ANALYSIS OF SPEED/POWER TRIAL DATA
ITTC 7.5 – 04 – 01 – 1.1 & 1.2
IMO MEPC – 65
ISO 15016 (2015)

Report No. 14325

Sea trials M.V. Bulker

Printing date: Monday, 23 April 2018

Trial date: Wednesday, 29 May 2013

Calculation date: Monday, 23 April 2018

Sea trials M.V. Bulker

Model test report No.	:	523546
Ship model No.	:	4321
Propeller models No.	:	1234

Shipyard	:	Shipbuilding Inc. Harbour 1
Yard reference	:	4711
Ordered by	:	Bulkers Inc. Haagsteeg 2, Wageningen

CONTENTS

Page

REVIEW OF TABLES AND FIGURES....3

1 INTRODUCTION....4

2 PARTICULARS OF SHIP AND TRIAL....5
- 2.1 Contractual trial loading condition....5
- 2.2 Contract loading condition....5
- 2.3 EEDI loading condition....6
- 2.4 Contractual Environmental conditions....6
- 2.5 EEDI Environmental conditions....6

3 SPEEDTRIALS....7

4 ANALYSIS OF SPEED TRIAL RESULTS....10
- 4.1 Introduction....10
- 4.2 True wind analysis....11
- 4.3 Corrections summary....13
- 4.4 Averaged corrected points....18
- 4.5 Ideal trial results....18

5 CONVERSION FROM TRIAL LOADING CONDITION TO OTHER STIPULATED LOADING CONDITIONS....20

6 CORRECTION FOR CONTRACT WEATHER AND SEA MARGIN....22
- 6.1 Contract/Service condition with sea margin....22

7 RESULTS CONTRACT CONDITION....23

8 CONCLUSIONS FOR CONTRACT....27

9 CONCLUSIONS FOR EEDI....28

10 AUTHENTICITY CHECK....31

CONDITIONS OF USE OF STAIMO SOFTWARE....32

REVIEW OF TABLES AND FIGURES

Tables

Table 1 Main particulars in contract trial condition 5
Table 2 Contract specifications 5
Table 3 EEDI specifications 6
Table 4 Contractual environmental conditions 6
Table 5 EEDI environmental conditions 6
Table 6 Main particulars of the ship at trial 7
Table 7 Environmental conditions during the speed trial 9
Table 8 Measured data 9
Table 9 True wind analysis 11
Table 10 Intermediate derived data 14
Table 11 Tidal curve during speed trials 15
Table 12 Corrected speed trial results 17
Table 13 Averaged corrected points 18
Table 14 Model test results compared with sea trial data under same conditions 18
Table 15 Ideal trial results in Ballast loading condition 19
Table 16 Ideal trial results in Ballast loading condition 20
Table 17 Ideal trial results in Laden/Design loading condition 21
Table 18 Ideal trial results in EEDI loading condition 21
Table 19 Trial results for contract loading- and weather conditions with 15% sea margin 22

Figures

Figure 1 Sign conventions 7
Figure 2 VTW and BTWD for all trial runs 12
Figure 3 STAWIND table 14 13
Figure 4 Tidal curve through all trial runs 16
Figure 5 Speed - power graph 23
Figure 6 Speed - RPM graph 24
Figure 7 RPM - power graph 25
Figure 8 Speed - power graph for EEDI condition 29

1 INTRODUCTION

The sea trials have been performed on board of M.V. Bulker.

The measurements were performed on 29-05-2013 in the Baltic Sea.

The average water depth was 38.0 m with an average wind speed of 8.5 m/s. The average wave height was 1.7 m with a period of 4.7 sec. The weather conditions during the trials were judged to be moderate, with respect to ideal weather conditions.

This report gives an overview of the measurements carried out during the speed trials. The analysis of the measurements and the corrections to arrive at the specified contract service conditions are described and finally, some conclusions are drawn.

Throughout this report SI units are used unless indicated otherwise. The analysis is based on the ITTC Guidelines for Speed/Power Trials 2014 approved by IMO/MEPC for EEDI determination and ISO 15016; 2015. The software of the calculations is classified by ABS in PDA Certificate Number 14-HS1152947-PDA, date of issue 26 February 2014, indicating that the software is in accordance with ITTC and IMO.

This report has been created with STAIMO version 2.5.0.

2 PARTICULARS OF SHIP AND TRIAL

M.V. Bulker with IMO number 1234567 has been built by Shipbuilding Inc.. The main particulars and some specifications of the ship are presented in the tables below.

2.1 Contractual trial loading condition

Loading condition: Ballast

DESIGNATION	SYMBOL	MAGNITUDE	UNIT
Length between perpendiculars	L_{PP}	205.50	m
Breadth on WL	B	32.26	m
Moulded draught on FP	T_F	7.30	m
Moulded draught on AP	T_A	4.80	m
Moulded displacement volume	∇	35477	m^3

Table 1 Main particulars in contract trial condition

2.2 Contract loading condition

Loading condition: Laden/Design

DESIGNATION	SYMBOL	MAGNITUDE	UNIT
Moulded draught on FP	T_F	11.50	m
Moulded draught on AP	T_A	11.50	m
Moulded displacement volume	∇	69822	m^3
Transverse wind exposed area	A	Not relevant	m^2
Contract shaft power	$PS_{contract}$	8550	kW
Contract propeller rotation rate	$N_{contract}$	110.0	RPM
Contract ship speed	$VS_{contract}$	14.20	kts
Shaft power at MCR	PS_{MCR}	9500	kW
Propeller rotation rate at MCR	N_{MCR}	110.0	RPM
Shaft power at NCR	PS_{NCR}	8550	kW
Propeller rotation rate at NCR	N_{NCR}	106.2	RPM

Table 2 Contract specifications

2.3 EEDI loading condition

DESIGNATION	SYMBOL	MAGNITUDE	UNIT
Moulded draught on FP	T_F	12.80	m
Moulded draught on AP	T_A	12.80	m
Moulded displacement volume	∇	78803	m^3
Shaft power at EEDI power	PS_{EEDI}	7125	kW

Table 3 EEDI specifications

2.4 Contractual Environmental conditions

DESIGNATION	SYMBOL	MAGNITUDE	UNIT
Definition		Ideal weather conditions	-
Description		Deep water, no wind, no waves and no current	-
Sea margin		15	%
True wind speed		0.0	m/s
Significant wave height		0.00	m
Significant wave period		0.0	s
Air temperature	T_{AIR}	15.0	deg C
Water temperature	T_{WATER}	15.0	deg C
Air density	ρ_{AIR}	1.225	kg/m^3
Water density	ρ_{WATER}	1025.8	kg/m^3

Table 4 Contractual environmental conditions

2.5 EEDI Environmental conditions

DESIGNATION	SYMBOL	MAGNITUDE	UNIT
Definition		EEDI condition	-
Description		Deep water, no wind, no waves and no current	-
Sea margin		0	%
True wind speed		0.00	m/s
Significant wave height		0.00	m
Significant wave period		0.00	s
Air temperature	T_{AIR}	15.0	deg C
Water temperature	T_{WATER}	15.0	deg C
Air density	ρ_{AIR}	1.225	kg/m^3
Water density	ρ_{WATER}	1025.8	kg/m^3

Table 5 EEDI environmental conditions

3 SPEEDTRIALS

The measurements were performed on 29-05-2013 in the Baltic Sea.

The measurements were conducted in moderate weather conditions. The average water-depth was 38.0 m. The water temperature was 20.0 deg C with a density of 1023.0 kg/m3. The air temperature was 25.0 deg C with an average true wind speed of 8.5 m/s. The average wave height was 1.7 m with a period of 4.7 sec.

During the speed trials the vessel had the following main particulars.

DESIGNATION	SYMBOL	MAGNITUDE	UNIT
Length between perpendiculars	L_{PP}	205.50	m
Breadth on WL	B	32.26	m
Moulded draught on FP	T_F	4.73	m
Moulded draught on AP	T_A	7.28	m
Moulded displacement volume	∇	35040	m^3
Midship section area	AM	190.0	m^2
Wetted appendage area	S_{App}	108	m^2
Wetted bare hull area (including skeg and rudder(s), if any)	S_S	8318	m^2
Projected transverse wind area	A	925	m^2
Height of anemometer above sea level	H_{Anom}	42.5	m
Shaft efficiency	η_S	0.99	-

Table 6 Main particulars of the ship at trial

For all runs an average time/length between start and finish for each trial run of 10 min was used. During each individual run, the environmental conditions were recorded (see Table 7).

