A new friction correction method for the open water characteristics of propellers

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1 Introduction

One of the main tasks of a model basin is the determination of the behaviour of a propeller at a ship. This characterisation is in general expressed by the so called open water characteristic. The classical way for the determination of the open water characteristic in full scale is the recalculation of a measured open water characteristic in model scale with scale factors of 10 to 50. The conditions for the friction in water in model and full scale are in general completely different and are dependent not only from the scale factor. The quality of the recalculation of the open water characteristic has a decisive influence of the quality of the propulsion prognosis of the vessel. The ITTC defined 1978 a standard for this recalculations of the open water characteristics for ship applications. But, it could not be demonstrated that these methods are independent of the used revolution numbers during the measuring of the open water characteristic in the model basin [13, 14 und 9]. In this paper it will be discussed some possibilities to improve the methods for the recalculation of measured open water characteristics from model scale to full scale. The advantages of these new methods will be demonstrated for conventional and unconventional (e.g. tip rake) propellers.

2 Theoretical basics of the new correction methods

The basic idea for the des ITTC-1978 Reynolds number correction can be summarised by the following formulas. The thrust and torque coefficient in full scale expressed by a correction

$$K_{TS} = K_{TM} - \Delta K_T$$
$$K_{QS} = K_{QM} - \Delta K_Q \qquad (1)$$

with

$$\Delta K_T = -\Delta C_D \cdot 0.3 \cdot \frac{P}{D} \cdot \frac{c \cdot Z}{D}$$
$$\Delta K_Q = \Delta C_D \cdot 0.25 \cdot \frac{c \cdot Z}{D} \qquad (2)$$

and the usual definitions of the pitch *P* chord length *c* and thickness *t* at the reference radius r/R = 0.75 (0.7), the diameter *D* and the blade number *Z*. The correction of the drug coefficient ΔC_D is expressed by $\Delta C_D = C_{DM} - C_{DS}$

(3)

with

$$C_{DM} = 2 \cdot \left(1 + 2 \cdot \frac{t}{c}\right) \cdot \left[\frac{0.044}{(Re_M)^{\frac{1}{6}}} - \frac{5}{(Re_M)^{\frac{2}{3}}}\right]$$
$$C_{DS} = 2 \cdot \left(1 + 2 \cdot \frac{t}{c}\right) \cdot \left(1.89 + 1.62 \cdot log \frac{c_S}{k_P}\right)^{-2.5} \qquad (4)$$

. The local Reynolds number at the radius *R* =0.75 denoted by Re_M with respect to the chord length in model scale c_M and the equivalent sand roughness in full scale by k_P . It is recommended that for the open water test the Reynolds number Re_M is bigger than 2.0E5. In following the indices S and M denote the situation in full scale or model scale respectively. The term $2 \cdot \left(1 + 2 \cdot \frac{t}{c}\right)$ in formulas (49 is called form factor for a profile and yields the correspondence between the friction coefficients of a one side of a flat plate – the second terms in formulas (4) in model and fill scale. To improve this type of Reynolds number correction for the open water characteristic it is appropriate to improve all terms of this procedure:

- improvement of the form factor of profiles
- improvement of the estimation of friction in model scale, especially under consideration of the transition between laminar and turbulent flow
- improvement of the estimation of friction in full scale, especially under consideration of the surface roughness
- improvement of the calculation of the corrections of thrust and torque coefficients
- taken into account of the configuration of the measurement equipment

1. Improvement of the form factor of profiles

The form factor in the set of ITTC1978 formulas for the calculation of the drug coefficient for profiles is defined by

$$C_D = 2 \cdot (1 + 2 \cdot \frac{t}{c}) \cdot C_F \, . \tag{5}$$

Already, Hoerner [3, 1965] gave a better formula

$$C_D = 2 \cdot (1 + 2 \cdot \frac{t}{c} + 60 \cdot (\frac{t}{c})^4) \cdot C_F \tag{6}$$

with the friction coefficient of one side of the flat plate C_F. Torenbeek [15, 1982] improved this formula to the term

$$C_D = 2 \cdot (1 + 2.7 \cdot \frac{t}{c} + 100 \cdot (\frac{t}{c})^4) \cdot C_F \, . \tag{7}$$

2. Improvement of the calculation of the flat plate friction under consideration of the transition of laminar to turbulent flow

The Reynolds numbers for propellers during model tests lie often in the transition zone between laminar and turbulent flows around the sectional profiles. The friction part in formula (4) for one side of the flat plate for the ITTC 1978 method is

$C_F = \cdot \left[\frac{0.044}{(Re)^{\frac{1}{6}}} - \frac{5}{(Re)^{\frac{2}{3}}} \right]$. The resulting curve is represented in figure 1 as the brown curve. This curve is in figure compared with the ITTC 1957 friction line (blue curve) and the curve for laminar flow (Blasius) is represented thin blue. The yellow curve is the usual transition curve between laminar and turbulent flow. For a better representation of the situation between laminar and turbulent flow for propeller it was defined a new curves by formula (8) („Lam.Turb.RS1“) and (9) („Lam.Turb.RS2“) which are represented in pink and green colours in figure 1.

$$\begin{aligned} C_F &= \cdot 0.3 \cdot \mathrm{Re}^{-0.333333333} \Big| \mathrm{Re} \le 10^6 \\ C_F &= \cdot 0.003 \big| 10^6 \le \mathrm{Re} \le 1.7 \cdot 10^6 \\ C_F &= \frac{3.913}{(\ln(\mathrm{Re}))^{2.58}} - \frac{1700}{\mathrm{Re}} \Big| 1.7 \cdot 10^6 \le \mathrm{Re} \end{aligned} \tag{8}$$

$$C_F = \cdot\frac{1.328}{\sqrt{\text{Re}}}\Bigg|\text{Re} \le 7858$$

$$C_F = \cdot\frac{0.01704}{\text{Re}^{0.11}}\Bigg|7858 \le \text{Re} \le 7.0\cdot 10^6 \tag{9}$$

$$C_F = \frac{3.913}{(\ln(\text{Re}))^{2.58}} - \frac{1700}{\text{Re}}\Bigg|7.0\cdot 10^6 \le \text{Re}$$

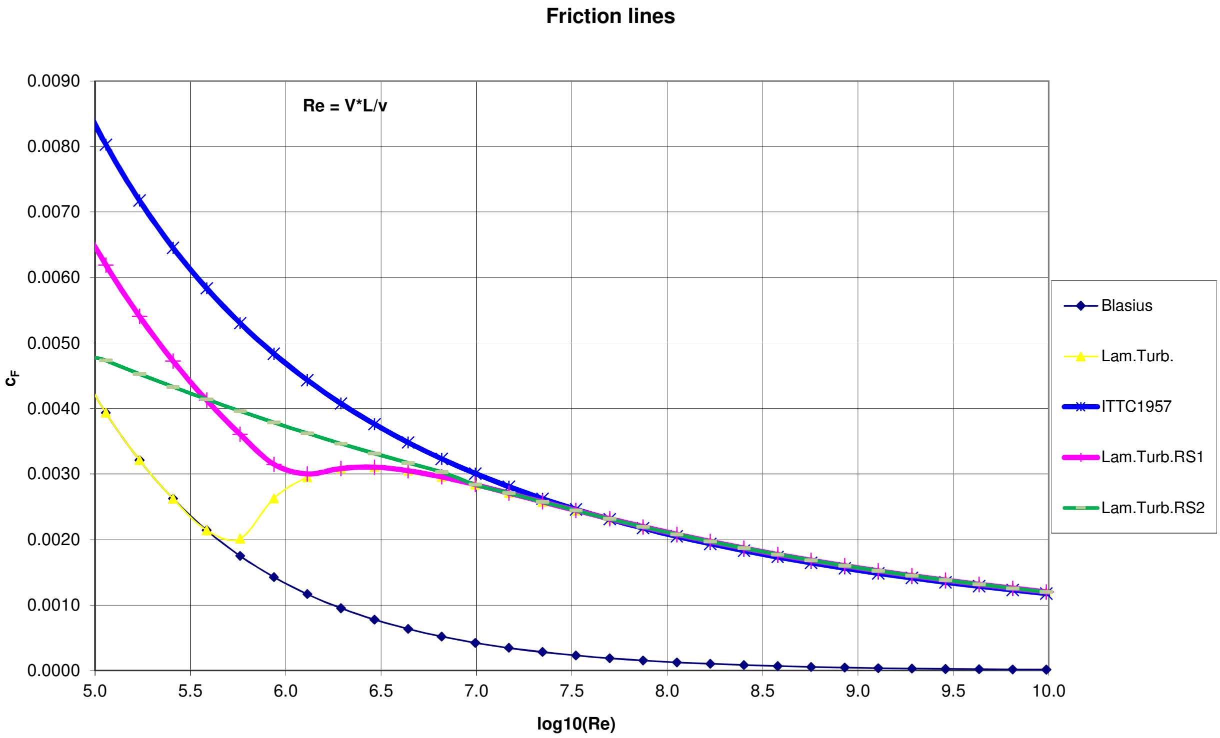


Figure 1: Different friction lines in dependence of the Reynolds number

Evidently, the ITTC 1978 friction line for the model scale is not applicable for Reynolds numbers lower than 3 * 10^5 ($\log_{10}(3*10^5) = 5.5$).

3. Improvement of the estimation of friction in full scale, especially under consideration of the surface roughness

A very good consideration of the surface properties (roughness) is given by the implicit representation of the friction coefficient following Schlichting/Gersten [11].

$$\sqrt{\frac{2}{c_F}} = \frac{1}{\kappa}\cdot log(\frac{c_F}{2}Re) + 5.0 - \frac{1}{\kappa}\cdot log(3.4 + k^+_{tech}) \tag{10}$$

([11], formula 17.40, page 530 inserted in formula 18.98, page 584) with an approximation of $k^+_{tech} = 0.001\cdot Re\cdot {k_P}/{c}$ and $\kappa = 0.41$ as Karman – constant. For a sand roughness of $.{k_P}/{c} = 0.00001$ this is represented in figure 2 by the brown curve in comparison to other friction lines.

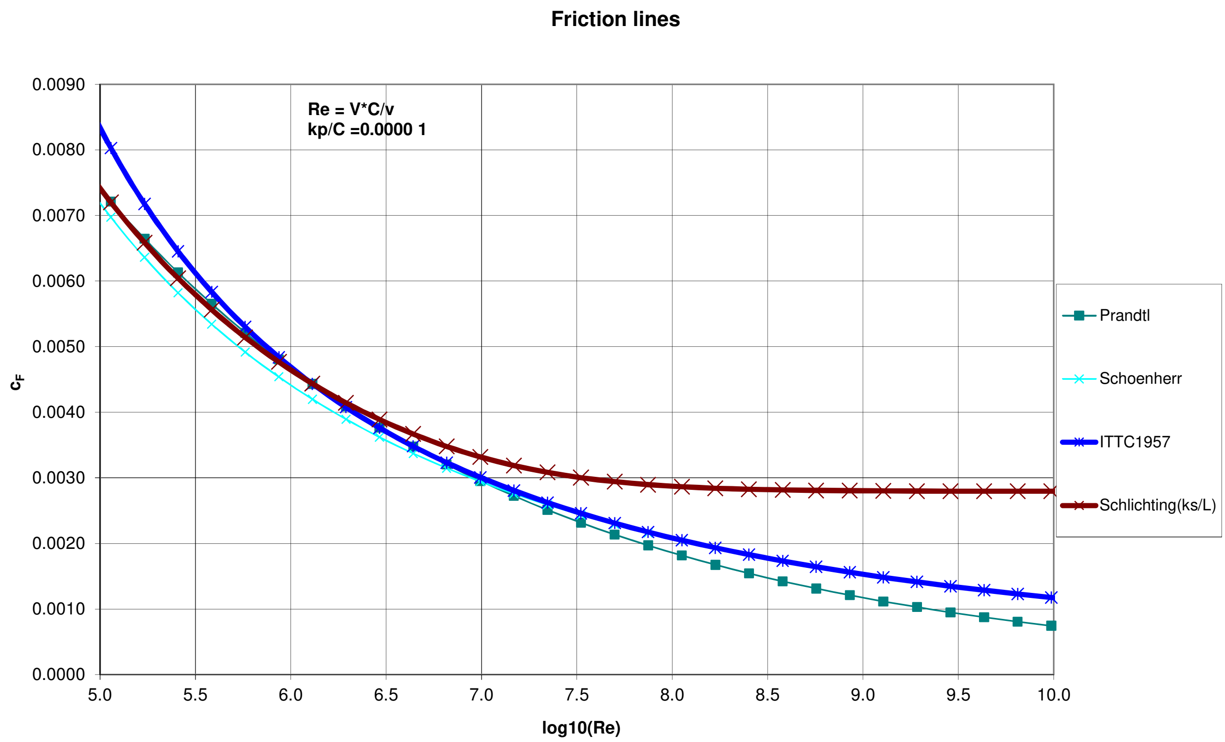


Figure 2: Schlichting/Gersten friction line (brown) for kp/C = 0.00001

4. Improvement of the calculation of ΔK_T and ΔK_Q

The main approach for the ITTC 1978 Reynolds number correction method based on (1):

$$K_{TS} = K_{TM} - \Delta K_T$$
$$K_{QS} = K_{QM} - \Delta K_Q \qquad (1)$$

with

$$\Delta K_T = -\Delta C_D \cdot 0.3 \cdot \frac{P}{D} \cdot \frac{c \cdot Z}{D}$$
$$\Delta K_Q = \Delta C_D \cdot 0.25 \cdot \frac{c \cdot Z}{D} \qquad (2)$$

using the main propeller parameters with respect to the reference radius r/R = 0.75. This can be improved by using the angle conditions of the blade at the reference radius. If ϕ is the geometrical angle of attack for the reference radius (r_R := r/R = 0.75), than follow for the frictional forces and moments on the blade in a simplified representation the following relations.

$$F_R = \frac{\rho}{2} \cdot C_D \cdot A_E \cdot V_R^2 = \frac{\rho}{2} \cdot C_D \cdot \frac{A_E}{A_0} \cdot A_0 \cdot V_R^2$$
$$F_x = F_R \cdot sin(\phi) \qquad . \qquad (11)$$
$$M_x = r_R \cdot \frac{D}{2} \cdot F_R \cdot cos(\phi)$$

With $V_R^2 = (J \cdot n \cdot D)^2 + (r_R \cdot n \cdot D \cdot \pi)^2$ follows

$$F_R = \frac{\rho}{2} \cdot C_D \cdot \frac{A_E}{A_0} \cdot A_0 \cdot V_R^2 = \frac{\rho}{2} \cdot C_D \cdot \frac{A_E}{A_0} \cdot \pi \cdot \frac{D^2}{4} \cdot ((J \cdot n \cdot D)^2 + (r_R \cdot n \cdot D \cdot \pi)^2)$$
$$F_x = F_R \cdot sin(\phi) \quad . \quad (12)$$
$$M_x = r_R \cdot \frac{D}{2} \cdot F_R \cdot cos(\phi)$$

The thrust and moment coefficients can than represented by

$$K_{F_R} = \frac{F_R}{\rho \cdot n^2 \cdot D^4} = \frac{1}{8} \cdot C_D \cdot \frac{A_E}{A_0} \cdot \pi \cdot (J^2 + (r_R \cdot \pi)^2)$$
$$K_{F_X} = K_{F_R} \cdot sin(\phi) \quad (13)$$
$$K_{M_X} = \frac{M_x}{\rho \cdot n^2 \cdot D^5} = \frac{r_R}{2} \cdot K_{F_R} \cdot cos(\phi)$$

Summarising these formulas, it can be derived a representation for the thrust and moment corrections ΔK_T and ΔK_Q by formula (14):

$$\Delta K_T = \frac{\pi}{8} \cdot \Delta C_D \cdot A_E/A_0 \cdot (J^2 + (r_R \cdot \pi)^2) \cdot sin(\phi)$$
$$\Delta K_Q = \frac{\pi \cdot r_R}{16} \cdot \Delta C_D \cdot A_E/A_0 \cdot (J^2 + (r_R \cdot \pi)^2) \cdot cos(\phi). \quad (14)$$
$$\phi = arctan(\frac{P_{r_R}/D}{r_R \cdot \pi})$$

The use of ϕ is a simplification, but it can be used in general for low loaded propellers.

5. Taking into account of the boundary layer of the test equipment (dynamometer)

The usual arrangement for the measuring of the open water characteristic of a propeller is represented in figure 3.

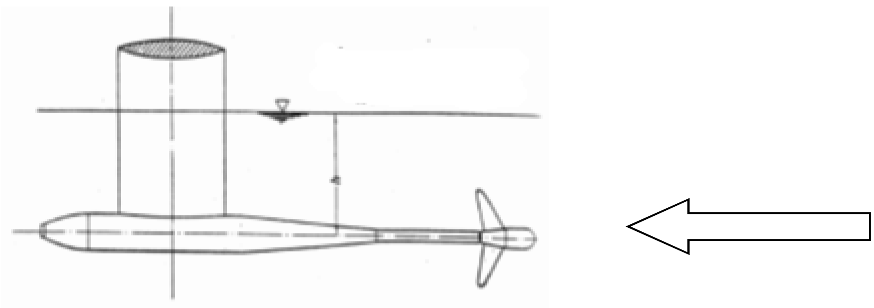


Figure 3: Usual arrangement for the determination of the open water characteristic of a propeller

The boundary layer around the dynamometer acts to the propeller by the backwater effect. This will be taken into account by a wake number w_{OW} which corrects the used inflow speed to the propeller.

$$w_{\mathrm{OW}} = \cdot 0.15 \cdot \frac{1}{(n_{\mathrm{M}} \cdot D_{\mathrm{M}})^4} \tag{15}$$

In other words the carriage speed must be corrected by a multiplication (1 – w_{ow}). The choice for w_{OW} (15) depends evidently from the special configuration of the used dynamometer.

3 Basics for the new strip correction methods

An arbitrary propeller of the diameter D_P is described by a set of radius dependent main parameters like chord length, pitch, skew, rake, profile thickness and profile camber in the standard dimension [m]. The propeller shall be act in a (homogeneous) inflow field described by the velocity V_a und the propeller rotates with the speed of *n* revolutions per second. The revolutions number generates for each radius an additional inflow speed V_U for the profiles. The vector sum of these speeds is described by V_R in dependence of the actual radius. With these speeds and the mean chord lengths for the strips it can be defined for each strip the Reynolds numbers. By the help of Torenbeeks [15] formula (7) for the form factor it can be derived from the flat plate friction coefficient C_{F} the drag coefficient C_{D} for each profile strip. The flat plate friction coefficient C_{F} can be defined in model and full scale by different formulas like e.g. (7) and (8). With the areas *S* of each strip, the resulting inflow speed V_R and the fluid density ρ it can be calculated the frictional forces along the profiles strips (profiles. These forces can be splitted in orthogonal parts in axial and tangential direction by using the geometrical angle of attack of the strips (profiles). This is a usual simplification because the frictional force directions at the strips are not identical to the angle of attack. But this simplification can be used for low loaded propellers. The sum of forces and moments over all radii yields the frictional part of propeller thrust and moment. By usual normalisation it can be derived then the frictional parts of the thrust coefficient and the torque coefficient. Using this procedure for model and full scale it can directly derived the frictional corrections by calculation of the difference of frictional thrust and torque coefficient for maodel and full scale. In the following these algorithm are explained more in detail in two steps.

1. Algorithms for the estimation of the propeller related data

In a preliminary step it must be calculated the following data derived from the propeller geometry. In general can be taken a arbitrary scaled propeller with a diameter D_{P}. The propeller shall be described by the following set of data for i = 1(hub),..,n(tip):

Radii [m] : r_{i}
Pitch [m] : P_{i}
Chord [m] : C_{i}
Rake [m] : B_{i}
Main profile data:
Thickness [m] : T_{i}
Camber [m] : F_{i}

Each strip shall be described by the following mean values of radii, pitches, chord lengths, thicknesses, geometrical angles of attack and the areas of the strips. Especially for CLT propeller, Tip – Fin Propeller and other types of unconventional propellers the areas of the strips can`t described only by the chord lengths and differences of radii but also by the differences of rakes.

The friction lines for the flat plated used from formula (8) or (9) for model scale and for full scale from formula (10).

	Calculations for all radii
Radii of references	$R_{ri} = \frac{(r_i + r_{i+1})}{2}$
Mean pitch for the strips	$P_{ri} = \frac{(P_i + P_{i+1})}{2}$
Mean chord length for the strips	$C_{ri} = \frac{(C_i + C_{i+1})}{2}$
Mean thickness for the strips	$T_{ri} = \frac{(T_i + T_{i+1})}{2}$
Reference area for the strips	$S_{ri} = \sqrt{((r_{i+1} - r_i)^2 + (B_{i+1} - B_i)^2))} \cdot C_{ri}$
Mean geometric angle of attack for the strips	$\phi_{ri} = arctan(\frac{P_{ri}}{2 \cdot R_{Ri} \cdot \pi})$

2. Algorithms for the calculation of the correction data

	Model scale (index M)	Full scale (index S)
Inflow velocity	$V_{aM} = J \cdot n_M \cdot D_M$	$V_{aS} = J \cdot n_S \cdot D_S$
	Calculations for all radii	
Tangential velocity	$V_{uMi} = 2 \cdot \pi \cdot n_M \cdot R_{ri} \cdot \frac{D_M}{D_P}$	$V_{uSi} = 2 \cdot \pi \cdot n_S \cdot R_{ri} \cdot \frac{D_S}{D_P}$
Resulting inflow speed to the profile	$V_{RMi} = \sqrt{(V_{aM}^2 + V_{uMi}^2)}$	$V_{RSi} = \sqrt{(V_{aS}^2 + V_{uSi}^2)}$
Reynoldszahl number	$\mathrm{Re}_{Mi} = V_{RMi} \cdot \frac{C_{ri}}{\nu_M} \cdot \frac{D_M}{D_P}$	$\mathrm{Re}_{Si} = V_{RSi} \cdot \frac{C_{ri}}{\nu_S} \cdot \frac{D_S}{D_P}$
Relative roughness	$kp_M / C_{Mri} = \frac{D_P \cdot kp_M}{C_{ri} \cdot D_M}$	$kp_S / C_{Sri} = \frac{D_P \cdot kp_S}{C_{Sri} \cdot D_S}$
Form factor for profile friction	$F_{\mathrm{FT}} = 2 \cdot (1 + 2.7 \cdot \frac{T_{ri}}{C_{ri}} + 100 \cdot (\frac{T_{ri}}{C_{ri}})^4)$	$F_{\mathrm{FT}} = 2 \cdot (1 + 2.7 \cdot \frac{T_{ri}}{C_{ri}} + 100 \cdot (\frac{T_{ri}}{C_{ri}})^4)$
Drug coefficient	$C_{\mathrm{DMi}} = F_{FT} \cdot C_{\mathrm{FM}}(Re_{Mi}, kp_M / C_{Mri})$	$C_{\mathrm{DSi}} = F_{FT} \cdot C_{\mathrm{FS}}(\mathrm{Re}_{Si}, kp_S / C_{Sri})$
Frictional forces at the profiles	$F_{Mi} = \frac{\rho}{2} \cdot C_{DMi} \cdot S_{ri} \cdot (\frac{D_M}{D_P})^2 \cdot V_{RMi}^2$	$F_{Si} = \frac{\rho}{2} \cdot C_{DSi} \cdot S_{ri} \cdot (\frac{D_S}{D_P})^2 \cdot V_{RSi}^2$
Geometrical angle of attack (arc)	$\phi_{ri} = arctan(\frac{P_{ri}}{2 \cdot R_{Ri} \cdot \pi})$	$\phi_{ri} = arctan(\frac{P_{ri}}{2 \cdot R_{Ri} \cdot \pi})$
Frictional forces in axial direction	$F_{xMi} = F_{Mi} \cdot sin(\phi_{ri})$	$F_{xSi} = F_{Si} \cdot sin(\phi_{ri})$
Frictional forces in tangential direction	$F_{tMi} = F_{Mi} \cdot cos(\phi_{ri})$	$F_{tSi} = F_{Si} \cdot cos(\phi_{ri})$
Thrust coefficient of the frictional forces	$K_{TMi} = \frac{z \cdot F_{xMi}}{\rho_M \cdot n_M^2 \cdot D_M^4}$	$K_{TSi} = \frac{z \cdot F_{xSi}}{\rho_S \cdot n_S^2 \cdot D_S^4}$
Torque coefficient of the frictional moments	$K_{QMi} = \frac{z \cdot F_{tMi} \cdot R_{ri} \cdot \frac{D_M}{D_S}}{\rho_M \cdot n_M^2 \cdot D_M^5}$	$K_{QSi} = \frac{z \cdot F_{tSi} \cdot R_{ri}}{\rho_S \cdot n_S^2 \cdot D_S^5}$

3. Algorithms for the calculation of the global corrections

	Global corrections	
	$K_{TS} = K_{TM} + \sum_{i=1}^{n-1} (K_{TMi} - K_{TSi})$	$K_{QS} = K_{QM} - \sum_{i=1}^{n-1} (K_{QMi} - K_{QSi})$

4 Example

Für die Propeller P1664, P1719, P1720, P1727, P1728, P1729 und P1730 aus den Berichten [16] und [17] und den dort zu findenden Messungen wird das oben vorgestellte Verfahren angewandt und die Ergebnisse auf den folgenden Seiten ausführlich dargestellt. Die Geometrie und die Hauptdaten der Propeller ergeben sich aus den Bildern 1, 6, 11, 16 und 21. Für jeweils drei Drehzahlen wurden Freifahrtmessungen in [16] und [17] realisiert. Die Hauptdaten zu den Messungen ergeben sich aus den jeweiligen Tabellen. Zum Versuchsaufbau und ergänzende Daten sei auf die Berichte [16] und [17] verwiesen. Die Propeller P1664 P1719 und P1720 gelten als konventionelle Propeller wogegen die anderen betrachteten Propeller als so genannte Tip Rake Propeller gelten und für diese als Grundlage für das vorliegende Forschungsvorhaben vermutet wurde, dass sie einer Sonderbehandlung bei der Reynoldszahlkorrektur bedürfen.

