Technical Circular to Licensees

7354

Remarks:		Sheet: 1 / 2
Subject: **RTA Engines**	Date: August 2002	Our Reference: 4032/Be/4041/Wi

ENGINE ALIGNMENT

The engine alignment procedure as described in the Marine Installation Manual (MIM) has been revised. The basis for this revision was an accumulation of experience gained by shipyards and WCH with existing ships. This experience has been combined with theoretical considerations to create the new procedure.

The aim of the new procedure is to give the yard a clear and feasible reference for the alignment process starting from the alignment calculation, including ship design aspects, up to the actual alignment in the ship. The final goals of the alignment are to be emphasized: **Optimised crankshaft deflections and static loads of the main bearings within the required limits for service**. These criteria replace the requirements for shear force and bending moment at the aft end engine flange as applied before this release.

The new guidelines are included in the Main Drawing List for Sulzer RTA engines as Group 9709 "Engine alignment". The drawings of Group 0305 "Allowable load engine flange DE" are no longer valid and have been replaced by the contents of Group 9709. At present it includes 3 parts:

1. Engine Alignment Outline: Information on the main goals to be achieved by the engine alignment and the basic principles to be applied to achieve them. (Dwg. no. 4-107.329.329)
2. Engine Alignment Calculation: Information on the method of calculation and the tools which are provided by Wärtsilä Switzerland Ltd. (Dwg. no. 4-107.329.214)
3. Engine Alignment Procedure: Information on the basic principles to be applied during alignment to achieve the target values for main bearing loads and crankshaft deflections. (Dwg. no. 4-107.329.293)

Possible future amendments to the guidelines will be made through drawing modification notices.

These guidelines replace Chapter L1.4.2 and parts of Chapter L1.4.7 in the MIM for all RTA engines. All other chapters in Section L of the MIM remain valid.

Enclosed with this Technical Circular to Licensees is the latest version of the PC program EnDyn suitable for the calculation of engine and shaft alignment as well as bending mode shapes (whirling). It is an extension of the program issued with our Technical Information Letter to Licensees of 27.10.00 used for the calculation of coupled axial vibrations of RTA diesel engines installations.

The program is based on the 3-D model of the shafting (obtained through reduction of a six dof FE model in super elements). The corresponding so-called engine data such as mass and stiffness coefficients are integrated in the program. Only the characteristics of the flywheel, the front end disc or torsional vibration damper (if any), the intermediate and propeller shafts, the shaft bearings as well as the propeller have to be determined as input data.

The User's Guide as well as an example are also integrated in the program package.

The following instructions should be carried out for a complete installation of EnDyn:

1. Save the file "endyn-v116-lc.exe" to your hard disc.
2. Double click this file on your hard disc to unzip it.
3. Change to the main directory of EnDyn. You will find the User's Guide as a PDF file in the "doc" subdirectory. This User's Guide contains a chapter about the setup procedure.
4. After configuration of the program, run the input file in the "exmpl" subdirectory in order to check your setup.

We trust that this new program will be useful to you and help you to easily carry out engine and shaft alignment calculations within a short time.

Wärtsilä Switzerland Ltd

Enclosures:

1. Modification notice 7-28.427
2. Main drawing 107.329.209 - “Engine Alignment”
3. Detail drawing 107.329.329 - “Engine Alignment Outline”
4. Detail drawing 107.329.214 - “Engine Alignment Calculation”
5. Detail drawing 107.329.293 - “Engine Alignment Procedure”
6. Calculation program package EnDyn-v116 “endyn-v116-lc.exe” (self-extracting ZIP file)

☐ DRAWING MODIFICATION	DRAW.NO.		MODIFICATION NO. **7-28.427**
☒ NEW MAIN DRAWING	DRAW.NO.	**107.329.209**	SHEET OF **1/1**
SEE CIRCULAR TO LICENSEES **7354**	☐ VARIANT ☐ INSTEAD OF	DRAW.NO. **see below**	MODIFICATION CLASS **H**
ENGINE TYPE **RTMOT**	VERSION	DRAWING TITLE **Engine Alignment**	GROUP NO. **9709**

● DESCRIPTION + REASON ● EXTENT OF MODIFICATION ● APPLICATION OF EXISTING PARTS ● INTERCHANGEABILITY

Description:

The documentation on engine alignment has been revised.

A new design group 9709 is introduced.

It replaces all drawings in design group 0305.

