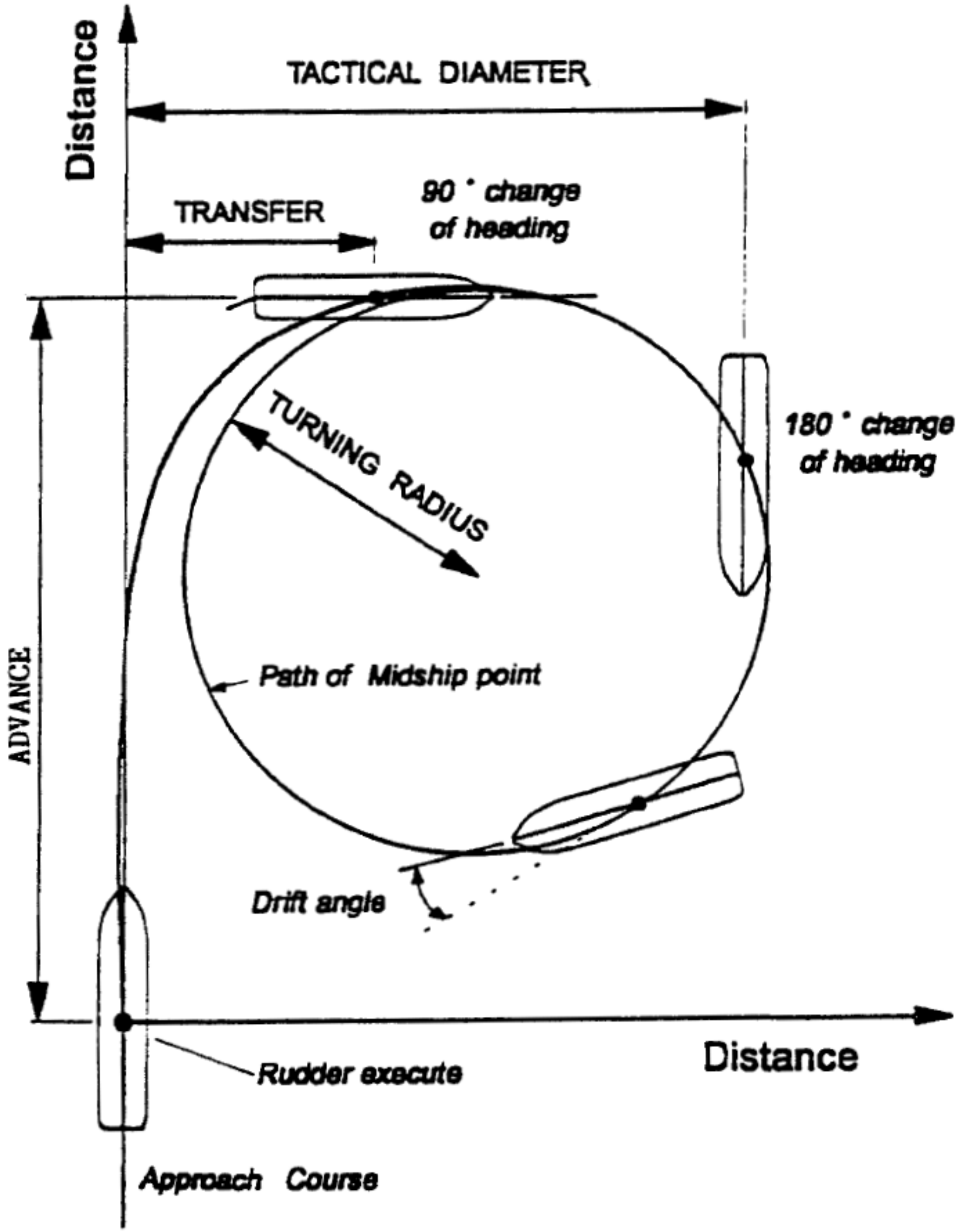
Types of Ship Maneuvers

- IMO standard maneuvers:
  - Zig-zag tests
    - 10º/ 10º to both sides
    - 20º/ 20º to both sides
  - Turning circle test
    - 35º rudder angle
  - Full astern stopping test
- Additional maneuvers:
  - Spiral test
  - Reverse spiral test
  - Pull-out maneuver
  - Very small zig-zag maneuver