Im den folgenden Tabellen und Bildern wird aus programmiertechnischen Gründen der übliche Index „S“ für Großausführung ersetzt durch die Abkürzung „_rey“ und der übliche Index „M“ für Modellmaßstab wird ersetzt durch „_mes“.

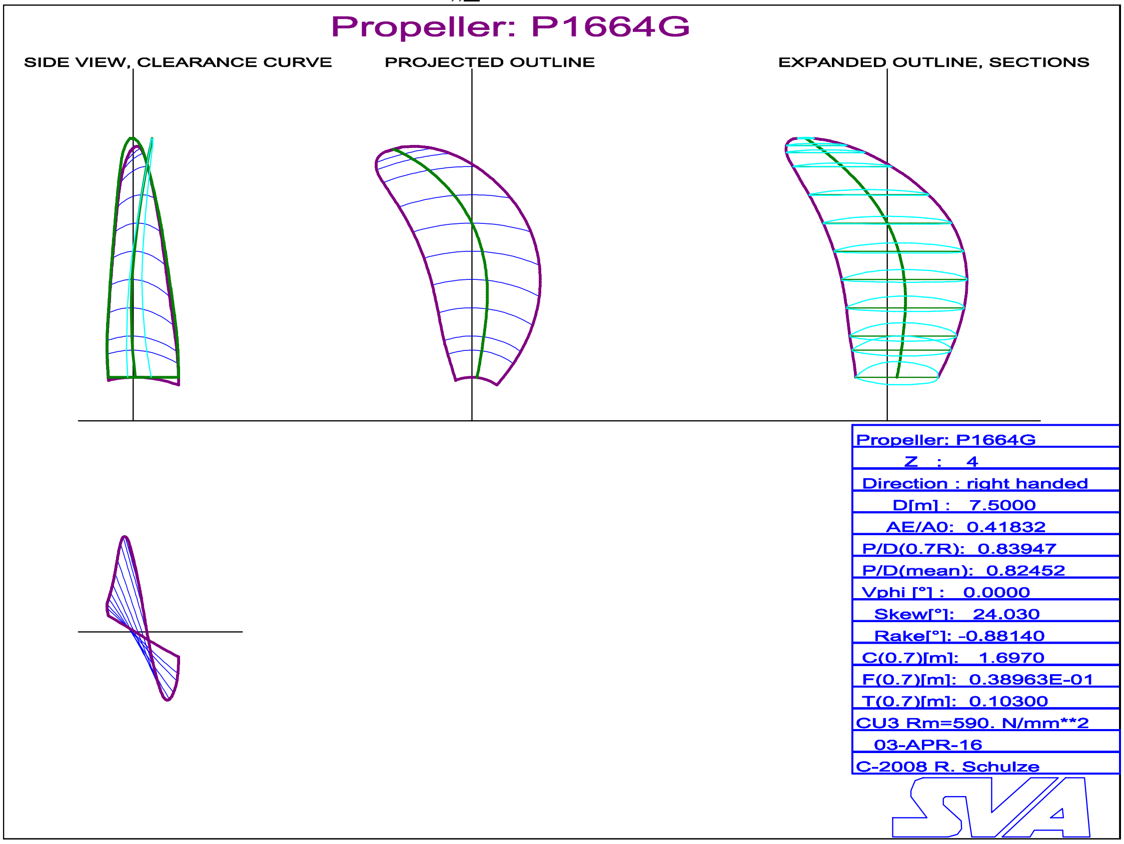


Bild 1: Geometrie und Hauptdaten des Propellers P1664

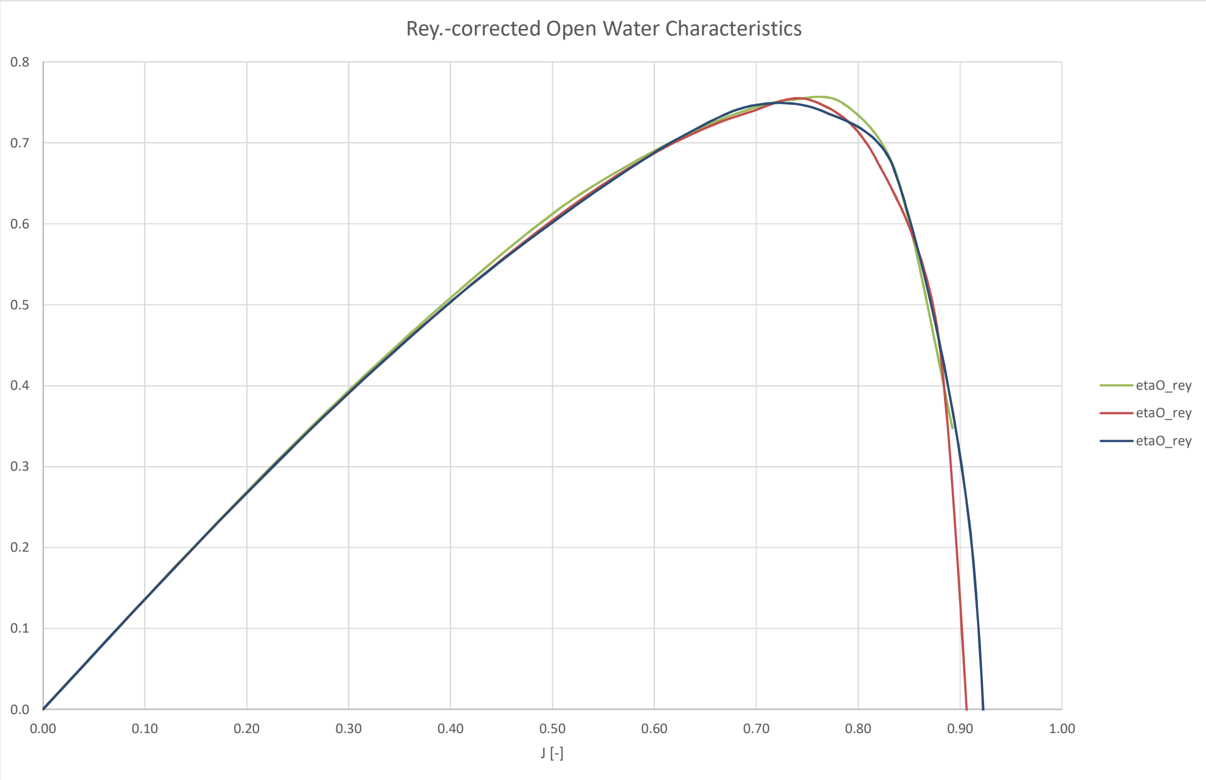


Bild 2: Vergleich der Wirkungsgrade aller Reynoldszahlkorrigierten Messwerte vom Propeller P1664

Tabelle 1: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 13F0676

Maßstab: 31.4286, n_M = 8 1/s, Messung: 13F0676

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.36173	0.43251	0.00000	0.00000	0.36285	0.42135	0.00000	209038.31250	31113018.00000
0.05418	0.34782	0.41723	0.07189	0.05418	0.34919	0.40635	0.07410	209069.39063	31117646.00000
0.10408	0.33717	0.40569	0.13767	0.10408	0.33882	0.39508	0.14206	209153.00000	31130088.00000
0.15777	0.32104	0.38992	0.20674	0.15777	0.32326	0.37982	0.21371	209301.73438	31152228.00000
0.21109	0.30470	0.37431	0.27348	0.21109	0.30734	0.36462	0.28318	209509.65625	31183174.00000
0.26281	0.28531	0.35519	0.33598	0.26281	0.28867	0.34625	0.34872	209768.46875	31221696.00000
0.31629	0.26465	0.33551	0.39707	0.31629	0.26844	0.32691	0.41335	210095.04688	31270304.00000
0.36602	0.24607	0.31792	0.45088	0.36602	0.25018	0.30967	0.47064	210452.28125	31323472.00000
0.41929	0.22580	0.29800	0.50564	0.41929	0.23049	0.29047	0.52951	210891.85938	31388898.00000
0.47159	0.20451	0.27622	0.55570	0.47159	0.20992	0.26954	0.58454	211380.37500	31461610.00000
0.52320	0.18256	0.25416	0.59812	0.52320	0.18895	0.24847	0.63322	211917.37500	31541534.00000
0.57634	0.15252	0.22225	0.62948	0.57634	0.16087	0.21903	0.67368	212526.85938	31632250.00000
0.62741	0.12702	0.19363	0.65504	0.62741	0.13474	0.19013	0.70764	213166.23438	31727414.00000
0.68253	0.10197	0.16499	0.67136	0.68253	0.10989	0.16193	0.73716	213914.75000	31838824.00000
0.73603	0.07571	0.13296	0.66704	0.73603	0.08466	0.13162	0.75343	214698.70313	31955506.00000
0.78634	0.05352	0.10616	0.63097	0.78634	0.06221	0.10413	0.74771	215486.96875	32072830.00000
0.83724	0.02944	0.08102	0.48424	0.83724	0.03950	0.07951	0.66203	216334.26563	32198940.00000
0.89253	-0.00006	0.04574	-0.00194	0.89253	0.01198	0.04898	0.34743	217310.71875	32344276.00000

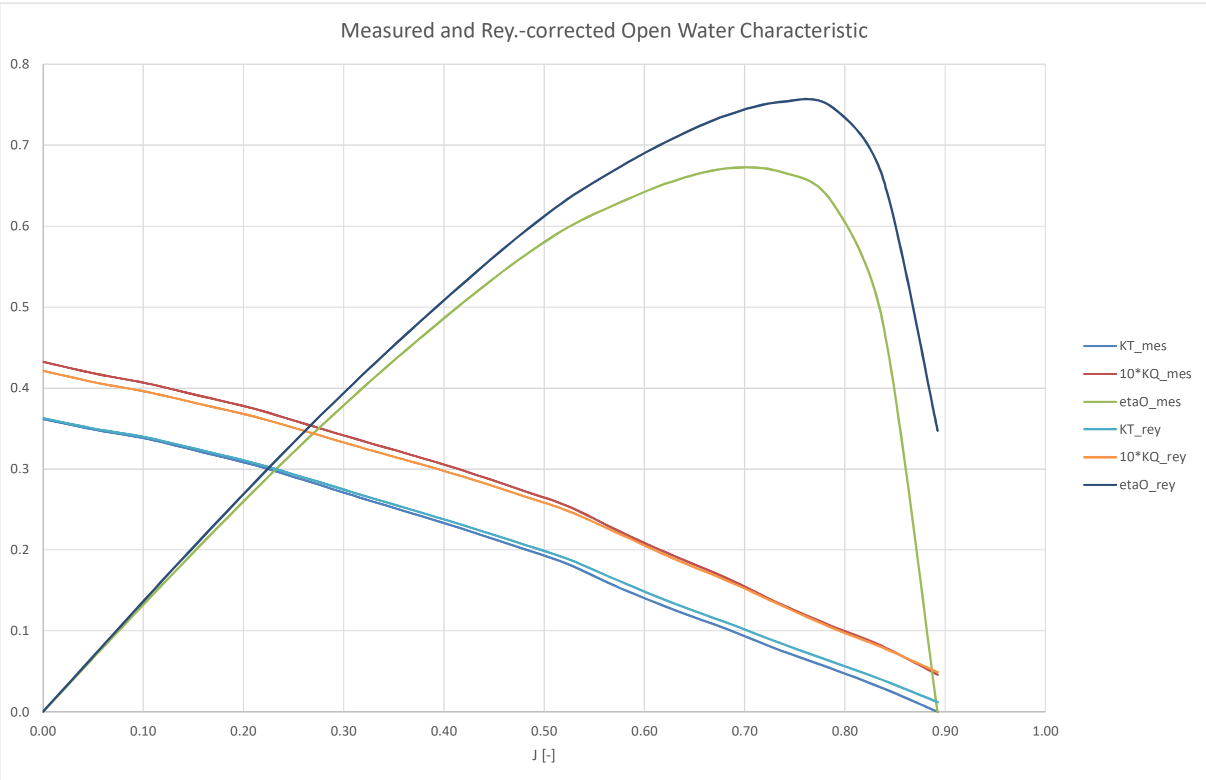


Bild 3: Gemessene und Reynoldszahlkorrigierte Messwerte der Messung 13F0676

Maßstab: 31.4286, Drehzahl n_M = 10 1/s, Messung: 13F0677

Tabelle 2: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 13F0677

Maßstab: 31.4286, n_M = 10 1/s, Messung: 13F0677

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00001	0.36310	0.43262	0.00001	0.00001	0.36404	0.42328	0.00001	261297.89063	31113018.00000
0.06355	0.34840	0.41631	0.08464	0.06355	0.34957	0.40722	0.08683	261351.34375	31119384.00000
0.12516	0.33043	0.39866	0.16511	0.12516	0.33192	0.38986	0.16959	261505.17188	31137700.00000
0.18818	0.30975	0.37837	0.24518	0.18818	0.31159	0.36992	0.25227	261766.23438	31168784.00000
0.25148	0.28765	0.35710	0.32240	0.25148	0.28985	0.34898	0.33242	262133.71875	31212542.00000
0.31312	0.26511	0.33626	0.39290	0.31312	0.26767	0.32846	0.40611	262592.53125	31267174.00000
0.37648	0.24171	0.31395	0.46131	0.37648	0.24462	0.30657	0.47811	263167.43750	31335628.00000
0.43823	0.21792	0.29082	0.52263	0.43823	0.22127	0.28394	0.54352	263827.84375	31414264.00000
0.50097	0.19247	0.26488	0.57936	0.50097	0.19630	0.25863	0.60517	264599.25000	31506116.00000
0.56315	0.16636	0.23755	0.62768	0.56315	0.17082	0.23211	0.65961	265462.81250	31608940.00000
0.62800	0.13314	0.20039	0.66407	0.62800	0.13870	0.19647	0.70558	266467.40625	31728560.00000
0.69133	0.10128	0.16319	0.68287	0.69133	0.10695	0.15964	0.73709	267549.78125	31857440.00000
0.75387	0.07286	0.12879	0.67878	0.75387	0.07859	0.12531	0.75247	268715.71875	31996270.00000
0.81694	0.04227	0.09625	0.57107	0.81694	0.04885	0.09323	0.68122	269987.96875	32147756.00000
0.87952	0.01106	0.05855	0.26445	0.87952	0.01874	0.05786	0.45339	271344.68750	32309302.00000
0.92219	-0.01649	0.02419	-1.00050	0.92219	-0.00641	0.02657	-0.35392	272322.93750	32425782.00000

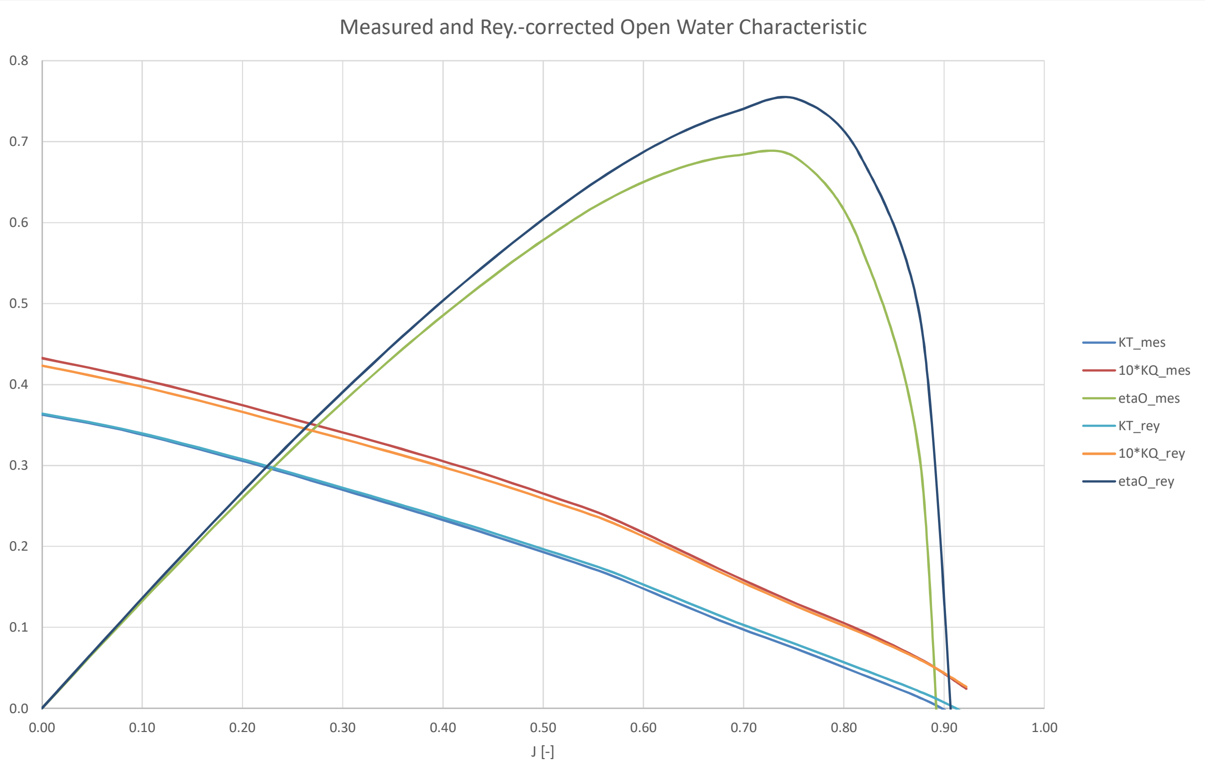


Bild 4: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 13F0677

Tabelle 3: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 13F0678

Maßstab: 31.4286, n_M = 18 1/s, Messung: 13F0678

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.37175	0.43884	0.00000	0.00000	0.37226	0.43372	0.00000	470336.18750	31113018.00000
0.07033	0.35174	0.41572	0.09471	0.07033	0.35234	0.41069	0.09603	470454.03125	31120814.00000
0.14029	0.33064	0.39469	0.18705	0.14029	0.33135	0.38976	0.18982	470804.90625	31144024.00000
0.20958	0.30666	0.37153	0.27532	0.20958	0.30750	0.36673	0.27968	471381.62500	31182174.00000
0.28001	0.28150	0.34747	0.36104	0.28001	0.28246	0.34279	0.36721	472200.71875	31236358.00000
0.34940	0.25445	0.32200	0.43943	0.34940	0.25555	0.31746	0.44763	473236.12500	31304850.00000
0.42026	0.22835	0.29708	0.51412	0.42026	0.22956	0.29268	0.52461	474525.90625	31390170.00000
0.48934	0.19921	0.26820	0.57847	0.48934	0.20062	0.26406	0.59171	476007.59375	31488184.00000
0.55868	0.17098	0.23855	0.63731	0.55868	0.17247	0.23457	0.65377	477715.43750	31601160.00000
0.62849	0.14225	0.20681	0.68802	0.62849	0.14394	0.20313	0.70879	479655.71875	31729510.00000
0.69872	0.10814	0.16732	0.71872	0.69872	0.11012	0.16401	0.74665	481828.59375	31873248.00000
0.76901	0.07603	0.13291	0.70014	0.76901	0.07805	0.12960	0.73713	484222.21875	32031588.00000
0.83551	0.04465	0.09643	0.61572	0.83551	0.04695	0.09367	0.66648	486685.46875	32194534.00000
0.90875	0.00433	0.04528	0.13839	0.90875	0.00696	0.04311	0.23367	489618.34375	32388544.00000
0.93402	-0.00895	0.02836	-0.46912	0.93402	-0.00639	0.02608	-0.36433	490683.06250	32458976.00000