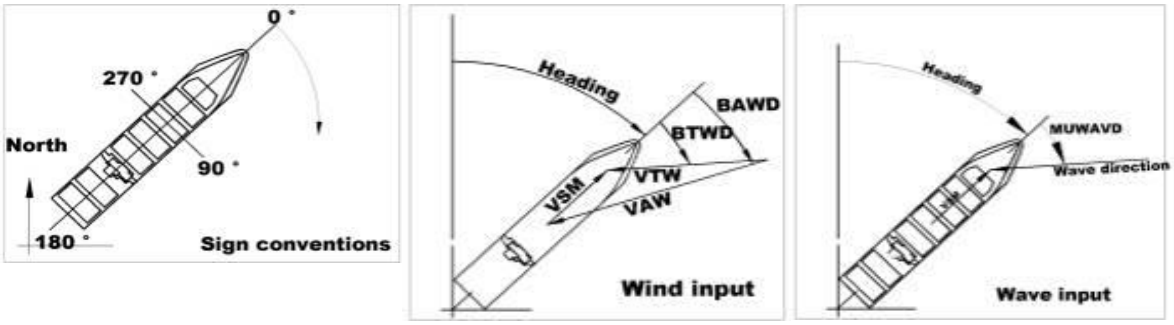

Figure 1 Sign conventions

General:

RUN [-]	RUNTIME [hh:mm]	POWERSETTING [-]	Air Temp. [deg C]	Air Dens. [kg/m^3]	Air Pres. [mbar]	Water Temp. [deg C]	Water Dens. [kg/m^3]
1	06:21	50% with	25.0	1.182	1012.00	20.0	1023.0
2	06:57	50% against	25.0	1.182	1012.00	20.0	1023.0
3	07:54	75% with	25.0	1.182	1012.00	20.0	1023.0
4	09:06	75% against	25.0	1.182	1012.00	20.0	1023.0
5	10:21	75% with	25.0	1.182	1012.00	20.0	1023.0
6	11:06	75% against	25.0	1.182	1012.00	20.0	1023.0
7	12:16	85% with	25.0	1.182	1012.00	20.0	1023.0
8	12:53	85% against	25.0	1.182	1012.00	20.0	1023.0
9	13:35	85% with	25.0	1.182	1012.00	20.0	1023.0
10	14:18	85% against	25.0	1.182	1012.00	20.0	1023.0
11	15:05	100% with	25.0	1.182	1012.00	20.0	1023.0
12	15:49	100% against	25.0	1.182	1012.00	20.0	1023.0

Wind:

RUN [-]	HEAD [deg]	VG [kts]	WD [m]	BAWD [deg]	VAW [m/s]
1	170.0	14.01	38	12.5	16.9
2	350.0	13.64	38	237.9	3.2
3	170.0	15.42	38	15.5	16.5
4	350.0	15.31	38	230.2	4.5
5	170.0	15.35	38	14.7	17.2
6	350.0	15.50	38	212.6	4.6
7	170.0	15.78	38	17.5	18.3
8	350.0	16.46	38	265.0	5.1
9	170.0	15.49	38	9.7	19.0
10	350.0	16.70	38	258.2	4.4
11	170.0	15.89	38	13.6	18.8
12	350.0	17.18	38	247.1	3.9

Waves:

RUN [-]	HEAD [deg]	VG [kts]	HW13 [m]	TWV [s]	MUWAVD [deg]	HS13 [m]	TSV [s]	MUSWELD [deg]	Waves within limits?
1	170.0	14.01	1.5	4.0	0	0.0	0.0	0	Below limit
2	350.0	13.64	1.5	4.0	180	0.0	0.0	0	Below limit
3	170.0	15.42	1.5	4.0	0	0.0	0.0	0	Below limit
4	350.0	15.31	1.5	4.0	180	0.0	0.0	0	Below limit
5	170.0	15.35	1.7	5.0	0	0.0	0.0	0	Below limit
6	350.0	15.50	1.7	5.0	180	0.0	0.0	0	Below limit
7	170.0	15.78	1.8	5.0	0	0.0	0.0	0	Below limit
8	350.0	16.46	1.8	5.0	180	0.0	0.0	0	Below limit
9	170.0	15.49	1.8	5.0	0	0.0	0.0	0	Below limit
10	350.0	16.70	1.8	5.0	180	0.0	0.0	0	Below limit
11	170.0	15.89	1.8	5.0	0	0.0	0.0	0	Below limit
12	350.0	17.18	1.8	5.0	180	0.0	0.0	0	Below limit

RUN	Trial run number
RUNTIME	Start time of trial run
POWERSETTING	Comments for a run
RUNDATE	Trial run date
Air Temp.	Air temperature
Air Dens.	Air density
Air Pres.	Air pressure
Water Temp.	Water temperature
Water Dens.	Water density
HEAD	Heading
VG	Ship speed over ground
WD	Water depth
BAWD	Measured relative wind direction at anemometer height
VAW	Measured relative wind speed at anemometer height
HW13	Significant wave height (wind waves)
TWV	Wave period (wind waves)
MUWAVD	Relative wave direction (wind waves)

HS13	Significant swell height (swell waves)
TSV	Swell period (swell waves)
MUSWELD	Relative swell direction (Swell waves)

Table 7 Environmental conditions during the speed trial

An overview of the measured speed, shaft power and propeller RPM during the speed trial runs can be found in Table 8.

The speed trials were conducted in moderate weather conditions.

```
Anemometer height      [m]: 42.5
Moulded draught on FP  [m]: 4.73
Moulded draught on AP  [m]: 7.28
Moulded displacement [m^3]: 35040
Shaft outer diameter  [mm]: 700
Shaft inner diameter  [mm]: 0
Shear modulus     [N/mm^2]: 82649
```

RUN [-]	RUNSET [-]	POWERSETTING [-]	VG [kts]	PS [kW]	RPM [rpm]
1	1	50% with	14.01	5010	85.8
2	1	50% against	13.64	4958	85.8
3	2	75% with	15.42	7704	97.6
4	2	75% against	15.31	7571	97.6
5	2	75% with	15.35	7723	97.6
6	2	75% against	15.50	7354	97.6
7	3	85% with	15.78	9224	103.0
8	3	85% against	16.46	9049	103.0
9	3	85% with	15.49	9175	103.0
10	3	85% against	16.70	9083	103.0
11	4	100% with	15.89	10352	107.2
12	4	100% against	17.18	10119	107.2

RUN	Trial run number
RUNSET	ID number for runs in same set
POWERSETTING	Comments for a run
VG	Ship speed over ground
PS	Shaft power
RPM	Propeller rotation rate

Table 8 Measured data

4 ANALYSIS OF SPEED TRIAL RESULTS

4.1 Introduction

The analysis is performed in six steps:

1. Correction from the measured speed/power data towards ideal trial weather conditions (paragraph True wind analysis, 4.3).
2. Correction from the trial loading condition towards the contractual trial loading condition (displacement correction up to 2%) (paragraph Corrections summary).
3. Conversion from the contractual trial loading condition towards the contract loading condition (if applicable).
4. Correction from the ideal contract condition to the contract weather condition (if applicable).
5. Correction for the specified sea margin towards the service condition (if applicable).
6. Conversion from the contractual trial loading condition towards the EEDI loading condition.

In order to determine the performance under ideal weather conditions, corrections have been applied to each individual run. To correct the individual results for their relative wind, first for each set of runs the correct true wind speed and direction is determined. After the individual corrections are made, the weighted true wind average for each set of runs is taken according to Pascal's Triangle. Based on this weighted true wind average, the run's relative wind vector is calculated.

The effect of current is eliminated by correcting the measured speeds with the 'iterative method'.

The averaged correction points are then compared with the tank test results to derive the offset. Measurements with a too low engine power setting are not taken into account for the calculation of the offset.

By adding the offset to the tank test in the contractual trial loading condition, the speed-power performance in the ideal contractual trial condition is found.

For the conversion to other stipulated conditions (contract loading condition or EEDI condition) the following steps are followed, according to ISO15016; 2015 Annex I:

- determine the achieved speed at 75% MCR in the ideal contractual trial condition according to the tank test
- determine the required power to achieve this speed in the ideal contractual trial condition based on the trials
- calculate the power ratio (facPS), by dividing the required power by 75% MCR
- multiply the tank test (contract condition and/or EEDI condition) with facPS to arrive at the ideal conditions in contract loading condition and/or EEDI condition.

To determine the achieved speed and RPM values at contract service conditions, the service power and RPM curves are intersected with the contract power of 8550 kW, MCR power of 9500 kW and NCR power of 8550 kW on the basis of a least square approximations.

To determine the achieved speed and RPM values at EEDI conditions, the power and RPM curves are intersected with the EEDI power of 7125 kW, on the basis of least square approximations.

Detailed descriptions concerning the theory behind all corrections are given in "ITTC Guidelines 2014" and in "ISO 15016; 2015".

