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To whom it may concern

Sub: **New ISO/CD 15016 Example**
here: **Re-evaluation according to the proposed rational method**
Ref.: Evaluations iso_fin4 to fin7.mcd

The present re-evaluation of the new ISO/CD 15016 example includes **the reduction to the no-wind and no-waves condition** according to the rational method and and **a statistical analysis as far as the size of the sample permits. In order to obtain the maximum size of the sample and to avoid the impression that data have been excluded purposely the data of all ten runs have been included. The analysis has been carried out ten times, successively leaving out the data of one run, and additionally one time including all data.**

Values computed according to the rational procedure are plotted in red, results of the reduced samples just dashed, results of the full sample denoted by boxes, final results denoted by pluses,
while the values taken from ISO/CD 15016 are plotted in blue and denoted by circles
and values according to the VWS method are plotted in black and denotes by crosses.

Units

$kN := 10^3 \cdot newton$

$N := newton$

$W := watt$

Test identification

TID := "23010"

New ISO/CD 15016 example

Constants

Length of ship

$L := 318 \cdot m$

$L := \frac{L}{m}$

Diameter of propeller

$D := 9.5 \cdot m$

$D := \frac{D}{m}$

Density of sea water

$\rho := 1.024 \cdot 10^3 \cdot kg \cdot m^{-3}$

$\rho := \frac{\rho}{kg \cdot m^{-3}}$

Density of air

$\rho_A := 1.225 \cdot kg \cdot m^{-3}$

$\rho_A := \frac{\rho_A}{kg \cdot m^{-3}}$

$g := 9.81$

Functions and subroutines

Normalise data

$JH(V,N) := \frac{V}{D \cdot N}$

$KP(P,N) := \frac{P}{\rho \cdot D^5 \cdot (N)^3}$

$Fn(V) := \frac{V}{\sqrt{g \cdot L}}$

$CP(P_B, V) := \frac{P_B}{\rho \cdot D^2 \cdot (V)^3}$

Sort runs

```
Sort(J_H, K_P, ψ) := | j_0 ← 0
                     | j_1 ← 0
                     | for i ∈ 0 .. last(J_H)
                     |   | if ψ_i > π
                     |   |   | S_(j_0, 0) ← J_H_i
                     |   |   | S_(j_0, 1) ← K_P_i
                     |   |   | j_0 ← j_0 + 1
                     |   | otherwise
                     |   |   | S_(j_1, 2) ← J_H_i
                     |   |   | S_(j_1, 3) ← K_P_i
                     |   |   | j_1 ← j_1 + 1
                     | S
```

Compute left-inverse

```
LeftInv(A) := | r ← rows(A)
              | c ← cols(A)
              | s ← svds(A)
              | for i ∈ 0 .. c − 1
              |   ISV_(i,i) ← (s_i)^-1
              | UV ← svd(A)
              | U ← submatrix(UV, 0, r − 1, 0, c − 1)
              | V ← submatrix(UV, r, r + c − 1, 0, c − 1)
              | A_inv.left ← V·ISV·U^T
              | A_inv.left
```

Solve cubic equations

$$\mathrm{Revs}(p, V, P, N) :=$$

$$n_i \leftarrow \mathrm{last}(V)$$

$$\text{for } i \in 0 .. n_i$$

$$\quad q_0 \leftarrow P_i$$

$$\quad q_1 \leftarrow V_i$$

$$\quad n \leftarrow N_i$$

$$\quad N_{rat_i} \leftarrow \mathrm{root}\left(q_0 - p_0 \cdot n^3 + p_1 \cdot n^2 \cdot q_1 , n\right)$$

$$N_{rat}$$

Analyse power supplied

$$\mathrm{Supplied}\left(D, \rho, t, \psi_0, V_G, n, P_B\right) :=$$

$$\text{for } i \in 0 .. \mathrm{last}(t)$$

$$\quad A_{sup_{i,0}} \leftarrow \left(n_i\right)^3$$

$$\quad A_{sup_{i,1}} \leftarrow -\left(n_i\right)^2 \cdot V_{G_i}$$

$$\quad d_{FM_i} \leftarrow \mathrm{if}\left(\psi_{0_i} < \pi, 1, -1\right)$$

$$\quad A_{sup_{i,2}} \leftarrow \left(n_i\right)^2 \cdot d_{FM_i}$$

$$\quad A_{sup_{i,3}} \leftarrow A_{sup_{i,2}} \cdot t_i$$

$$\quad A_{sup_{i,4}} \leftarrow A_{sup_{i,2}} \cdot \left(t_i\right)^2$$

$$\quad A_{sup_{i,5}} \leftarrow A_{sup_{i,2}} \cdot \left(t_i\right)^3$$

$$X_{sup} \leftarrow \mathrm{LeftInv}\left(A_{sup}\right) \cdot P_B$$

$$E_{sup} \leftarrow P_B - A_{sup} \cdot X_{sup}$$

$$p_0 \leftarrow X_{sup_0}$$

$$p_1 \leftarrow X_{sup_1}$$

$$\text{for } j \in 0 .. 3$$

$$\quad v_j \leftarrow \frac{X_{sup_{2+j}}}{X_{sup_1}}$$

$$\text{for } i \in 0 .. \mathrm{last}(t)$$

$$\quad V_{F.rat_i} \leftarrow v_0 + v_1 \cdot t_i + v_2 \cdot \left(t_i\right)^2 + v_3 \cdot \left(t_i\right)^3$$

$$\quad V_{S0.rat_i} \leftarrow V_{G_i} - V_{F.rat_i} \cdot d_{FM_i}$$

$$P_{B.rat_i} \leftarrow p_0 \cdot (n_i)^3 - p_1 \cdot (n_i)^2 \cdot V_{S0.rat_i}$$

$$J_{H.rat_i} \leftarrow \frac{V_{S0.rat_i}}{D \cdot n_i}$$

$$K_{P.rat_i} \leftarrow \frac{P_{B.rat_i}}{\rho \cdot D^5 \cdot (n_i)^3}$$

$$\left[E_{sup} \;\; V_{F.rat} \;\; V_{S0.rat} \;\; P_{B.rat} \;\; J_{H.rat} \;\; K_{P.rat} \;\; p \right]$$

