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EXPERIENCE IN USING THE FORM FACTOR METHOD

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ABSTRACT

The 15th ITTC in 1978 recommended the use of a new performance prediction method, known since then as ITTC-78-Method.

This method includes the application of form factor k in the extrapolation of the ship resistance and the power from model test results.

The adoption of the form factor represents an improvement in comparison with the traditional methods. The consequent application of this method, however, is accompanied by new error sources when calculating the performance, which must be taken into account when using the method.

The present paper gives a brief discussion of the method of determining the factor and the method of using it. Error sources are pointed out which may occur when determining the form factor. The significant influence of the chosen form factor on the extrapolated values of ship's resistance and performance are demonstrated by means of an example of the calculation of a ship with or without bulbous bow for several draughts.

NOMENCLATURE

A_T	Transverse area above water
B	Breadth of ship
C	Coefficient in general
C_{AA}	Air resistance coefficient $C_{AA} = 0.001\ A_T/S$
C_B	Block coefficient $C_B = \nabla/L_{PP}\ B\ T$
C_F	Frictional resistance coefficient $C_F = R_F/0.5\ \rho\ V^2\ S$
$C_{F\ ITTC\ 57}$	Specific frictional resistance coefficient according ITTC-57-Line $C_F = 0.075/(\lg Rn-2)^2$
C_{FM}, C_{FS}	Frictional resistance coefficient
C_{FO}	Frictional resistance coefficient in two dimensional flow
C_R	Residuary resistance coefficient $C_R = C_{TM} - (1+k)\ C_{FM}$
C_{RO}	Residuary resistance coefficient $C_{RO} = C_{TM} - C_{FM}$
C_{TM}, C_{TS}	Total resistance coefficient $C_T = R_T/0.5\ \rho\ V^2\ S$
C_V	Total viscous resistance coeff. $C_V = R_V/0.5\ \rho\ V^2\ S$
Fn	Froude number $Fn = V/\sqrt{g\ L}$
g	Acceleration due to gravity
k	Form factor
K_S	Roughness height
L	Length of a ship
L_{PP}, L_{WL}	
N	Exponent of Fn
P_E	Effektive power $P_E = R_T\ V$
r	Form factor $r = (1+k)$
R_n	Reynolds number $R_n = V\ L/\nu$
R_F	Frictional resistance
R_T	Total resistance
R_V	Total viscouse resistance
S	Wetted surface
T	Draught, middle
T_A	Draught, aft (at AP)
T_F	Draught, fore (at FP)
V	Speed
ν	Coefficient of kinematic
ρ	Mass density
ΔC_F	Roughness allowance
ΔP_E	Difference in effektive power
ΔV	Difference in speed
∇	Displacement volume

Used indexes

M	Model
S	Ship
PP	Perpendiculars
WL	Waterline

Used abbreviations

B1, B2	Bulbous bow num. 1, num. 2
T1, T2, T3	Draught num. 1 ... 3
ITTC	Internationale Towing Tank Conference
SVA	Schiffbau-Versuchsanstalt Potsdam, Model Test Tank Laboratory Potsdam

1. INTRODUCTION

Froude's method is used in nearly all model testing laboratories all over the world when extrapolating the resistance of a full-scale ship from model test results.

This method ist characterized by the division of the total resistance into two parts, namely the frictional resistance and the residual resistance, either of them being scaled up in accordance with a proper scaling law:

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$$C_{TM} = C_{FM} + C_{RO} \qquad (1)$$

$$C_{TS} = C_{FS} + C_{RO} \qquad (2)$$

The frictional resistance coefficient, C_F, is included in the calculation of the full-scale ship by means of a frictional line of a flat plate taking Reynolds's Law into account. The residual resistance coefficient, C_{RO}, is assumed to be equal for model and full-scale ship, Froude's Law being duly observed.

Using this relatively simple extrapolation method, some important physical facts concerning the three-dimensional flow around the ship are neglected, of course. Therefore, improvement of this method was started from the beginning of its use. First of all, an empirical "roughness allowance", C_F (in recent time also called C_A) was introduced, thus summarily eliminating some shortcomings of the method.

$$C_{TM} = C_{FM} + C_{RO} \qquad (3)$$

$$C_{TS} = C_{FS} + C_{RO} + C_F \qquad (4)$$

The amount of the roughness allowance is mainly dependent on the ship's length, but also on the block coefficient and the roughness of the ship's surface. Apart from this, the proper experience of each model testing laboratory may also be considered when determining the amount of the roughness allowance.

G. Hughes, in (1), has revised the division of the resistance proportions already in 1954, and his revision was the basis for the so-called form factor method.

$$C_{TM} = (1+k)\ C_{FM} + C_R \qquad (5)$$

$$C_{TS} = (1+k)\ C_{FS} + C_R + C_F \qquad (6)$$

Using the form factor k, the three-dimensional flow around the ship is taken into account by calculating that proportion of the frictional resistance caused by ship's shape. The form factor is assumed to be equal for model and full-scale ship. This method gives a better reflection of the physical conditions of the flow around the ship, but it is not a really three-dimensional extrapolation method.

In the definition by ITTC 1978, form factor k is determined from the ratio of the specific total viscous resistance coefficient, C_V, of the model or the full-scale ship to the frictional resistance coefficient, C_{FO}, of a flat plate, using the same Reynolds number.

$$r = 1 + k = \frac{C_V}{C_F\ ITTC\ 57} \qquad (7)$$

The ITTC 1957 line is used as frictional line.

When the form factor method is used for calculation, the meaning of the residual resistance coefficient, C_R, differs from its previous meaning. It is frequently denominated as resistance proportion of free surfaces. The values of C_R determined by means of the form factor method as per equation (5) are different from the C_{RO} values as per equation (1) and (3) in the following way:

$$C_R = C_{RO} - k\ C_{FM} \qquad (8)$$

This correlation is well known to all specialists, of course. But errors may easily occur if personnel with little training are at work, especially when the results of previous test series are used for designing a ship, the more so as the ITTC continues using the same symbol, namely C_R, for both different coefficients of residual resistance (cf. also Fig.9).

The essential problem for the use of the form factor method, however, is the correct determination of form factor k, as the chosen amount of k has a considerable effect on the predicted resistance of the ship and thus on the predicted speed. The present paper aims at the discussion of this problem. As the form factor effects the predicted resistance in the same way as the power calculated from propulsion test results, this discussion is limited to the more simple case, namely the resistance.

2. RECOMMENDATIONS OF ITTC 1978 FOR THE DETERMINATION OF THE FORM FACTOR

The 15th ITTC 1978 has recommended the adoption of a new performance conversion method [4]. An integral part of the extrapolation of the performance of the full-scale ship with the use of this method is the adoption of the form factor.