4.2 True wind analysis

To determine the true wind speed and direction, for each set of trial runs the speed vector is averaged.

Height of anemometer: 42.5 [m]
Height of reference anemometer: 10.0 [m]
Height correction factor: 0.81 [-]

Averaged wind speed and direction values:

WINDSET [-]	VTWX_avrg [m/s]	VTWY_avrg [m/s]	VTW_avrg [m/s]	VTWC_avrg [m/s]	BTWD_avrg [deg]	Wind within limits?
1	1.57	9.43	9.56	7.77	189.4	Within limit Bft 6
2	2.24	9.90	10.15	8.26	192.8	Within limit Bft 6
3	1.58	10.71	10.83	8.81	188.4	Within limit Bft 6
4	3.62	9.91	10.55	8.58	200.1	Within limit Bft 6
5	1.95	10.62	10.80	8.78	190.4	Within limit Bft 6
6	2.17	10.76	10.98	8.93	191.4	Within limit Bft 6

Final corrected wind speed and direction values:

RUN [-]	RUNSET [-]	WINDSET [-]	VG [kts]	VAW [m/s]	BAWD [deg]	VTW [m/s]	BTWD [deg]	VTWC [m/s]	BTWCD [deg]	VAWC [m/s]	BAWCD [deg]
1	1	1	14.01	16.93	12.5	10.01	191.5	7.77	189.4	14.77	10.1
2	1	1	13.64	3.19	237.9	9.12	187.2	7.77	189.4	2.61	263.1
3	2	2	15.42	16.51	15.5	9.12	198.9	8.26	192.8	15.87	11.6
4	2	2	15.31	4.48	230.2	11.28	187.8	8.26	192.8	3.20	274.7
5	2	3	15.35	17.18	14.7	9.75	196.6	8.81	188.4	16.49	9.7
6	2	3	15.50	4.58	212.6	12.09	181.8	8.81	188.4	2.80	262.1
7	3	4	15.78	18.31	17.5	10.85	200.5	8.58	200.1	16.13	15.5
8	3	4	16.46	5.09	265.0	10.25	199.7	8.58	200.1	4.43	283.6
9	3	5	15.49	18.98	9.7	11.21	186.6	8.78	190.4	16.49	10.7
10	3	5	16.70	4.42	258.2	10.44	194.5	8.78	190.4	3.08	276.7
11	4	6	15.89	18.78	13.6	11.00	193.7	8.93	191.4	16.80	11.2
12	4	6	17.18	3.91	247.1	10.97	189.2	8.93	191.4	3.30	279.2

RUN	Trial run number
RUNSET	Double run ID for runs in same set
WINDSET	ID number for identical wind conditions
VTWX_avrg	Calculated average true wind speed at anemometer height in X direction
VTWY_avrg	Calculated average true wind speed at anemometer height in Y direction
VTW_avrg	Calculated average true wind speed at anemometer height
VTWC_avrg	Calculated average true wind speed at 10 m height
BTWD_avrg	Calculated average true wind direction at anemometer height
VG	Ship speed over ground
VAW	Measured relative wind speed at anemometer height
BAWD	Measured relative wind direction at anemometer height
VTW	Calculated true wind speed at anemometer height
BTWD	Calculated true wind direction at anemometer height
VTWC	Corrected average true wind speed at reference height
BTWCD	Corrected average true wind direction at reference height
VAWC	Corrected relative wind speed at reference height
BAWCD	Corrected relative wind direction at reference height

Table 9 True wind analysis

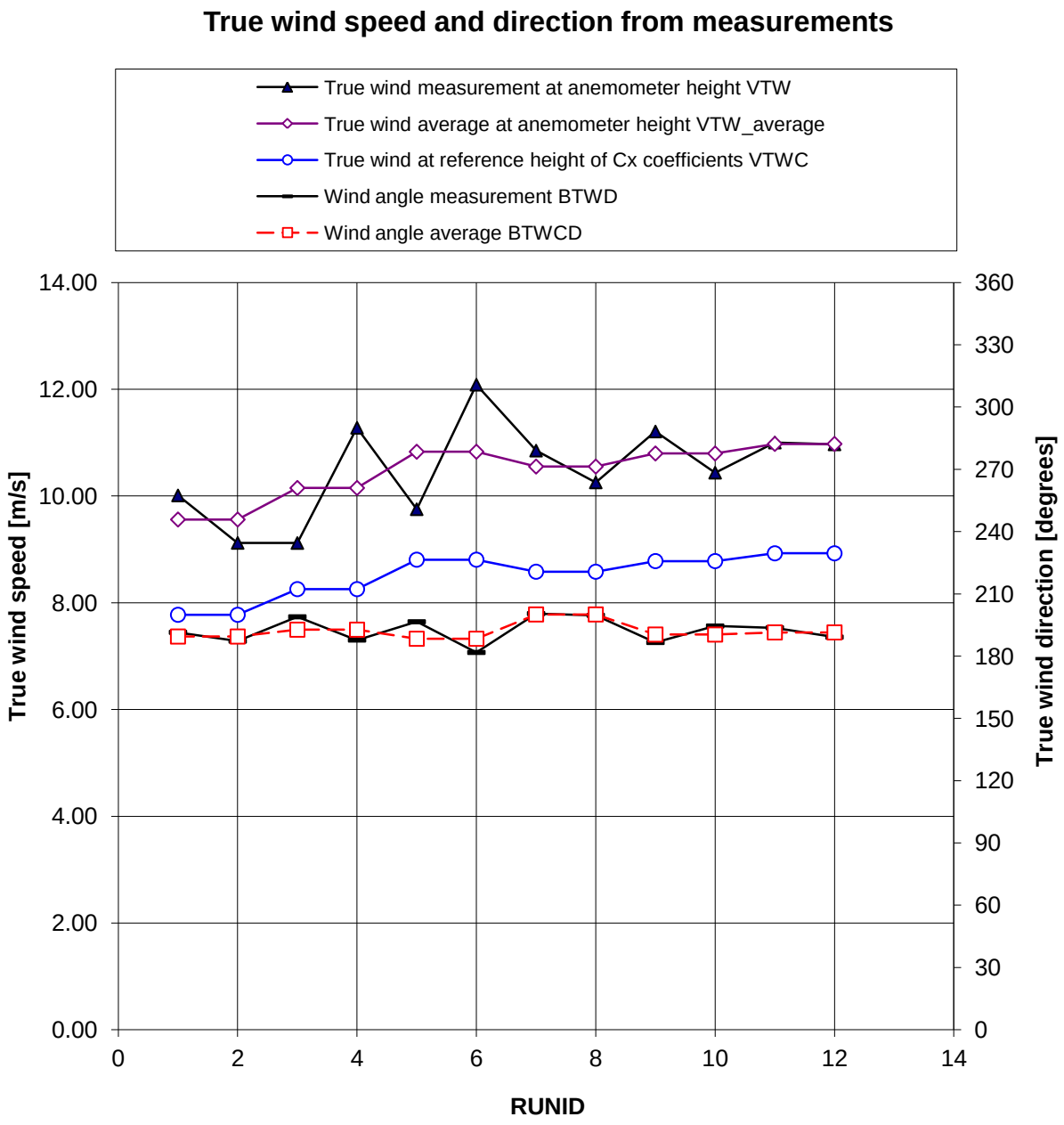

Figure 2 VTW and BTWD for all trial runs

4.3 Corrections summary

In order to compare the speed trial results with the contract specifications, corrections must be applied for the weather conditions during the trials.

The measurements are corrected using the following methods:

Power corrections:

Temperature method:	ITTC/ISO conventions
Density method:	ITTC conventions
Displacement method:	Admiralty coefficient (ITTC/ISO). The difference between the contract trial displacement and actual trial displacement is within the limit of 2% displacement. The displacement used for the calculations is 35040 m^3.
Wind method:	STAWIND method (pre-selected cx values)
Ship type for Cx table selection:	Bulk carrier
Superstructure:	Normal
Loading condition:	Ballast
Reference height Anemometer:	10.0 m
	Wind table: STAWIND table 14.