Analyse power required

$\text{Required}(V_{S0}, P_B, Env) :=$

$$g \leftarrow 9.81$$
$$V_{WindR} \leftarrow \left(Env_{0,0}\right)_{0,0}$$
$$\psi_{WindR} \leftarrow \left(Env_{0,0}\right)_{0,1}$$
$$T_{Seas} \leftarrow \left(Env_{0,1}\right)_{0,0}$$
$$H_{Seas} \leftarrow \left(Env_{0,1}\right)_{0,1}$$
$$\psi_{SeasR} \leftarrow \left(Env_{0,1}\right)_{0,2}$$
$$T_{Swell} \leftarrow \left(Env_{0,2}\right)_{0,0}$$
$$H_{Swell} \leftarrow \left(Env_{0,2}\right)_{0,1}$$
$$\psi_{SwellR} \leftarrow \left(Env_{0,2}\right)_{0,2}$$

for $i \in 0 .. \text{last}(V_{S0})$

$$A_{req_{i,0}} \leftarrow \left(V_{S0_i}\right)^1$$
$$A_{req_{i,1}} \leftarrow \left(V_{S0_i}\right)^2$$
$$A_{req_{i,2}} \leftarrow \left(V_{S0_i}\right)^3$$
$$V_{WindR.x} \leftarrow V_{WindR_i} \cdot \cos\left(\psi_{WindR_i}\right)$$
$$A_{req_{i,3}} \leftarrow V_{WindR.x} \cdot \left|V_{WindR.x}\right| \cdot V_{S0_i}$$
$$V_{Seas.x} \leftarrow \frac{g \cdot T_{Seas_i}}{2 \cdot \pi} \cdot \cos\left(\psi_{SeasR_i} + \pi\right)$$
$$A_{req_{i,4}} \leftarrow \left(H_{Seas_i}\right)^2 \cdot \left(V_{S0_i} + V_{Seas.x}\right) \cdot \left(V_{S0_i}\right)^2$$
$$V_{Swell.x} \leftarrow \frac{g \cdot T_{Swell_i}}{2 \cdot \pi} \cdot \cos\left(\psi_{SwellR_i} + \pi\right)$$

$$A_{req_{i,5}} \leftarrow \left(H_{Swell_i}\right)^2 \cdot \left(V_{S0_i} + V_{Swell.x}\right) \cdot \left(V_{S0_i}\right)^2$$

$$X_{req} \leftarrow \mathrm{LeftInv}\left(A_{req}\right) \cdot P_B$$

$$E_{req} \leftarrow P_B - A_{req} \cdot X_{req}$$

$$P_{AWind} \leftarrow A_{req}^{\langle 3 \rangle} \cdot X_{req_3}$$

$$P_{ASeas} \leftarrow A_{req}^{\langle 4 \rangle} \cdot X_{req_4}$$

$$P_{ASwell} \leftarrow A_{req}^{\langle 5 \rangle} \cdot X_{req_5}$$

$$P_{AWaves} \leftarrow P_{ASeas} + P_{ASwell}$$

$$\text{for } i \in 0 .. \mathrm{last}\left(V_{S0}\right)$$

$$\quad P_{AAir_i} \leftarrow \left(V_{S0_i}\right)^3 \cdot X_{req_3}$$

$$P_{B0} \leftarrow P_B - P_{AWaves} - P_{AWind} + P_{AAir}$$

$$\left[E_{req} \;\; P_{AWind} \;\; P_{AWaves} \;\; P_{B0}\right]$$

Power supplied

Data reported from traditional trial measurements

time: row 48

$$t := \begin{bmatrix} 16.792 \\ 18.830 \\ 20.826 \\ 23.053 \\ 24.986 \\ 26.682 \\ 30.597 \\ 32.433 \\ 34.231 \\ 35.849 \end{bmatrix} \cdot \mathrm{hr}$$

course: row 3

$$\psi_0 := \begin{bmatrix} 5.901 \\ 2.909 \\ 5.901 \\ 2.909 \\ 5.901 \\ 2.909 \\ 2.909 \\ 5.901 \\ 2.909 \\ 5.901 \end{bmatrix} \cdot \mathrm{rad}$$

speed over ground: row 4

$$V_G := \begin{bmatrix} 4.409 \\ 5.561 \\ 6.050 \\ 7.182 \\ 7.218 \\ 8.082 \\ 8.416 \\ 7.773 \\ 8.437 \\ 7.922 \end{bmatrix} \cdot \frac{m}{sec}$$

frequency of revolution:
row 5

brake power measured:
row 6

$$n := \begin{bmatrix} 0.7317 \\ 0.7300 \\ 0.9267 \\ 0.9267 \\ 1.0467 \\ 1.0467 \\ 1.0933 \\ 1.0950 \\ 1.1167 \\ 1.1133 \end{bmatrix} \cdot Hz \qquad P_B := \begin{bmatrix} 5711 \\ 5533 \\ 11349 \\ 11140 \\ 16200 \\ 16190 \\ 18500 \\ 18330 \\ 19450 \\ 19756 \end{bmatrix} \cdot kW$$

Data non-dimensionalized in view of further use in some mathematical subroutines, which by definition cannot handle arguments with (different) dimensions

$$t := \frac{t}{hr} \qquad \psi_0 := \frac{\psi_0}{rad} \qquad V_G := \frac{V_G}{m \cdot sec^{-1}} \qquad n := \frac{n}{Hz} \qquad P_B := \frac{P_B}{W}$$

Normalised data

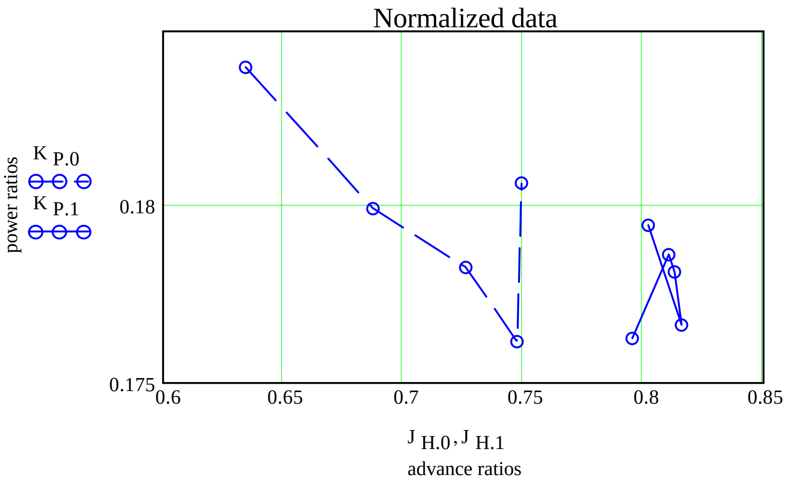
$i := 0 .. last(t)$

$$J_{H_i} := JH\left(V_{G_i}, n_i\right) \qquad K_{P_i} := KP\left(P_{B_i}, n_i\right)$$