Reason:

New alignment instructions and guidelines are introduced by group 9709:
Engine alignment is focused on crank web deflections and main bearing loads with attention to draught related ship hull bending.

Bending moment and shear force at crankshaft aft end flange are not further considered. Relevant limits - previously provided by design group 0305 - are obsolete.

Extent of Modification:

Grp.	Engine(s)	Drawing no(s).	Index	Drawing Title
9709	RTMOT	107.329.209	-	Engine Alignment
		107.329.329	-	Engine Alignment Outline
		107.329.214	-	Engine Alignment Calculation
		107.329.293	-	Engine Alignment Procedure
0305	RTA48T/T-B	107.298.235	a	Allowable load engine flange DE
	RT58T/T-B RTflex58T-B	107.298.226	a	Allowable load engine flange DE
	RTA68T-B	107.316.863	-	Allowable load engine flange DE
	RTA84T/T-B/T-D	107.298.238	-	Allowable load engine flange DE
	4-7RTA84C/CU	107.298.239	-	Allowable load engine flange DE
	8-12RTA84C/CU	107.298.240	-	Allowable load engine flange DE
	6-7RTA96C/C-B	107.298.236	-	Allowable load engine flange DE
	8-12RTA96C/C-B	107.298.237	-	Allowable load engine flange DE
	RTA52/U/U-B	107.298.245	a	Allowable load engine flange DE
	RTA62/U/U-B	107.298.247	b	Allowable load engine flange DE
	RTA72/U/U-B	107.298.249	b	Allowable load engine flange DE

The drawing 107.245.966 “Engine and shaft alignment” (group 9710)
is replaced by drawing 107.329.214 “Engine Alignment Calculation”.

The drawing 107.246.511 “Engine alignment procedure” (group 9710)
is replaced by drawing 107.329.293 “Engine Alignment Procedure”.

WÄRTSILÄ

Technical Circular to Licensees 7354, Enclosure 1

Wärtsilä Switzerland Ltd.	**MODIFICATION NOTICE**	**Issued:** Name **J.Bergande**	Dept. **4032**	Date **16.8.2002**	Approved

Exec. code number			Pos. code no.		Article number	Designation	Source of supply	Modification letter	
		200			Drawing number	Material and remarks	Mass kg/piece		
		*	001		107.329.329.500	Engine Alignment Outline		-	
				4-107.329.329					
		*	002		107.329.214.500	Engine Alignment Calculation		-	
				4-107.329.214					
		*	003		107.329.293.500	Engine Alignment Procedure		-	
				4-107.329.293					

Technical Circular to Licensees 7354, Enclosure 2

Q-Code	X	X	X	X	X

-	7-28.427	16.8.02							Replaced by:	PC
									Substitute for: Group 0305	

WÄRTSILÄ Wärtsilä Switzerland Ltd.	RTMOT		**Engine Alignment** direct-coupled marine propulsion		Group **9709**
	Drawn: J.Bergande 14.8.02 Verif: Dr.R.Holtbecker 15.8.02	E	**4-107.329.209**	**H**	**1 / 1**

Subject:

These INSTRUCTIONS provide information on the BASIC PRINCIPLES OF ALIGNMENT for direct-coupled Sulzer RT marine propulsion engines to the responsible parties.

Contents:

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1 Alignment focusing on crank web deflections and main bearing loads

The final engine alignment has to guarantee crank web deflections and bearing loads within admissible limits at all normal ship service conditions (see table 1).

The influence of ship service conditions (draught, etc.) on bearing loads and crank web deflections need to be taken into consideration at alignment.

The alignment include among others the following items:

a) Specific static main bearing loads are defined for alignment calculation.
b) Crankshaft models with own mass and bearing stiffness are issued for calculating static main bearing loads.
c) Engine alignment is verified by crank web deflection readings for all cylinders and jack-up test results for aftmost 3 engine main bearings.

2 Limits for service condition

The limits for crank web deflections and static main bearing loads have to be maintained in normal ship service conditions, i.e.:

a) Ship afloat, ballast to full draught, trim within the limits for normal operation.
b) Propeller-, intermediate shaft(s) and engine coupled.
c) Engine cold or hot.
d) No temporary supports engaged.

The limits for static main bearing loads listed in table 1 apply on jack-up test results.