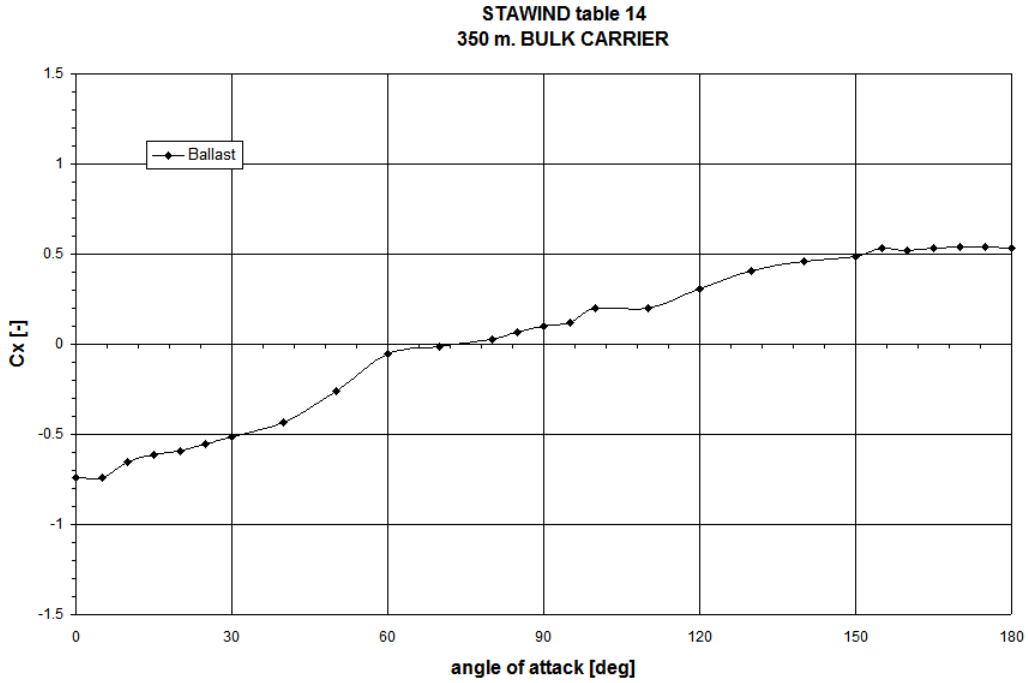

Figure 3 STAWIND table 14

Wave method :	STAWAVE1 method (no ship motion due to waves)
Swell method:	STAWAVE1 method (no ship motion due to waves)
Used bow length:	23.00 m
Spectrum:	No spectrum used
Propeller load:	Overload factors as derived from model tests
	8.00% ETAD decrease per 100% load increase

Speed corrections:
Water depth method: Lackenby

RPM corrections:
RPM method: Overload as derived from model tests (based on RPM/power and RPM/speed)
20.00% RPM increase per 100% power increase
33.00% RPM increase per 100% speed increase

The corrections are performed according the procedure described in “ITTC Guidelines 2014 and ISO 15016; 2015”. All parameters for corrections are treated separately. Power settings below 65 % MCR will be discarded which is in accordance with “ITTC Guidelines 2014/ISO 15016; 2015”.

The following intermediate (calculated) values were used:

Gravitational acceleration:	9.8067	[m/s^2]
Kinematic viscosity for water on trial:	1.051E-06	[m^2/s]
Air density on trial:	1.182	[kg/m^3]
Transverse wind exposed area	925	[m^2]

RUN [-]	RUNSETID [-]	ReWATER [-]	Cfa [-]	CX [-]	VAWC [m/s]	RWIND [kN]	VAWREF [m/s]	CXI [-]	RWINDI [kN]	RAA [kN]
1	1	1.343E+09	1.470E-03	-0.649	14.77	-77.3	7.21	-0.740	-21.0	-56.3
2	1	1.437E+09	1.470E-03	0.149	2.61	0.6	7.02	-0.740	-19.9	20.5
3	2	1.493E+09	1.451E-03	-0.630	15.87	-86.7	7.93	-0.740	-25.5	-61.3
4	2	1.590E+09	1.451E-03	0.072	3.20	0.4	7.88	-0.740	-25.1	25.5
5	2	1.507E+09	1.451E-03	-0.655	16.49	-97.4	7.90	-0.740	-25.2	-72.2
6	2	1.588E+09	1.451E-03	0.167	2.80	0.7	7.97	-0.740	-25.7	26.4
7	3	1.575E+09	1.443E-03	-0.608	16.13	-86.5	8.12	-0.740	-26.7	-59.9
8	3	1.661E+09	1.443E-03	0.008	4.43	0.1	8.47	-0.740	-29.0	29.1
9	3	1.562E+09	1.443E-03	-0.640	16.49	-95.1	7.97	-0.740	-25.7	-69.4
10	3	1.668E+09	1.443E-03	0.056	3.08	0.3	8.59	-0.740	-29.9	30.2
11	4	1.619E+09	1.438E-03	-0.634	16.80	-97.9	8.17	-0.740	-27.0	-70.9
12	4	1.702E+09	1.438E-03	0.036	3.30	0.2	8.84	-0.740	-31.6	31.8

RUN [-]	RUNSET [-]	ETAD [-]
1	1	0.721
2	1	0.721
3	2	0.714
4	2	0.714
5	2	0.714
6	2	0.714
7	3	0.709
8	3	0.709
9	3	0.709
10	3	0.709
11	4	0.705
12	4	0.705

RUN	Trial run number
RUNSET	Double run ID for runs in same set
ReWATER	Reynolds number for trial run
Cfa	Frictional coefficient for trial run
CX	Wind resistance coefficient for trial run
VAWC	Averaged and corrected apparent wind speed
RWIND	Wind resistance for trial run
VAWREF	Apparent wind speed for ideal trial run
CXI	Wind resistance coefficient for ideal trial run
RWINDI	Wind resistance for ideal trial run
RAA	Wind resistance for trial run minus wind resistance for ideal trial run
ETAD	Propulsive efficiency for trial run

Table 10 Intermediate derived data

In the iterative method a theoretical current curve is computed on the basis of a speed/power curve after correction for environmental effects using current curve found by minimizing the function $\sum\left(P\left(V_S'\right)_i - P_{Ci}\right)^2$ (see ISO 15016; 2015, Annex F, Effect of current). Below the subsequent iteration values of this function are presented:

```
Convergence report of the Iterative Method:

Initial solution: 10060891
Iteration step 1: 221834, convergence factor: 0.97795088, error reduced
Iteration step 2: 214742, convergence factor: 0.03196875, error reduced
Iteration step 3: 210265, convergence factor: 0.02084938, error reduced
Iteration step 4: 207773, convergence factor: 0.01185240, error reduced
Iteration step 5: 206422, convergence factor: 0.00649950, error reduced

Convergence to an accuracy of 0.01 was achieved in 5 steps.
Minimum error = 206422 was achieved in iteration step 5.
```

The tidal curve resulting from the analysis is presented in the following table and graph:

RUN [-]	RUNTIME [hh:mm]	RUNTYPE [-]	VGM [kts]	VCX [kts]	VCXR [kts]
1	06:26	Forward run	14.01	0.72	0.66
2	07:02	Return run	13.64	0.67	0.63
3	07:59	Forward run	15.42	0.41	0.58
4	09:11	Return run	15.31	0.51	0.49
5	10:26	Forward run	15.35	0.51	0.37
6	11:11	Return run	15.50	0.23	0.28
7	12:21	Forward run	15.78	0.14	0.13
8	12:58	Return run	16.46	0.05	0.05
9	13:40	Forward run	15.49	-0.07	-0.04
10	14:23	Return run	16.70	-0.17	-0.12
11	15:10	Forward run	15.89	-0.20	-0.20
12	15:54	Return run	17.18	-0.23	-0.27

RUN	Trial run number
RUNTIME	Time at middle of run
RUNTYPE	Run direction Forward or Return
VGM	Ship speed over ground
VCX	Current velocity as difference between run speed and iterative current curve
VCXR	Current velocity in ship direction from iterative current curve