Check of consistency

$$J_{H.0} := Sort\left(J_H, K_P, \psi_0\right)^{<0>} \qquad K_{P.0} := Sort\left(J_H, K_P, \psi_0\right)^{<1>}$$

$$J_{H.1} := Sort\left(J_H, K_P, \psi_0\right)^{<2>} \qquad K_{P.1} := Sort\left(J_H, K_P, \psi_0\right)^{<3>}$$



Input data for statistical analysis

$i := 0 .. \mathrm{last}(t)$

$j := 0 .. \mathrm{last}(t) - 1$

$K_{j,i} := \mathrm{if}(j<i, j, j+1)$

$t_{S_{j,i}} := t_{K_{j,i}} \qquad \psi_{0S_{j,i}} := \psi_{0_{K_{j,i}}} \qquad V_{GS_{j,i}} := V_{G_{K_{j,i}}} \qquad n_{S_{j,i}} := n_{K_{j,i}} \qquad P_{BS_{j,i}} := P_{B_{K_{j,i}}}$

Evaluation

$Res_{supS_i} := \mathrm{Supplied}\left(D, \rho, t_S^{\langle i \rangle}, \psi_{0S}^{\langle i \rangle}, V_{GS}^{\langle i \rangle}, n_S^{\langle i \rangle}, P_{BS}^{\langle i \rangle}\right)$

$\left[E_{supS}^{\langle i \rangle} \;\; V_{F.ratS}^{\langle i \rangle} \;\; V_{S0.ratS}^{\langle i \rangle} \;\; P_{B.ratS}^{\langle i \rangle} \;\; J_{H.ratS}^{\langle i \rangle} \;\; K_{P.ratS}^{\langle i \rangle} \;\; p_{ratS}^{\langle i \rangle}\right] := Res_{supS_i}$

$Res_{sup} := \mathrm{Supplied}\left(D, \rho, t, \psi_0, V_G, n, P_B\right)$

$\left[E_{sup} \;\; V_{F.rat} \;\; V_{S0.rat} \;\; P_{B.rat} \;\; J_{H.rat} \;\; K_{P.rat} \;\; p_{rat}\right] := Res_{sup}$

ISO/CD evaluation:

current at each run:
row 52

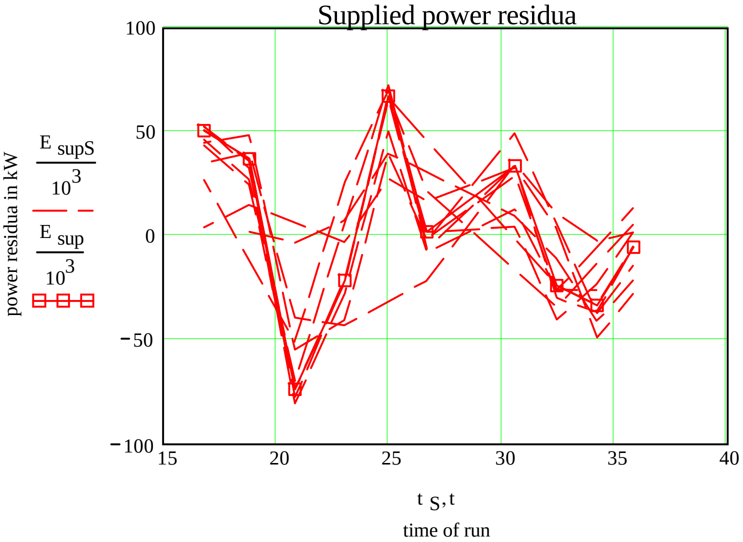
$$V_{F.ISO} := \begin{bmatrix} 0.494 \\ 0.527 \\ 0.525 \\ 0.484 \\ 0.442 \\ 0.404 \\ 0.324 \\ 0.296 \\ 0.273 \\ 0.275 \end{bmatrix} \cdot \frac{m}{sec}$$

$$V_{F.ISO} := \frac{V_{F.ISO}}{m \cdot sec^{-1}}$$

Plots of results

Power residua

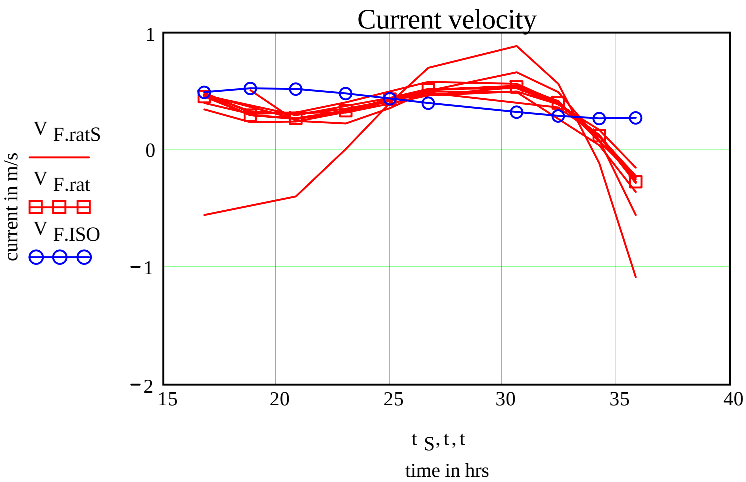
$$e_{supS_i} := \frac{\left| E_{supS}^{\langle i \rangle} \right|}{10^3}$$