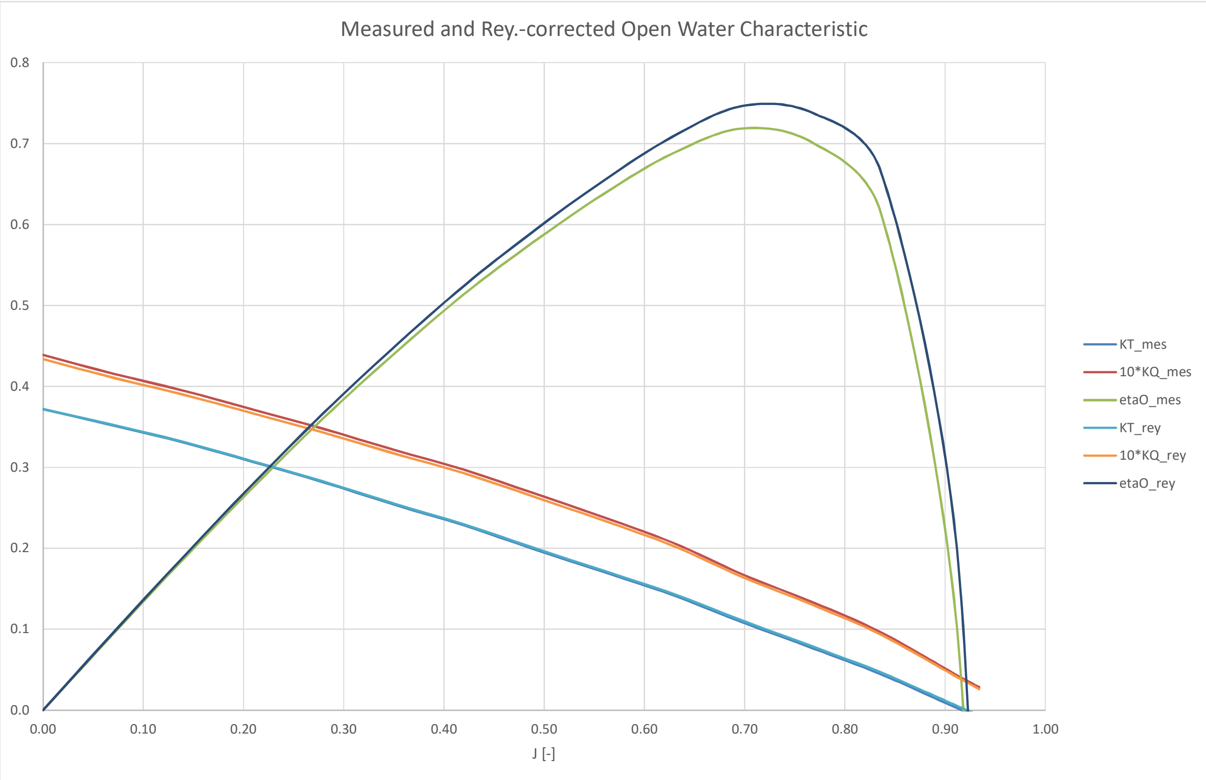


Bild 5: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 13F0678

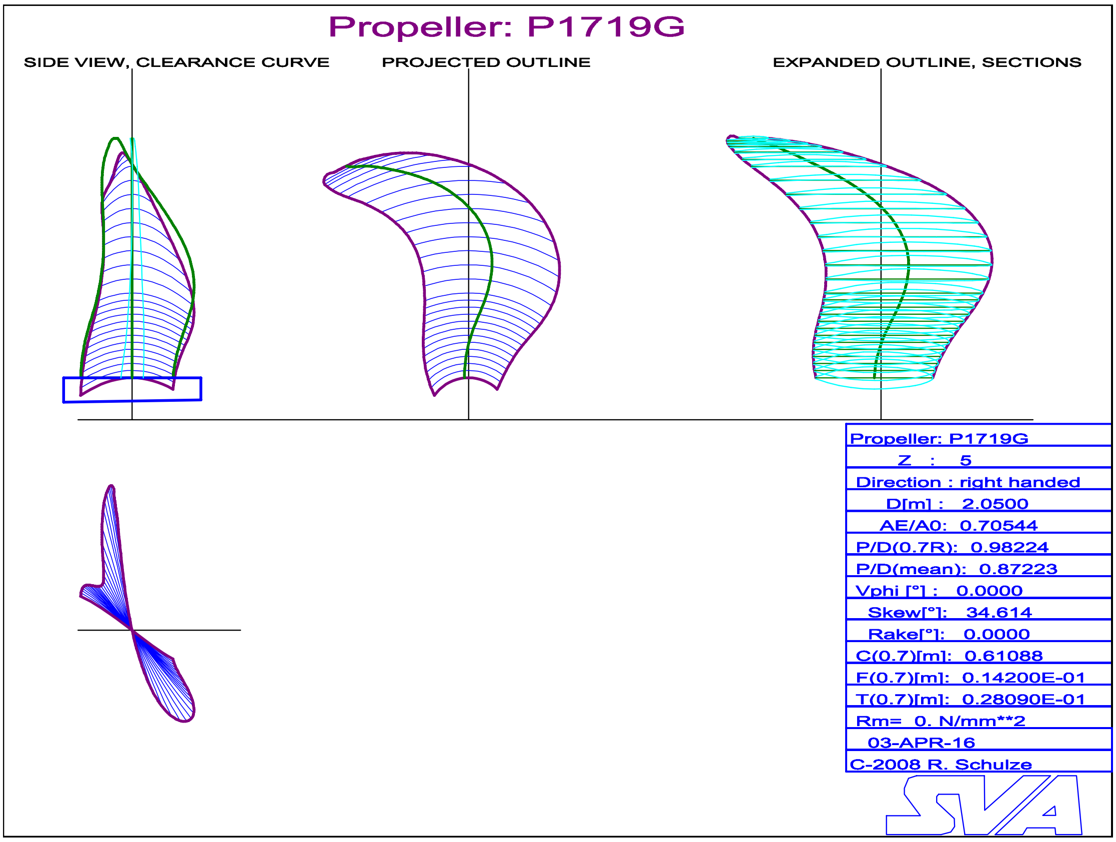


Bild 6: Geometrie und Hauptdaten des Propellers P1719

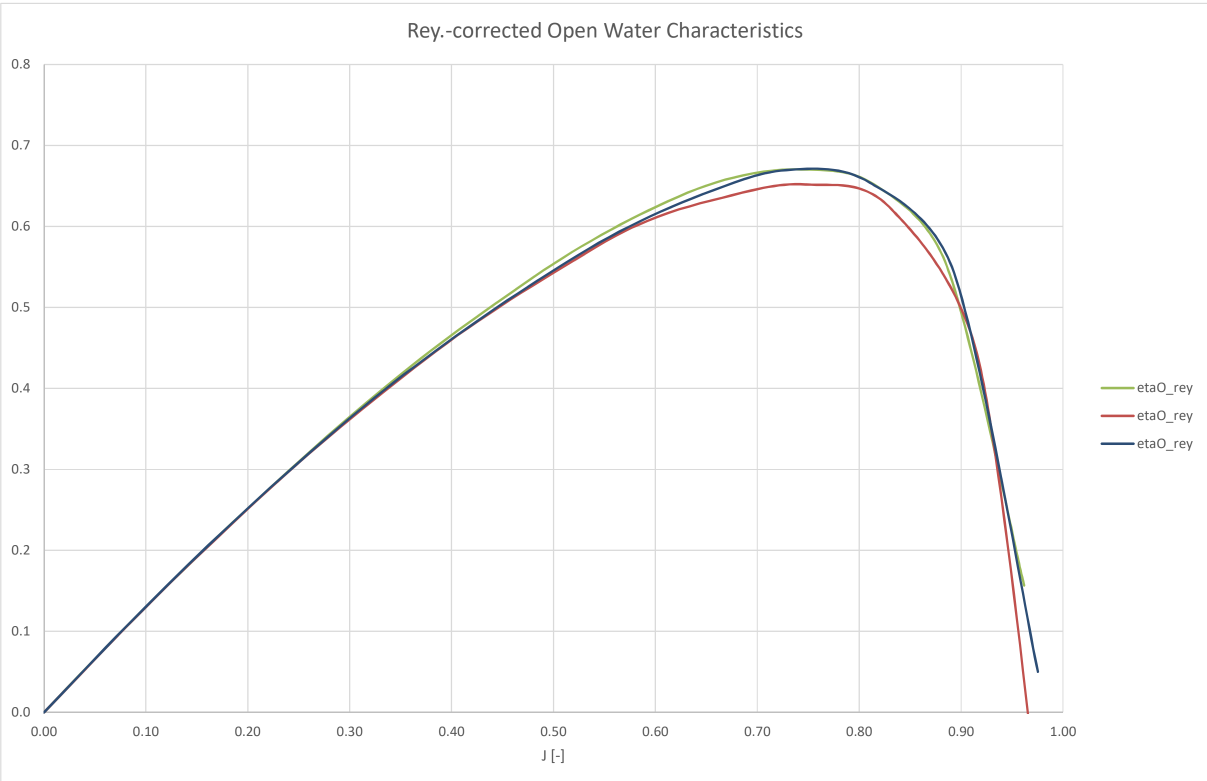


Bild 7: Vergleich der Wirkungsgrade aller reynoldszahlkorrigierten Messwerte vom Propeller P1719

Tabelle 4: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0105

Maßstab: 11.389, n_M = 15 1/s, Messung: 15F0105

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.47583	0.58139	0.00000	0.00000	0.47709	0.56994	0.00000	297723.81250	13147215.00000
0.07402	0.44841	0.55728	0.09480	0.07402	0.44998	0.54610	0.09708	297806.43750	13150865.00000
0.14799	0.41934	0.53342	0.18516	0.14799	0.42125	0.52251	0.18989	298053.93750	13161794.00000
0.22209	0.38887	0.50937	0.26985	0.22209	0.39113	0.49876	0.27719	298466.81250	13180026.00000
0.29619	0.35920	0.48294	0.35062	0.29619	0.36177	0.47272	0.36076	299044.06250	13205517.00000
0.37056	0.32789	0.45583	0.42423	0.37056	0.33088	0.44596	0.43759	299787.75000	13238357.00000
0.44440	0.29584	0.42783	0.48908	0.44440	0.29926	0.41846	0.50582	300687.78125	13278102.00000
0.51876	0.26114	0.39347	0.54796	0.51876	0.26511	0.38490	0.56867	301755.50000	13325251.00000
0.59429	0.22428	0.35681	0.59453	0.59429	0.22877	0.34881	0.62032	303003.96875	13380382.00000
0.66885	0.18636	0.31692	0.62597	0.66885	0.19165	0.31015	0.65778	304396.50000	13441876.00000
0.74336	0.13798	0.25989	0.62812	0.74336	0.14450	0.25504	0.67033	305944.84375	13510249.00000
0.81487	0.09730	0.21134	0.59712	0.81487	0.10363	0.20629	0.65150	307576.00000	13582280.00000
0.88611	0.05313	0.15885	0.47173	0.88611	0.06065	0.15533	0.55068	309340.12500	13660181.00000
0.96191	0.00050	0.09358	0.00821	0.96191	0.00946	0.09241	0.15665	311366.93750	13749684.00000

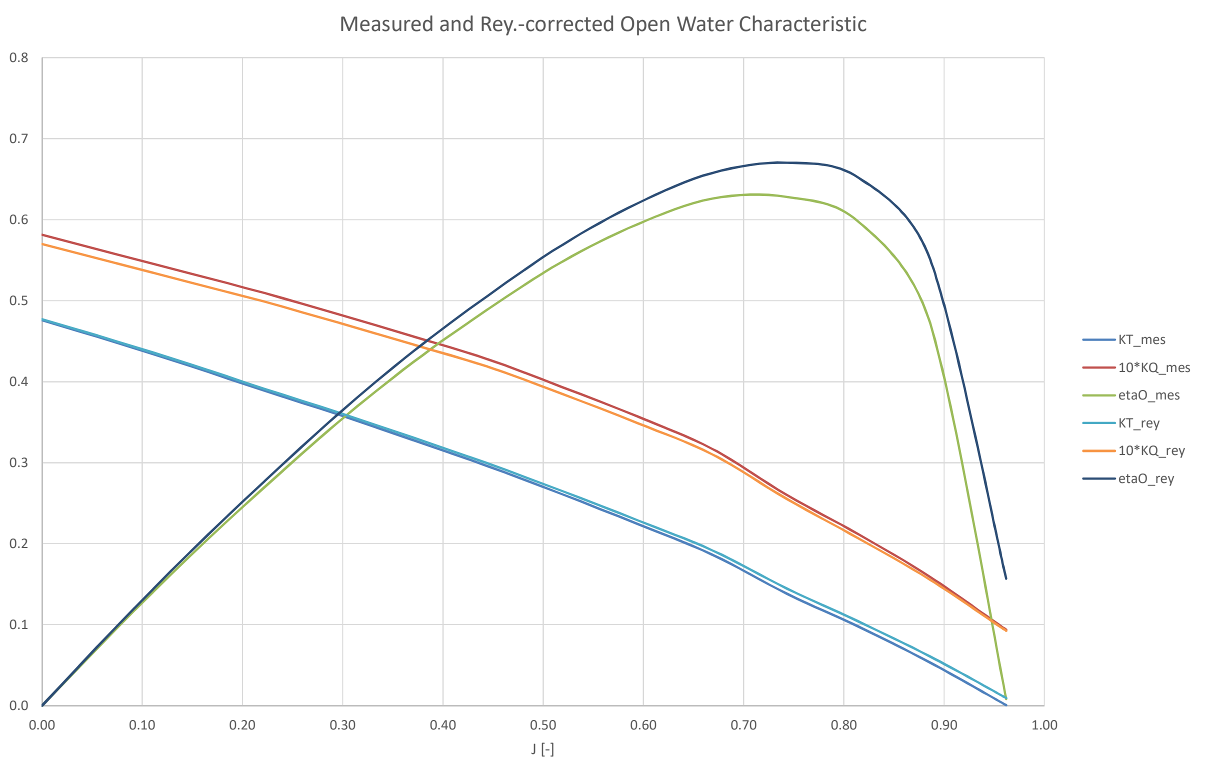


Bild 8: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0105

Tabelle 5: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0106

Maßstab: 11.389, n_M = 20 1/s, Messung: 15F0106

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.47598	0.57493	0.00000	0.00000	0.47687	0.56685	0.00000	396965.06250	13147215.00000
0.08314	0.44622	0.55316	0.10674	0.08314	0.44731	0.54524	0.10855	397104.06250	13151818.00000
0.16619	0.41276	0.52619	0.20748	0.16619	0.41407	0.51847	0.21124	397520.12500	13165598.00000
0.24927	0.37880	0.49815	0.30168	0.24927	0.38033	0.49062	0.30754	398212.68750	13188536.00000
0.33253	0.34259	0.46870	0.38684	0.33253	0.34439	0.46143	0.39500	399182.62500	13220659.00000
0.41634	0.30408	0.43420	0.46405	0.41634	0.30614	0.42725	0.47479	400435.84375	13262165.00000
0.49941	0.26753	0.40220	0.52870	0.49941	0.26978	0.39548	0.54220	401949.53125	13312298.00000
0.58212	0.22937	0.36351	0.58459	0.58212	0.23199	0.35737	0.60144	403722.28125	13371009.00000
0.66450	0.18553	0.31971	0.61372	0.66450	0.18863	0.31413	0.63506	405747.90625	13438097.00000
0.74747	0.14133	0.26899	0.62505	0.74747	0.14470	0.26410	0.65178	408046.37500	13514220.00000
0.83205	0.09365	0.21224	0.58434	0.83205	0.09762	0.20824	0.62079	410651.75000	13600509.00000
0.91957	0.03358	0.13587	0.36169	0.91957	0.03840	0.13317	0.42206	413621.25000	13698857.00000
1.00290	-0.02177	0.06788	-0.51186	1.00290	-0.01713	0.06462	-0.42316	416701.71875	13800880.00000

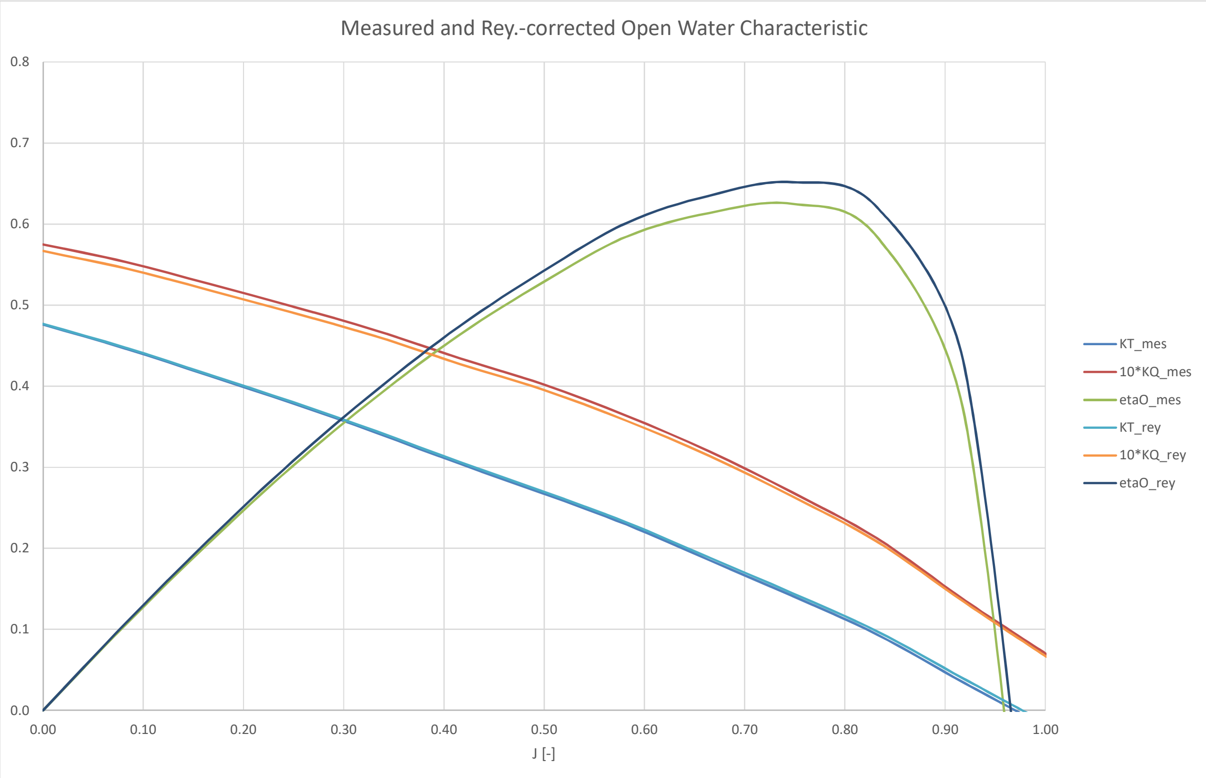


Bild 9: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0106

Tabelle 6: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0107

Maßstab: 11.389, n_M = 24 1/s, Messung: 15F0107

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00001	0.47963	0.57293	0.00001	0.00001	0.48030	0.56682	0.00001	476358.09375	13147215.00000
0.08079	0.44779	0.54964	0.10476	0.08079	0.44860	0.54364	0.10611	476515.59375	13151562.00000
0.16147	0.41541	0.52436	0.20359	0.16147	0.41636	0.51848	0.20637	476986.87500	13164569.00000
0.24232	0.38209	0.49820	0.29578	0.24232	0.38320	0.49247	0.30009	477773.03125	13186267.00000
0.32336	0.34674	0.46794	0.38135	0.32336	0.34803	0.46240	0.38734	478874.78125	13216675.00000
0.40399	0.31021	0.43694	0.45648	0.40399	0.31166	0.43157	0.46432	480280.56250	13255474.00000
0.48494	0.27429	0.40423	0.52371	0.48494	0.27588	0.39910	0.53353	481999.87500	13302925.00000
0.56442	0.23751	0.36711	0.58118	0.56442	0.23932	0.36232	0.59336	483984.93750	13357712.00000
0.64705	0.19638	0.32372	0.62472	0.64705	0.19844	0.31930	0.64002	486356.84375	13423175.00000
0.72850	0.15505	0.27647	0.65024	0.72850	0.15737	0.27251	0.66956	488997.84375	13496066.00000
0.81060	0.10648	0.21888	0.62761	0.81060	0.10922	0.21547	0.65393	491959.46875	13577804.00000
0.89312	0.05863	0.16455	0.50643	0.89312	0.06166	0.16151	0.54264	495233.78125	13668174.00000
0.97538	-0.00129	0.09083	-0.02203	0.97538	0.00289	0.08965	0.05007	498788.90625	13766293.00000

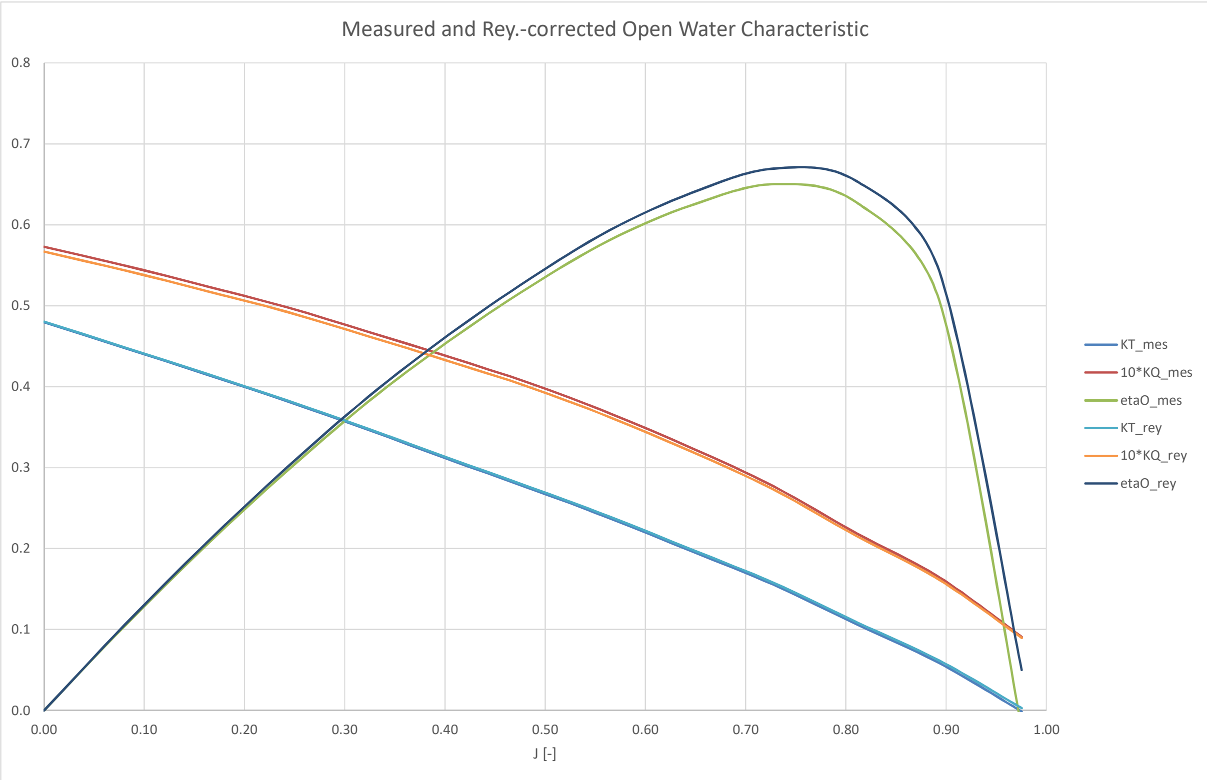


Bild 10: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0107

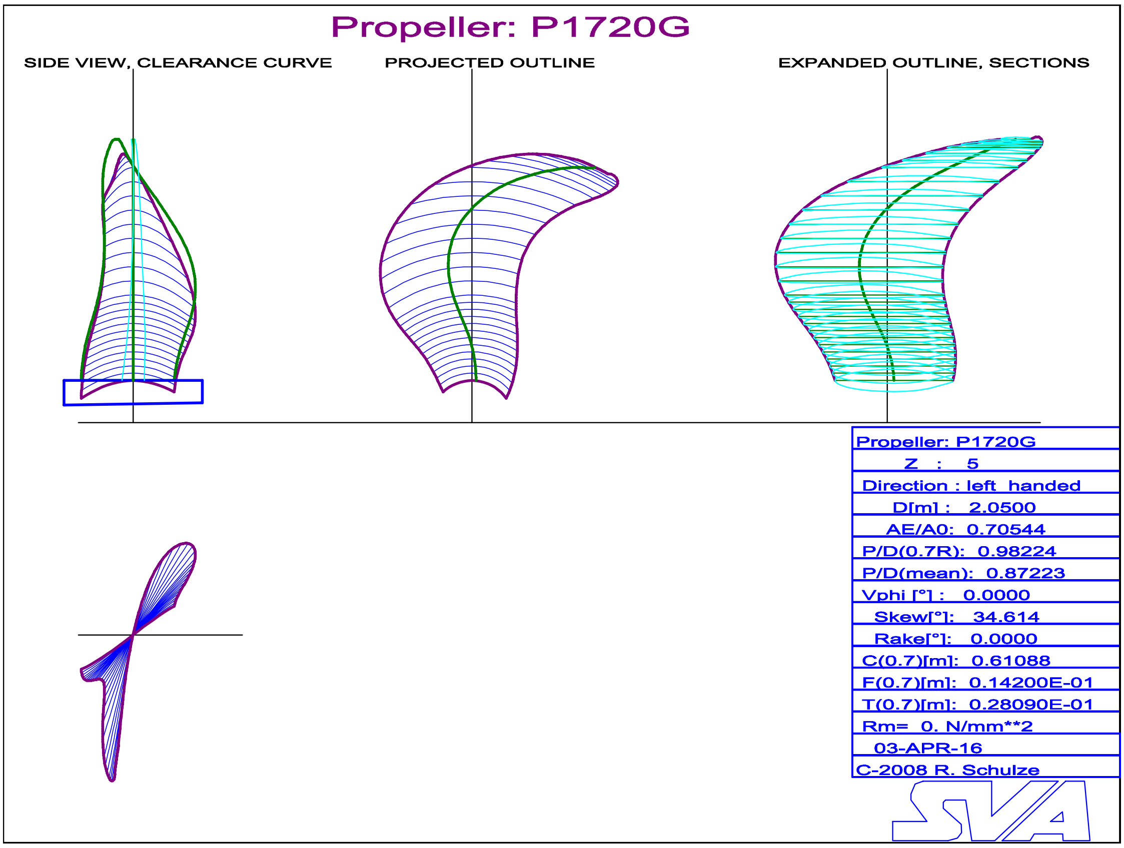


Bild 11: Geometrie und Hauptdaten des Propellers P1720

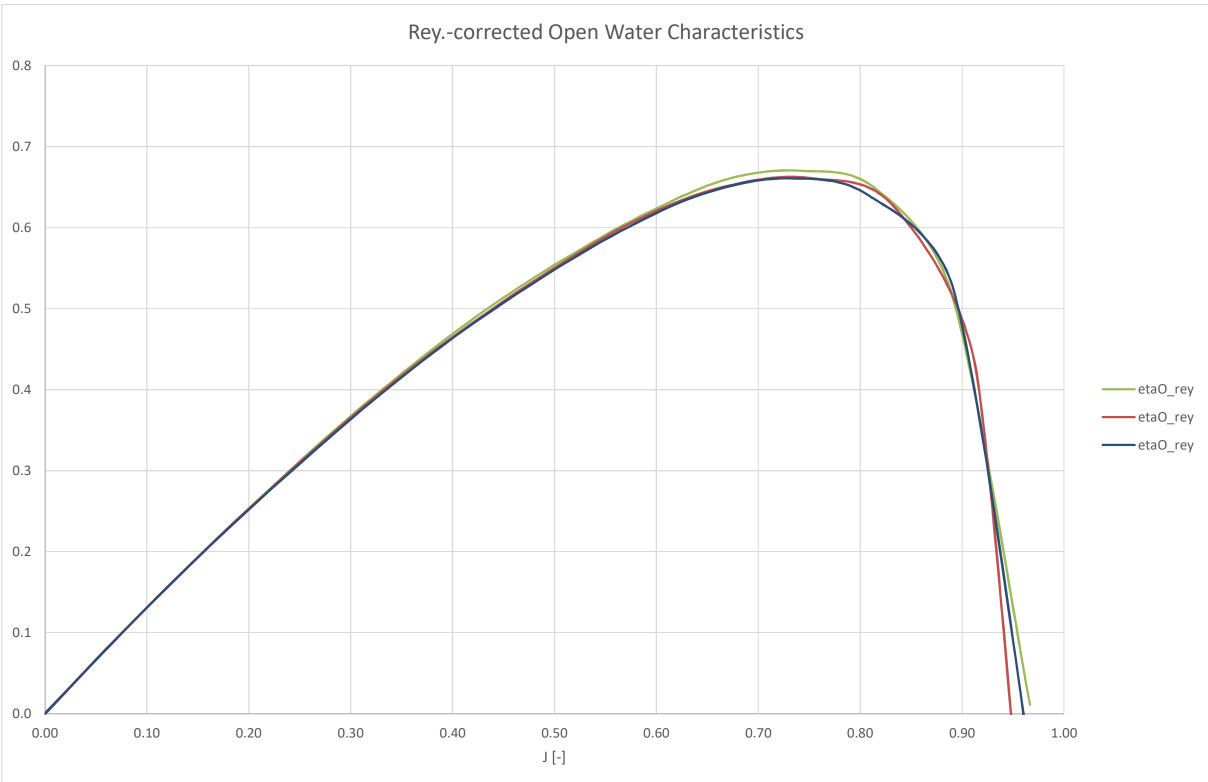


Bild 12: Vergleich der Wirkungsgrade aller reynoldszahlkorrigierten Messwerte vom Propeller P1720