The resistance coefficient of the full-scale ship will then be determined by means of the following formula:

$$C_{TS} = (1+k)\ C_{FS} + C_R + \Delta C_F + C_{AA} \qquad (9)$$

where:

- $(1+k)$ = Form factor as per Prohaska, determined from resistance test
- C_{FS}, C_{FM} = Frictional coefficient as per ITTC 57

$$C_F = \frac{0{,}075}{(\log_{10} R_n - 2)^2} \qquad (10)$$

$$R_n = \frac{V \cdot L}{\nu} \qquad (11)$$

C_R = Residual resistance coefficient

$$C_R = C_{TM} - (1+k)\ C_{FM} \qquad (12)$$

ΔC_F = Roughness allowance

$$\Delta C_F = [105\ (K_S/L_{WL})^{1/3} - 0{,}64]\ 10^{-3} \qquad (13)$$

$$K_S = 150\ 10^{-6}\ m$$

C_{AA} = Air resistance coefficient

$$C_{AA} = 0{,}001\ A_T/S \qquad (14)$$

For determining the form factor, the relatively simple method of Prohaska is recommended which is based on the fundamental idea that resistance is only generated by friction for very small Froude numbers. On this condition, the form factor is precisely expressed by the ratio between the specific total viscous resistance coefficient, C_V, of a model or a full-scale ship and the two-dimensional frictional resistance coefficient, C_{FO}, of a flat plate with the same Reynolds numbers. ITTC [5] recommends to carry out resistance tests within the range of Froude numbers from $0.12 < F_n$, 0.20 in this connection.

The form factor results from:

$$(1+k) = C_T/C_F - C\ F_n^{\,n}/C_F \qquad (15)$$

Coefficients k, N and C are determined approximately with the help of the least square method. N = 4 is recommended as exponent of the Froude number. If linearization cannot be obtained with N = 4, N can be modified.

3. EXPERIENCE IN DETERMINING THE FORM FACTOR

In author's experience, a minimum of 7 measuring points within the range $0.12 < F_n < 0.20$ in equidistant speed steps are necessary for a sufficiently exact determination of the form factor using Prohaska's method.

The form factor can be easily calculated by a computer programm or in a graphical way. The graphical solution, which can also be computer-aided, will be preferred in most cases as it enables the measuring person to estimate the quality of the measuring points on the basis of his own experience.

Fig. 1 shows the graphical method of determination of the form factor as per Prohaska. Form factor (1+k) according to equation (15) for $F_n \rightarrow 0$ is given by the intersection point of the line of best approximation of all C_T/C_F values with the ordinate ($F_n = 0$). For all normal ships without bulbous bow it is sufficient to use N = 4 as exponent for F_n. If the points cannot be connected by a straight line, a slightly curved single-valued line will give the same values of the form factor as a line stretched by an other exponent.

In the case of 5 to 6 m model length and Froude numbers $F_n < 0.12$ laminar flow must be expected, which results in low resistance values of the model. Therefore, the measuring points with $F_n < 0.12$ must be examined whether or not they are useful. Ships with a high block coefficient show a more rapid increase of the total resistance coefficient when comming close to the upper speed limit. Measuring points in that range must also be examined for usability.

It is recommended in every case to check the form factors determined from experimental dates with the help of empirical formulae, which are based on the evaluation of a large number of model tests. Care must be taken to make clear on which frictional line the formulae are based. The following three formulae are related to the ITTC 1957 frictional line:

acc. to Watanabe [3]:

$$k = -0.095 + 25.6 \frac{C_B}{\left(\frac{L_{WL}}{B}\right)^2 \sqrt{\frac{B}{T}}} \qquad (16)$$

acc. to 13th ITTC 1972 [2]:

$$k = 0.017 + 20 \frac{C_B}{\left(\frac{L}{B}\right)^2 \sqrt{\frac{B}{T}}} \qquad (17)$$

own approximate formula:

$$k = 0.4\, C_B - 0.1 \qquad (18)$$

Formula (18) is a coarse approximation, but it is good for a quick preliminary check of form factors determined by means of tests because of its simple structure. The formula holds true for fully loaded vessels without bulbous bows with normal shapes and not extreme block coefficients. It is based on model test results of the model test tank laboratory Potsdam, GDR (SVA).

The form factor has been extensively discussed since the ITTC 1978 method has been adopted 10 years ago. Several proposals [5], [6], [7] have been submitted on how the form factor can be determined more safely, but also more intricately.

Up to now, the Performance Committee has adhered to its recommendation of 1978 because of the simplicity of Prohaska's method, but has pointed out in 1984 [6] the following possible errors:

- Separation on a model may give too high a form factor;
- Laminar flow on a model may give too low a form factor;
- Wave breaking may disturb the linearity of the resistance coefficient;
- Interaction between propeller and hull may influence the form factor;
- It may be difficult to take the appendages into account;
- Tank blockage may influence the form factor;
- The form factor is dependent on the Froude number;
- The form factor may be dependent on the Reynolds number;
- Bulbous bows may also disturb the linearity of the resistance coefficient.

All the above listed effects are to be taken into account when determining the form factor by means of Prohaska's method in order to avoid errors in the performance prediction.

The present paper gives a discussion on the last item of the above list, i. e. the influence of the shape of the fore body, particularily of bulbous bows of different shapes, and also the influence of different draughts and trim conditions on the form factor. The great influence of the chosen form factor on the predicted performance of the full-scale ship is to be demonstrated.

4. DETERMINATION OF THE FORM FACTOR OF A MODEL WITH DIFFERENT SHAPES OF THE BOW

Choise of the model and test conditions

In order to illustráte the problem of form factor determination for different shapes of the fore bodies, a model has been chosen for which resistance test results have been available for a ship without bulbous bow and for several variants of the bulbous bow, which illustrated the extremely large influence of the fore body shape on the resistance properties. A big fishing vessel model was chosen, for which test results with a good bulbous bow (B1), a bad bulbous bow (B2), and a version without bulbous bow, each tested at three different draughts, have been available.

Table 1: Main dimensions of the ship without bulbous bow

		T1	T2	T3
L_{PP}	m	153.00	153.00	153.00
L_{WL}	m	154.88	147.76	142.81
B	m	23.50	23.50	23.50
T_A	m	8.28	7.55	6.20
T_F	m	8.28	6.55	3.70
S	m^2	4417	3989	3327
∇	m^3	19360	16095	10770
C_B	-	0.650	0.635	0.605

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The Table 1 shows the main data of the ship without bulbous bow at three draughts. Fig. 2 shows the contours of the fore and aft bodies as well as frame no. 20 of all three variants.