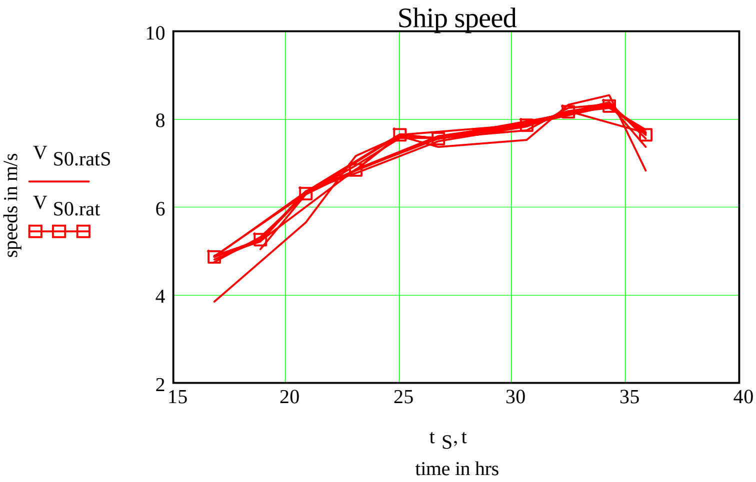
$$e_{supS} = \begin{bmatrix} 70.552 \\ 105.775 \\ 74.621 \\ 128.374 \\ 89.437 \\ 131.137 \\ 121.767 \\ 120.96 \\ 121.701 \\ 130.637 \end{bmatrix}$$

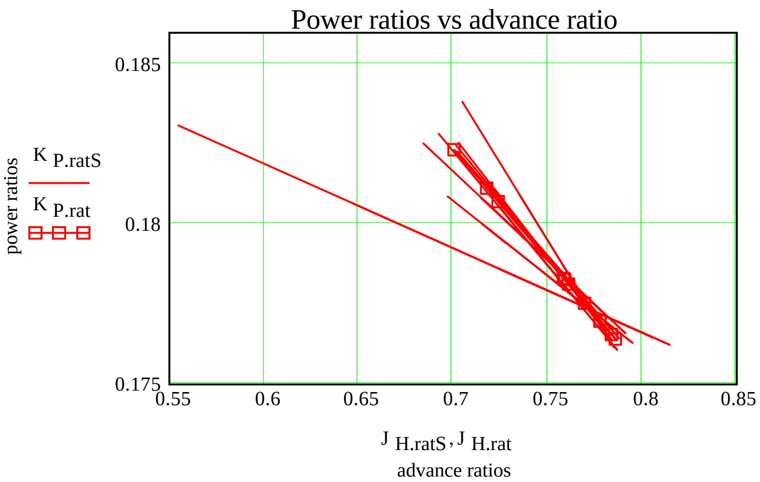
According to the root mean squares of the residua no sample is to be excluded or to be preferred.

Current velocities



The sample without the data of the second run provides exceptional current values. Consequently this sample could be kept on the basis of the argument that the 'obvious' results are completely distorted by the data of run 2! This course of action has been followed in the evaluation of the METEOR tests in 1990. But in the present case it turned out to provide 'unlikely' results as far as this line of thought has been followed.





$$V_{S0.ratS_{j,i}} := V_{S0.rat_{K_{j,i}}}$$

Power required

Relative wind measured

relative wind velocity:
row 7

$$V_{WindR} := \begin{bmatrix} 13.5 \\ 4.0 \\ 15.0 \\ 2.8 \\ 16.0 \\ 0.7 \\ 0.4 \\ 16.5 \\ 0.0 \\ 16.5 \end{bmatrix} \cdot \frac{m}{sec}$$

relative wind direction:
row 8

$$\psi_{WindR} := \begin{bmatrix} -0.1745 \\ 2.5307 \\ -0.1745 \\ 2.3562 \\ 0.0873 \\ 2.6180 \\ 2.3562 \\ 0.0873 \\ 2.5307 \\ -0.1745 \end{bmatrix} \cdot rad$$

Non-dimensional values, not normalized(!), in coherent units

$V_{WindR} := \frac{V_{WindR}}{m \cdot sec^{-1}}$ $\qquad \psi_{WindR} := \frac{\psi_{WindR}}{rad}$

Sea state observed

mean wave period (seas)
row 12

$$T_{Seas} := \begin{bmatrix} 3.90 \\ 3.90 \\ 3.90 \\ 3.90 \\ 3.90 \\ 3.90 \\ 2.80 \\ 2.80 \\ 2.80 \\ 2.80 \end{bmatrix} \cdot sec$$

significant wave height (seas)
row 13

$$H_{Seas} := \begin{bmatrix} 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \\ 1.00 \\ 0.50 \\ 0.50 \\ 0.50 \\ 0.50 \end{bmatrix} \cdot m$$

incident angle of wave (seas)
row 14

$$\psi_{SeasR} := \begin{bmatrix} 2.97 \\ -0.17 \\ 2.97 \\ -0.17 \\ 2.97 \\ -0.17 \\ -0.17 \\ 2.97 \\ -0.17 \\ 2.97 \end{bmatrix}$$

$T_{Seas} := \frac{T_{Seas}}{sec}$ $\qquad H_{Seas} := \frac{H_{Seas}}{m}$

Swell state observed

mean wave period (swell)
row 15

$$T_{Swell} := \begin{bmatrix} 10.59 \\ 10.59 \\ 10.59 \\ 10.59 \\ 11.32 \\ 11.32 \\ 11.32 \\ 11.32 \\ 11.32 \\ 11.32 \end{bmatrix} \cdot sec$$

significant wave height (swell)
row 16

$$H_{Swell} := \begin{bmatrix} 2.00 \\ 2.00 \\ 2.00 \\ 2.00 \\ 2.50 \\ 2.50 \\ 2.50 \\ 2.50 \\ 3.00 \\ 3.00 \end{bmatrix} \cdot m$$

incident angle of wave (swell)
row 17

$$\psi_{SwellR} := \begin{bmatrix} 0.6981 \\ -2.4435 \\ 0.6981 \\ -2.4435 \\ 0.6981 \\ -2.4435 \\ -2.4435 \\ 0.6981 \\ -2.4435 \\ 0.6981 \end{bmatrix}$$

$T_{Swell} := \frac{T_{Swell}}{sec}$ $\qquad H_{Swell} := \frac{H_{Swell}}{m}$

Input data for statistical analysis

$V_{WindRS_{j,i}} := V_{WindR_{K_{j,i}}}$ $\quad \Psi_{WindRS_{j,i}} := \Psi_{WindR_{K_{j,i}}}$

$WindS_i := \left[V_{WindRS}^{<i>} \quad \Psi_{WindRS}^{<i>} \right]$

$Wind := \left[V_{WindR} \quad \Psi_{WindR} \right]$

$T_{SeasS_{j,i}} := T_{Seas_{K_{j,i}}}$ $\quad H_{SeasS_{j,i}} := H_{Seas_{K_{j,i}}}$ $\quad \Psi_{SeasRS_{j,i}} := \Psi_{SeasR_{K_{j,i}}}$