Tabelle 7: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0112

Maßstab: 11.389, n_M = 1/s, Messung: 15F0112

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.46812	0.56113	0.00000	0.00000	0.46901	0.55305	0.00000	396965.06250	13147215.00000
0.08302	0.43991	0.54108	0.10742	0.08302	0.44099	0.53314	0.10929	397103.65625	13151805.00000
0.16642	0.40716	0.51569	0.20912	0.16642	0.40846	0.50795	0.21299	397521.65625	13165649.00000
0.24968	0.37382	0.48882	0.30389	0.24968	0.37533	0.48129	0.30990	398216.78125	13188671.00000
0.33331	0.33903	0.45860	0.39217	0.33331	0.34080	0.45134	0.40056	399193.00000	13221003.00000
0.41648	0.30110	0.42599	0.46852	0.41648	0.30317	0.41903	0.47957	400438.15625	13262242.00000
0.49971	0.26332	0.39063	0.53611	0.49971	0.26560	0.38401	0.55007	401955.50000	13312495.00000
0.58278	0.22528	0.35227	0.59316	0.58278	0.22789	0.34613	0.61068	403737.46875	13371513.00000
0.66621	0.18054	0.30490	0.62784	0.66621	0.18371	0.29950	0.65038	405792.68750	13439580.00000
0.75086	0.13237	0.25043	0.63166	0.75086	0.13589	0.24566	0.66104	408145.71875	13517511.00000
0.83591	0.08429	0.19282	0.58161	0.83591	0.08826	0.18880	0.62195	410776.90625	13604654.00000
0.91565	0.02980	0.12637	0.34360	0.91565	0.03465	0.12353	0.40880	413482.37500	13694257.00000
1.00360	-0.03204	0.05010	-1.02148	1.00360	-0.02697	0.04764	-0.90423	416728.62500	13801771.00000

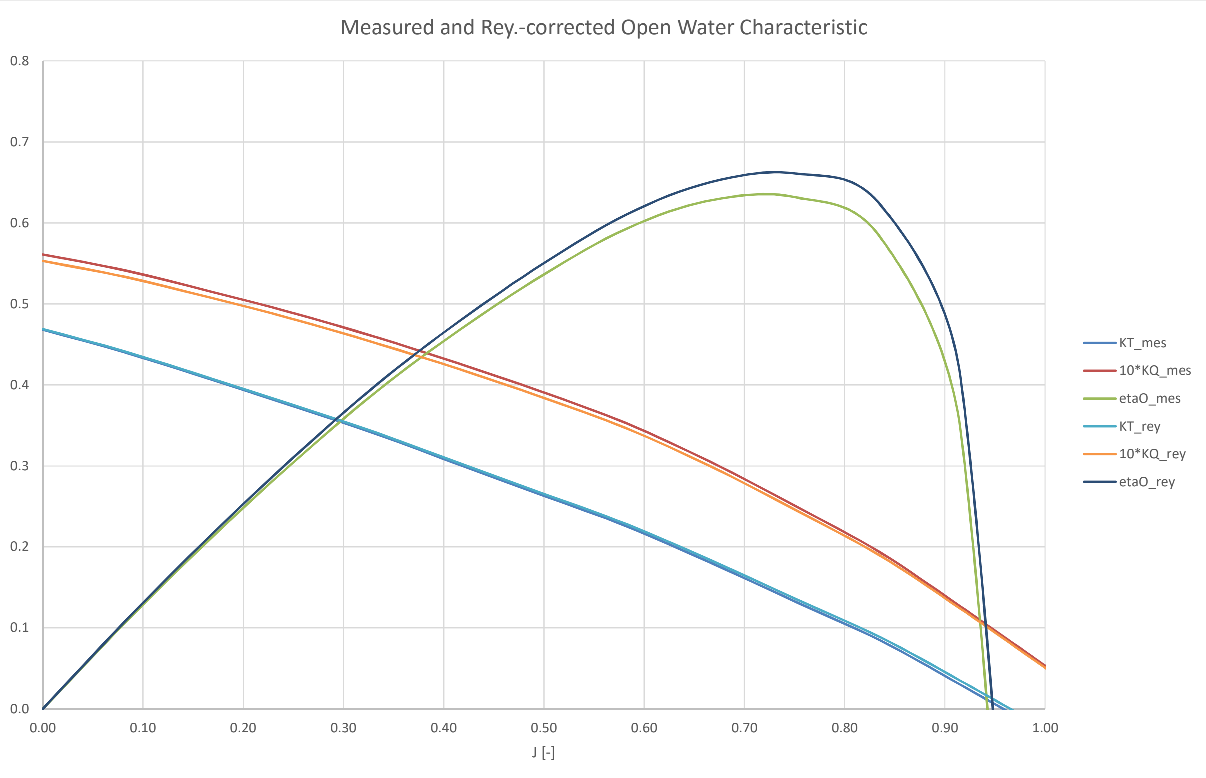


Bild 13: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0112

Tabelle 8: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0113

Maßstab: 11.389, n_M = 20 1/s, Messung: 15F0113

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.46812	0.56113	0.00000	0.00000	0.46901	0.55305	0.00000	396965.06250	13147215.00000
0.08302	0.43991	0.54108	0.10742	0.08302	0.44099	0.53314	0.10929	397103.65625	13151805.00000
0.16642	0.40716	0.51569	0.20912	0.16642	0.40846	0.50795	0.21299	397521.65625	13165649.00000
0.24968	0.37382	0.48882	0.30389	0.24968	0.37533	0.48129	0.30990	398216.78125	13188671.00000
0.33331	0.33903	0.45860	0.39217	0.33331	0.34080	0.45134	0.40056	399193.00000	13221003.00000
0.41648	0.30110	0.42599	0.46852	0.41648	0.30317	0.41903	0.47957	400438.15625	13262242.00000
0.49971	0.26332	0.39063	0.53611	0.49971	0.26560	0.38401	0.55007	401955.50000	13312495.00000
0.58278	0.22528	0.35227	0.59316	0.58278	0.22789	0.34613	0.61068	403737.46875	13371513.00000
0.66621	0.18054	0.30490	0.62784	0.66621	0.18371	0.29950	0.65038	405792.68750	13439580.00000
0.75086	0.13237	0.25043	0.63166	0.75086	0.13589	0.24566	0.66104	408145.71875	13517511.00000
0.83591	0.08429	0.19282	0.58161	0.83591	0.08826	0.18880	0.62195	410776.90625	13604654.00000
0.91565	0.02980	0.12637	0.34360	0.91565	0.03465	0.12353	0.40880	413482.37500	13694257.00000
1.00360	-0.03204	0.05010	-1.02148	1.00360	-0.02697	0.04764	-0.90423	416728.62500	13801771.00000

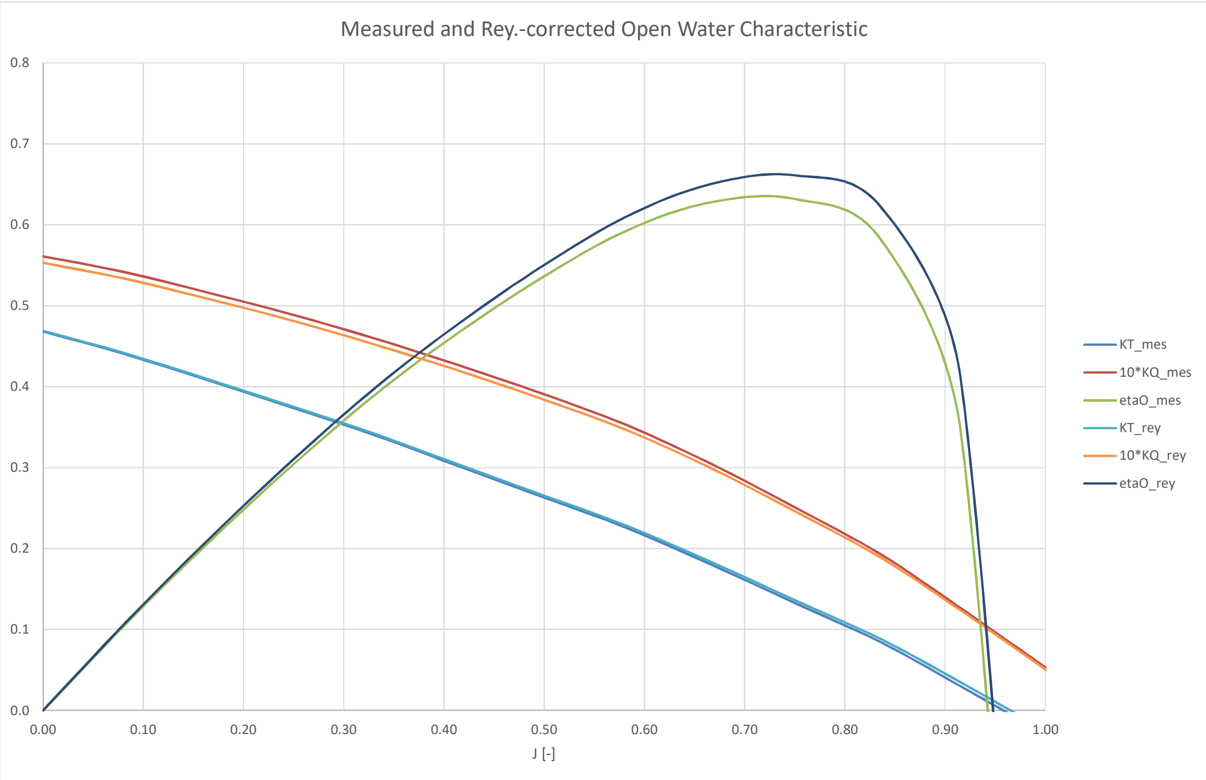


Bild 14: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0113

Tabelle 9: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0114

Maßstab: 11.389, n_M = 24 1/s, Messung: 15F0114

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.46977	0.56099	0.00000	0.00000	0.47044	0.55488	0.00000	476358.09375	13147215.00000
0.08090	0.44136	0.54099	0.10505	0.08090	0.44216	0.53498	0.10642	476516.00000	13151574.00000
0.16162	0.40929	0.51637	0.20389	0.16162	0.41025	0.51050	0.20671	476988.03125	13164602.00000
0.24255	0.37463	0.48871	0.29592	0.24255	0.37574	0.48299	0.30032	477775.71875	13186341.00000
0.32294	0.34183	0.46035	0.38165	0.32294	0.34307	0.45478	0.38772	478868.28125	13216495.00000
0.40341	0.30729	0.43024	0.45857	0.40341	0.30872	0.42487	0.46653	480269.34375	13255164.00000
0.48481	0.26977	0.39589	0.52579	0.48481	0.27140	0.39078	0.53588	481996.84375	13302842.00000
0.56510	0.23318	0.35953	0.58331	0.56510	0.23498	0.35471	0.59579	484003.18750	13358216.00000
0.64744	0.19169	0.31523	0.62660	0.64744	0.19380	0.31086	0.64242	486368.75000	13423504.00000
0.72888	0.14741	0.26698	0.64051	0.72888	0.14980	0.26300	0.66073	489010.87500	13496425.00000
0.80956	0.10213	0.21484	0.61250	0.80956	0.10479	0.21137	0.63876	491920.09375	13576718.00000
0.89219	0.05155	0.15179	0.48223	0.89219	0.05472	0.14916	0.52090	495195.25000	13667110.00000
0.97514	-0.01022	0.07439	-0.21327	0.97514	-0.00611	0.07293	-0.12995	498778.09375	13765995.00000

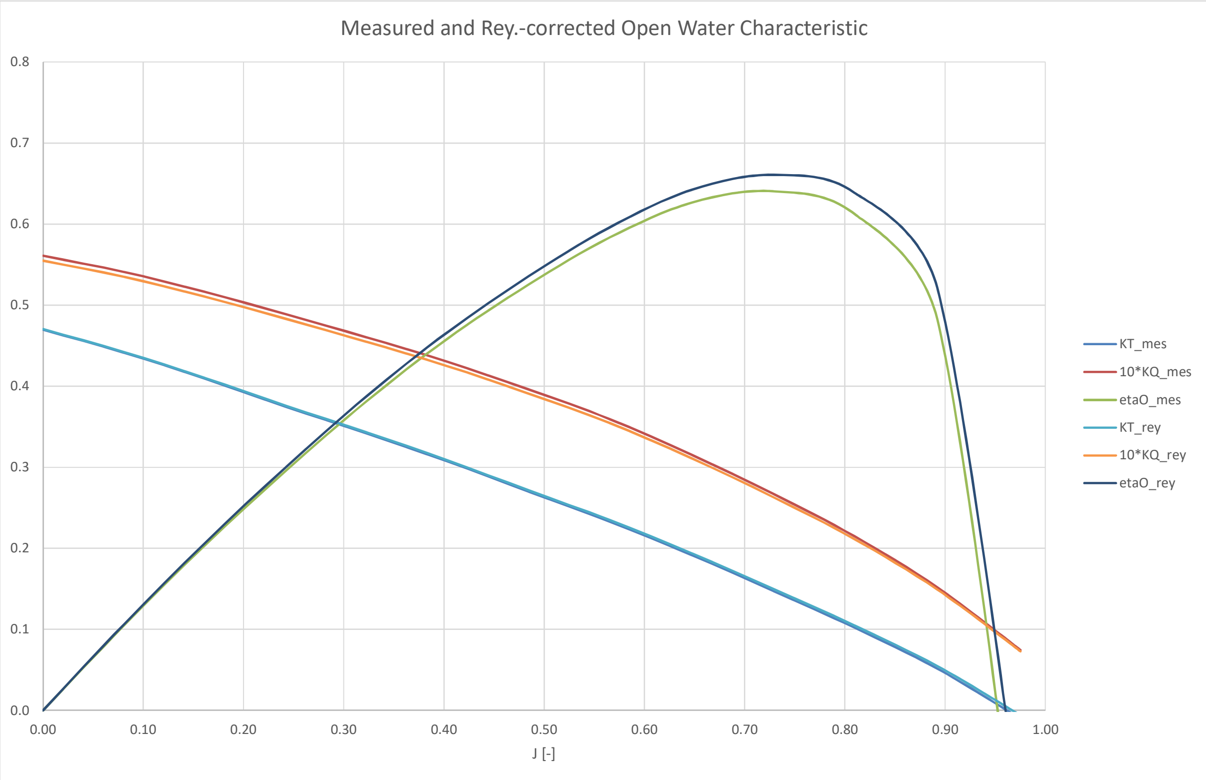


Bild 15: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0114

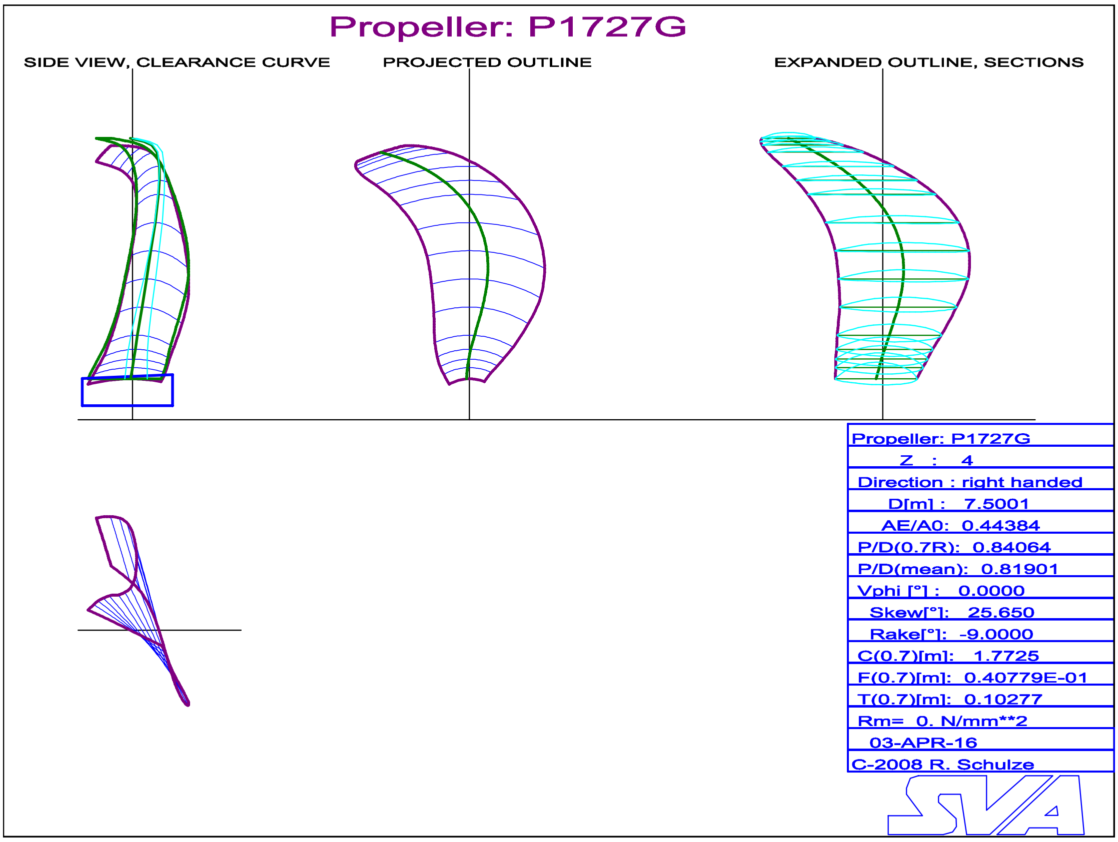


Bild 16: Geometrie und Hauptdaten des Propellers P1727

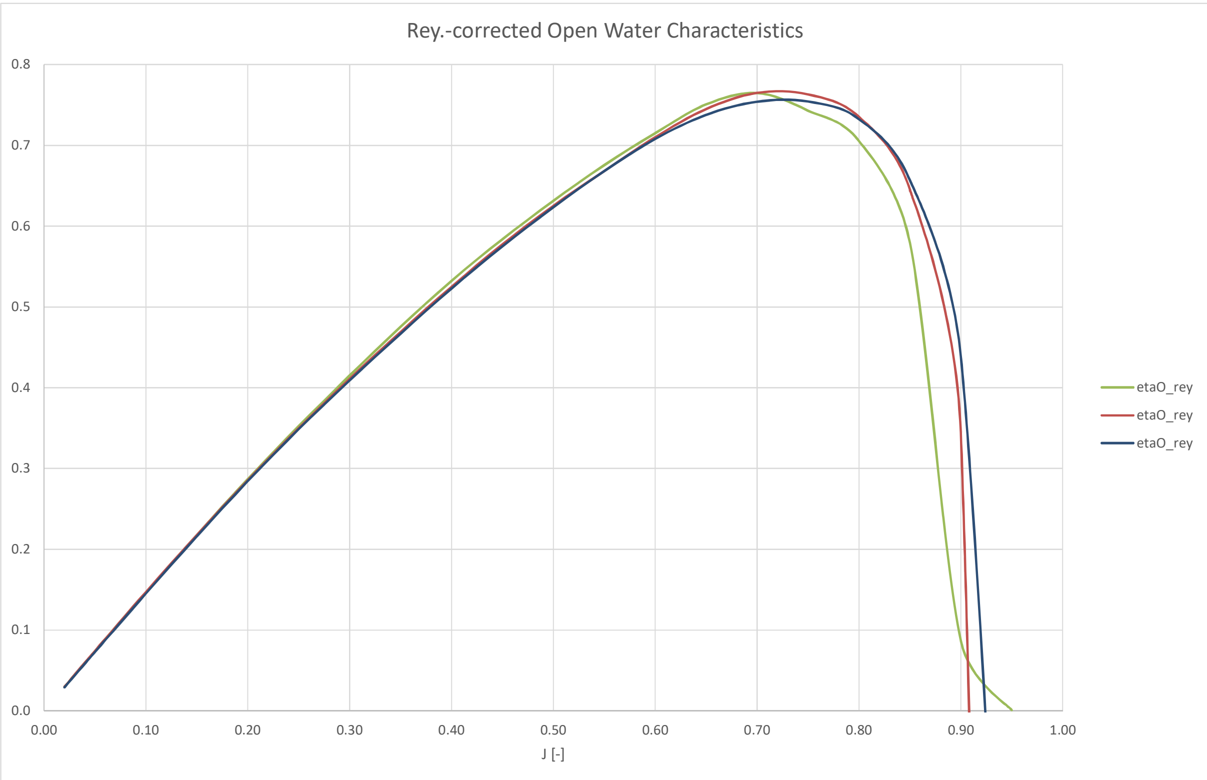


Bild 17: Vergleich der Wirkungsgrade aller reynoldszahlkorrigierten Messwerte vom Propeller P1727