The tests have been carried out with constant displacement for each draught, therefore, slight differences of the draught between the individual variants have occurred. The model is made of wood, the surface coated with varnish. To generate turbulence the model without bulbous bow was fitted with two rows of pins of cylindrical shape (2.5 mm diameter and height, 25 mm spacing) on frame 19, and each two rows of such pins were fitted on frames 19 and 20 (FP) of the models with bulbous bow.

The tests have been carried out in the towing tank of the model testing tank laboratory Potsdam (SVA). The towing tank dimensions are as follows:

$$L = 280 \text{ m}$$
$$B = 9 \text{ m}$$
$$D = 4.5 \text{ m}$$

A mechanical balance has been used as measuring instrument. The speed range investigated was the F_n range $0.12 < F_n < 0.27$, sometimes $0.10 < F_n$ 0.27.

Determination of form factors

The form factors of every test have been determined in accordance with the above described Prohaska's method in a graphical way as shown in Fig. 1.

Figs. 3 to 5 show the work diagrams for the determination of the form factors for the three different fore body shapes. It is obvious that the form factors of the ship without bulbous bow can be easily determined with the recommended F_n exponent $N = 4$. The same holds true for bulbous bow B1. The resistance line of bulbous bow B2 with T2 and T3 is not linear which is mainly caused by wave breaking. So the form factor cannot be determined safely and unambiguously in this way. Modification of the F_n exponent N is no remedy either, so the form factor is formally determined with the help of the Prohaska method, since other methods do not result in better values, too.

Table 2 contains the form factors determined for the model from Figs. 3 to 5 according to the Prohaska method.

Table 2: Form factors (1+k) acc. to Prohaska

bow type	Approximation line	T1	T2	T3
normal	Straight line	1.178	1.170	1.164
B1	Straight line	1.178	1.162	1.258
B2	Straight line	1.29	1.43	1.37
	Parabola	1.28	1.36	1.25

The calculated values for the ship without bulbous bow and for bulbous bow B1 are useful after preliminary check. Doubtful is the value B1/T3. The values for bulbous bow B2, however, seem to be too high, even without check calculation for comparison purpose. The use of a parabola as approximate line does not result in substantially better values.

As a check, the calculated form factors should be compared with such values determined from empirical approximate formulae (16) to (18).

Table 3 contains the values for the ship without bulb. For models with bulb the approximate formulae result in nearly the same values.

Table 3: Form factors (1+k) according to approximate formulae

Formula		T1	T2	T3
Watanabe	(16)	1.132	1.130	1.098
ITTC 72	(17)	1.199	1.181	1.148
Author	(18)	1.160	1.155	1.142

The values calculated from the different empirical formulae are differing, as it was expected. But the range of expectation and the trends are clearly demonstrated. Useful values have been determined even with the primitive estimate formula (18).

A comparison with the form factors determined experimentally and listed in Table 2 shows that those for the ship without bulbous bow at all three draughts are within the range of expectation, so they can be taken as correct. The same holds true for the model with bulbous bow B1 at draughts T1 and T2. The experimental value of T3 is, however, too high which may be caused by wave breaking in ballast condition.

Furthermore, the comparison shows that the form factors determined by means of the Prohaska method for the bad bulbous bow B2 are significantly to high.

5. INFLUENCE OF THE CHOSEN FORM FACTOR ON THE PREDICTED EFFECTIVE POWER

Over the years, every model testing laboratory will gain their own experience in extrapolating the model test results to the full-scale ship, and consequently the extrapolation methods are differing widely. For instance, most of the test laboratories have particular rules for the determination of form factor k and roughness allowance C_F, and also for the determination of sea trial and service allowances and when considering the air resistance.

In the present paper only the influence of the form factor is discussed. But for comparison purposes the roughness allowance must also be taken into account, as the ITTC 1978 extrapolation method including the adoption of the form factor method contains a definite correlation between roughness allowance and ship's length, cf. formula (13).

In order to illustrate the great influence of the chosen form factor on the effective power extrapolated for the full-scale ship, the results of all 9 resistance tests have been converted in three variants:

Variant (1) SVA method
(1+k) = 1 in all cases
$\Delta C_F = 0.0002$ in all cases

Variant (2) ITTC 1978
(1+k) acc. to Prohaska, Table 2
ΔC_F acc. to (13), Table 4

Variant (3) ITTC 1978
(1+k) = 1.178 in all cases
ΔC_F acc. to (13), Table 4.

The roughness allowances ΔC_F according to formula (13) for all cases investigated are listed in Table 4.

Table 4: Roughness allowance $10^3 \times \Delta C_F$ acc. to ITTC 1978 (13)

bow type	T1	T2	T3
normal	0.399	0.415	0.427
B1	0.399	0.413	0.399
B2	0.399	0.409	0.399

The resistance proportion caused by air according to formula (14) has been omitted as it is not significant for this comparison.

Figures 6 to 8 show the results of resistance tests in the form $C_{RO} = f(F_n)$. This form of presentation renders possible a clear judgment on the quality of the bulbous bows investigated, as the "old" value of C_{RO} according to formula (3) is used. Furthermore, this form is good for statistical purposes. The great differences of the C_R values calculated in the variants (1), (2), (3) are shown in Fig. 9.

The best ship's shape out of the three investigated models is bulbous bow B1 at all three draughts. This is especially evident for mean draught T2, cf. Fig. 7. But this mode of presentation cannot be used for estimating the percentage of power saving or the gain in speed. For this purpose the only useful mode is to plot the effective power or the resistance directly over the speed as shown in Fig. 13 as an example for draught T2.

However, when the power is directly plotted in this way, the differences between the values determined according to the different methods cannot be plotted anough clearly, as the curves are very narrow to each other and crossing. The total resistance coefficient, C_{TS}, is the quantity best serving for comparison purposes.

The C_{TS} values are plotted separately for the three draughts investigated in Fig. 10 to 12. The considerable influence of the conversion method chosen, i. e. of the form factor, on the values predicted for the ship is clearly visible for all three draughts. The differences of the three shape variants measured in the model test according to method (1) are also proved for the full-scale ship in their entirety. Not so when method (2) is formally used, which leads to a falsification of the test results and may, when the form factors experimentally determined for every loading condition are consequently applied, even lead to the reversion of the trends determined in tests.