$SeasS_i := \left[T_{SeasS}^{<i>} \quad H_{SeasS}^{<i>} \quad \Psi_{SeasRS}^{<i>} \right]$

$Seas := \left[T_{Seas} \quad H_{Seas} \quad \Psi_{SeasR} \right]$

$T_{SwellS_{j,i}} := T_{Swell_{K_{j,i}}}$ $\quad H_{SwellS_{j,i}} := H_{Swell_{K_{j,i}}}$ $\quad \Psi_{SwellRS_{j,i}} := \Psi_{SwellR_{K_{j,i}}}$

$SwellS_i := \left[T_{SwellS}^{<i>} \quad H_{SwellS}^{<i>} \quad \Psi_{SwellRS}^{<i>} \right]$

$Swell := \left[T_{Swell} \quad H_{Swell} \quad \Psi_{SwellR} \right]$

$Env_{S_i} := \left[WindS_i \quad SeasS_i \quad SwellS_i \right]$

$Env := (Wind \quad Seas \quad Swell)$

Evaluation

$Res_{reqS_i} := Required\left(V_{S0.ratS}^{<i>}, P_{BS}^{<i>}, Env_{S_i} \right)$

$\left[E_{reqS}^{<i>} \quad P_{AWind.ratS}^{<i>} \quad P_{AWaves.ratS}^{<i>} \quad P_{B.ratS}^{<i>} \right] := Res_{reqS_i}$

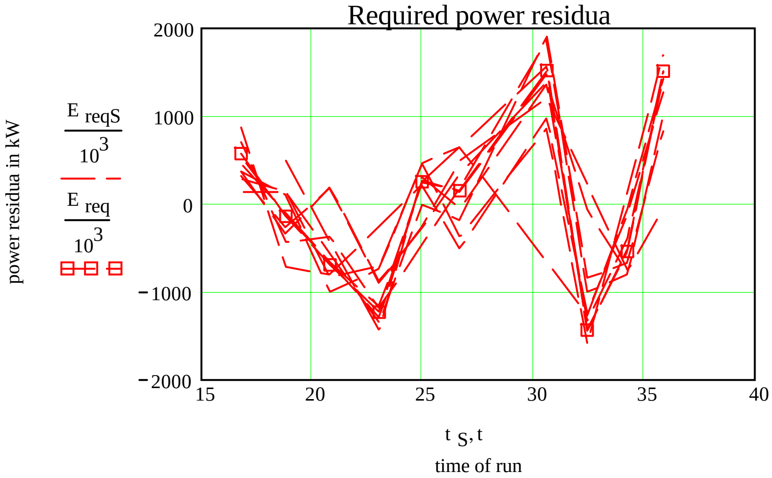
$Res_{req} := Required\left(V_{S0.rat}, P_B, Env \right)$

$\left[E_{req} \quad P_{AWind.rat} \quad P_{AWaves.rat} \quad P_{B.rat} \right] := Res_{req}$

Plots of results

Power residua

$e_{reqS_i} := \dfrac{\left| E_{reqS}^{<i>} \right|}{10^6}$



$$e_{reqS} = \begin{bmatrix} 2.895 \\ 3.049 \\ 2.728 \\ 2.53 \\ 2.904 \\ 3.05 \\ 2.45 \\ 1.838 \\ 2.79 \\ 1.949 \end{bmatrix}$$

According to the root mean squares of the residua no sample is to be excluded or to be preferred.

Additional power and resistance due to wind according to ISO/CD evaluation

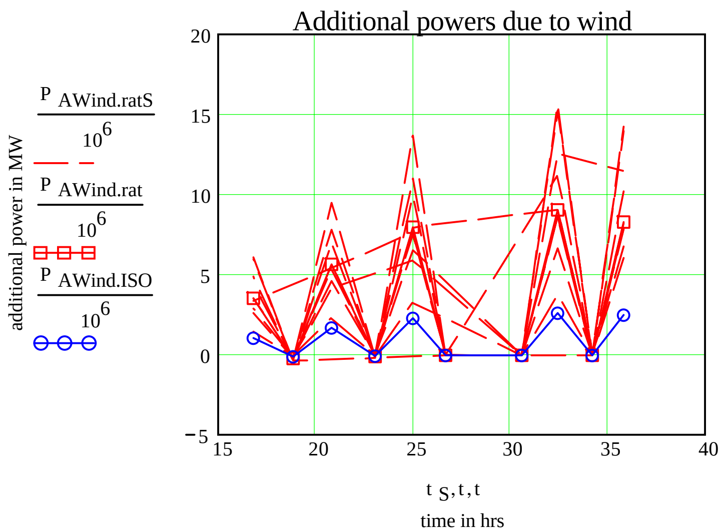
resistance increase due to wind row 29:

$$R_{AWind.ISO} := \begin{bmatrix} 131.5 \\ -10.9 \\ 162.3 \\ -4.5 \\ 181.2 \\ -0.3 \\ -0.1 \\ 192.7 \\ 0 \\ 196.5 \end{bmatrix} \cdot 10^3 \cdot N$$

$\eta_D := 0.6$ Propulsive efficiency, crude estimate for plausibility checks only!

$$R_{AWind.ISO} := \frac{R_{AWind.ISO}}{N}$$

$$P_{AWind.ISO_i} := \frac{R_{AWind.ISO_i} \cdot V_{S0.rat_i}}{\eta_D}$$



$$\frac{|P_{AWind.rat}|}{|P_{AWind.ISO}|} = 3.382$$

Additional power and resistance due to waves

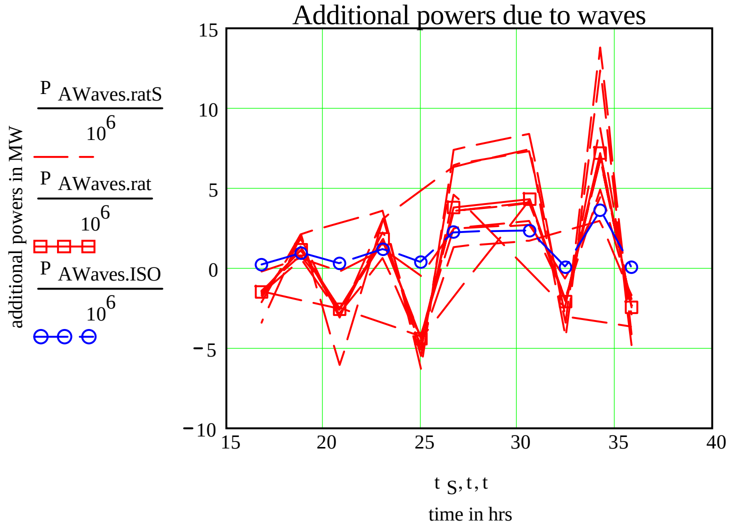
according to ISO/CD evaluation

resistance increase due to waves row 30:

$$R_{AWaves.ISO} := \begin{bmatrix} 31.4 \\ 111.8 \\ 31.4 \\ 106.9 \\ 31.4 \\ 182.6 \\ 180.1 \\ 7.9 \\ 264.7 \\ 7.9 \end{bmatrix} \cdot 10^3 \cdot N$$

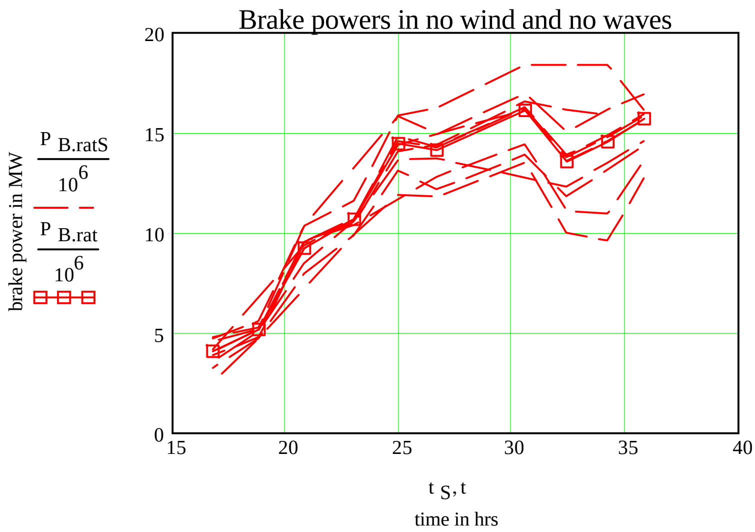
$$R_{AWaves.ISO} := \frac{R_{AWaves.ISO}}{N}$$

$$P_{AWaves.ISO_i} := \frac{R_{AWaves.ISO_i} \cdot V_{S0.rat_i}}{\eta_D}$$



$$\frac{\left|P_{AWaves.rat}\right|}{\left|P_{AWaves.ISO}\right|} = 2.173$$

Brake power at no wind and no waves



Checking results

The following steps are necessary in view of the very large residua in the power required.
These are due to the extremely low resolution in the observation of the wave data.
And this is the first time that values are being disregarded in the evaluation!

Fairing

$i := 0 .. \text{last}(t) - 3$ $\quad j := 0 .. 3$ $\quad$ cubic 'spline'!

$A_{i,j} := \left(V_{S0.rat_i}\right)^j$ $\quad B_i := P_{B.rat_i}$

$X := \text{LeftInv}(A) \cdot B$

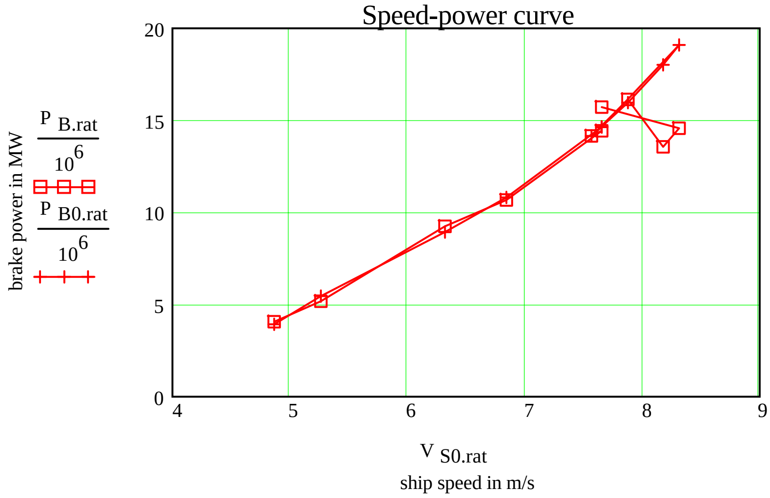
Actually only runs 8and 9
needed to be disregarded!

Extrapolating

$i := 0 .. \text{last}(t)$

$A_{i,j} := \left(V_{S0.rat_i}\right)^j$

$P_{B0.rat} := A \cdot X$



Interpolating

$k := 0..74$

$V_{S0.int_k} := 4.8 + 0.05 \cdot k$

$A_{k,j} := \left(V_{S0.int_k}\right)^j$

$P_{B0.int} := A \cdot X$

$n_{int_k} := 1$ initial values

Final performance

Final performance data according to rational evaluation

$n_{0.ratS}^{\langle i \rangle} := \mathrm{Revs}\left(p_{ratS}^{\langle i \rangle}, V_{S0.ratS}^{\langle i \rangle}, P_{B.ratS}^{\langle i \rangle}, n_S^{\langle i \rangle}\right)$

$n_{0.rat} := \mathrm{Revs}\left(p_{rat}, V_{S0.rat}, P_{B0.rat}, n\right)$

$n_{0.int} := \mathrm{Revs}\left(p_{rat}, V_{S0.int}, P_{B0.int}, n_{int}\right)$ all non-dimensional values in coherent units

frequency of revolution: ship speed: brake power:

$$n_{0.rat} = \begin{bmatrix} 0.656 \\ 0.729 \\ 0.861 \\ 0.919 \\ 1.017 \\ 1.005 \\ 1.047 \\ 1.089 \\ 1.110 \\ 1.017 \end{bmatrix} \quad V_{S0.rat} = \begin{bmatrix} 4.869 \\ 5.263 \\ 6.320 \\ 6.845 \\ 7.652 \\ 7.566 \\ 7.875 \\ 8.174 \\ 8.313 \\ 7.654 \end{bmatrix} \quad \frac{P_{B0.rat}}{10^6} = \begin{bmatrix} 3.952 \\ 5.464 \\ 8.960 \\ 10.848 \\ 14.654 \\ 14.171 \\ 15.996 \\ 18.044 \\ 19.109 \\ 14.661 \end{bmatrix}$$