Tabelle 10: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0167

Maßstab: 31.4286, n_M = 10 1/s, Messung: 15F0167

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.02000	0.37298	0.41043	0.02893	0.02000	0.37438	0.39961	0.02982	276442.87500	32916350.00000
0.05000	0.36309	0.40176	0.07192	0.05000	0.36464	0.39105	0.07420	276472.28125	32919850.00000
0.10000	0.34653	0.38803	0.14213	0.10000	0.34832	0.37749	0.14686	276577.28125	32932354.00000
0.15000	0.33062	0.37505	0.21045	0.15000	0.33259	0.36464	0.21775	276752.18750	32953180.00000
0.20000	0.31519	0.36231	0.27691	0.20000	0.31743	0.35207	0.28699	276996.87500	32982316.00000
0.25000	0.29693	0.34819	0.33931	0.25000	0.29957	0.33817	0.35247	277311.18750	33019738.00000
0.30000	0.27985	0.33503	0.39882	0.30000	0.28257	0.32503	0.41509	277694.81250	33065420.00000
0.35000	0.26376	0.32241	0.45571	0.35000	0.26673	0.31256	0.47537	278147.53125	33119324.00000
0.40000	0.24674	0.30870	0.50884	0.40000	0.25015	0.29917	0.53230	278668.96875	33181414.00000
0.45000	0.22672	0.29206	0.55597	0.45000	0.23076	0.28303	0.58393	279258.78125	33251642.00000
0.50000	0.20617	0.27403	0.59871	0.50000	0.21050	0.26531	0.63137	279916.50000	33329958.00000
0.55000	0.18426	0.25319	0.63703	0.55000	0.18934	0.24534	0.67553	280641.65625	33416302.00000
0.60000	0.15967	0.22794	0.66890	0.60000	0.16542	0.22091	0.71505	281433.71875	33510616.00000
0.65000	0.13411	0.19987	0.69414	0.65000	0.14043	0.19353	0.75068	282292.15625	33612828.00000
0.70000	0.10537	0.17020	0.68972	0.70000	0.11283	0.16438	0.76468	283216.34375	33722872.00000
0.75000	0.07609	0.13933	0.65190	0.75000	0.08346	0.13408	0.74300	284205.62500	33840668.00000
0.80000	0.04923	0.10727	0.58435	0.80000	0.05684	0.10259	0.70549	285259.37500	33966140.00000
0.85000	0.02183	0.07441	0.39694	0.85000	0.03011	0.07028	0.57952	286376.81250	34099192.00000
0.90000	-0.00692	0.03944	-0.25136	0.90000	0.00221	0.03629	0.08704	287557.25000	34239748.00000
0.95000	-0.03731	0.00209	-26.94298	0.95000	-0.02762	-0.00054	0.00100	288799.87500	34387712.00000

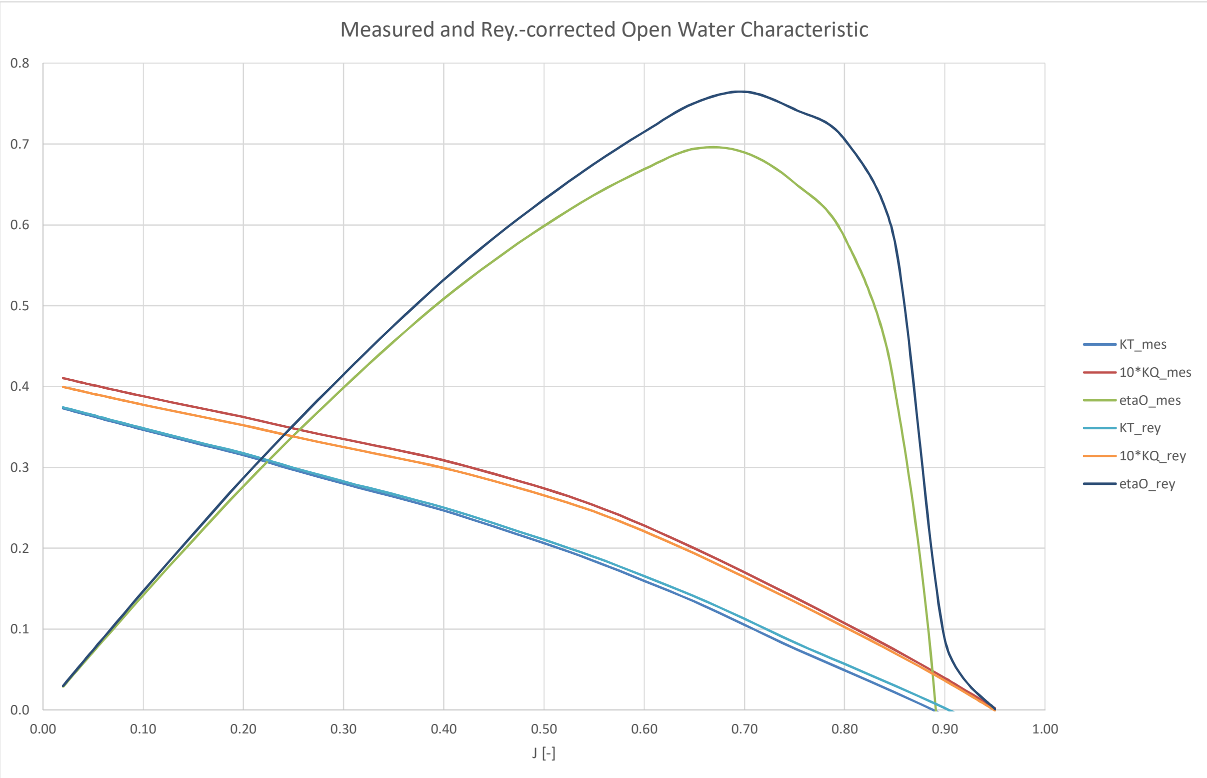


Bild 18: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0167

Tabelle 11: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0168

Maßstab: 31.4286, n_M = 18 1/s, Messung: 15F0168

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.02000	0.37936	0.41119	0.02937	0.02000	0.38018	0.40493	0.02989	497597.18750	32916350.00000
0.05000	0.36913	0.40223	0.07303	0.05000	0.37000	0.39600	0.07435	497650.12500	32919850.00000
0.10000	0.35165	0.38759	0.14440	0.10000	0.35260	0.38142	0.14713	497839.12500	32932354.00000
0.15000	0.33412	0.37371	0.21344	0.15000	0.33514	0.36757	0.21767	498153.93750	32953180.00000
0.20000	0.31691	0.36081	0.27959	0.20000	0.31801	0.35470	0.28539	498594.40625	32982316.00000
0.25000	0.29993	0.34846	0.34247	0.25000	0.30110	0.34237	0.34992	499160.12500	33019738.00000
0.30000	0.28368	0.33708	0.40183	0.30000	0.28491	0.33099	0.41099	499850.65625	33065420.00000
0.35000	0.26771	0.32551	0.45813	0.35000	0.26903	0.31949	0.46906	500665.56250	33119324.00000
0.40000	0.25094	0.31194	0.51214	0.40000	0.25239	0.30601	0.52506	501604.15625	33181414.00000
0.45000	0.23226	0.29585	0.56227	0.45000	0.23389	0.29006	0.57749	502665.81250	33251642.00000
0.50000	0.21034	0.27570	0.60712	0.50000	0.21223	0.27016	0.62514	503849.68750	33329958.00000
0.55000	0.18672	0.25259	0.64707	0.55000	0.18867	0.24713	0.66828	505154.96875	33416302.00000
0.60000	0.16434	0.22911	0.68494	0.60000	0.16640	0.22375	0.71014	506580.71875	33510616.00000
0.65000	0.14124	0.20449	0.71452	0.65000	0.14348	0.19925	0.74494	508125.90625	33612828.00000
0.70000	0.11676	0.17876	0.72772	0.70000	0.11922	0.17363	0.76496	509789.43750	33722872.00000
0.75000	0.09091	0.15124	0.71751	0.75000	0.09356	0.14636	0.76305	511570.15625	33840668.00000
0.80000	0.06421	0.12076	0.67703	0.80000	0.06705	0.11611	0.73526	513466.87500	33966140.00000
0.85000	0.03718	0.08873	0.56684	0.85000	0.04018	0.08426	0.64515	515478.28125	34099192.00000
0.90000	0.00863	0.05380	0.22991	0.90000	0.01195	0.04970	0.34450	517603.03125	34239748.00000
0.95000	-0.02258	0.01464	-2.33246	0.95000	-0.01904	0.01074	-2.68114	519839.78125	34387712.00000

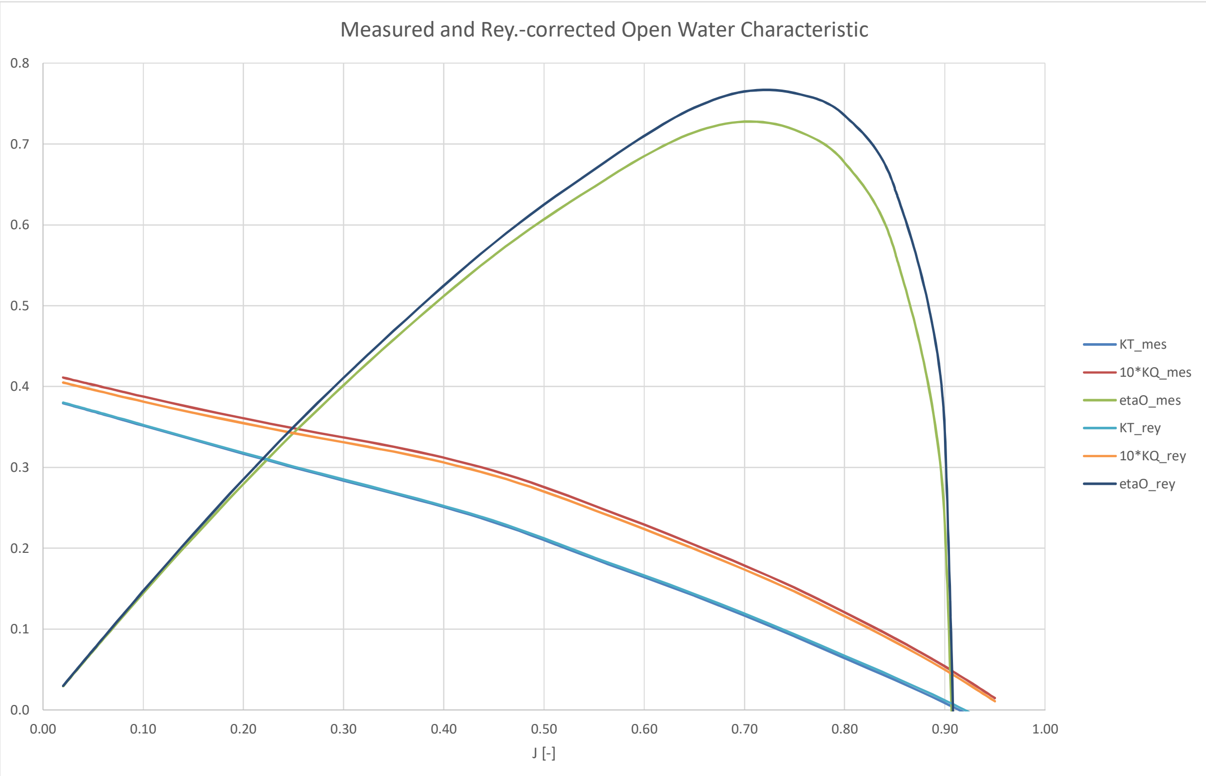


Bild 19: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0168

Tabelle 12: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0169

Maßstab: 31.4286, n_M = 25 1/s, Messung: 15F0169

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.02000	0.39264	0.43276	0.02888	0.02000	0.39320	0.42870	0.02919	691107.18750	32916350.00000
0.05000	0.38142	0.42068	0.07215	0.05000	0.38200	0.41664	0.07296	691180.68750	32919850.00000
0.10000	0.36198	0.40108	0.14364	0.10000	0.36261	0.39708	0.14534	691443.18750	32932354.00000
0.15000	0.34204	0.38245	0.21350	0.15000	0.34272	0.37849	0.21617	691880.50000	32953180.00000
0.20000	0.32203	0.36518	0.28070	0.20000	0.32276	0.36123	0.28441	692492.18750	32982316.00000
0.25000	0.30225	0.34983	0.34378	0.25000	0.30302	0.34588	0.34859	693277.93750	33019738.00000
0.30000	0.28384	0.33619	0.40312	0.30000	0.28464	0.33224	0.40905	694237.06250	33065420.00000
0.35000	0.26647	0.32285	0.45976	0.35000	0.26730	0.31893	0.46687	695368.81250	33119324.00000
0.40000	0.24890	0.30802	0.51444	0.40000	0.24980	0.30415	0.52287	696672.43750	33181414.00000
0.45000	0.22922	0.29055	0.56503	0.45000	0.23022	0.28675	0.57500	698146.93750	33251642.00000
0.50000	0.20810	0.27072	0.61170	0.50000	0.20917	0.26698	0.62345	699791.25000	33329958.00000
0.55000	0.18640	0.24938	0.65427	0.55000	0.18752	0.24569	0.66813	701604.12500	33416302.00000
0.60000	0.16468	0.22738	0.69159	0.60000	0.16588	0.22374	0.70799	703584.31250	33510616.00000
0.65000	0.14187	0.20437	0.71814	0.65000	0.14317	0.20078	0.73767	705730.43750	33612828.00000
0.70000	0.11801	0.17994	0.73063	0.70000	0.11940	0.17642	0.75398	708040.87500	33722872.00000
0.75000	0.09347	0.15366	0.72607	0.75000	0.09493	0.15024	0.75425	710514.12500	33840668.00000
0.80000	0.06865	0.12536	0.69726	0.80000	0.07020	0.12203	0.73248	713148.43750	33966140.00000
0.85000	0.04349	0.09621	0.61153	0.85000	0.04513	0.09295	0.65686	715942.06250	34099192.00000
0.90000	0.01689	0.06407	0.37769	0.90000	0.01869	0.06101	0.43874	718893.12500	34239748.00000
0.95000	-0.01168	0.02793	-0.63217	0.95000	-0.00979	0.02495	-0.59355	721999.68750	34387712.00000

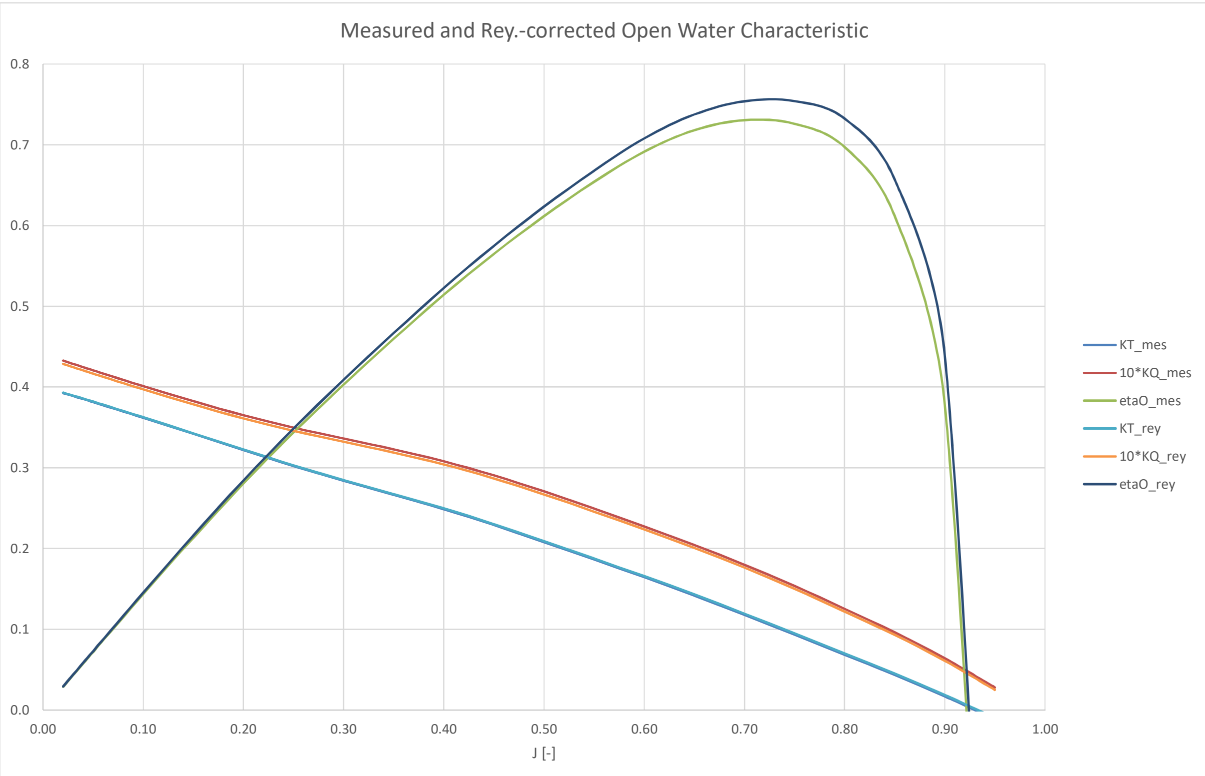


Bild 20: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0169

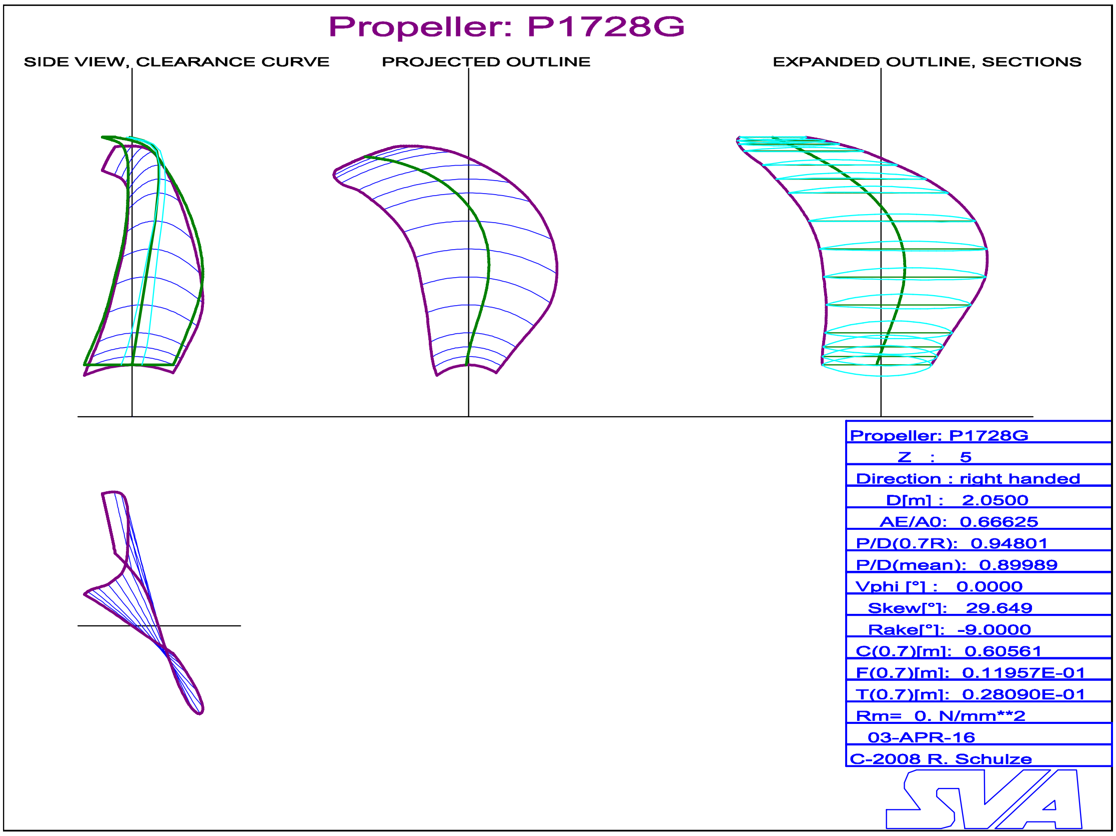


Bild 21: Geometrie und Hauptdaten des Propellers P1728

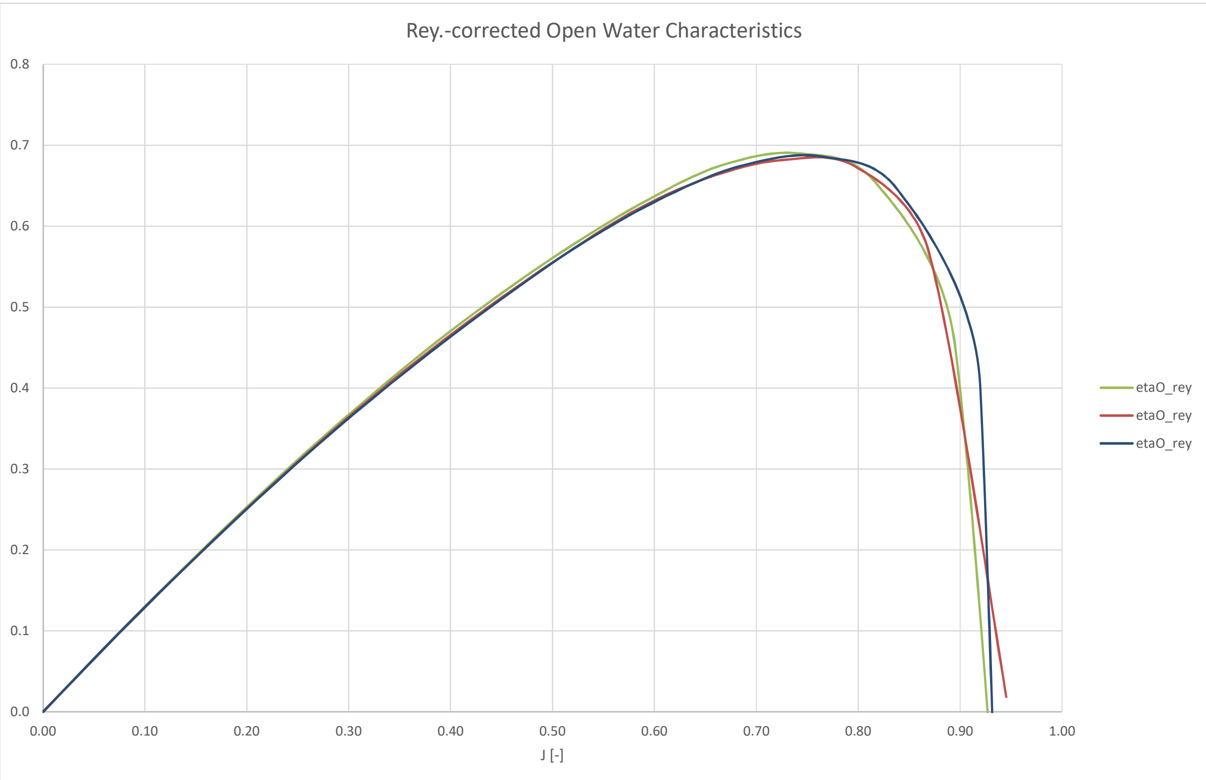


Bild 22: Vergleich der Wirkungsgrade aller reynoldszahlkorrigierten Messwerte vom Propeller P1728