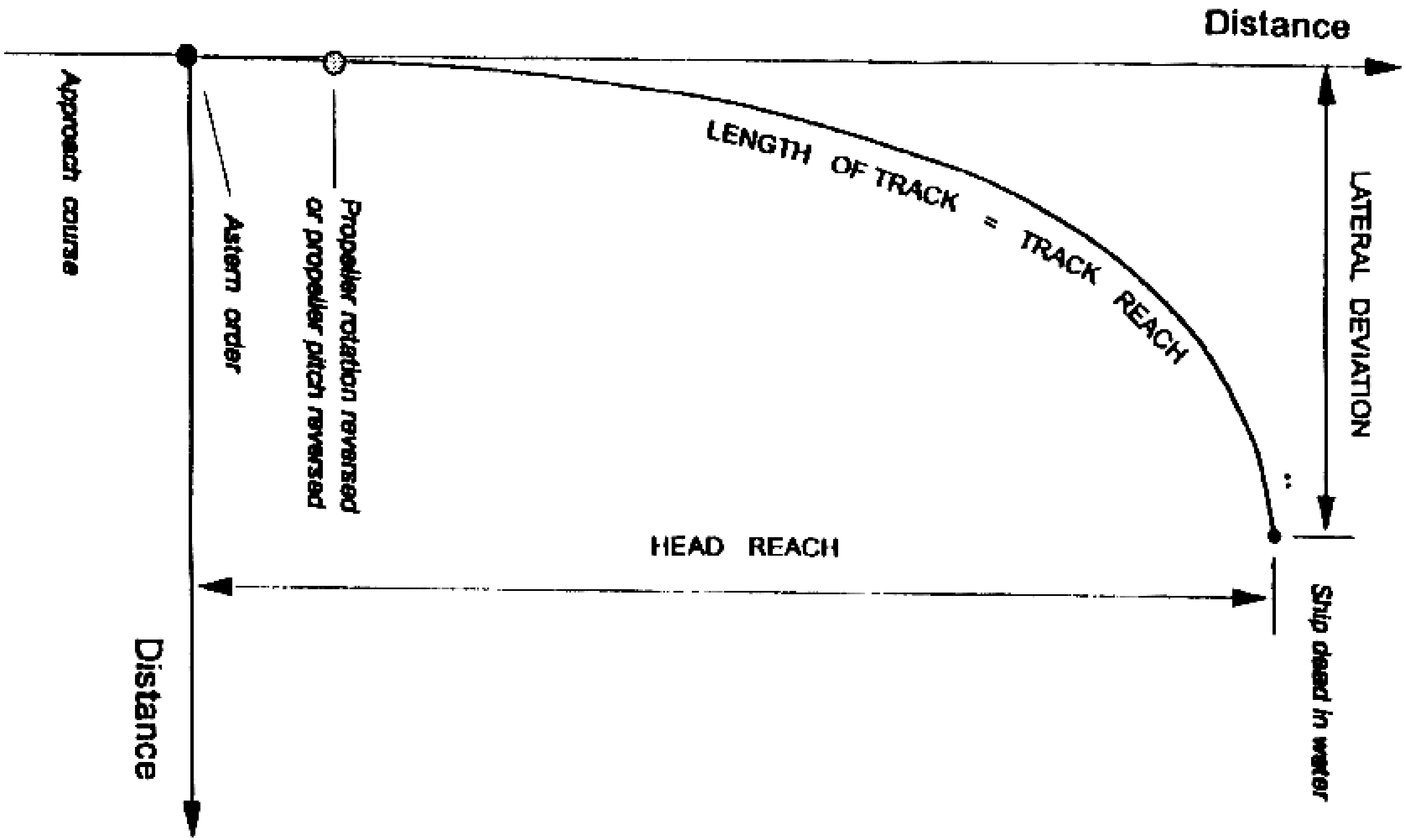
Zig-zag maneuver



Turning Circle Maneuver

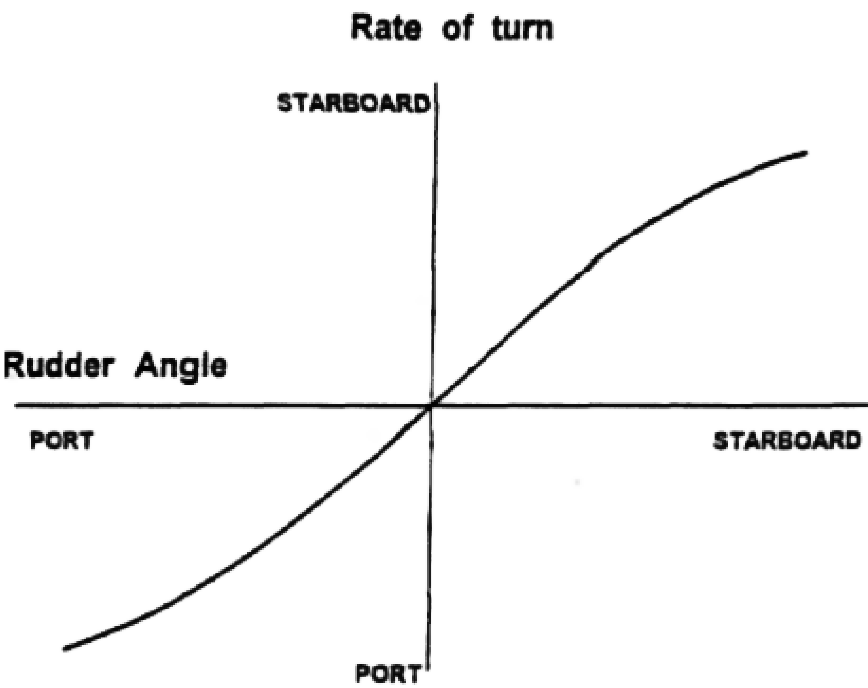


Stopping test



Spiral test

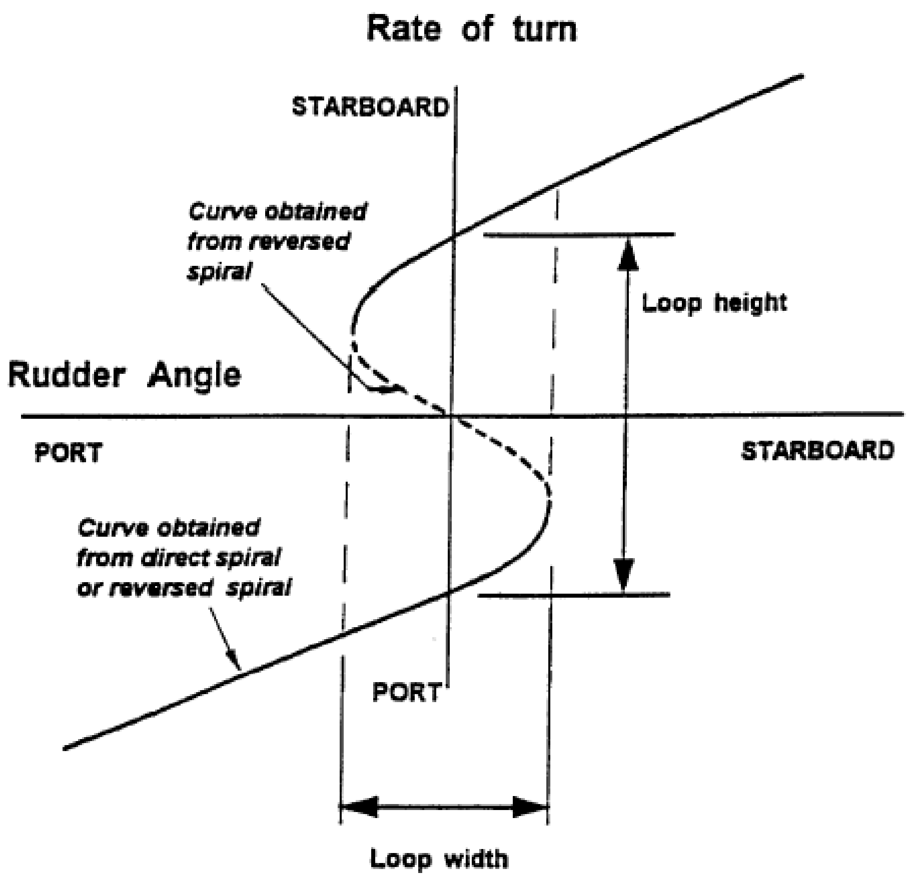
1. The ship is brought to a steady course and speed according to the specific initial condition
2. The recording of data starts
3. The rudder is turned about 15 degrees and held until the yaw rate remains constant for approximately one minute
4. The rudder angle is then decreased in approximately 5 degree increments. At each increment the rudder is held fixed until a steady yaw rate is obtained, measured and then decreased again
5. This is repeated for different rudder angles starting from large angles to both port and starboard; and
6. When a sufficient number of points is defined, data recording stops.