Table 11 Tidal curve during speed trials

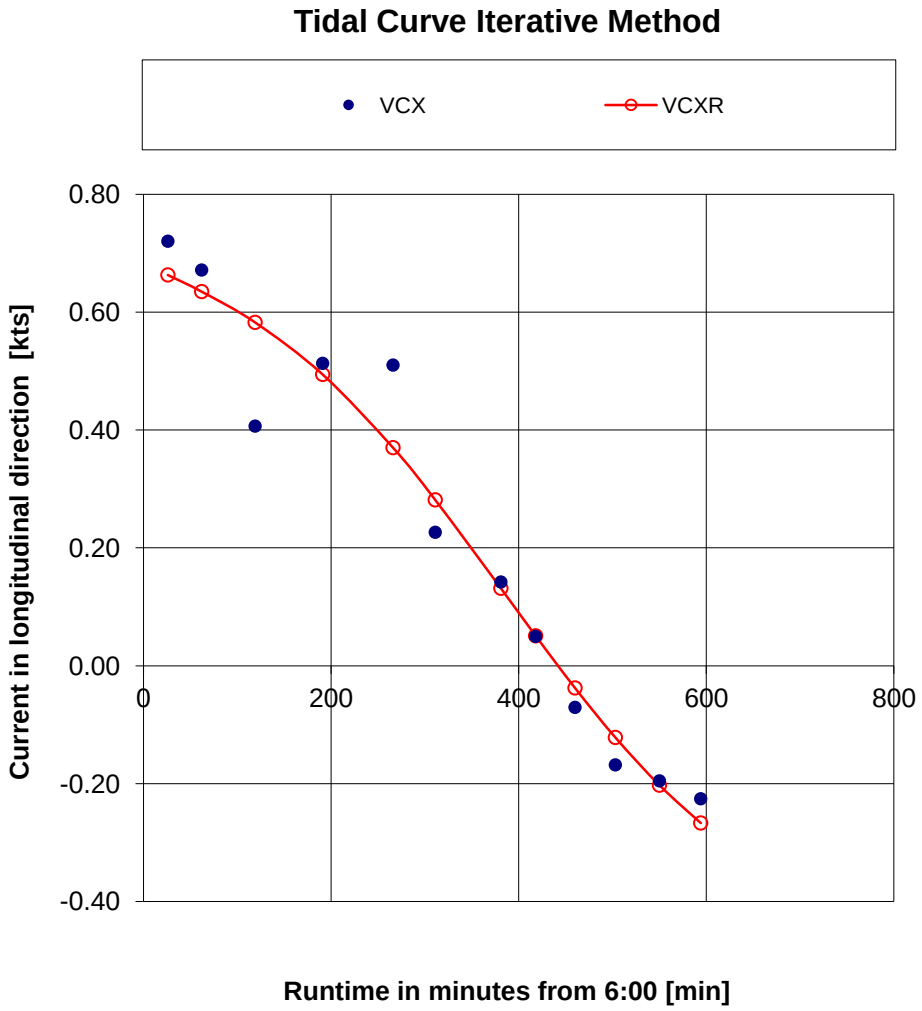

Figure 4 Tidal curve through all trial runs

This has resulted in the following individual corrections and averaged values for “M.V. Bulker”:

	measurements				corrections								corrected			
RUN	VGM	PSM	PDM	NM	DVS	DVC	TEMP	DENS	DISP	WIND	WAVES	LOAD	dN	VSC	PDC	PSC	NC
[-]	[kts]	[kW]	[kW]	[RPM]	[kts]	[kts]	[kW]	[kW]	[kW]	[kW]	[kW]	[kW]	[RPM]	[kts]	[kW]	[kW]	[RPM]
Run set:		1															
1	14.01	5,010	4,960	85.8	0.14	-0.67	43	14	41	-563	-532	-102	-4.3	13.49	3,864	3,903	81.5
2	13.64	4,958	4,908	85.8	0.14	0.64	53	14	41	199	0	23	1.4	14.41	5,235	5,288	87.2
									Set averages ideal trial:					13.95	4,549	4,595	84.3
Note: Power setting too low, this averaged set is disregarded for the speed power curve.																	
Run set:		2															
3	15.42	7,704	7,627	97.6	0.16	-0.58	59	21	63	-681	-598	-108	-3.3	14.99	6,387	6,452	94.3
4	15.31	7,571	7,495	97.6	0.16	0.49	71	21	62	281	0	32	1.5	15.96	7,960	8,041	99.1
5	15.35	7,723	7,646	97.6	0.16	-0.37	60	21	64	-798	-768	-142	-4.5	15.14	6,085	6,146	93.1
6	15.50	7,354	7,280	97.6	0.16	0.28	71	20	61	295	0	33	1.5	15.94	7,758	7,836	99.1
									Set averages ideal trial:					15.53	7,035	7,106	96.3
Note: No remarks on power settings.																	
Run set:		3															
7	15.78	9,224	9,132	103.0	0.16	-0.13	69	25	76	-685	-907	-137	-3.7	15.81	7,576	7,652	99.3
8	16.46	9,049	8,959	103.0	0.17	0.05	81	25	74	348	0	39	1.6	16.68	9,523	9,619	104.6
9	15.49	9,175	9,083	103.0	0.16	0.04	67	25	76	-780	-907	-148	-4.1	15.69	7,420	7,495	98.9
10	16.70	9,083	8,992	103.0	0.17	-0.12	82	25	75	365	0	41	1.6	16.75	9,576	9,673	104.6
									Set averages ideal trial:					16.21	8,497	8,583	101.8
Note: No remarks on power settings.																	
Run set:		4															
11	15.89	10,352	10,248	107.2	0.16	0.20	75	28	85	-822	-937	-150	-3.8	16.26	8,531	8,617	103.4
12	17.18	10,119	10,018	107.2	0.18	-0.27	87	28	83	399	0	44	1.7	17.09	10,657	10,764	108.9
									Set averages ideal trial:					16.67	9,594	9,690	106.1
Note: No remarks on power settings.																	

General remarks:
- None

RUN	Trial run number
VGM	Measured ship speed (over ground)
PSM	Total measured shaft power
PDM	Total measured delivered power (PSM*ETAS)
NM	Measured propeller rotation rate
DVS	Shallow water speed correction
DVC	Current correction derived by means of iterative method
TEMP	Delivered power correction for difference in temperature
DENS	Delivered power correction for difference in density
DISP	Delivered power correction for difference in displacement
WIND	Delivered power correction for resistance caused by wind
WAVES	Delivered power correction for resistance due to waves (wind and swell waves)
LOAD	Delivered power correction for efficiency effects of changed propeller loading
dN	RPM correction
VSC	Corrected ship speed
PDC	Corrected delivered power
PSC	Corrected shaft power (PDC/ETAS)
NC	Corrected propeller rotation rate

Table 12 Corrected speed trial results

4.4 Averaged corrected points

Taking into account the corrections as described in paragraph 4.3, the following averaged corrected points are determined:

Vs [kts]	Ps [kW]	Ns [RPM]	ETAD [-]	VOL [m^3]
15.53	7,106	96.3	0.714	35,477
16.21	8,583	101.8	0.710	35,477
16.67	9,690	106.1	0.705	35,477

Vs Ship speed (Ideal trial)
Ps Shaft power (Ideal trial)
Ns Propeller rotation rate (Ideal trial)
ETAD Propulsive efficiency
VOL Moulded displacement volume (Contract trial condition)

Table 13 Averaged corrected points

The ideal trial weather condition is defined as: no wind, no waves, deep water, water temperature of 15 deg C., air temperature of 15 deg C., water density of 1025 kg/m^3, air density of 1.225 kg/m^3.

4.5 Ideal trial results

The ideal trial points are compared with the model test results in identical weather conditions to find the offset to the tank test for each averaged corrected point. The weighted average of these offsets will be added to the model test results to calculate the ideal trial curve in the contractual trial loading condition:

Vs [kts]	Pm [kW]	Nm [RPM]	Pt [kW]	Nt [-]	RUNSUM [-]	dPs [kW]	dNs [-]
15.53	7,699	98.5	7,106	96.3	4	-593	-2.2
16.21	9,213	104.3	8,583	101.8	4	-630	-2.5
16.67	10,478	108.8	9,690	106.1	2	-787	-2.7
					Weighted average:	-647	-2.4

This means that based on the speed trials at 75% MCR, the vessel performs 8.32% better than expected according to the model test results.
Vs Ship speed through water
Pm Shaft power from model test results in contractual trial loading condition (ideal weather condition)
Nm Propeller rotation rate from model test results in contractual trial loading condition (ideal weather condition)
Pt Shaft power from speed trial in contractual trial loading condition (ideal weather condition)
Nt Propeller rotation rate from speed trial in contractual trial loading condition (ideal weather condition)
RUNSUM Number of runs per averaged speed point
dPs Shaft power offset on model test results
dNs Propeller rotation rate offset on model test results

Table 14 Model test results compared with sea trial data under same conditions

Performance in ideal contractual trial loading condition based on speed/power tests:

Vs [kts]	Pm [kW]	Nm [RPM]	dPS [kW]	dNs [-]	Ps [kW]	Ns [RPM]	ETAD [-]
11.00	2,313	66.3	-647	-2.4	1,666	63.9	0.726
12.00	3,035	72.6	-647	-2.4	2,388	70.2	0.727
13.00	4,018	79.6	-647	-2.4	3,371	77.2	0.725
14.00	5,225	86.8	-647	-2.4	4,578	84.4	0.720
15.00	6,728	94.3	-647	-2.4	6,081	91.9	0.716
16.00	8,716	102.5	-647	-2.4	8,069	100.1	0.710
16.50	9,987	107.1	-647	-2.4	9,340	104.7	0.705
17.00	11,503	112.3	-647	-2.4	10,856	109.9	0.700

Vs	Ship speed through water
Pm	Shaft power from model test results in contractual trial loading condition (ideal weather condition)
Nm	Propeller rotation rate from model test results in contractual trial loading condition (ideal weather condition)
dPs	Shaft power offset on model test results
dNs	Propeller rotation rate offset on model test results
Ps	Ship shaft power in contractual trial loading condition (ideal weather condition)
Ns	Ship propeller rotation rate in contractual trial loading condition (ideal weather condition)
ETAD	Propulsive efficiency

Table 15 Ideal trial results in Ballast loading condition

5 CONVERSION FROM TRIAL LOADING CONDITION TO OTHER STIPULATED LOADING CONDITIONS

For further analysis towards other loading conditions, model test data is used to derive the ideal trial results in the Laden/Design condition.