Discussion of draught T2 shall serve as an example for this. As mentioned above, the best resistance properties over the entire speed range have been determined when testing the model of bulbous bow 1 at draught T2, cf. Fig. 7. Bulbous bow B2 is an improvement compared with ships without bulbous bow only when V > 16.5 knots. When using the extrapolation method (1) these relations are not altered as Fig. 11 shows. If, however, the form factor experimentally determined according to method (2) is used, the ship with bulbous bow 2 is substantially better than the ship without bulbous bow beginning with V = 14.5 knots, and for V > 16 knots ist es even better than the ship with bulbous bow 1 which is evidently an error.

Fig. 11 shows also that the trends stated during model testing are maintained with the proposed method (3), i. e. constant form factor for all models and all draughts, as well as with method (1).

Fig. 13 illustrates the effective power of the full-scale ships without bulbous bow and with bulbous bow 2 as an example of T2 in order to demonstrate the great influence of the chosen extrapolation method on the predicted effective power and speed of the ship. The differences between methods (1) and (3) are small, namely less than 3 % for the power and less than 0.1 knot for the speed. The result of the model test, namely that the bulbous bow 2 is better than the ship without bulbous bow only when V > 16.5 knots is also maintained in both methods.

Method (2) turns the entire test result upside down. According to this method, B2 is better than the ship without bulbous bow already when V > 14 knots. The too high form factor of variant B2 results in a substantially more favourable extrapolation. In the concrete case V = 17 knots, the error amounts to about 16 % of the effective power or ca. 0.8 knots in speed.

Finally it should be pointed out once more that the above example is a decidedly extreme case, but one which may occur in the practical work of a model testing laboratory.

In cases where tests are carried out exclusively with ship models with bulbous bows the influence of which on the form factor cannot be definitely predicted, the choice of the correct form factor is a special problem.

6. CONCLUSIONS

1. The determination of the form factor from ship model tests is difficult.

2. The choice of the form factor has a considerable influence on the predicted effective power and speed of the ship.

3. Sometimes it is better to use a form factor determined by means of a safe empirical formula than one determined formally from test results.

4. When extrapolating the test results with different shapes of a ship type and at different draughts the same form factor should be used in all cases.

5. The "previous" residual resistance coefficient, $C_{RO} = C_{TM} - C_{FM}$ is more suitable for statistical work than the "new" residual resistance coeff., $C_R = C_{TM} - (1+k)\, C_{FM}$.

7. REFERENCES

[1] Huges, G., Friction and Form Resistance in Turbulent Flow, and a Proposed Formulation for Use in Model and Ship Correlation Transactions of the Institution of Navel Architects, Vol. 96, p. 314, London 1954

[2] Proceedings of the 13th International Towing Tank Conference, Report of Performance Committee, Berlin, Hamburg 1972

[3] Proceedings of the 14th International Towing Tank Conferenz, Report of Performance Committee, Ottawa 1975

[4] Proceedings of the 15th International Towing Tank Conferenz, Report of Performance Committee, Wageningen 1978

[5] Proceedings of the 16th International Towing Tank Conferenz, Report of Performance Committee, Leningrad 1981

[6] Proceedings of the 17th International Towing Tank Conferenz, Report of Performance Committee, Goeteborg 1984

[7] Proceedings of the 18th International Towing Tank Conferenz, Report of Performance Committee, Kobe 1987

[8] Munk, T., Method for Analysis of Results from Tests in Still Water with Ship Models, Danish Maritime Institute, SL 79901.12, Rep. No.1 Lyngby 1979/80

[9] Harvald, Sv. Aa.; Hee, J. M., The Form Factor on Friction 1+k, Proceedings 4th International Congress International Maritime Association of East Mediterranean, Varna 1987

[10] Nawrocki, St., The influence of form faktor "k" on resistance prediction according to ITTC recommendation Budownictwo Okretowe nr. 10/1987, Gdansk

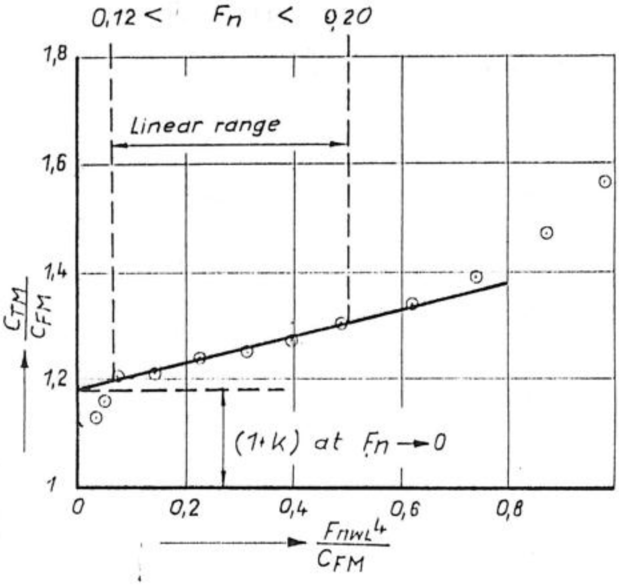

Fig. 1 Graphically determination of form factor (1+k) according to Prohaska-method