Reverse spiral test

1. The ship is steered to obtain a constant yaw rate
2. The mean rudder angle to produce this yaw rate is measured
3. This is repeated for several yaw rates, and the curve of yaw rate vs. Rudder angle is created

- More rapid method than direct spiral
- Requires very accurate yaw rate measurement instrument



Free-running manoeuvring tests

- Full geometrical similarity
- Speeds are Froude scaled
- Hull friction scale effect (tow rope) can be corrected by use of air fan
- Electric motor shall ideally be controlled to emulate ship engine characteristics
  - Constant motor power is a simpler alternative
  - Constant propeller speed (what you get with an electric motor without some kind of automatic control) give much too high thrust during the manoeuver

Free-running maneuvering tests - measurements

- Propeller revs
- Rudder angle
- Speed
- Heading
- Position
  - Alternatively: 6 DoF position measurement
- Rate of turn (for instance by use of gyro)
  - Important for fast models and when using auto-pilot

Maneuvering tests with fixed model

The model is subject to forced motions, and the applied forces are measured

- Planar Motion Mechanism (PMM)
- Rotating arm
- Yawed model tests

- Measurement of:
  - Speed
  - Position
  - Forces

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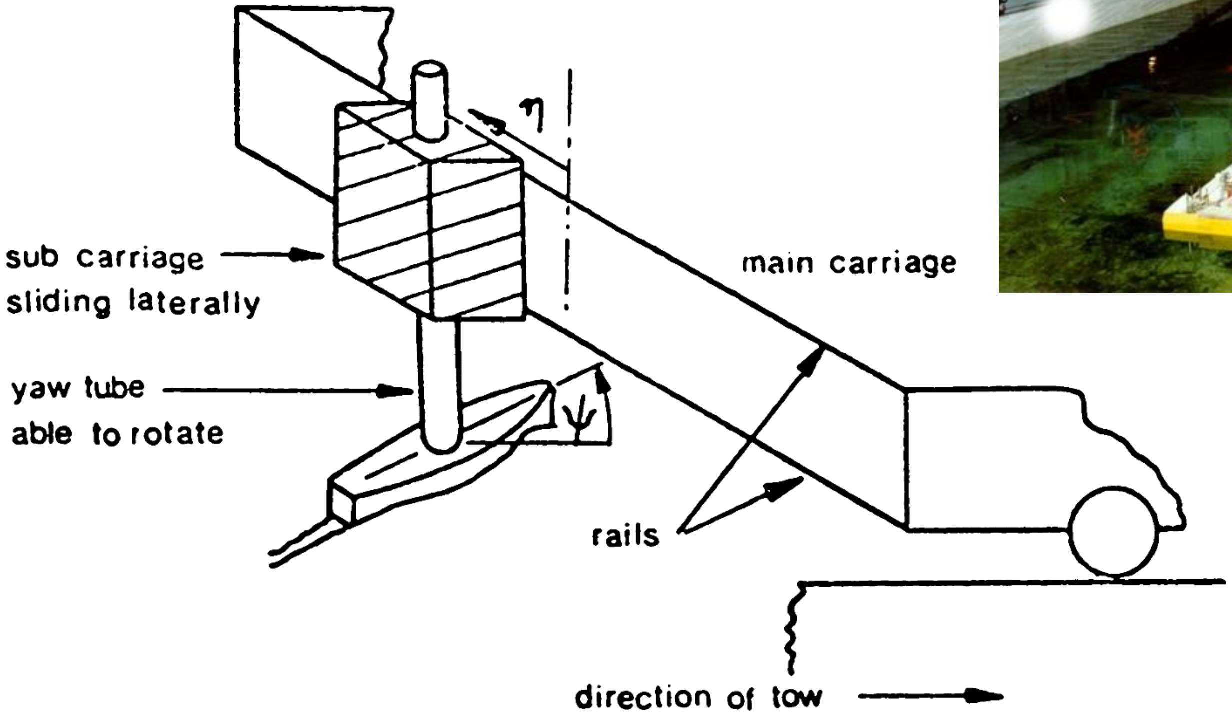
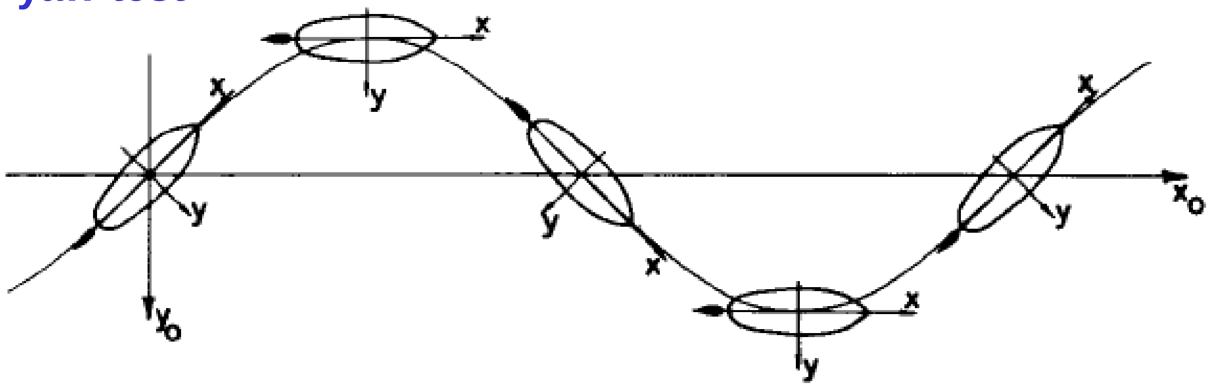
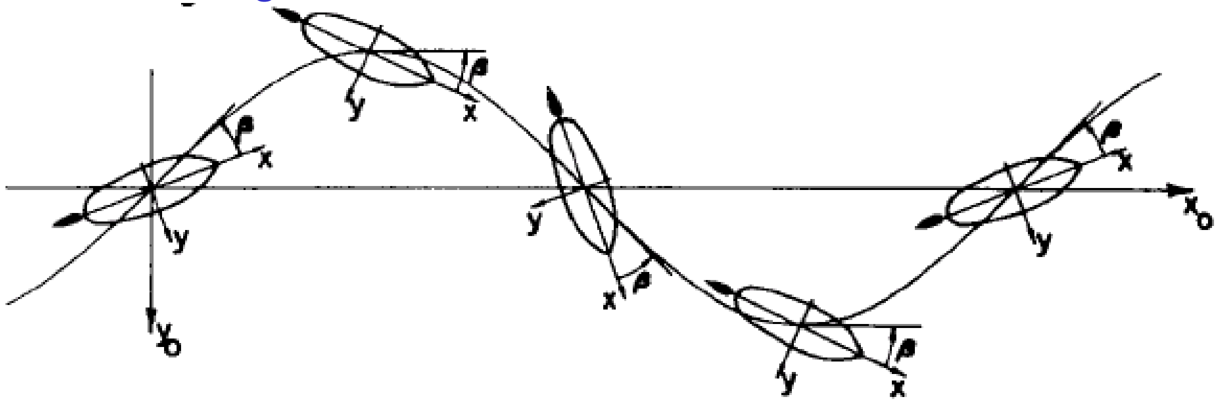
Planar Motion Mechanism (PMM)