Tabelle 13: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0183

Maßstab: 11.389 n_M = 15 1/s, Messung: 15F0183

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.47288	0.57943	0.00000	0.00000	0.47417	0.56761	0.00000	295155.43750	13033798.00000
0.07385	0.44825	0.55854	0.09433	0.07385	0.44986	0.54699	0.09667	295236.96875	13037400.00000
0.14770	0.41806	0.53221	0.18465	0.14770	0.42002	0.52099	0.18952	295481.43750	13048195.00000
0.22156	0.38972	0.50719	0.27095	0.22156	0.39193	0.49620	0.27853	295888.53125	13066172.00000
0.29554	0.36133	0.48318	0.35175	0.29554	0.36389	0.47248	0.36226	296458.59375	13091345.00000
0.36989	0.33098	0.45626	0.42705	0.36989	0.33404	0.44613	0.44079	297194.21875	13123829.00000
0.44374	0.29511	0.42189	0.49401	0.44374	0.29889	0.41265	0.51155	298085.15625	13163173.00000
0.51764	0.25570	0.38083	0.55316	0.51764	0.26011	0.37252	0.57526	299135.21875	13209542.00000
0.59251	0.21312	0.33295	0.60362	0.59251	0.21812	0.32557	0.63178	300359.00000	13263583.00000
0.66682	0.17143	0.28460	0.63926	0.66682	0.17695	0.27798	0.67558	301730.90625	13324166.00000
0.74443	0.12195	0.22599	0.63935	0.74443	0.12850	0.22076	0.68966	303328.71875	13394724.00000
0.81949	0.07492	0.16867	0.57933	0.81949	0.08191	0.16429	0.65028	305031.90625	13469935.00000
0.89486	0.02435	0.10377	0.33424	0.89486	0.03222	0.10099	0.45438	306895.71875	13552239.00000
0.97193	-0.02591	0.03589	-1.11663	0.97193	-0.01798	0.03376	-0.82370	308957.81250	13643298.00000

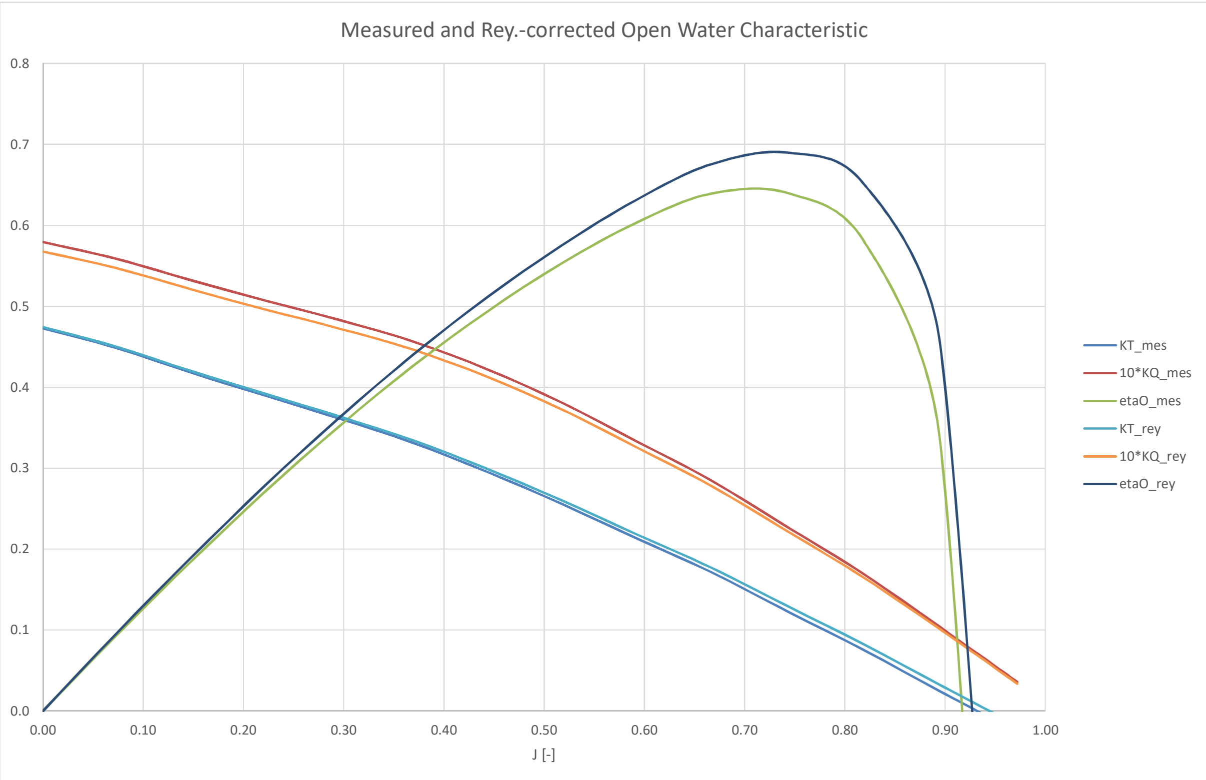


Bild 23: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0183

Tabelle 14: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0184

Maßstab: 11.389, n_M = 20 1/s, Messung: 15F0184

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.48114	0.58590	0.00000	0.00000	0.48206	0.57754	0.00000	393540.59375	13033798.00000
0.07215	0.45035	0.55916	0.09248	0.07215	0.45145	0.55096	0.09409	393644.34375	13037235.00000
0.14431	0.42082	0.53431	0.18089	0.14431	0.42209	0.52626	0.18421	393955.56250	13047542.00000
0.21671	0.39158	0.50885	0.26542	0.21671	0.39303	0.50098	0.27058	394475.78125	13064771.00000
0.28867	0.36331	0.48383	0.34499	0.28867	0.36494	0.47614	0.35213	395198.43750	13088706.00000
0.36111	0.33190	0.45589	0.41841	0.36111	0.33382	0.44850	0.42776	396131.84375	13119619.00000
0.43352	0.29765	0.42329	0.48517	0.43352	0.29986	0.41630	0.49699	397269.87500	13157310.00000
0.50601	0.26132	0.38587	0.54539	0.50601	0.26384	0.37935	0.56011	398612.68750	13201783.00000
0.57786	0.22287	0.34240	0.59863	0.57786	0.22578	0.33649	0.61709	400142.59375	13252453.00000
0.65137	0.17837	0.29105	0.63533	0.65137	0.18170	0.28569	0.65933	401910.50000	13311005.00000
0.72523	0.13655	0.24209	0.65104	0.72523	0.13998	0.23699	0.68175	403890.50000	13376581.00000
0.79808	0.09377	0.18859	0.63153	0.79808	0.09766	0.18431	0.67303	406040.56250	13447790.00000
0.86881	0.04770	0.12992	0.50773	0.86881	0.05217	0.12651	0.57029	408312.40625	13523031.00000
0.94543	-0.00410	0.06109	-0.10087	0.94543	0.00072	0.05848	0.01857	410974.84375	13611210.00000

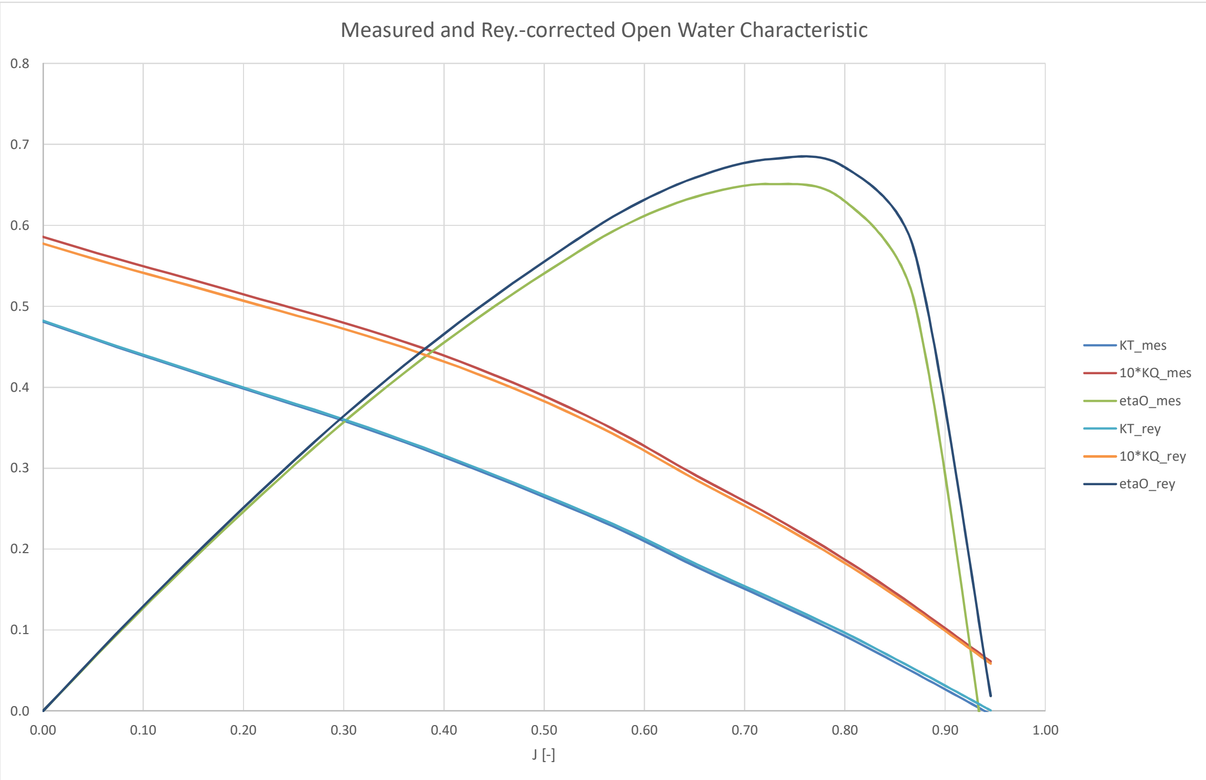


Bild 24: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0184

Tabelle 15: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0185

Maßstab: 11.389, n_M = 24 1/s, Messung: 15F0185

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.48154	0.58446	0.00000	0.00000	0.48223	0.57813	0.00000	472248.68750	13033798.00000
0.07625	0.45142	0.55881	0.09804	0.07625	0.45225	0.55259	0.09932	472387.78125	13037637.00000
0.15246	0.41853	0.53090	0.19129	0.15246	0.41950	0.52481	0.19396	472804.46875	13049137.00000
0.22871	0.38723	0.50378	0.27979	0.22871	0.38832	0.49782	0.28394	473498.50000	13068292.00000
0.30488	0.35514	0.47585	0.36214	0.30488	0.35640	0.47006	0.36790	474467.31250	13095031.00000
0.38126	0.32012	0.44374	0.43775	0.38126	0.32157	0.43819	0.44531	475713.62500	13129428.00000
0.45798	0.28416	0.40789	0.50779	0.45798	0.28578	0.40260	0.51739	477240.34375	13171565.00000
0.53324	0.24768	0.36879	0.56997	0.53324	0.24953	0.36386	0.58202	479003.15625	13220218.00000
0.61129	0.20378	0.31901	0.62148	0.61129	0.20595	0.31454	0.63703	481105.59375	13278244.00000
0.68838	0.16158	0.26997	0.65572	0.68838	0.16389	0.26574	0.67566	483452.78125	13343025.00000
0.76612	0.11695	0.21633	0.65917	0.76612	0.11955	0.21259	0.68568	486088.09375	13415758.00000
0.84168	0.07123	0.15837	0.60253	0.84168	0.07413	0.15519	0.63990	488903.65625	13493466.00000
0.91990	0.02142	0.09287	0.33762	0.91990	0.02474	0.09042	0.40058	492077.62500	13581065.00000
0.99676	-0.03571	0.01510	-3.75098	0.99676	-0.03157	0.01395	-3.59159	495448.46875	13674099.00000

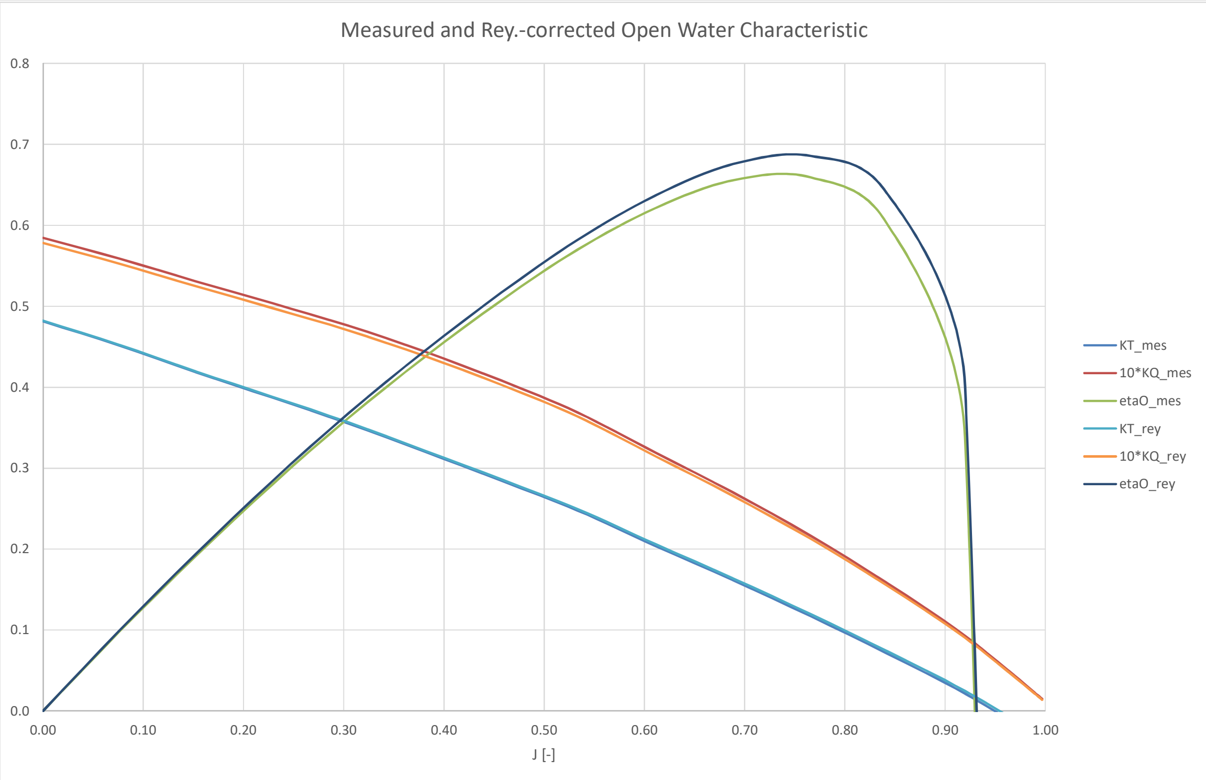


Bild 25: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0185

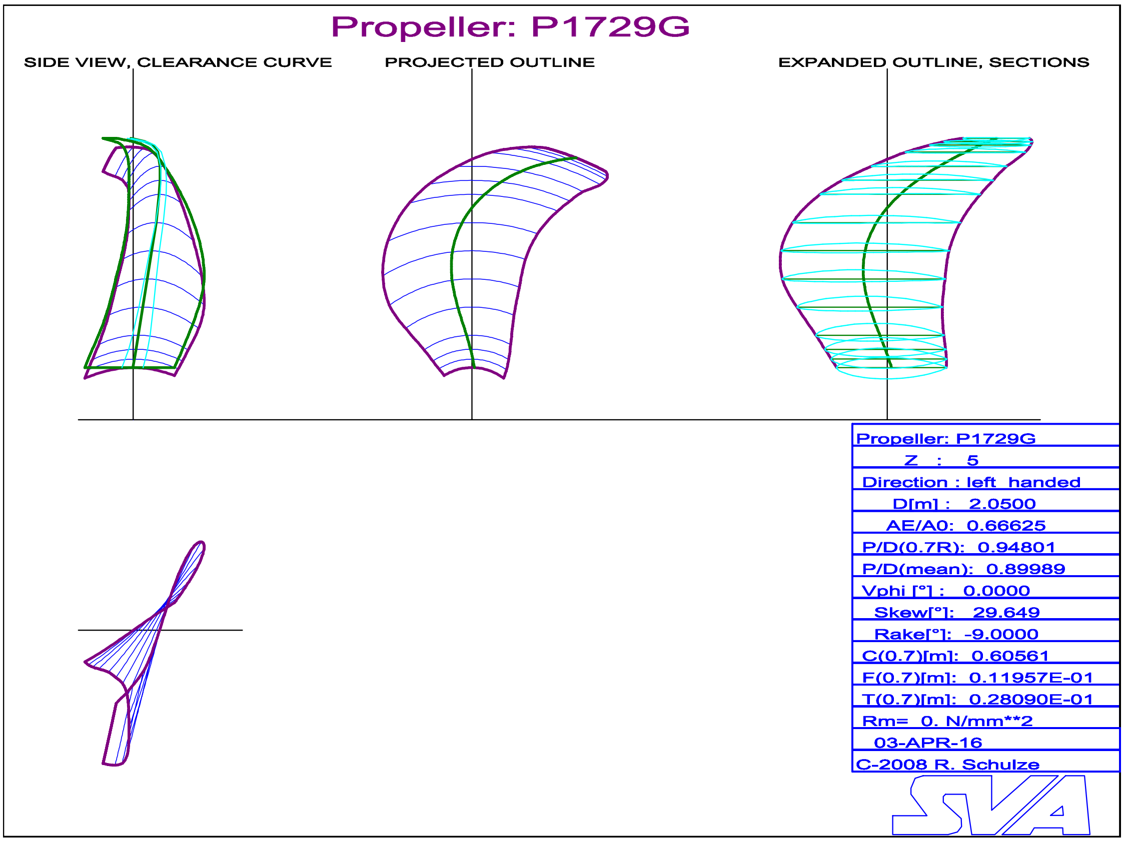


Bild 26: Geometrie und Hauptdaten des Propellers P1729

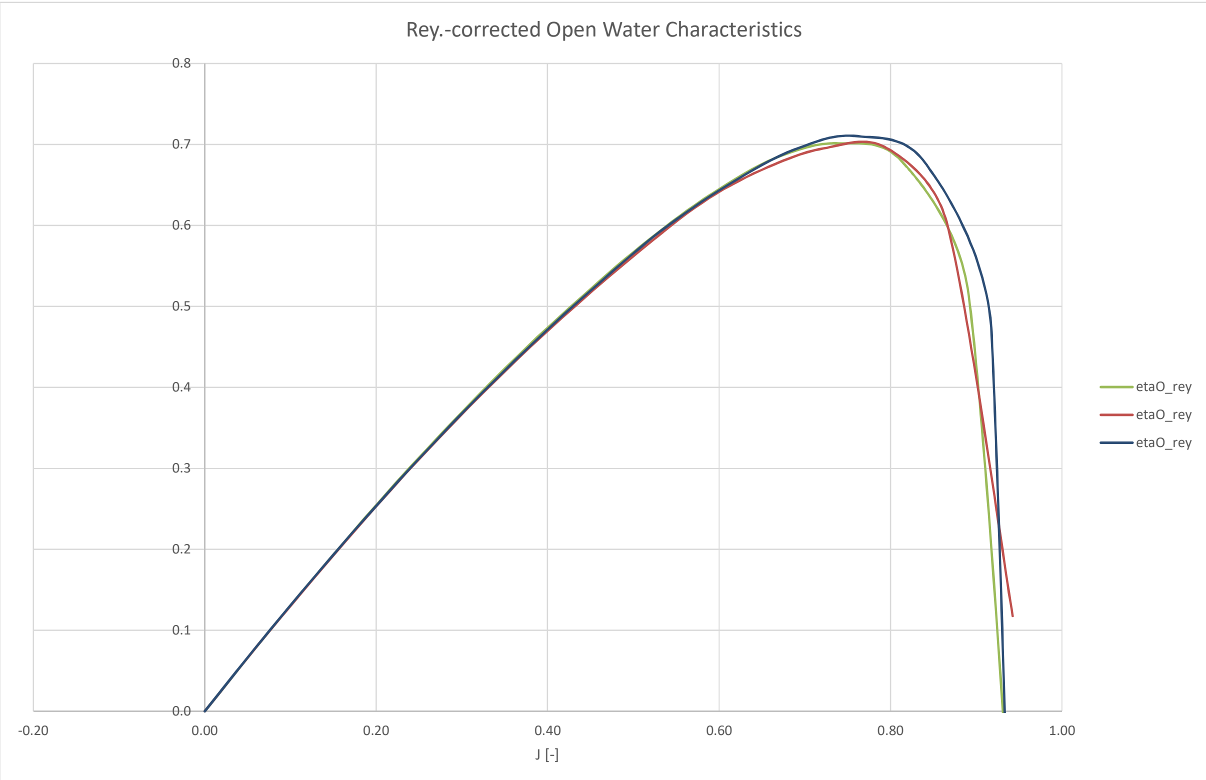


Bild 27: Vergleich der Wirkungsgrade aller reynoldszahlkorrigierten Messwerte vom Propeller P1729

Tabelle 16: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0187

Maßstab: 11.389, n_M = 15 1/s, Messung: 15F0187

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.47947	0.58313	0.00000	0.00000	0.48076	0.57131	0.00000	295155.43750	13033798.00000
0.07380	0.44940	0.55648	0.09486	0.07380	0.45104	0.54496	0.09722	295236.87500	13037394.00000
0.14774	0.41806	0.52938	0.18569	0.14774	0.42003	0.51816	0.19060	295481.62500	13048203.00000
0.22167	0.38918	0.50333	0.27279	0.22167	0.39141	0.49237	0.28046	295889.25000	13066204.00000
0.29575	0.35985	0.47839	0.35407	0.29575	0.36245	0.46774	0.36475	296460.43750	13091426.00000
0.36919	0.32894	0.45055	0.42899	0.36919	0.33200	0.44044	0.44292	297186.53125	13123490.00000
0.44383	0.29435	0.41758	0.49792	0.44383	0.29801	0.40823	0.51567	298086.34375	13163225.00000
0.51742	0.25585	0.37658	0.55949	0.51742	0.26021	0.36826	0.58189	299131.84375	13209393.00000
0.59063	0.21506	0.33150	0.60983	0.59063	0.21998	0.32393	0.63837	300326.31250	13262140.00000
0.66606	0.17303	0.28364	0.64668	0.66606	0.17860	0.27705	0.68338	301716.09375	13323511.00000
0.73980	0.12393	0.22417	0.65093	0.73980	0.13065	0.21933	0.70136	303228.71875	13390308.00000
0.81579	0.07660	0.16460	0.60420	0.81579	0.08341	0.16018	0.67612	304944.37500	13466069.00000
0.89130	0.02819	0.10210	0.39166	0.89130	0.03577	0.09893	0.51287	306804.25000	13548200.00000
0.96695	-0.02101	0.03615	-0.89450	0.96695	-0.01285	0.03421	-0.57784	308819.84375	13637206.00000