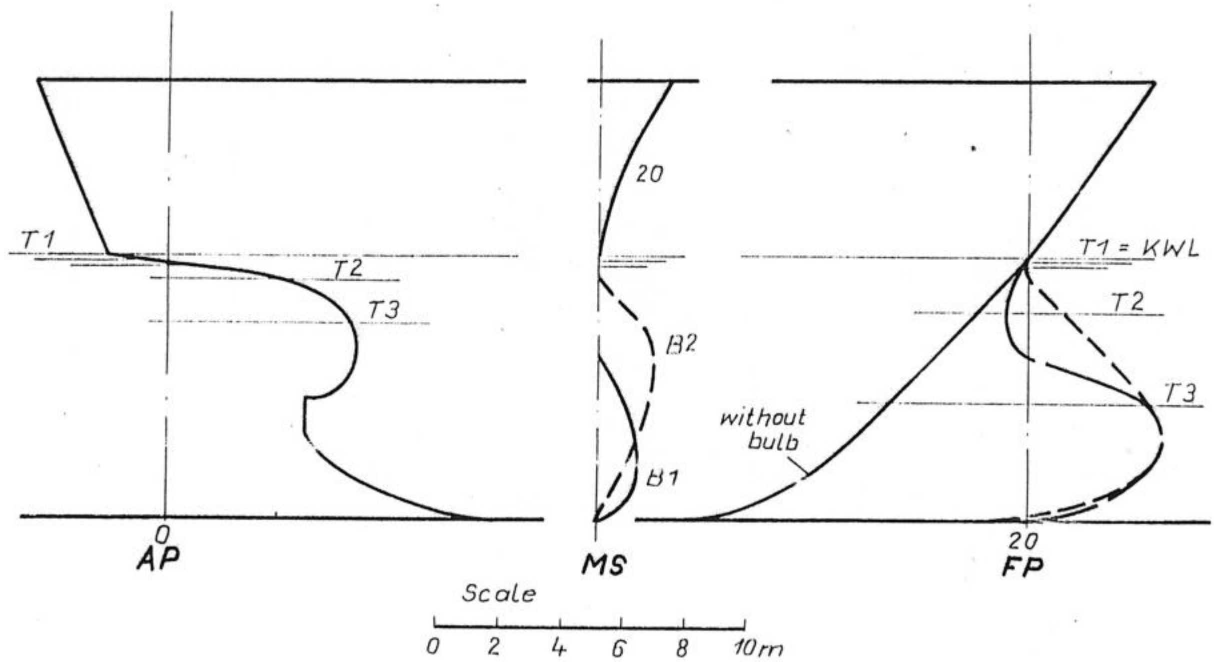

Fig. 2 Profiles of stern and bow and frame 20

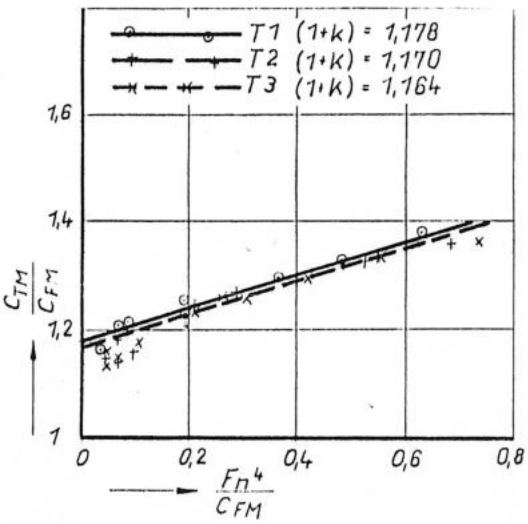

Fig. 3 Form factor according to Prohaska, model without bulbous bow

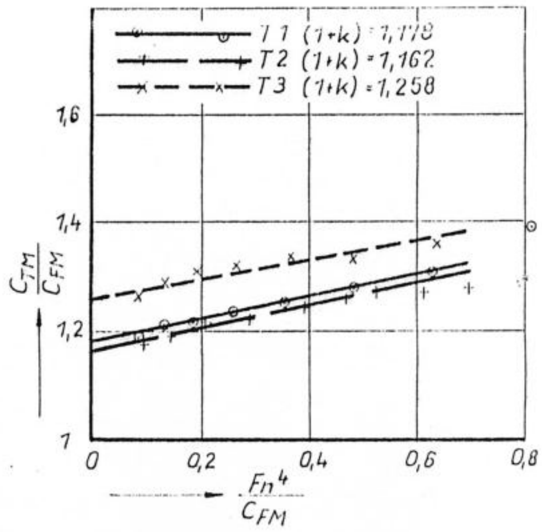

Fig. 4 Form factor according to Prohaska, model with bulbous bow B1

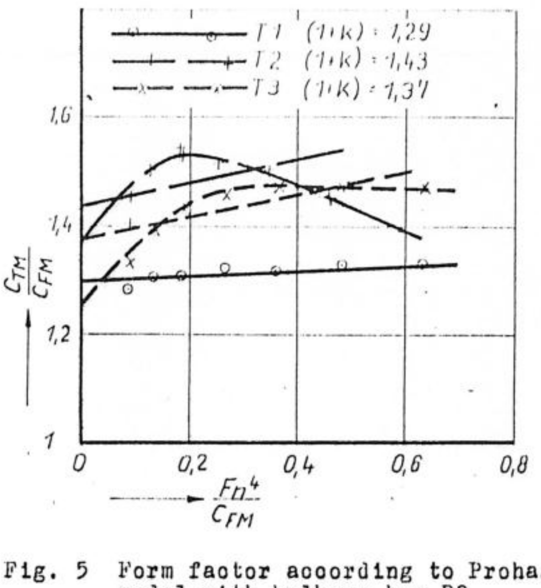

Fig. 5 Form factor according to Prohaska model with bulbous bow B2

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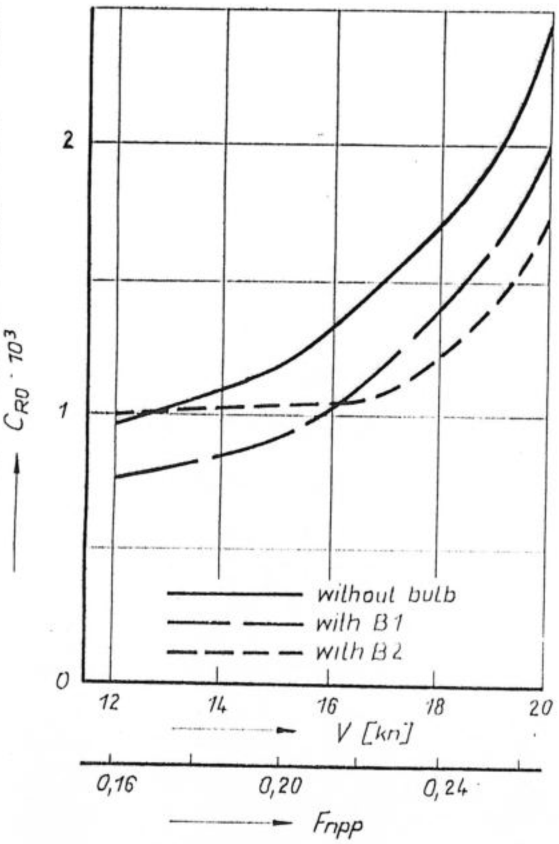