Final performance data according to **ISO evaluation**

frequency of revolution: row 61 (5)

$$n_{0.ISO} := \begin{bmatrix} 0.7317 \\ 0.7300 \\ 0.9267 \\ 0.9267 \\ 1.0467 \\ 1.0467 \\ 1.0933 \\ 1.0950 \\ 1.1167 \\ 1.1133 \end{bmatrix} \cdot Hz$$

ship speed: row 65

$$V_{S0.ISO} := \begin{bmatrix} 5.230 \\ 5.238 \\ 6.852 \\ 6.861 \\ 7.932 \\ 7.946 \\ 8.315 \\ 8.327 \\ 8.501 \\ 8.480 \end{bmatrix} \cdot \frac{m}{sec}$$

brake power: row 63

$$P_{B0.ISO} := \begin{bmatrix} 5331 \\ 5293 \\ 10839 \\ 10838 \\ 15582 \\ 15578 \\ 17945 \\ 17696 \\ 18606 \\ 19022 \end{bmatrix} \cdot kW$$

Non-dimensional values, not normalized(!), in coherent units

$$n_{0.ISO} := \frac{n_{0.ISO}}{Hz} \qquad V_{S0.ISO} := \frac{V_{S0.ISO}}{m \cdot sec^{-1}} \qquad P_{B0.ISO} := \frac{P_{B0.ISO}}{W}$$

Final performance data according to **VWS evaluation**
already non-dimensional values in coherent units

$n_{0.VWS} :=$ READPRN("NNico.prn")

$V_{S0.VWS} :=$ READPRN("VNico.prn")

$P_{B0.VWS} :=$ READPRN("PBNico.prn")

$ii := 0 .. \mathrm{last}(n_{0.VWS})$

frequency of revolution:

$$n_{0.VWS} = \begin{bmatrix} 0.731 \\ 0.927 \\ 1.047 \\ 1.094 \\ 1.115 \end{bmatrix}$$

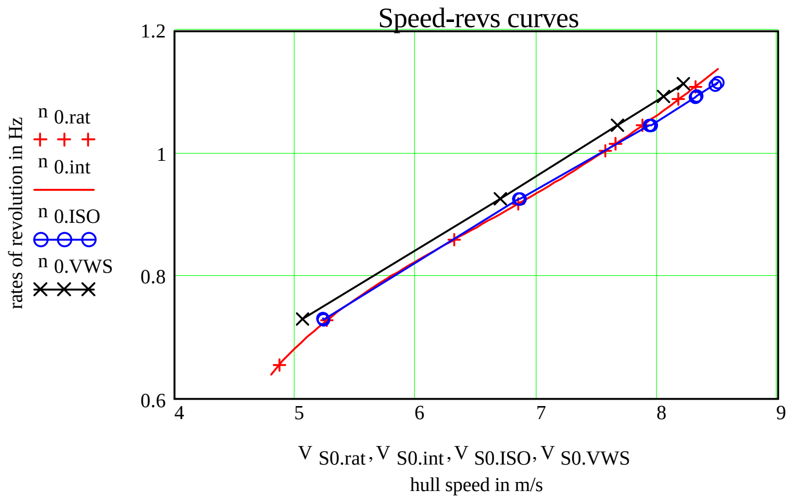
ship speed:

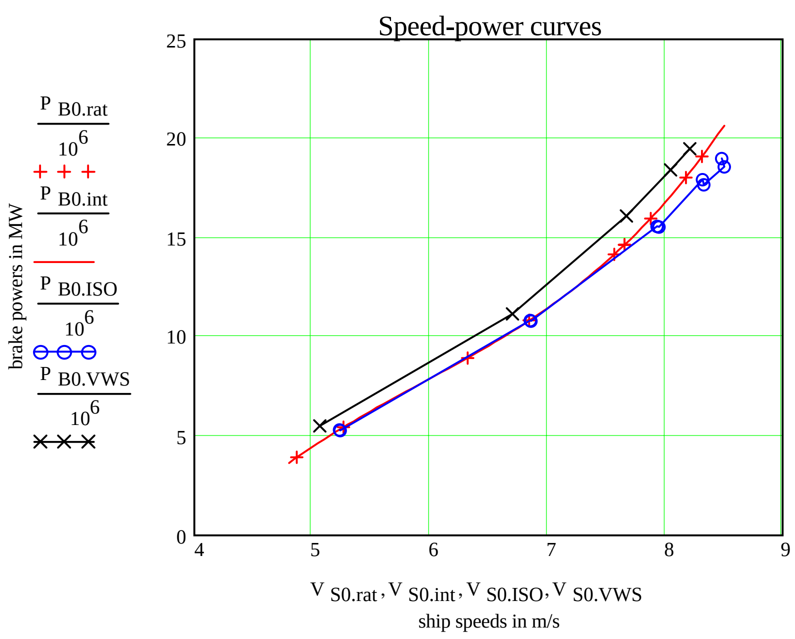
$$V_{S0.VWS} = \begin{bmatrix} 5.063 \\ 6.701 \\ 7.670 \\ 8.047 \\ 8.211 \end{bmatrix}$$

brake power:

$$\frac{P_{B0.VWS}}{10^6} = \begin{bmatrix} 5.520 \\ 11.190 \\ 16.120 \\ 18.430 \\ 19.500 \end{bmatrix}$$