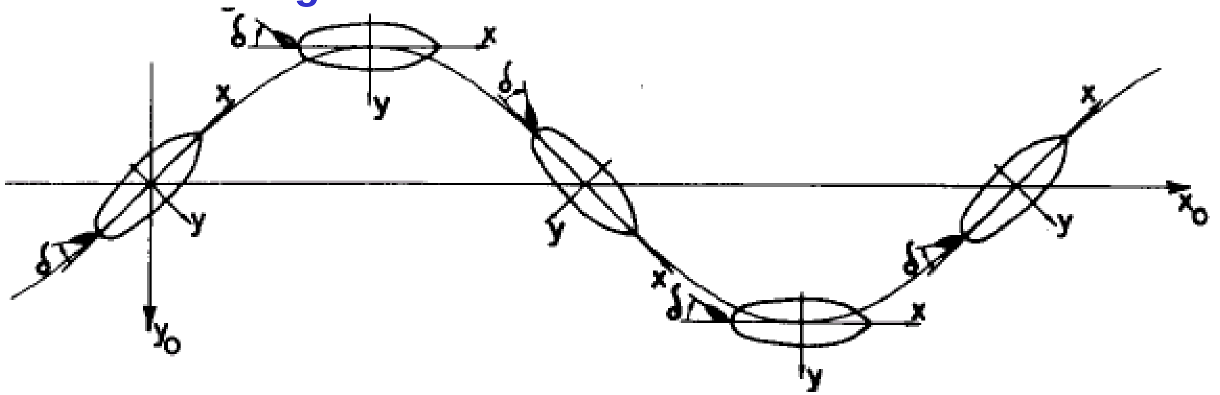
Pure yaw test



Yaw and drift angle test

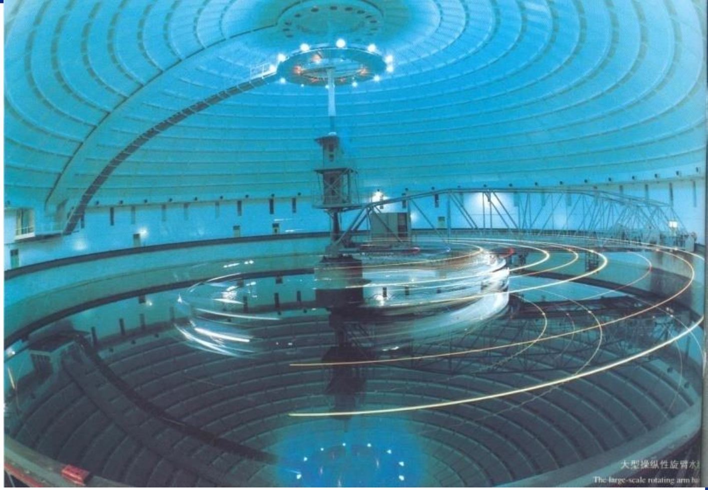


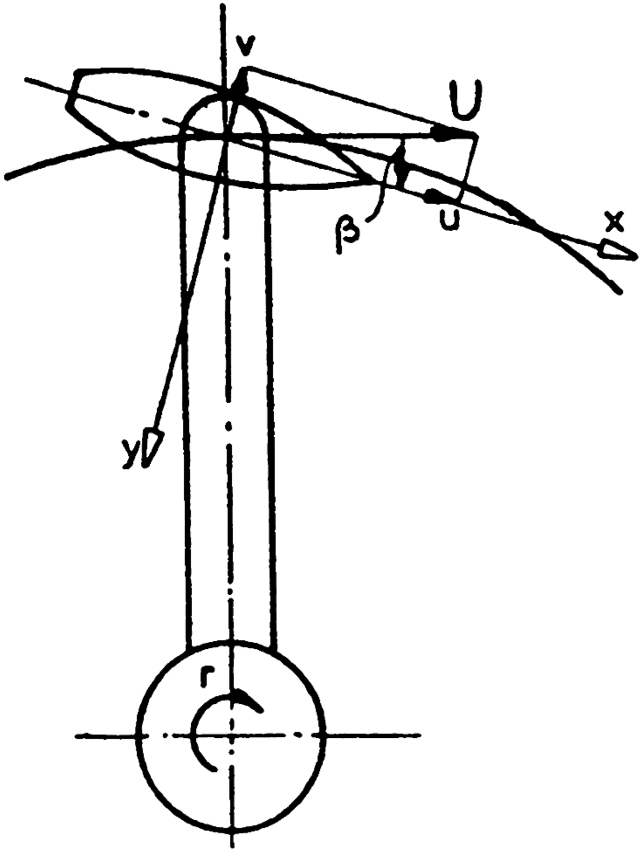
Yaw and rudder angle test



Rotating arm tests

- Set parameters:
  - Arm rotation speed
  - Model position (radius)
  - Model yaw angle
- Gives complete control of:
  - Surge speed
  - Yaw rate
  - Sway speed
- Measurement of:
  - Forces (in 6 DoF)
  - Speed
  - Radius, yaw angle
  - Rudder





ITTC: International Towing Tank Conference

- The ultimate source of accumulated knowledge on model testing
- Work is performed in groups of 6-10 technical experts
- Work is presented every third year in a common conference
- Proceedings from the ITTC conferences are valuable references
- ITTC maintains standards of model testing and analysis techniques

- ITTC Permanent web-site – contains standards for model testing: http://ittc.info/

Ship model testing - Summary

- Resistance, propulsion and propeller open water tests are performed to determine accurately the speed-power performance of the ship in full scale
- Cavitation tests are done in order to ensure that the ship propeller will not get cavitation problems
  – Typical cavitation problems are:
    - erosion damage to propeller and rudder
    - Noise and pressure pulses induced on the hull from the propeller cavitation
- Manoeuvring tests are performed to verify the manoeuvrability of the ship
  – Compliance with IMO criteria for manoeuvrability
  – Detect and repair directional instability