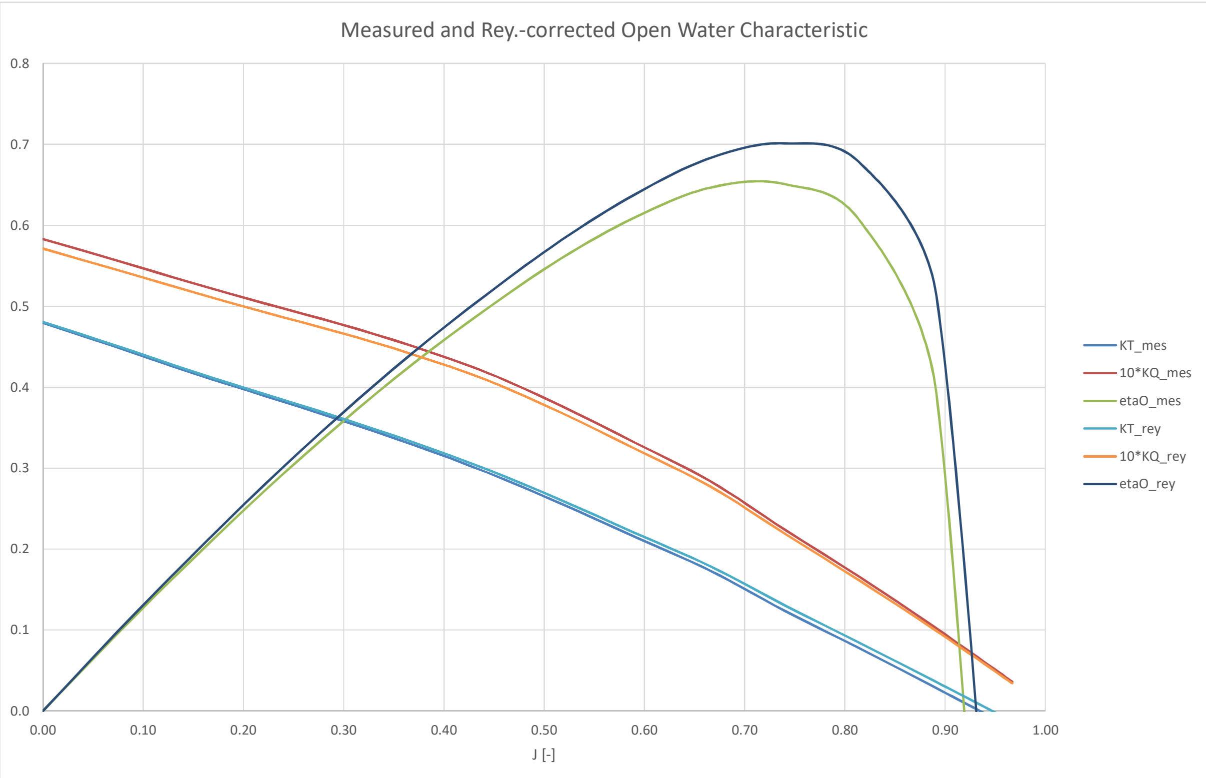


Bild 28: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0187

Tabelle 17: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0188

Maßstab: 11.389, n_M = 20 1/s, Messung: 15F0188

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.47953	0.58021	0.00000	0.00000	0.48045	0.57185	0.00000	393540.59375	13033798.00000
0.07255	0.45377	0.55907	0.09372	0.07255	0.45488	0.55087	0.09535	393645.50000	13037274.00000
0.14464	0.42148	0.53170	0.18248	0.14464	0.42279	0.52369	0.18585	393957.46875	13047605.00000
0.21710	0.39316	0.50656	0.26818	0.21710	0.39459	0.49868	0.27341	394479.12500	13064883.00000
0.29000	0.36374	0.48129	0.34882	0.29000	0.36539	0.47361	0.35609	395213.71875	13089212.00000
0.36215	0.33257	0.45338	0.42279	0.36215	0.33448	0.44600	0.43226	396146.75000	13120113.00000
0.43469	0.29834	0.42064	0.49068	0.43469	0.30054	0.41365	0.50266	397289.90625	13157974.00000
0.50724	0.26310	0.38374	0.55350	0.50724	0.26557	0.37719	0.56840	398637.21875	13202596.00000
0.58042	0.22453	0.34037	0.60938	0.58042	0.22745	0.33446	0.62822	400200.75000	13254379.00000
0.64924	0.18161	0.29134	0.64412	0.64924	0.18500	0.28603	0.66832	401856.40625	13309213.00000
0.72129	0.14096	0.24358	0.66433	0.72129	0.14432	0.23840	0.69495	403779.78125	13372914.00000
0.79523	0.09904	0.19154	0.65444	0.79523	0.10290	0.18720	0.69567	405952.81250	13444883.00000
0.86540	0.05078	0.12946	0.54026	0.86540	0.05540	0.12627	0.60423	408198.75000	13519267.00000
0.94252	0.00032	0.06224	0.00776	0.94252	0.00463	0.05891	0.11782	410869.93750	13607735.00000

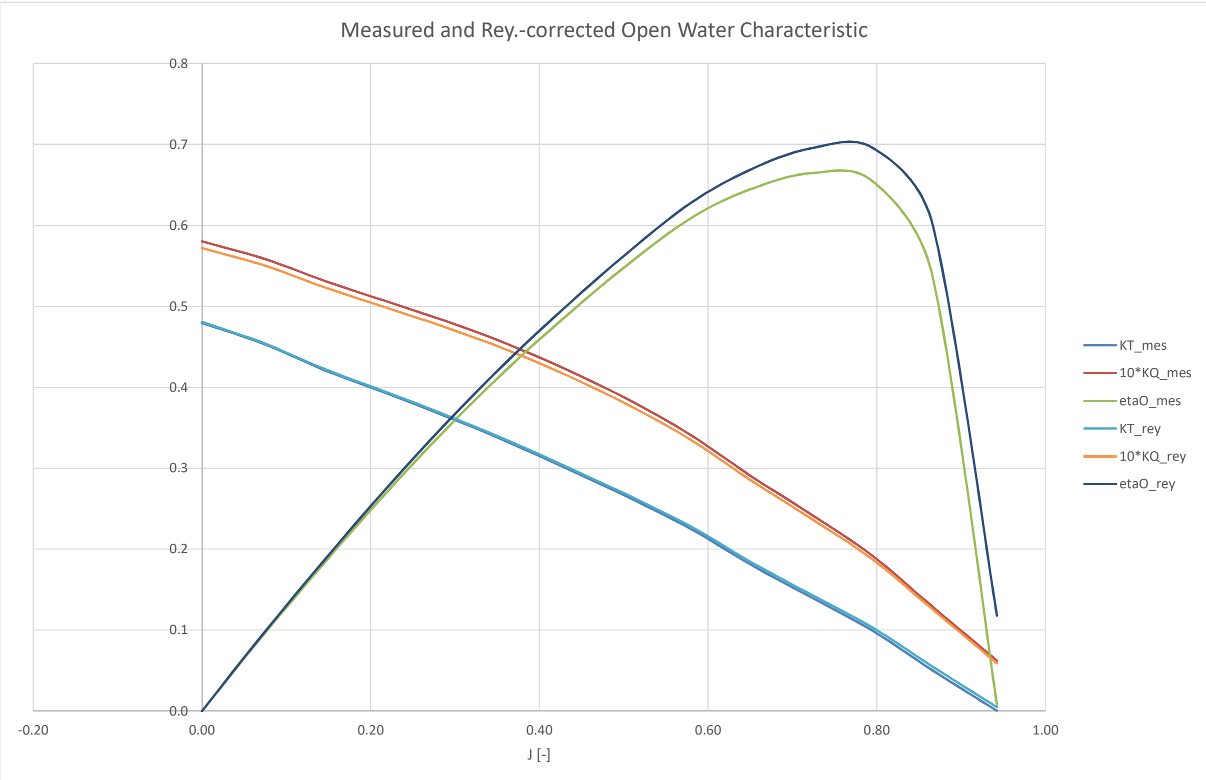


Bild 29: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0188

Tabelle 18: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0189

Maßstab: 11.389, n_M = 24 1/s, Messung: 15F0189

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.48200	0.57888	0.00000	0.00000	0.48269	0.57255	0.00000	472248.68750	13033798.00000
0.07617	0.45358	0.55527	0.09903	0.07617	0.45441	0.54905	0.10034	472387.50000	13037629.00000
0.15211	0.42098	0.52740	0.19324	0.15211	0.42196	0.52132	0.19595	472801.90625	13049067.00000
0.22840	0.38914	0.49987	0.28299	0.22840	0.39024	0.49391	0.28721	473495.09375	13068199.00000
0.30542	0.35688	0.47160	0.36785	0.30542	0.35813	0.46581	0.37373	474475.15625	13095247.00000
0.38138	0.32262	0.43991	0.44515	0.38138	0.32406	0.43435	0.45286	475715.78125	13129488.00000
0.45693	0.28800	0.40583	0.51608	0.45693	0.28960	0.40051	0.52584	477217.62500	13170938.00000
0.53259	0.25159	0.36689	0.58126	0.53259	0.25345	0.36197	0.59353	478986.84375	13219767.00000
0.61070	0.20584	0.31546	0.63421	0.61070	0.20805	0.31101	0.65018	481088.65625	13277777.00000
0.68932	0.16445	0.26772	0.67390	0.68932	0.16670	0.26342	0.69427	483483.03125	13343860.00000
0.76185	0.12245	0.21726	0.68339	0.76185	0.12506	0.21353	0.71016	485936.40625	13411572.00000
0.84241	0.07386	0.15581	0.63555	0.84241	0.07676	0.15263	0.67430	488932.06250	13494250.00000
0.91806	0.02529	0.09241	0.39982	0.91806	0.02859	0.08990	0.46459	491999.96875	13578922.00000
0.99628	-0.03074	0.01604	-3.03842	0.99628	-0.02683	0.01461	-2.91100	495426.62500	13673497.00000

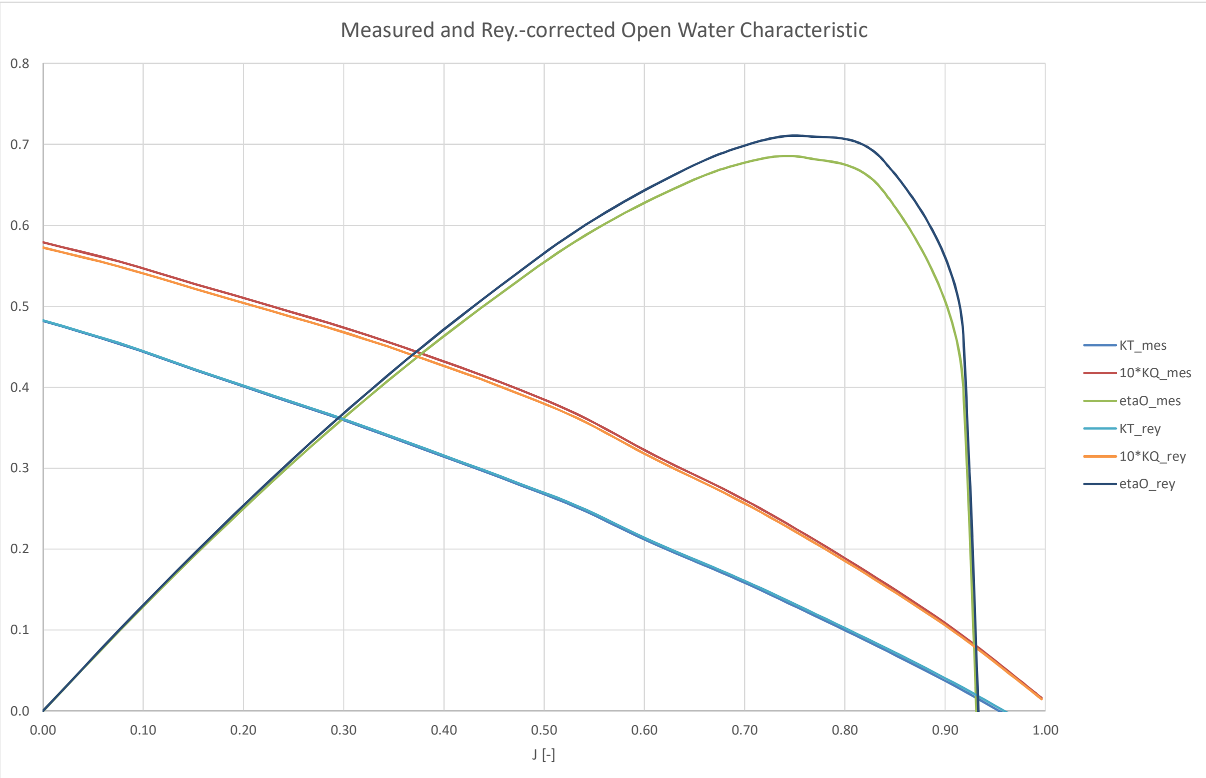


Bild 30: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0189

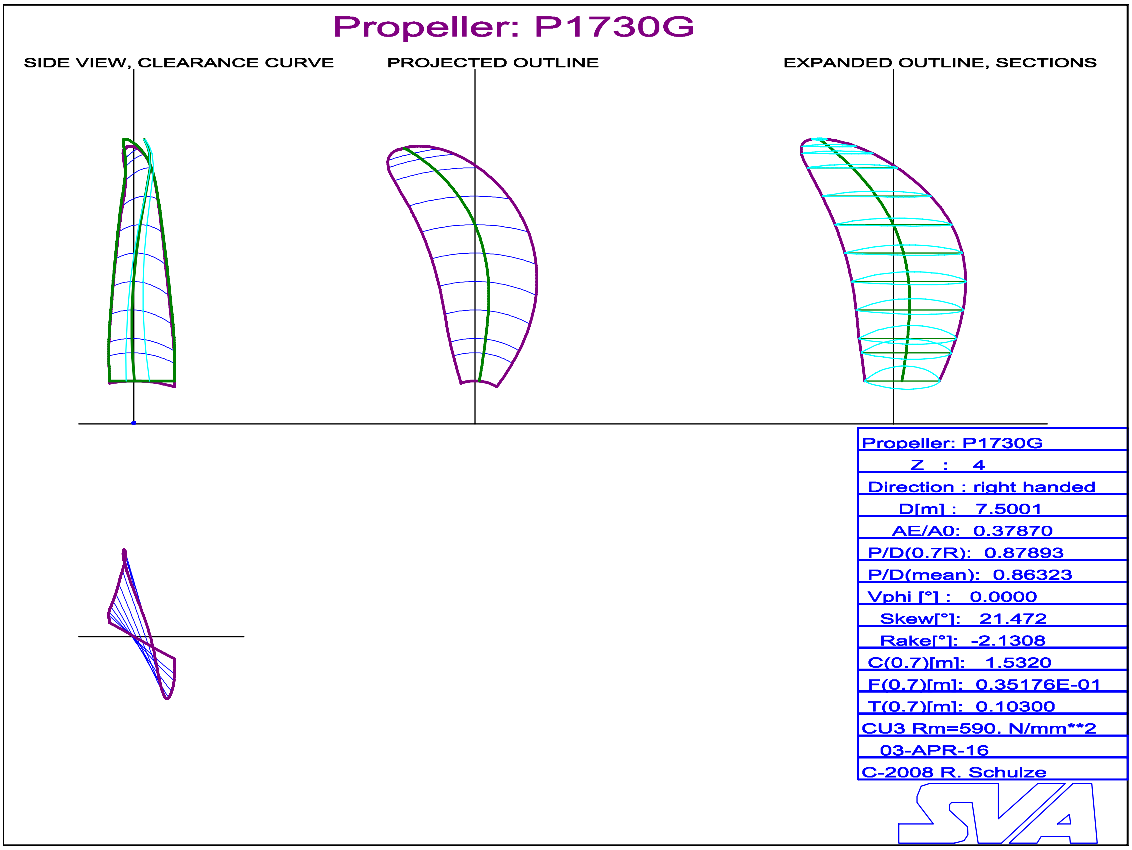


Bild 31: Geometrie und Hauptdaten des Propellers P1730

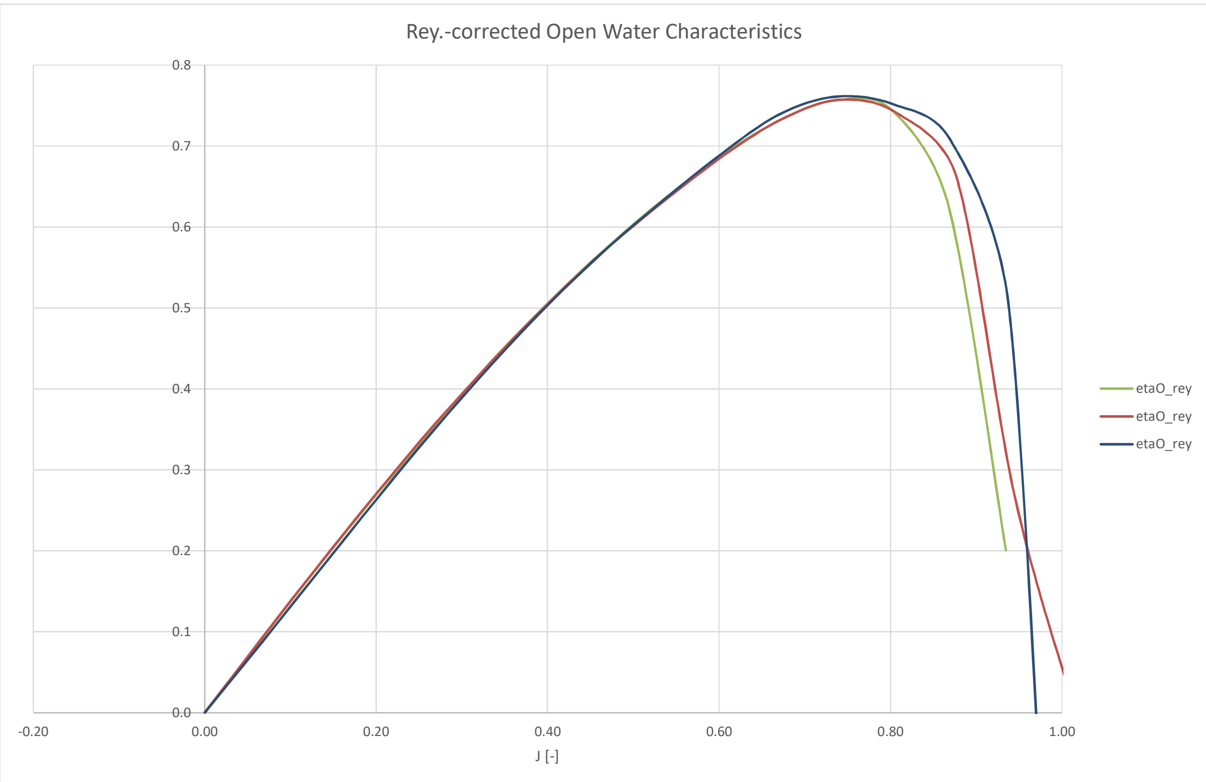


Bild 32: Vergleich der Wirkungsgrade aller reynoldszahlkorrigierten Messwerte vom Propeller P1730

Tabelle 19: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0171

Maßstab: 31.4286, n_M = 10 1/s, Messung: 15F0171

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.37863	0.44603	0.00000	0.00000	0.37959	0.43684	0.00000	236035.51563	28105000.00000
0.06710	0.35950	0.42635	0.09005	0.06710	0.36073	0.41744	0.09229	236089.34375	28111410.00000
0.13425	0.33985	0.40672	0.17854	0.13425	0.34139	0.39810	0.18323	236250.92188	28130650.00000
0.20146	0.31745	0.38591	0.26375	0.20146	0.31939	0.37762	0.27119	236520.32813	28162728.00000
0.26861	0.29393	0.36509	0.34418	0.26861	0.29622	0.35712	0.35461	236896.70313	28207544.00000
0.33557	0.27070	0.34296	0.42155	0.33557	0.27334	0.33539	0.43527	237378.21875	28264878.00000
0.40277	0.24523	0.32041	0.49062	0.40277	0.24835	0.31318	0.50833	237967.42188	28335036.00000
0.46997	0.22036	0.29766	0.55374	0.46997	0.22379	0.29084	0.57553	238662.01563	28417742.00000
0.53708	0.19428	0.27272	0.60893	0.53708	0.19830	0.26667	0.63564	239459.92188	28512750.00000
0.60446	0.16448	0.24105	0.65644	0.60446	0.16938	0.23631	0.68957	240364.81250	28620496.00000
0.67148	0.13139	0.20365	0.68949	0.67148	0.13715	0.20016	0.73227	241366.85938	28739810.00000
0.73415	0.09866	0.16485	0.69925	0.73415	0.10489	0.16210	0.75610	242394.76563	28862204.00000
0.80105	0.06747	0.12917	0.66594	0.80105	0.07370	0.12616	0.74478	243587.71875	29004250.00000
0.86776	0.03285	0.09018	0.50315	0.86776	0.04020	0.08873	0.62570	244874.25000	29157440.00000
0.93454	-0.00128	0.04486	-0.04251	0.93454	0.00613	0.04548	0.20055	246257.59375	29322156.00000

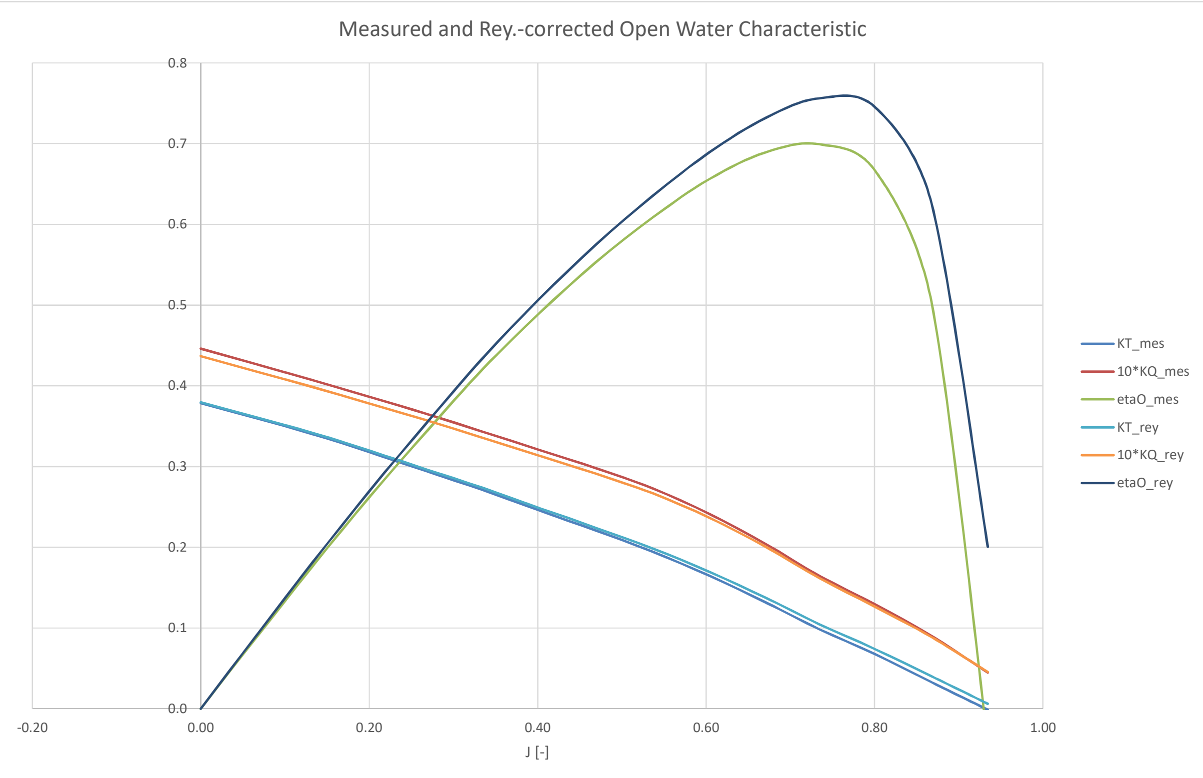


Bild 33: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F01171

Tabelle 20: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0172

Maßstab: 31.4286, n_M = 18 1/s, Messung: 15F0172

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00001	0.38190	0.44633	0.00001	0.00001	0.38245	0.44113	0.00001	424863.90625	28105000.00000
0.06747	0.36300	0.42449	0.09183	0.06747	0.36363	0.41939	0.09311	424961.87500	28111482.00000
0.13492	0.34161	0.40244	0.18227	0.13492	0.34235	0.39744	0.18497	425255.56250	28130908.00000
0.20243	0.31916	0.38174	0.26936	0.20243	0.32000	0.37682	0.27360	425745.00000	28163286.00000
0.26988	0.29632	0.36116	0.35241	0.26988	0.29727	0.35634	0.35833	426428.71875	28208514.00000
0.33733	0.27256	0.34105	0.42906	0.33733	0.27362	0.33632	0.43679	427306.12500	28266554.00000
0.40481	0.24912	0.32082	0.50029	0.40481	0.25028	0.31621	0.50995	428376.53125	28337362.00000
0.47222	0.22438	0.29868	0.56460	0.47222	0.22569	0.29424	0.57647	429636.75000	28420726.00000
0.53983	0.19865	0.27487	0.62092	0.53983	0.20008	0.27061	0.63526	431090.68750	28516906.00000
0.60743	0.17292	0.24853	0.67264	0.60743	0.17452	0.24456	0.68988	432732.75000	28625528.00000
0.67489	0.14252	0.21487	0.71245	0.67489	0.14447	0.21140	0.73407	434556.96875	28746202.00000
0.74215	0.10731	0.17391	0.72883	0.74215	0.10952	0.17079	0.75741	436558.03125	28878574.00000
0.80963	0.07523	0.13804	0.70225	0.80963	0.07743	0.13494	0.73938	438746.03125	29023310.00000
0.87708	0.04143	0.09516	0.60779	0.87708	0.04392	0.09272	0.66123	441110.90625	29179750.00000
0.94467	0.00531	0.04732	0.16862	0.94467	0.00811	0.04541	0.26837	443656.25000	29348124.00000
1.01230	-0.03434	-0.00735	0.01134	1.01230	-0.03112	-0.00851	0.01313	446375.90625	29528032.00000