Technical Circular to Licensees 7354, Enclosure 3

Table 1	Limits for SERVICE CONDITION					
	Vertical Deflection Limits [mm]		Static Main Bearing Loads [kN]			
			mb1; mb3-(n)		mb2	
Engine type	Good	Admissible	Fmin.	Fmax.	Fmin.	Fmax.
RT52 / U / U-B	± 0.28	± 0.54	16	320	16	64
RT62 / U / U-B	± 0.32	± 0.64	24	470	24	94
RT72 / U / U-B	± 0.38	± 0.76	32	630	32	126
RT48T / T-B	± 0.31	± 0.62	15	290	15	58
RT58T / T-B	± 0.37	± 0.74	21	430	21	86
RT68T-B	± 0.43	± 0.86	28	560	28	112
RT84T / T-B / T-D	± 0.40	± 0.80	23	940	23	282
RT60C	± 0.30	± 0.60	23	460	23	92
RT84C	± 0.30	± 0.60	45	890	45	178
RT96C/C-B	± 0.33	± 0.66	53	1050	53	210

3 Consideration of ship draught for alignment

Final alignment is usually done at very light draught or in dry-dock.

The ship draught influence on the bearing loads as shown in table 2 needs to be considered in the alignment calculation to get an alignment which is within the limits of table 1.

Table 2	Influence of ship draught on static main bearing loads		
	mb1 (aftmost)	mb2	mb3
Change from LIGHT to FULL draught	***In***crease	***De***crease	***De***crease

To ensure that the main bearing loads are within the limits for service it is up to the experience of responsible parties:

- either to apply the static main bearing loads recommended for alignment (see doc. 107.329.214 “Engine Alignment Calculation”),
- or to adapt the static main bearing loads at alignment according to their experience.

4 Recommendations for ship design process

With larger distances between stern tube, intermediate and engine main bearings the bearing load variations are getting lower.

Larger bearing distances (i.e. reduced number of propulsion shaft bearings) should be considered as an aim in ship hull and propulsion shaft design.

Subject:

This GUIDELINE provides information on the ALIGNMENT CALCULATION AND LAYOUT for direct-coupled Sulzer RT marine propulsion engines to the responsible parties.

Contents:

1 Calculation results

The alignment calculation provides the required values for the propulsion shaft and engine alignment in the ship:

a) vertical bearing offsets,
b) gap and sag values,
c) static bearing loads.

2 Alignment condition

The general boundary conditions during final engine alignment are defined as follows:

a) Ship at light draught (partial propeller submersion) or in dock (no propeller submersion).
b) Propeller-, intermediate shaft(s) and engine coupled according to alignment calculation and shipyards practice.
c) Engine cold.
d) No temporary supports engaged.

3 Static main bearing loads for alignment calculation

Final alignment is usually done at very light draught or in dry-dock.

The ship draught influence on the bearing load as shown in table 1 needs to be considered.

Table 1	**Influence of ship draught on static main bearing loads**		
	mb1 (aftmost)	**mb2**	**mb3**
Change from LIGHT to FULL draught	***In***crease	***De***crease	***De***crease

Technical Circular to Licensees 7354, Enclosure 4

To ensure that the main bearing loads are within the limits for service it is up to the experience of responsible parties:

- either to apply the static main bearing loads recommended in Table 2,
- or to adapt the static main bearing loads at alignment according to their experience.

For instance special cases (e.g. VLCCs) may require higher loads on main bearing #2 leading to lower load on main bearing #1 at alignment. In such cases pls. contact Wärtsilä Switzerland Ltd.

Table 2	**Recommended static main bearing loads for ALIGNMENT CALCULATION [kN]**			
Engine main bearing nos.	**mb1; mb3-(n)**		**mb2**	
Engine type	Fmin.	Fmax.	Fmin.	Fmax.
RT52 / U / U-B	16	320	80	112
RT62 / U / U-B	24	470	118	165
RT72 / U / U-B	32	630	158	221
RT48T / T-B	15	290	73	102
RT58T / T-B	21	430	108	151
RT68T-B	28	560	140	196
RT84T / T-B / T-D	23	940	282	423
RT60C	23	460	115	161
RT84C	45	890	223	312
RT96C/C-B	53	1050	263	368

Bending moment and shear force at crankshaft aft end flange are not considered.

3.1 Comparison of calculated and measured bearing loads

Calculated and measured main bearing loads can not be compared directly.

The recommended static main bearing loads of table 2 refer to zero crank angle position (aftmost cyl.1 in “TDC” position). The alignment calculation has to be made and judged in this position.