Plots of final results





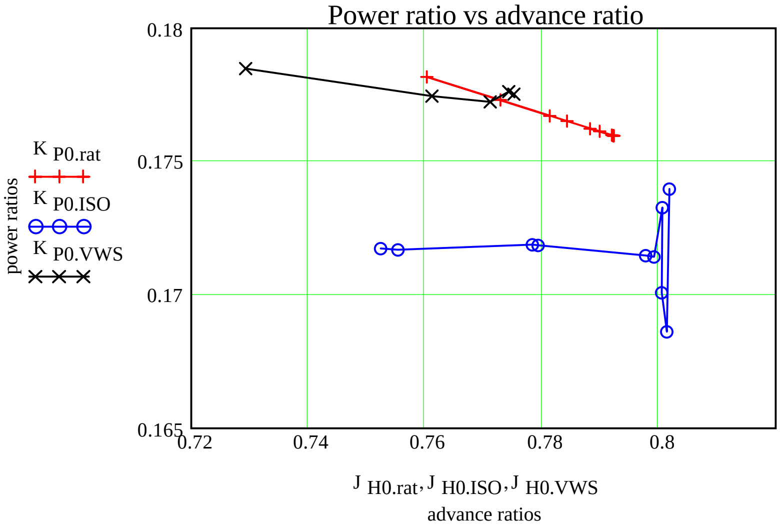
Normalized values

Advance ratios, power ratios

$$J_{H0.rat_i} := JH\left(V_{S0.rat_i}, n_{0.rat_i}\right) \qquad K_{P0.rat_i} := KP\left(P_{B0.rat_i}, n_{0.rat_i}\right)$$

$$J_{H0.ISO_i} := JH\left(V_{S0.ISO_i}, n_{0.ISO_i}\right) \qquad K_{P0.ISO_i} := KP\left(P_{B0.ISO_i}, n_{0.ISO_i}\right)$$

$$J_{H0.VWS_{ii}} := JH\left(V_{S0.VWS_{ii}}, n_{0.VWS_{ii}}\right) \qquad K_{P0.VWS_{ii}} := KP\left(P_{B0.VWS_{ii}}, n_{0.VWS_{ii}}\right)$$



Normalized values

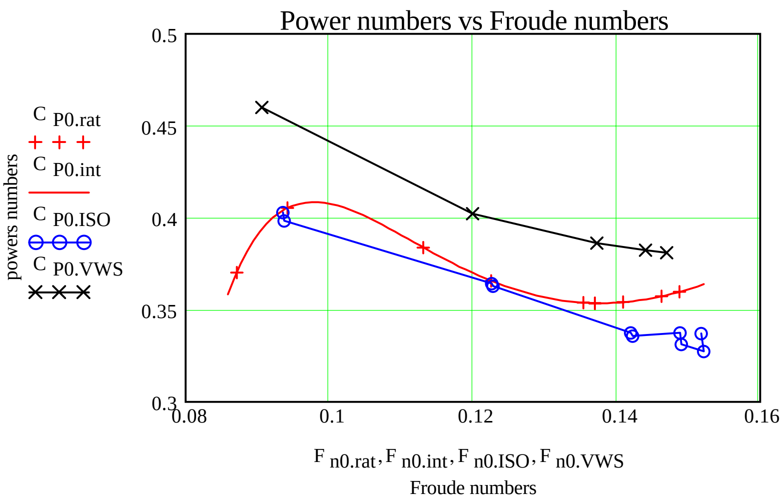
Froude numbers, power numbers

$F_{n0.rat_i} := Fn\left(V_{S0.rat_i}\right)$ $\quad C_{P0.rat_i} := CP\left(P_{B0.rat_i}, V_{S0.rat_i}\right)$

$F_{n0.int_k} := Fn\left(V_{S0.int_k}\right)$ $\quad C_{P0.int_k} := CP\left(P_{B0.int_k}, V_{S0.int_k}\right)$

$F_{n0.ISO_i} := Fn\left(V_{S0.ISO_i}\right)$ $\quad C_{P0.ISO_i} := CP\left(P_{B0.ISO_i}, V_{S0.ISO_i}\right)$

$F_{n0.VWS_{ii}} := Fn\left(V_{S0.VWS_{ii}}\right)$ $\quad C_{P0.VWS_{ii}} := CP\left(P_{B0.VWS_{ii}}, V_{S0.VWS_{ii}}\right)$



Conclusions

The new ISO/CD 15016 example provides another test case for the rational evaluation of trials proposed. **There remain differences in the evaluations** further to be analysed. Independent of this analysis **the differences** in magnitude and, particularly, in trend of the normalized results between the proposed rational and the proposed ISO evaluations **can be ascribed to inconsistencies in the ISO procedure.**

Of course the rational method proposed does not yet cope with all the problems and details being still in its infancy and needing the joint effort and agreement of all experts before it can be established as a standard. **The advantages of the rational procedure are a minimum number of conventions and the consistent application of systems identification methods <u>requiring no reference to model test results and other prior data, as it should be.</u>**

The propeller performance in the behind condition, i.e. in the full scale wake (!), and the current velocity can be identified simultaneously by solving one set of linear equations. After the 'calibration' the propeller power characteristic in the behind condition can be used for monitoring purposes, e.g. to determine the value of current velocity from measured values of the rate of revolution and the torque, or to determine the value of resistance after additional calibrations or even crude assumptions.

Further the power required due to the resistance in water, in wind and in waves can be identified simultaneously by solving another set of linear equations. Identifying parameters of models from observed data, even visually observed wave data, has the advantage that **<u>systematic errors in the observations are to a great extent automatically accounted for.</u> In case of the proposed, very involved ISO method this does not apply, although it is based on the same crude wave data. This fact is one major reason for the <u>concerns about the method expressed nearly unisono by experts in shipyards and institutions.</u>**

From the data at hand the values of the added power due to waves being identified according to the rational method are more than twice as large as the 'nominal' values computed according to the proposed ISO method. And the latter was particularly designed to deal with this problem, just with reference to the very crude data of wave observation, but without any reference to the observed data of brake power!

In view of the ill-conditioned problems arising there is no chance to solve the equations with do-it-yourself algorithms, **singular value decomposition is an absolute requirement**. In a great number of examples, based on actual data from industry, it has been shown that this procedure is superior to the traditional procedures of solving eight or ten simultaneous equations iteratively. The author has no idea how this can be done reliably!

In his contribution to the discussion of the Report of the Specialist Committee on Trials and Monitoring to the 22nd ITTC in Seoul and Shanghai September 05/11, 1999 **the author fully endorses Recommendation 5 to the Conference concerning the recording of 'time histories'. Even if runs are considered stationary sound performance and confidence analyses have to be based on 'instantaneous' values of the data. The present samples of at best eight 'doubtful' averages are just too small in size for serious applications of statistical methods.**

Many problems in the evaluation of trials are due to waiting for steady conditions and using ill-defined average values. In the METEOR and CORSAIR trials **quasisteady test manoeuvres have been shown to be much superior to steady testing, providing not only much more information, but at the same time <u>the necessary references for the suppression of the omnipresent noise</u>, even at service conditions in heavy weather.**

END Rational re-evaluation of new ISO/CD 15016 example

Mi Sep 15 11:28:02 1999