Fig. 6 Residuary resistance coefficient C_{RO}
T1 = 8,28 m, even keel

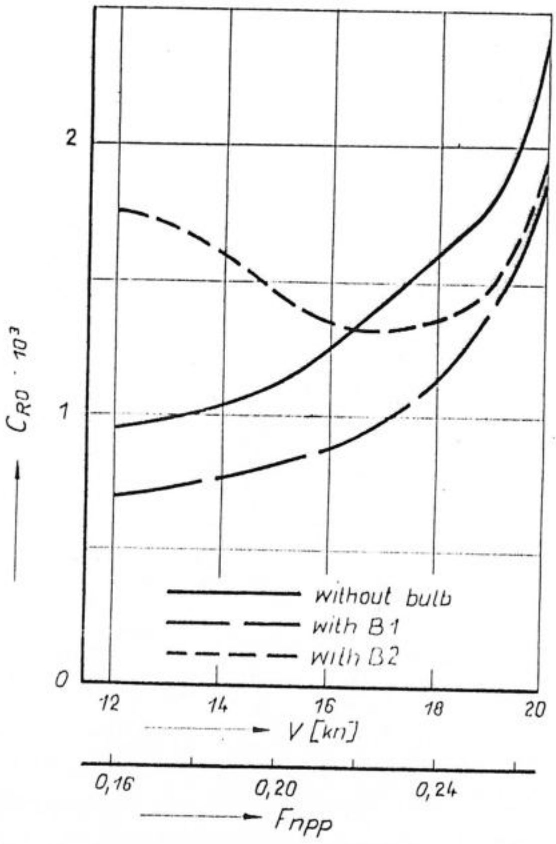

Fig. 7 Residuary resistance coefficient C_{RO}
T2 = 7,05 m, 1,00 m trim

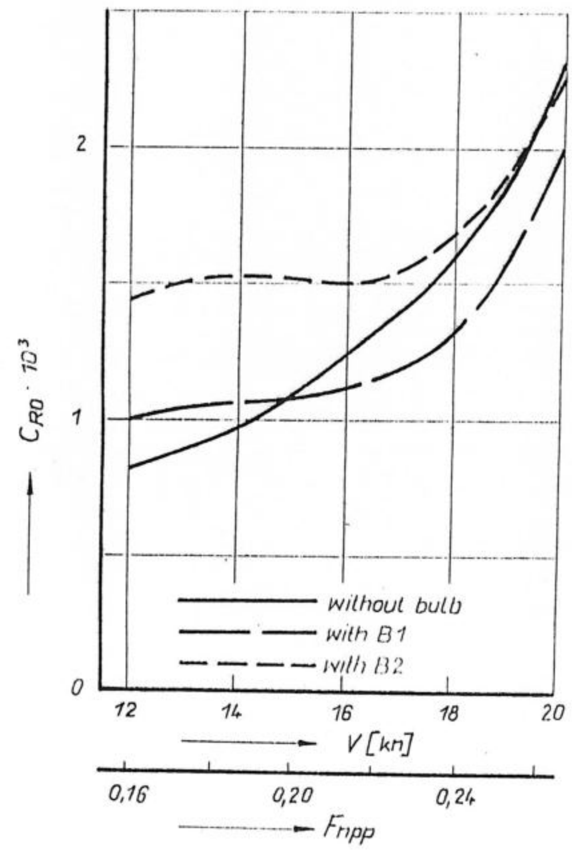

Fig. 8 Residuary resistance coefficient C_{RO}
T3 = 4,90 m, 2,50 m trim

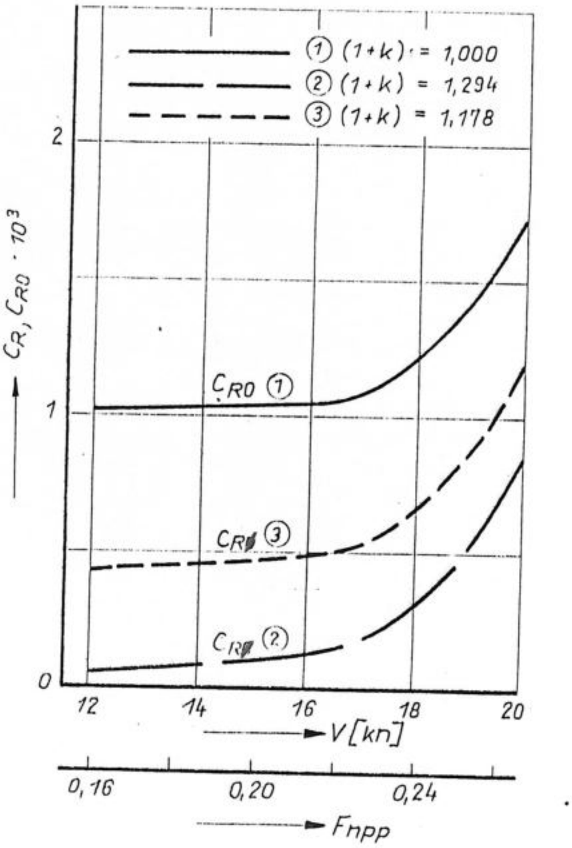

Fig. 9 Residuary resistance coefficients according to different methods, bulbous bow B2, T1 = 8,28 m