Jack-up tests for mb2 and 3 are made at crank angle 90 degree (aftmost cyl.1 in “EXH” position). For this condition the jack-up test results probably deviate as follows:

- mb2 shows 20..30 per cent lower loads than at zero degree crank angle
- mb3 shows 20..30 per cent higher loads than at zero degree crank angle

In addition to the a.m. tolerances an accuracy tolerance of ± 20% is usual for the jack-up test.

4 Crankshaft models

The applied calculation model should include the following features to calculate the bearing loads of the engine:

a) full crankshaft model with own mass, incl. masses of running gear and gearwheel
b) elastic main bearing supports.

These items are implemented features of both crankshaft models provided by Wärtsilä:

1. RTA crankshaft models which are integrated part of new released alignment program EnDyn.
2. Equivalent crankshaft model (see Appendix 1).

4.1 Flywheel mass consideration

The actual flywheel mass has to be added at aftmost node of crankshaft model.

5 Recommendations for alignment layout

With larger distance between propulsion shaft bearings the bearing load variation is getting lower. Larger bearing distances should be considered as an aim in ship hull and propulsion shaft design.

To avoid excessive unloading of main bearing #1 during operation it is strongly recommended to keep whenever possible vertical offset position of main bearing #1 above the connection line of the two nearest shaft line bearings:

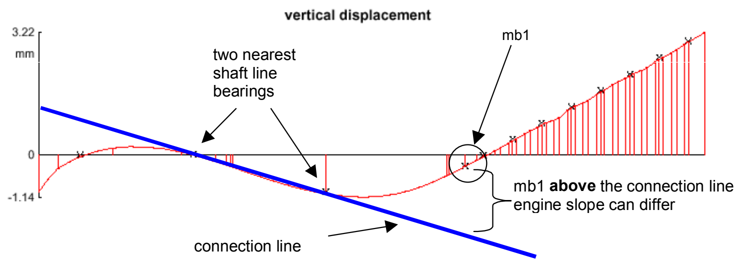


Fig.1: WCH recommendation for engine alignment (for reference)

6 Service related influences on alignment

The calculation of service conditions is optional. It may help to estimate the service related changes of static bearing loads in service.

6.1 Draught related ship hull bending

Experience shows that the draught related ship hull bending is the most important factor influencing static main bearing loads.

Increase of ship draught leads to ship hull bending below the shaft line up to engine free end. This leads to an increased downward load on crankshaft aft end flange and shifts static load from mb2 to aftmost mb1 in general.

The change of vertical offsets for shaft and main bearings depends on ship draught and design. No general rule for estimations is available.

6.2 Engine service temperature

The vertical thermal growth of engine due to higher temperature in operation leads to a shift of static load from mb2 to aftmost mb1.

The involved increase of engine main bearing height by temperature comparing to shaft bearings can be estimated as below:

$$\Delta h_{mb} = h_{found} \cdot C \cdot \frac{11.5 \cdot (55°C - t_{ref})}{10^6 \ °C} \ [mm]$$

Δh_{mb} [mm]:	Increase of engine main bearing height from cold to hot condition
h_{found} [mm]:	Main bearing foundation height (see Appendix 1)
C [-]:	Correction factor 0.3 to 0.5 (according to shipyard's experience)
t_{ref} [°C]:	Reference temperature for foundation and ship hull around the engine

Example for Sulzer 5-8RTflex60C engine:

$t_{ref} = 20°C$

$$\Delta h_{mb} = 1306mm \cdot 0.4 \cdot \frac{11.5 \cdot (55°C - 20°C)}{10^6 \ °C}$$