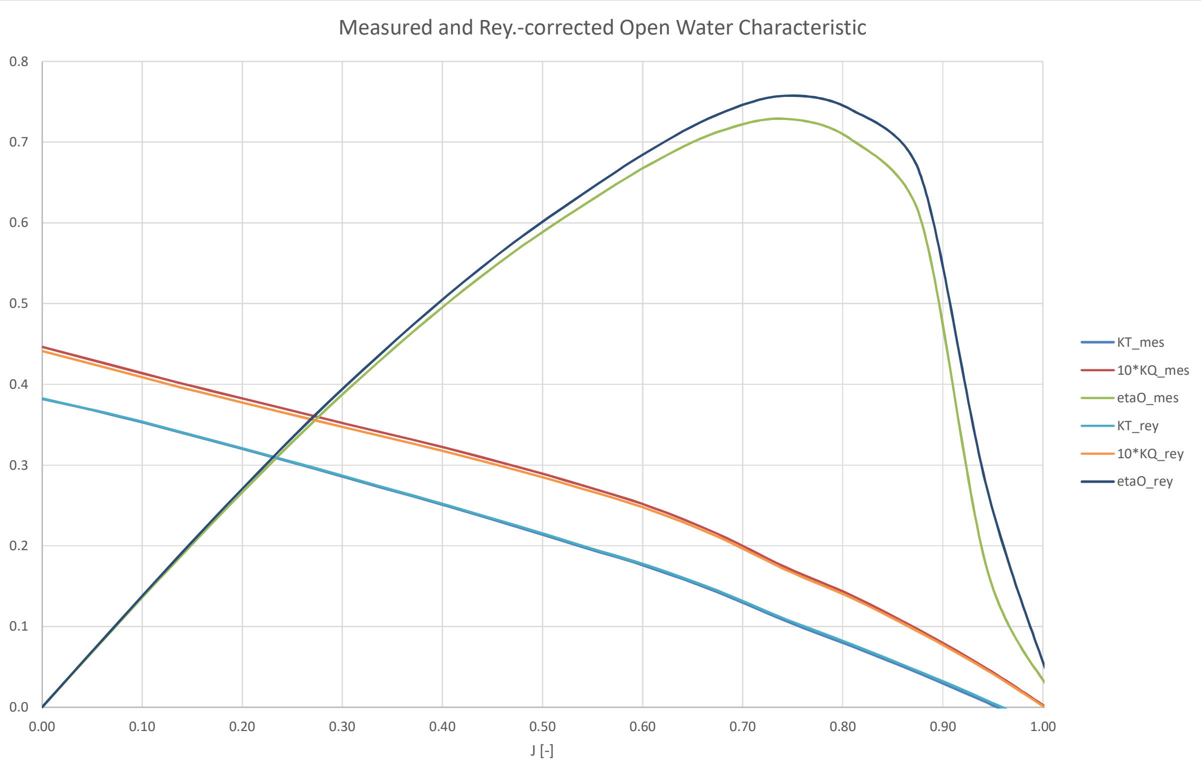


Bild 34: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F01172

Tabelle 21: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F0173

Maßstab: 31.4286, n_M = 25 1/s, Messung: 15F0173

J_mes	KT_mes	10*KQ_mes	etaO_mes	J_rey	KT_rey	10*KQ_rey	etaO_rey	RnM	RnS
0.00000	0.39833	0.49550	0.00000	0.00000	0.39867	0.49222	0.00000	590088.75000	28105000.00000
0.06696	0.38052	0.46797	0.08665	0.06696	0.38091	0.46475	0.08734	590222.81250	28111384.00000
0.13395	0.35820	0.43757	0.17452	0.13395	0.35865	0.43443	0.17600	590624.93750	28130536.00000
0.20092	0.33163	0.40489	0.26191	0.20092	0.33216	0.40183	0.26433	591294.31250	28162420.00000
0.26789	0.30524	0.37546	0.34662	0.26789	0.30583	0.37245	0.35009	592230.25000	28206996.00000
0.33502	0.27707	0.34686	0.42592	0.33502	0.27772	0.34391	0.43059	593434.56250	28264356.00000
0.40180	0.25134	0.32181	0.49945	0.40180	0.25202	0.31889	0.50540	594895.43750	28333934.00000
0.46881	0.22585	0.29785	0.56577	0.46881	0.22659	0.29500	0.57312	596622.81250	28416208.00000
0.53580	0.19968	0.27251	0.62485	0.53580	0.20048	0.26975	0.63378	598609.37500	28510822.00000
0.60286	0.17511	0.24718	0.67973	0.60286	0.17597	0.24453	0.69044	600855.31250	28617794.00000
0.66971	0.14627	0.21491	0.72545	0.66971	0.14729	0.21249	0.73882	603347.75000	28736504.00000
0.73685	0.11434	0.18021	0.74408	0.73685	0.11546	0.17789	0.76115	606102.50000	28867710.00000
0.80381	0.08457	0.14817	0.73019	0.80381	0.08571	0.14595	0.75131	609097.62500	29010360.00000
0.87078	0.05266	0.10775	0.67727	0.87078	0.05394	0.10588	0.70599	612336.93750	29164644.00000
0.93780	0.01948	0.06364	0.45688	0.93780	0.02090	0.06201	0.50290	615818.87500	29330484.00000
0.98766	-0.00752	0.02698	-0.43830	0.98766	-0.00594	0.02562	-0.36431	618562.81250	29461174.00000

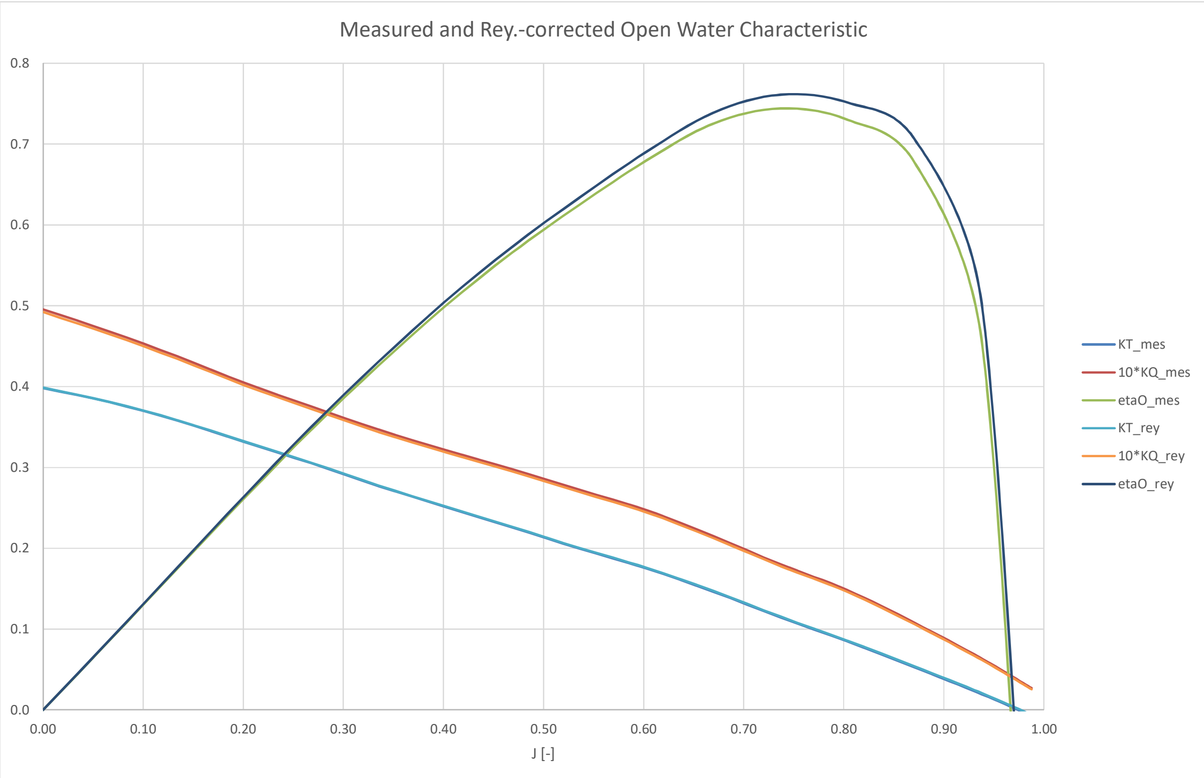


Bild 35: Gemessene und reynoldszahlkorrigierte Messwerte der Messung 15F01173

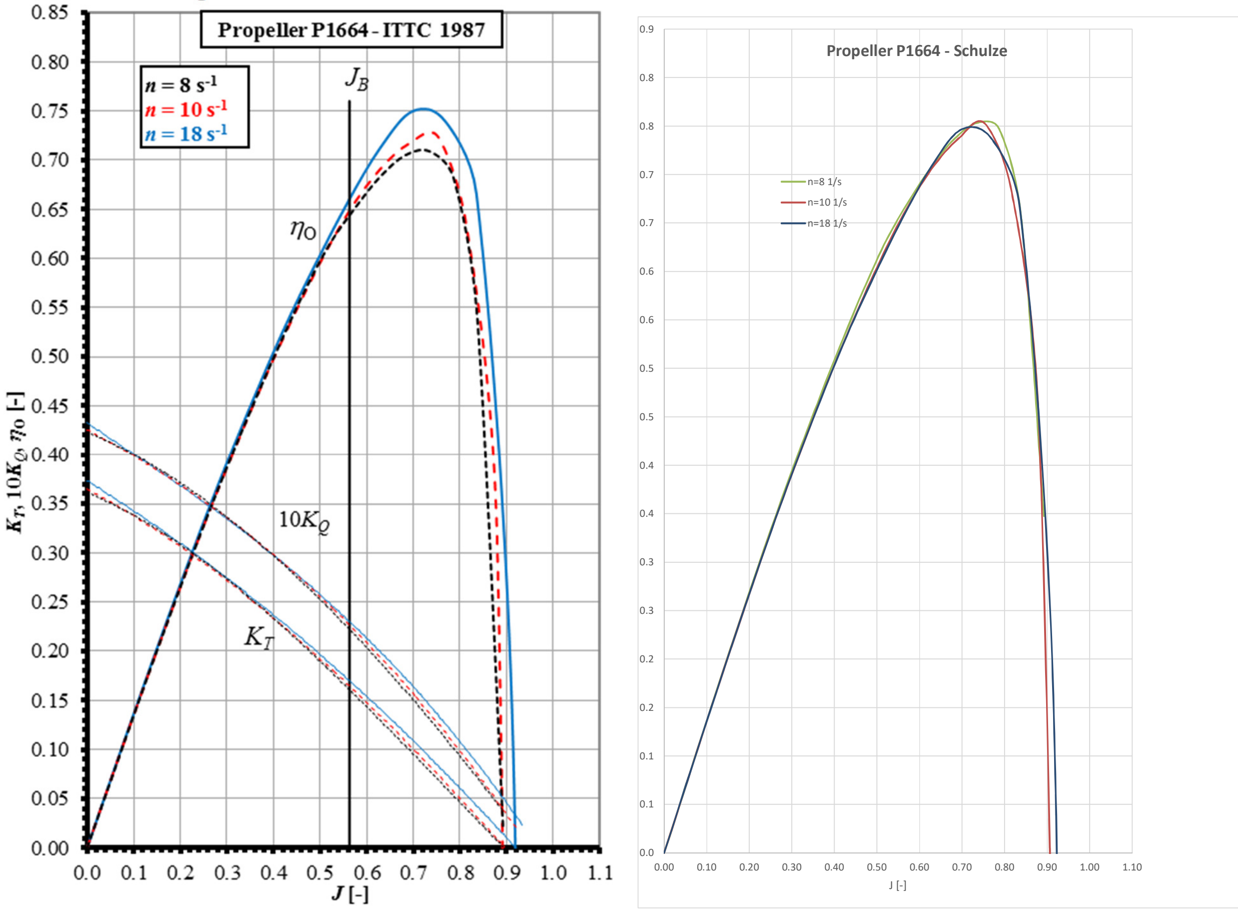
5 Zusammenfassung

- Im Vergleich zu den in den Berichten [16] und [17] verwendeten unterschiedlichen Reynoldszahlkorrekturen ergeben sich mit den hier beschriebenen Prozeduren erhebliche Verbesserungen.

- Unabhängig von den mit unterschiedlichen Drehzahlen gewonnenen Freifahrtkurven ergeben sich fast identische Freifahrtkurven in der Großausführung.

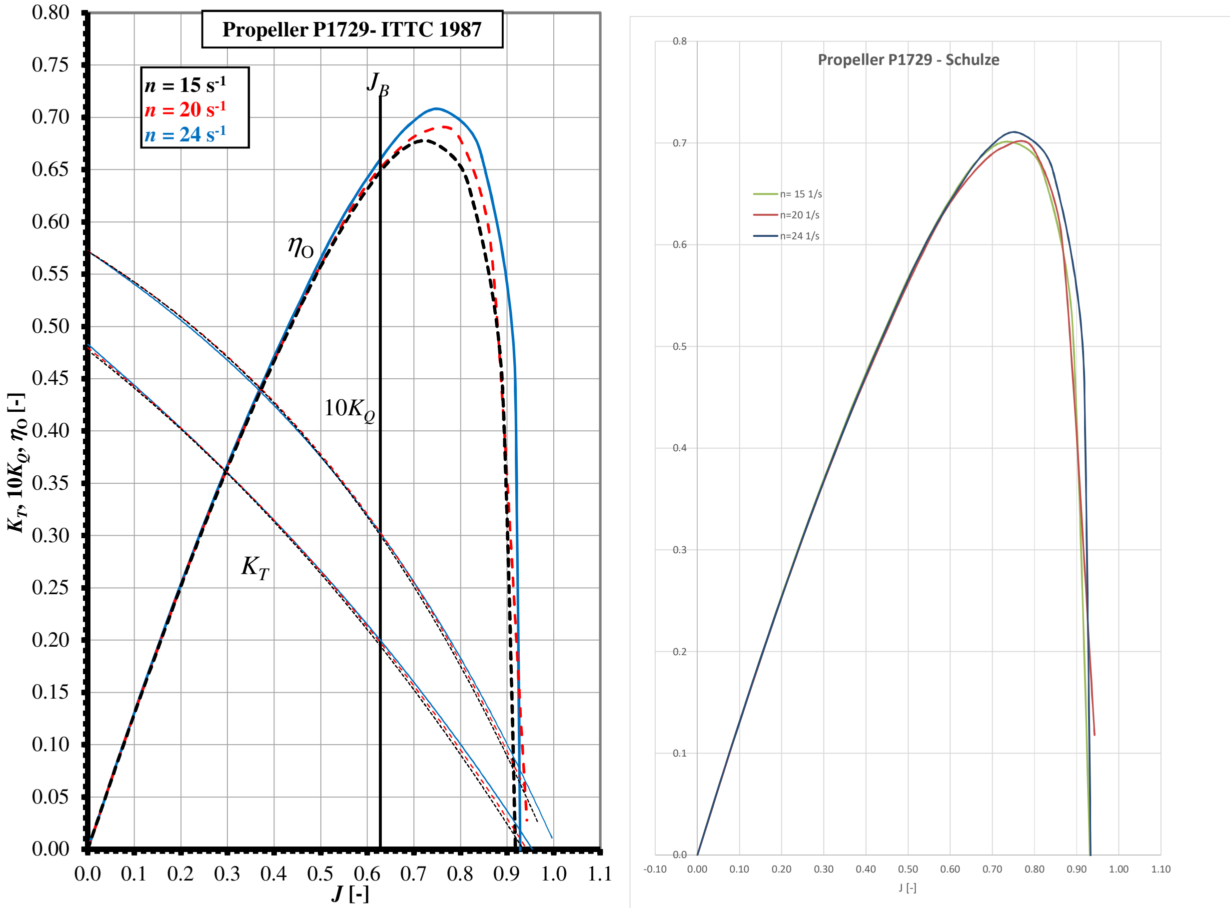
- Es erwies sich, dass mit dem hier abgeleiteten Formelsatz sowohl die Freifahrtkurven konventioneller Propeller als auch so genannter Tip Rake Propeller korrigieren lassen. Beispielhaft seien die Ergebnisse der ITTC 1978 Reynoldszahlkorrekturen aus Bericht [16] für den (konventionellen) Propeller P1664 zitiert (linkes Diagramm) und dem hier beschriebenen Verfahren (rechtes Diagramm) gegenübergestellt (nur Wirkungsgrade).

Korrigierte Freifahrtcharakteristiken für die Großausführung von P1664



Beispielhaft seien die Ergebnisse der ITTC 1978 Reynoldszahlkorrekturen aus Bericht [17] für den Tip Rake Propeller P1729 zitiert (linkes Diagramm) und dem hier beschriebenen Verfahren (rechtes Diagramm) gegenübergestellt (nur Wirkungsgrade).

Korrigierte Freifahrtcharakteristiken für die Großausführungen von P1729



- Unter Verweis auf [16] und [17] lassen sich durch die Verwendung der Streifenmethode nach [15] keine besseren Ergebnisse als die nach der ITTC 1978 – Methode erwarten. Die Streifenmethode wurde erstmals in 1982 in [18] zur Reibungskorrektur in Wirbelgitterverfahren verwendet und wurde später wieder in [10] und [15] aufgegriffen und modifiziert.

- Die wesentlichen Unterschiede des hier beschriebenen Verfahrens im Vergleich zur ITTC 1978 Methode ergeben sich 1. aus dem unterschiedlichen Ansatz zur Berechnung des Formfaktors für Profile, 2. aus der verwendeten Reibungskennlinie im Modellmaßstab (deutlich andere Erfassung des Übergangs von laminarer zu turbulenter Strömung), 3. aus der verwendeten Reibungskennlinie für die Großausführung unter Berücksichtigung von Reynoldszahl <u>und</u> Rauheit und 4. aus der Berücksichtigung der Stauwirkung durch das Dynamometer. Der Formelsatz ist überschaubar und einfach zu programmieren (auch wenn für Punkt 3 eine implizite Gleichung gelöst werden muss).

6 References

[1] GUR, O.; MASON, W. H.; SCHETZ, J. A.
Full-Configuration Drag Estimation,
JOURNAL OF AIRCRAFT, Vol. 47, No. 4, July–August 2010

[2] GUTSCHE, F.
Einwirkung der Rauhigkeit an Schiffsschrauben auf Leistungsaufnahme und Wirkungsgrad. Bd. 3. Schiffbauforschung, 1963

[3] HOERNER, S. F.
Fluid Dynamic Drag, Hoerner Fluid Dynamics, Bakersfield, CA, 1965.

[4] HÜBNER, T.
Vergleich dreier Verfahren zur Umrechnung (Extrapolation) von Propellerfreifahrtergebnissen auf andere Reynoldszahlen.
Institut für Schiffbau der Universität Hamburg, Diplomarbeit, 1996

[5] LERBS, H. W.
On the Effects of Scale and Roughness on Free Running Propellers.
Journal of the American Society of Naval Engineers, 1951

[6] MEYNE, K.
Experimentelle und theoretische Betrachtungen zum Maßstabseffekt bei Modellpropelleruntersuchungen. Schiffstechnik, Band 15, Heft 77, 1968

[7] MEYNE, K.
Untersuchung der Propellergrenzschichtströmung und der Einfluss der Reibung auf die Propellerkenngrößen. STG-Jahrbuch, Band 66, 1972

[8] MEYNE, K.
Propeller mit Skew - Ergebnisse und Erfahrungen.
HANSA Schifffahrt - Schiffbau - Hafen, 1982

[9] MÜLLER, S. B.
Numerische Untersuchung der Maßstabseffekte an Schiffspropellern,
Universität Duisburg-Essen, Fakultät für Ingenieurwissenschaften,
Abteilung Maschinenbau
Dissertation zur Erlangung des akademischen Grades Dr. – Ing.
Tag der mündlichen Prüfung: 1. Dezember 2010

[10] PRAEFKE, E.
Multi-Component Propulsors for Merchant Ships - Design Considerations and Model Test Results; Appendix A: Scale Effect. SNAME Symposium "Propellers/Shafting".
Virginia Beach, USA, 1994

[11] SCHLICHTING, H.; GERSTEN, K.
Grenzschichttheorie, 10., überarbeitete Auflage,
Springer-Verlag Berlin Heidelberg New York 2006,
ISBN-10 3-540-23004-1, ISBN-13 978-3-540-23004-5

[12] SNAME
ITTC 1978: Performance Prediction Method for Single Screw Ships - Report of the Performance Committee of the 15th International Towing Tank Conference.
Den Haag, The Netherlands, 1978

[13] SNAME
ITTC 1984: Report of the Propeller Committee of the 17th International Towing Tank Conference. Göteborg, Sweden, 1984

[14] SNAME
ITTC 1993:
Report of the Propeller Committee of the 20th International Towing Tank Conference. San Francisco, California, USA, 1993

[15] TORENBEEK, E.
Synthesis of Subsonic Airplane Design, Delft Univ. Press, Delft,
The Netherlands and Martinus Nijhoff, Hague, The Netherlands, 1982.

[15] TOMASZ BUGALSKI, HEINRICH STRECKWALL,
JAN A. SZANTYR
Critical review of propeller performance scaling methods,
Based on model experiments and numerical calculations
POLISH MARITIME RESEARCH, No 4 (80) 2013 Vol 20, GDAŃSK UNIVERSITY OF TECHNOLOGY, Faculty of Ocean Engineering & Ship Technology

[16] KLOSE, R.
Propulsions- und Nachstromversuche zur Anwendung und Analyse verschiedener Reynoldszahlkorrekturverfahren für Propeller mit konventioneller Geometrie und Tip Rake Propeller, Teilbericht zum FuE-Vorhaben „Weiterentwicklung der Prognoseverfahren für Tip Rake Propeller", Modell M1467S045 Propeller P1664, P1727, P1730,
Bericht 4375, Schiffbau-Versuchsanstalt Potsdam, Potsdam März 2016

[17] KLOSE, R.
Propulsions- und Nachstromversuche zur Anwendung und Analyse verschiedener Reynoldszahlkorrekturverfahren für Propeller mit konventioneller Geometrie und Tip Rake Propeller, Teilbericht zum FuE-Vorhaben „Weiterentwicklung der Prognoseverfahren für Tip Rake Propeller", Modell M1484Z001 Propeller P1719, P1720, P1728, P1729
Bericht 4375.1, Schiffbau-Versuchsanstalt Potsdam, Potsdam März 2016

[18] GREELY, D. S. and KKERWIN, J.E.
Numerical Methods for Propeller Design and Analysis in Steady Flow Trans. SNAME, Vol. 90, 1982, pp. 415-453

[19] SCHULZE, R.
Über ein Verfahren zur Reynoldszahlkorrektur von gemessenen Freifahrtkurven von Propellern, Teilbericht zum FuE-Vorhaben „Weiterentwicklung der Prognoseverfahren für Tip Rake Propeller", Modell M1484Z001 Propeller P1719, P1720, P1728, P1729
Bericht 4485, Schiffbau-Versuchsanstalt Potsdam, Potsdam April 2016

[20] SCHULZE, R.
Neue Verfahren zur Reynoldszahlkorrektur für Freifahrtmessungen an Modellpropellern, #
STG- Sprechtag „Moderne Propulsionskonzepte", 16. Juni 2016, Hamburg

[21] Pérez-Sobrino, M; González-Adalid, J; Quereda, R; Soriano, C; Morán, A; Gennaro, G
Scale effects in open water test results for performance prediction of conventional and unconventional propellers, INA 2016, April