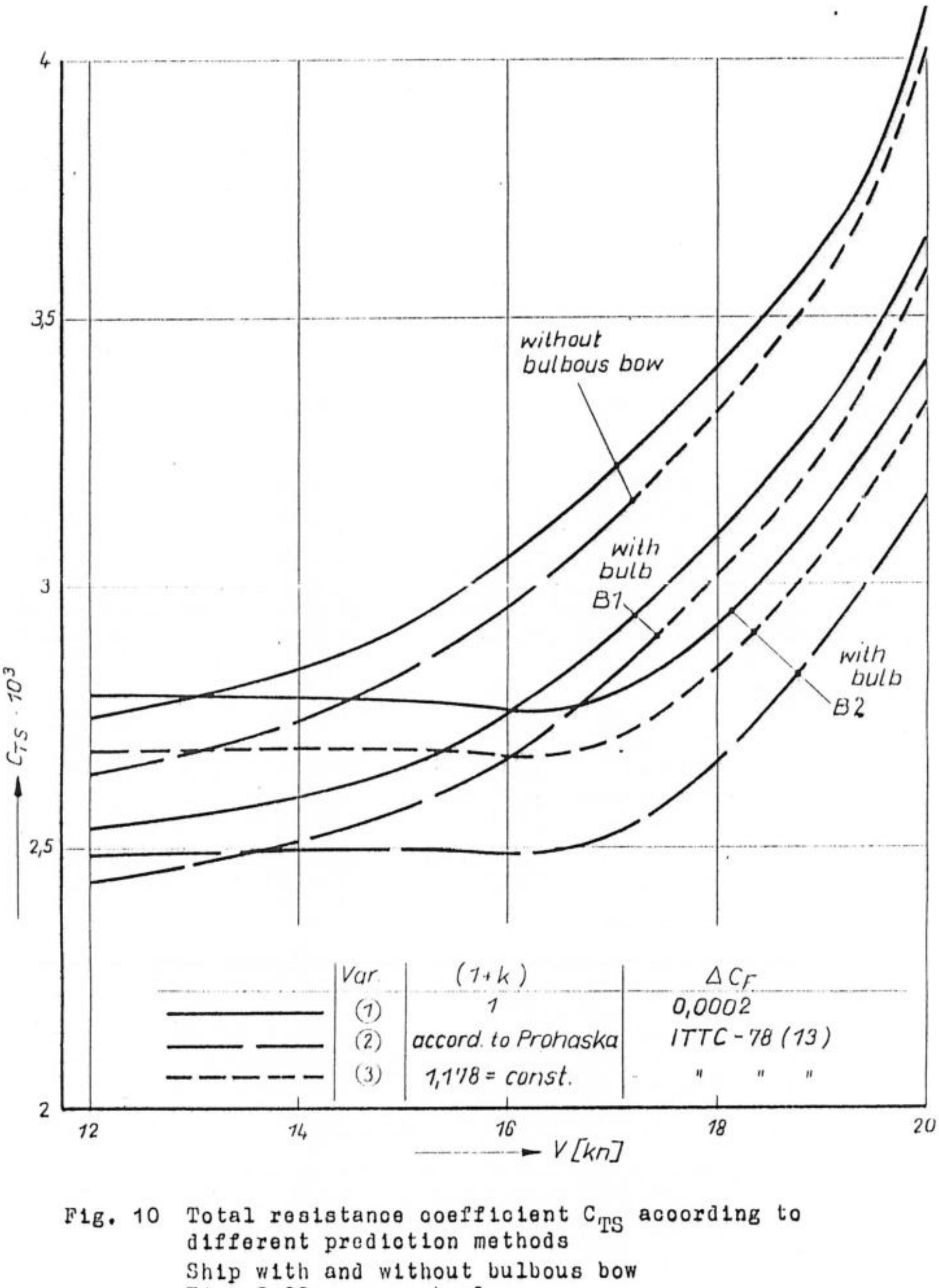

Fig. 10 Total resistance coefficient C_{TS} according to different prediction methods
Ship with and without bulbous bow
T1 = 8,28 m, even keel

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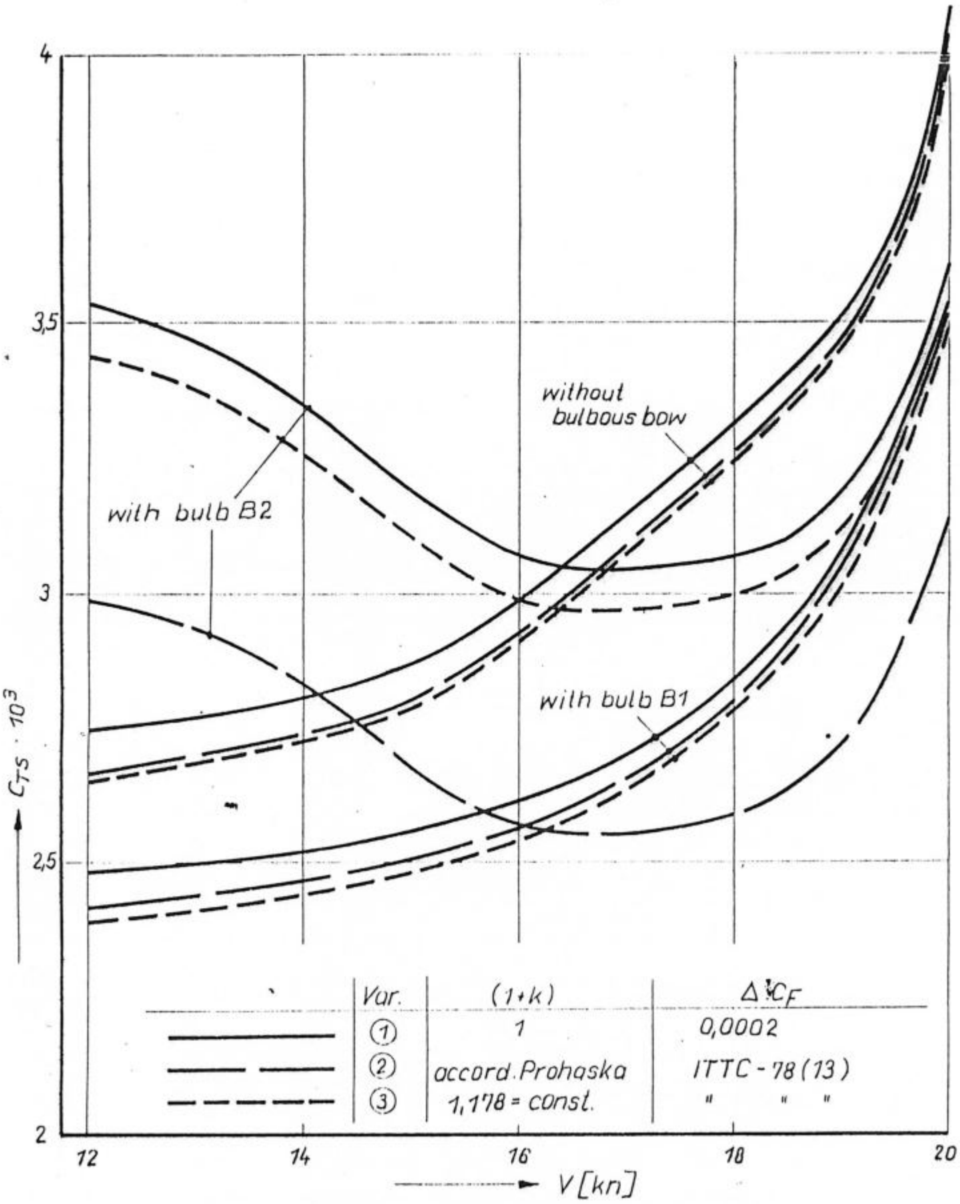

Fig. 11 Total resistance coefficient C_{TS} according to different prediction methods
Ship with and without bulbous bow
T2 = 7,05, 1,00 m trim