Vs [kts]	Pm [kW]	Nm [RPM]	dPS [kW]	dNs [-]	Ps [kW]	Ns [RPM]	ETAD [-]
11.00	2,313	66.3	-647	-2.4	1,666	63.9	0.726
12.00	3,035	72.6	-647	-2.4	2,388	70.2	0.727
13.00	4,018	79.6	-647	-2.4	3,371	77.2	0.725
14.00	5,225	86.8	-647	-2.4	4,578	84.4	0.720
15.00	6,728	94.3	-647	-2.4	6,081	91.9	0.716
16.00	8,716	102.5	-647	-2.4	8,069	100.1	0.710
16.50	9,987	107.1	-647	-2.4	9,340	104.7	0.705
17.00	11,503	112.3	-647	-2.4	10,856	109.9	0.700

Vs	Ship speed through water
Pm	Shaft power from model test results in contractual trial loading condition (ideal weather condition)
Nm	Propeller rotation rate from model test results in contractual trial loading condition (ideal weather condition)
dPs	Shaft power offset on model test results
dNs	Propeller rotation rate offset on model test results
Ps	Ship shaft power in contractual trial loading condition (ideal weather condition)
Ns	Ship propeller rotation rate in contractual trial loading condition (ideal weather condition)
ETAD	Propulsive efficiency

Table 16 Ideal trial results in Ballast loading condition

At 75% MCR, corresponding with 7125 kW the achieved speed based on the corrected trial results is 15.56 kts at 96.4 RPM in the contractual trial condition. At this speed, a power of 7772 kW at 98.8 RPM is required according to the model test results.

Therefore:

facPs = PStrials / PSmodel = 7125 kW / 7772 kW = 0.917.
facNs = Ntrials / Nmodel = 96.4 RPM / 98.8 RPM = 0.975.

These factors are multiplied with the tank test results in any other loading condition than the contractual trial loading condition.

Performance in ideal contract loading condition based on speed/power tests:

Vs [kts]	Pm [kW]	Nm [RPM]	facPs [kW]	facN [-]	Ps [kW]	Ns [RPM]	ETAD [-]
11.00	3,084	73.4	0.917	0.975	2,827	71.6	0.700
12.00	4,068	80.4	0.917	0.975	3,730	78.4	0.694
13.00	5,169	87.3	0.917	0.975	4,739	85.1	0.700
14.00	6,527	94.5	0.917	0.975	5,984	92.1	0.700
14.50	7,404	98.4	0.917	0.975	6,788	95.9	0.696
15.00	8,451	102.6	0.917	0.975	7,748	100.0	0.691
16.00	10,992	111.5	0.917	0.975	10,077	108.7	0.690

Vs Ship speed through water
Pm Shaft power from model test results in contract loading condition (ideal weather condition)
Nm Propeller rotation rate from model test results in contract loading condition (ideal weather condition)
facPS Shaft power correction factor on model test results
facNs Propeller rotation rate correction factor on model test results
Ps Ship shaft power in contract loading condition (ideal weather condition)
Ns Ship propeller rotation rate in contract loading condition (ideal weather condition)
ETAD Propulsive efficiency

Table 17 Ideal trial results in Laden/Design loading condition

Performance in EEDI loading condition (ideal weather condition) based on speed/power tests:

Vs [kts]	Pm [kW]	Nm [RPM]	facPs [kW]	facN [-]	Ps [kW]	Ns [RPM]	ETAD [-]
11.00	3,259	74.9	0.917	0.975	2,989	73.0	0.683
12.00	4,299	82.0	0.917	0.975	3,942	80.0	0.677
13.00	5,462	89.1	0.917	0.975	5,009	86.9	0.683
14.00	6,898	96.4	0.917	0.975	6,325	94.0	0.683
14.50	7,824	100.4	0.917	0.975	7,175	97.9	0.679
15.00	8,931	104.7	0.917	0.975	8,190	102.1	0.674
16.00	11,616	113.7	0.917	0.975	10,652	110.9	0.673

Vs Ship speed through water
Pm Shaft power from model test results in EEDI loading condition (ideal weather condition)
Nm Propeller rotation rate from model test results in EEDI loading condition (ideal weather condition)
facPs Shaft power correction factor on model test results
facNs Propeller rotation rate correction factor on model test results
Ps Ship shaft power in EEDI loading condition (ideal weather condition)
Ns Ship propeller rotation rate in EEDI loading condition (ideal weather condition)
ETAD Propulsive efficiency

Table 18 Ideal trial results in EEDI loading condition

6 CORRECTION FOR CONTRACT WEATHER AND SEA MARGIN

6.1 Contract/Service condition with sea margin

Resulting service data with 15% sea margin:

Vs [kts]	Ps [kW]	Ns [RPM]	DP [kW]	DN [RPM]	P [kW]	N [RPM]
11.00	2,827	71.6	424.1	2.1	3,252	73.7
12.00	3,730	78.4	559.4	2.4	4,289	80.7
13.00	4,739	85.1	710.8	2.6	5,450	87.7
14.00	5,984	92.1	897.6	2.8	6,882	94.9
14.50	6,788	95.9	1,018.2	2.9	7,806	98.8
15.00	7,748	100.0	1,162.2	3.0	8,910	103.0
16.00	10,077	108.7	1,511.6	3.3	11,589	112.0

Vs	Ship speed through water
Ps	Ship shaft power in contract loading condition (contract weather condition)
Ns	Ship propeller rotation rate in contract loading condition (contract weather condition)
DP	Shaft power correction for sea margin
DN	Correction for ship propeller rotation rate as result of sea margin
P	Ship shaft power in contract loading condition (service condition)
N	Ship propeller rotation rate in contract loading condition (service condition)

Table 19 Trial results for contract loading- and weather conditions with 15% sea margin

7 RESULTS CONTRACT CONDITION

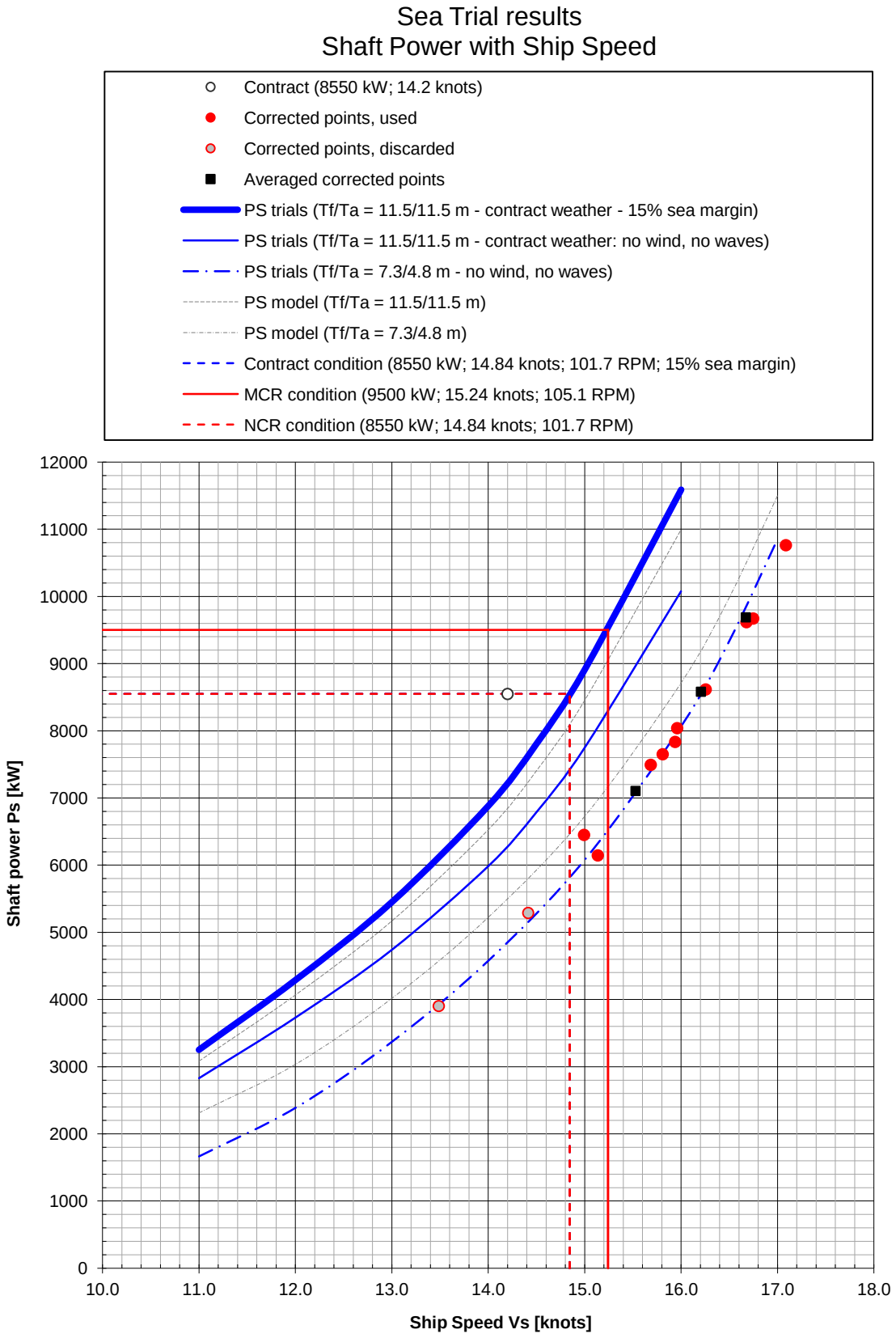

Figure 5 Speed - power graph

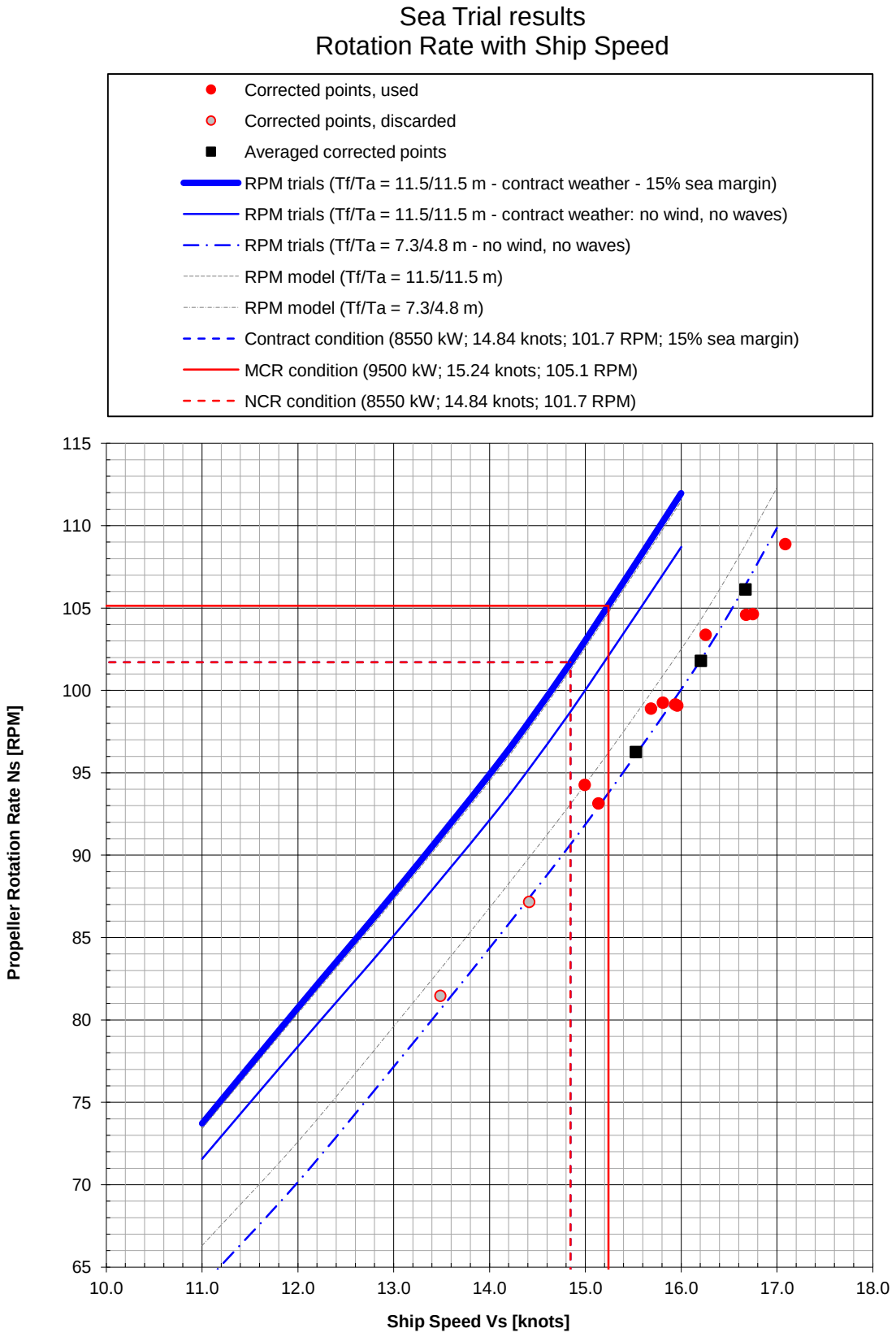

Figure 6 Speed - RPM graph

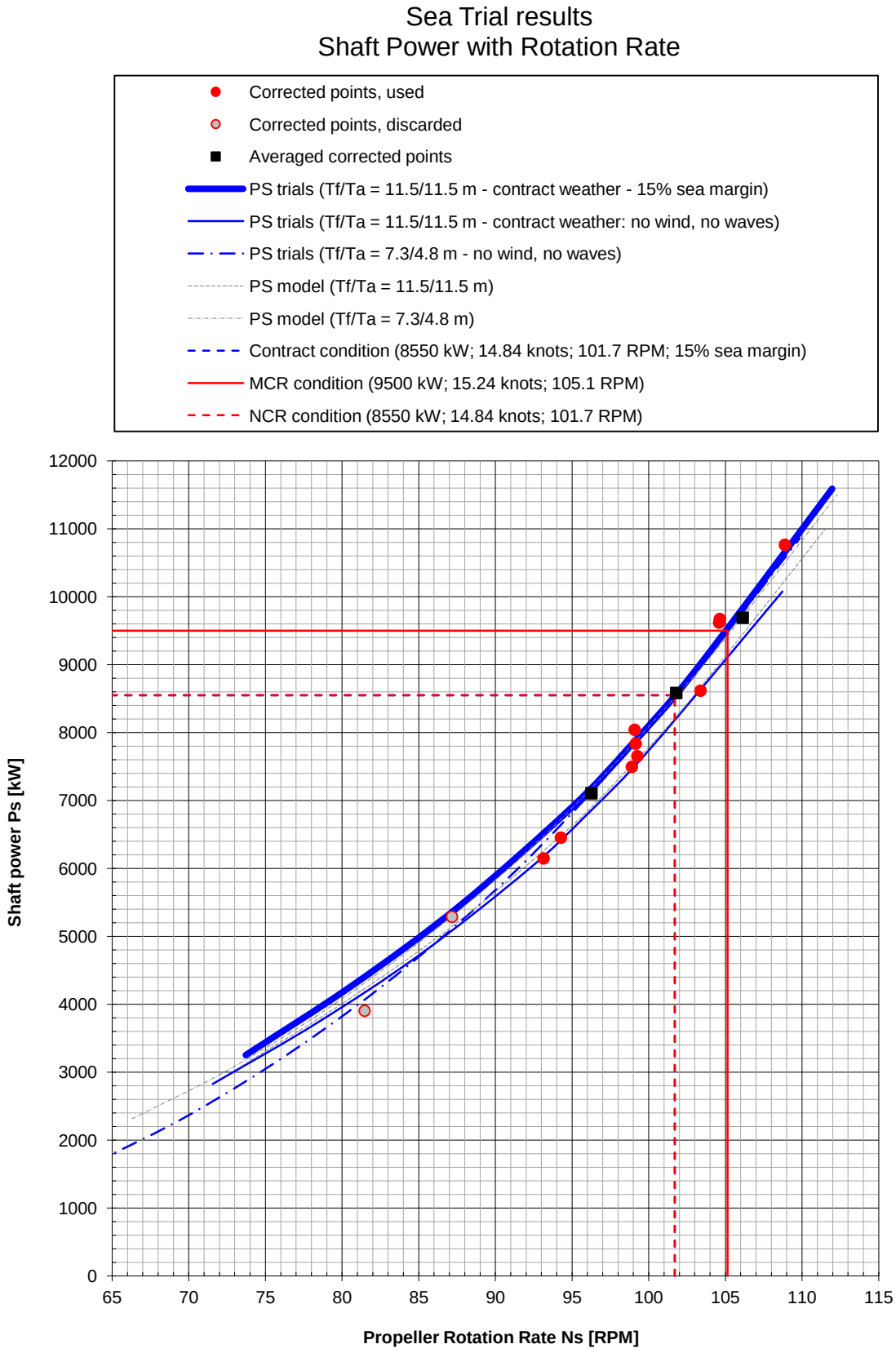

Figure 7 RPM - power graph

The contract service curve is intersected with the contract power of 8550 [kW]. A double quadratic interpolation procedure through the points is used to determine a service speed of 14.84 kts at 101.7 RPM with 15% sea margin at a Laden/Design contract loading condition, a true wind speed of 0.0 m/s, a significant wave height of 0.00 m and a significant wave period of 0.0 s.