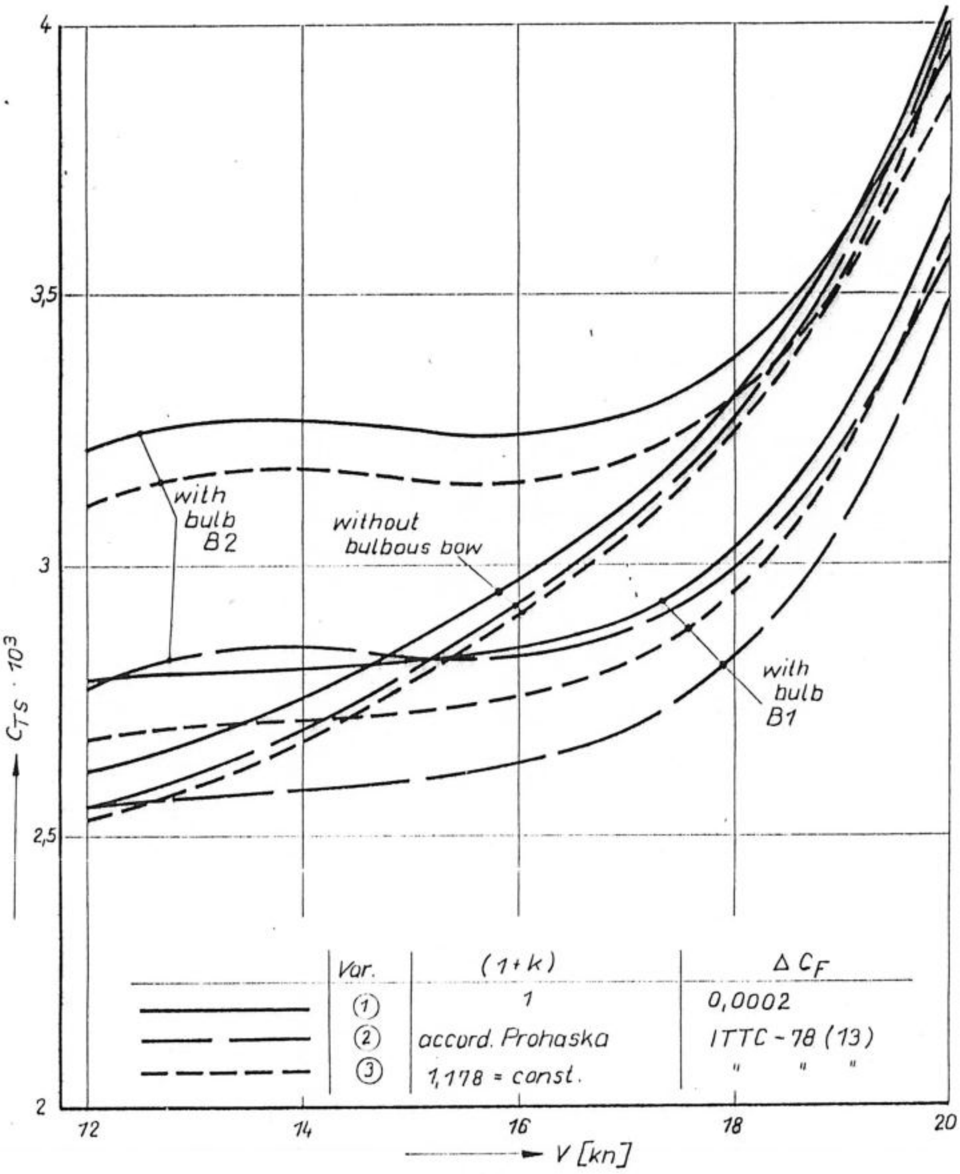

Fig. 12 Total resistance coefficient C_{TS} according to different prediction methods
Ship with and without bulbous bow
T3 = 4,95 m, 2,50 m trim

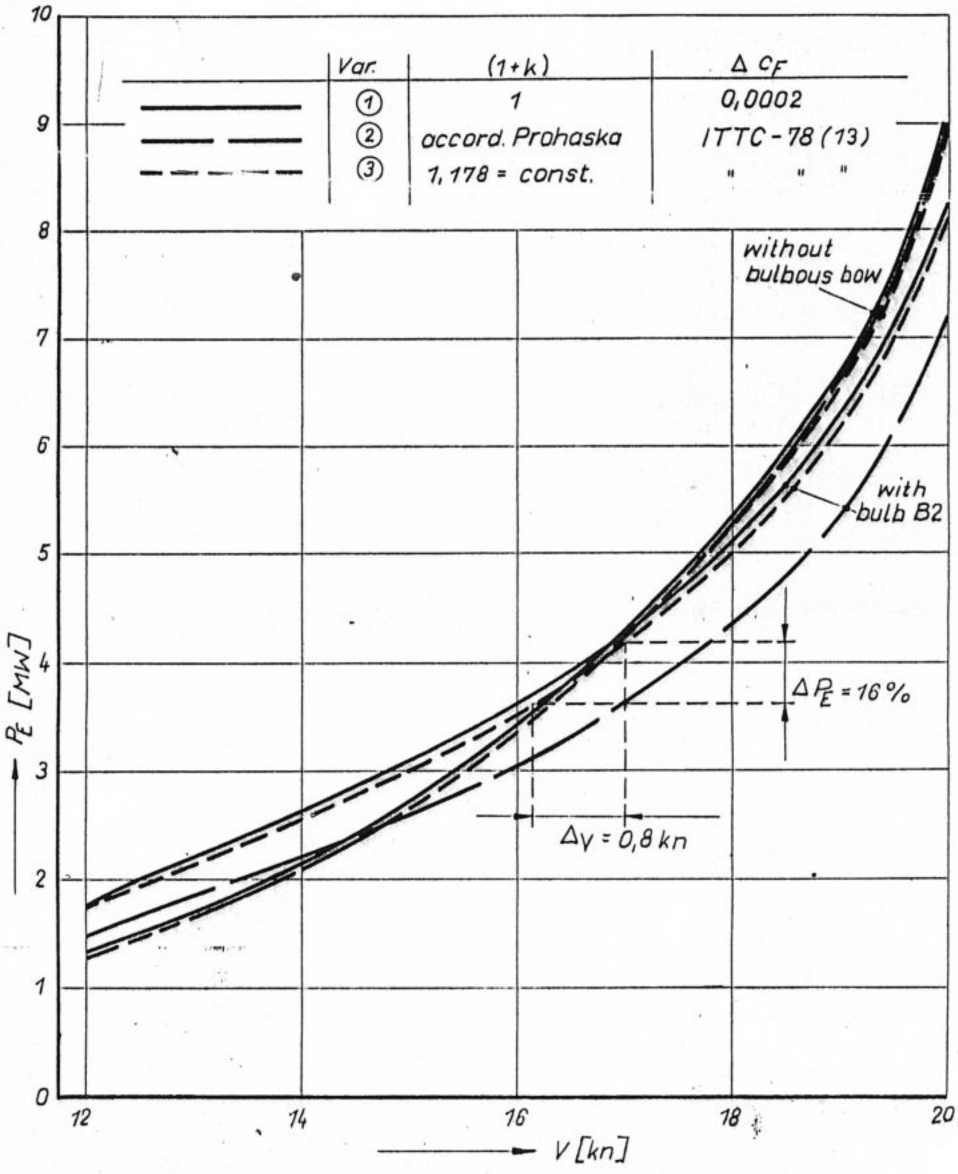

Fig. 13 Effektive power P_E, according to different prediction methods
Ship with and without bulbous bow
T2 = 7,05 m, 1,00 m trim