At a MCR power of 9500 kW a speed is found of 15.24 kts at 105.1 RPM.

At a NCR power of 8550 kW a speed is found of 14.84 kts at 101.7 RPM.

The rotation rate at NCR without sea margin is 103.2 and the contract rotation rate at NCR was 106.2 RPM.

Therefore the light running margin is -2.81% (the propeller is heavy running).

8 CONCLUSIONS FOR CONTRACT

Based on the speed trial the following conclusions can be drawn:

- The speed trials were performed in moderate weather.
- A service curve is determined on the basis of the speed trials:
  - Corrected for deviations from ideal trial weather conditions;
  - Convert to the correct Laden/Design contract loading condition;
  - Taking into account the environmental conditions of a true wind speed of 0.0 m/s, a significant wave height of 0.00 m and a significant wave period of 0.0 s.
  - Using a sea margin of 15%

  The theoretical background for all corrections is described in “ITTC Guidelines 2014” and ISO 15016; 2015.
- The achieved speed at the agreed contractual service condition using the service curve is 14.84 kts at 8550 kW and 101.7 RPM.
- To achieve the contract speed of 14.20 kts, a total shaft power of 7233 kW is required.
- Speed at MCR using the service curve is 15.24 kts at 9500 kW and 105.1 RPM.
- Speed at NCR using the service curve is 14.84 kts at 8550 kW and 101.7 RPM.

The light running margin is -2.81% (the propeller is heavy running).

9 CONCLUSIONS FOR EEDI

Based on the speed trial the following conclusions can be drawn:

- The speed trials were performed in moderate weather.
- An EEDI curve is determined on the basis of the speed trials:
  - Corrected for deviations from ideal trial weather conditions;
  - Convert to the EEDI loading condition;
  - Taking into account the environmental conditions of a true wind speed of 0.0 m/s, a significant wave height of 0.0 m and a significant wave period of 0.0 s.
  - Using a sea margin of 0%

  The theoretical background for all corrections is described in “ITTC Guidelines 2014” and ISO 15016; 2015.

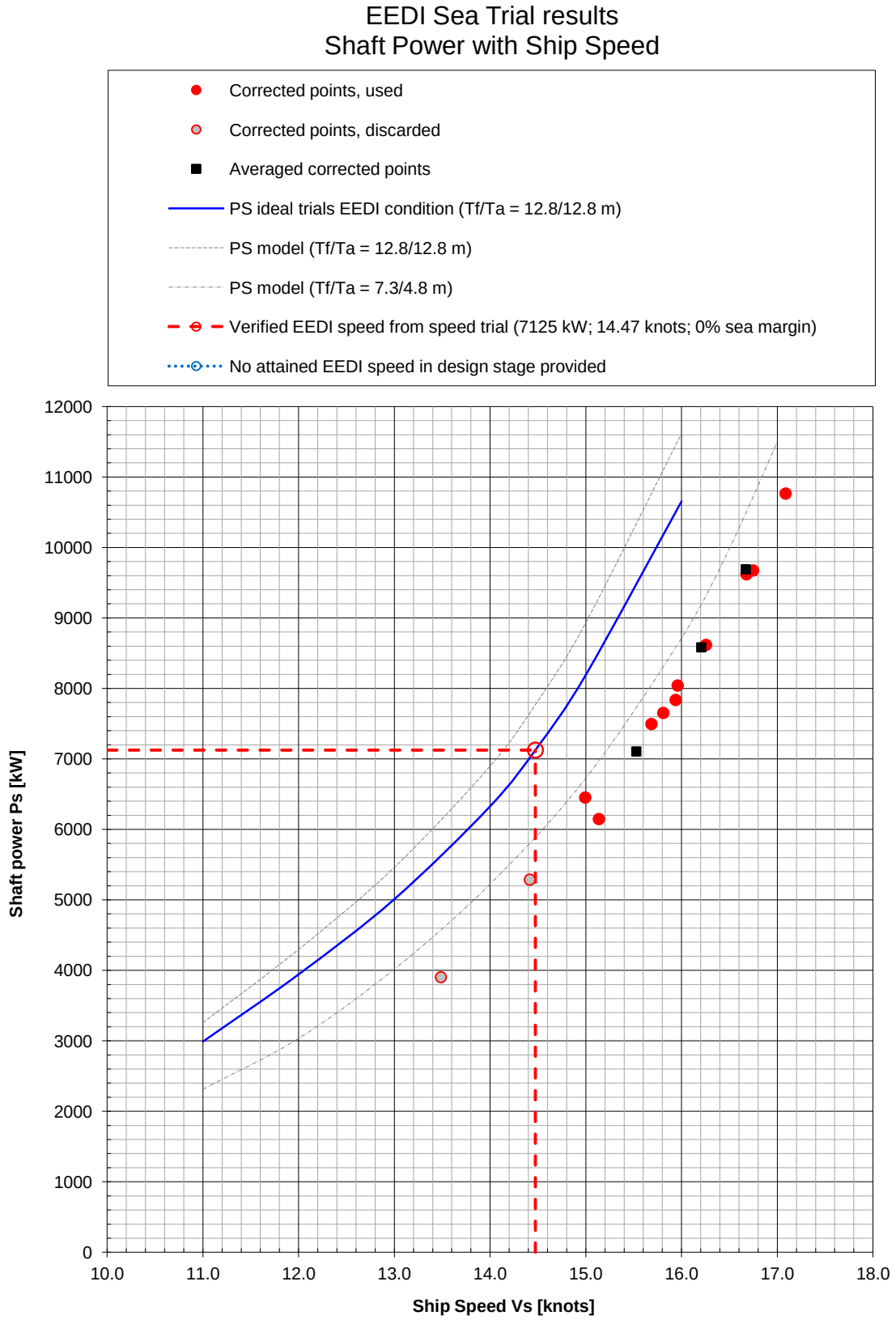

Figure 8 Speed - power graph for EEDI condition

- The verified speed at the EEDI condition using the EEDI curve is

  14.47 kts at 7125 kW and 97.67 RPM

  Shiptype: Bulk carrier

  Displacement: 78803 m^3

  Main engine power: 9500 kW

The verifier present during the sea trials was M. Verifier from Verfying Inc..

10 AUTHENTICITY CHECK

In order to verify that:

- the proper software version is used and
- the software used is indeed the certified software according to the IMO/ITTC approved method,

it is possible to verify this calculation by means of a verification code.

The verification code for this calculation is **1472**

For verification go to www.staimo.org and fill-in the following data:

STAIMO version number	2.5.0
Ship's IMO number	1234567
Speed at contract trial condition	15.37
Speed at EEDI condition	14.47
Length between perpendiculars	205.50

The computer program behind the website will inform you whether the correct version of the software is used and whether the analysis is done according the IMO-ITTC method or with a computer program / analysis method from an undefined source.

CONDITIONS OF USE OF STAIMO SOFTWARE

1. STAIMO is developed on behalf of STA-Group. All rights on the software vest in STA-Group. It has been made available by STA-Group as Freeware on www.staimo.org. The person that downloads the Software from the site is referred to as User.
2. User shall not transfer or sub license STAIMO or any part thereof to any third party. The User shall take appropriate measures to ensure the observation of this clause within his organisation.
3. STAIMO, including any Service, Support and consultancy, is provided "AS IS", without warranty of any kind, express or implied, including but not limited to the warranties of merchantability, fitness for a particular purpose and non-infringement. In no event shall the authors or copyright holders be liable for any claim, damages or other liability, whether in an action of contract, tort or otherwise, arising from, out or in connection with the software or the use or other dealings in the software.
4. STA-Group is entitled to withdraw STAIMO from the web site and to cancel the right to use STAIMO at any time.
5. User shall observe the information provided on www.staimo.org. User shall use the most recent version of STAIMO available on the web site at that time.
6. In case User encounters any error or any problem in the use of STAIMO User shall inform STA-Group immediately and provide required information on this problem through info@staimo.org.

By downloading STAIMO, User accepts, and places himself under the obligation to observe the above Conditions of Use.