$\underline{\Delta h_{mb} = 0.21mm}$

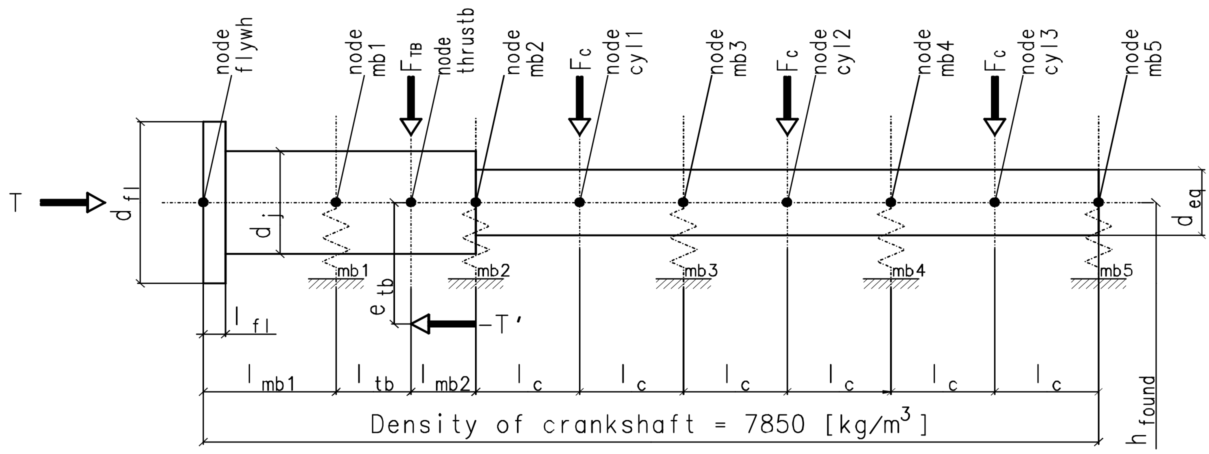
6.3 Propeller thrust

Calculation with propeller thrust includes the moment induced by the eccentricity (“e_{tb}“ in Appendix 1) of the thrust bearing.

Calculations with maximum propeller thrust provide low or zero load for aftmost mb1 at alignment condition (i.e. ship hull deformation not considered). The thermal rise of engine main bearing is not sufficient to avoid the a.m. substantial load reduction for mb1.

This is acceptable because the draught related ship hull bending which is involved until the full thrust is available will have shifted static load from mb2 to aftmost mb1.

Appendix 1: Equivalent Crankshaft Models for Sulzer RT-Engines



Equivalent Crankshaft Models for Sulzer RT-Engines													
Designation	l_{fl}	d_{fl}	l_{mb1}	d_j	l_{tb}	l_{mb2}	d_{eq}	l_C	F_{TB}	F_C	h_{found}	e_{tb}	Bearing Stiffness	Bearing Clearance
Engine Type	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[N]	[N]	[mm]	[mm]	[N/m]	[mm]
5-8 RT52U / U-B	130	885	615	560	467.5	212.5	346	460	21'052	88'506	1'150	-208	4.5E+09	0.6
5-8 RT62U	160	1120	720	670	530	250	410	550	30'646	145'453	1'350	-295	4.5E+09	0.7
5-8 RT62U-B	160	1120	507	670	373	220	413	550	31'529	148'877	1'350	-232	4.5E+09	0.7
5-8 RT72U	185	1240	840	780	590	280	480	645	41'271	228'328	1'600	-315	5.0E+09	0.8
5-8 RT72UB	185	1240	590	780	420	270	482	645	41'271	236'549	1'600	-263	5.0E+09	0.8
5-8 RT48T	125	915	471	572	287.5	196.5	309	417	15'107	78'814	1'085	-188	3.0E+09	0.6
5-8 RT48T-B	125	915	451	585	287.5	196.5	309	417	14'960	76'390	1'085	-188	3.0E+09	0.6
5-8 RT58T	150	1110	515	690	347.5	237.5	371	503	25'673	138'115	1'300	-228	3.5E+09	0.7
5-8 RT58T-B	150	1110	520	706	367.5	237.5	375	503	25'418	138'341	1'300	-228	3.5E+09	0.7
5-8 RT68T-B	175	1300	622	828	448	270	441	590	24'535	213'740	1'520	-276	4.0E+09	0.8
5-7 RT84T	220	1460	1080	980	670	330	566	750	95'118	381'354	1'800	-385	6.0E+09	1.0
5-7 RT84T-B / T-D	220	1460	870	980	635	365	552	750	59'282	350'894	1'800	-299	6.0E+09	1.0
8-9 RT84T-B / T-D	220	1460	870	980	635	365	552	750	37'818	350'894	1'800	-317	6.0E+09	1.0
5-8 RT60C	160	1120	550	730	412	235	404	520	30'411	146'856	1'306	-250	5.0E+09	0.7
6-7 RT84C long crankshaft	170	1370	1192.5	870	577.5	330	576	800	98'846	323'593	1'600	-349	6.5E+09	0.9
8-12 RT84C long crankshaft	170	1370	1192.5	870	577.5	330	576	800	66'688	323'593	1'600	-349	6.5E+09	0.9
6-7 RT84C short crankshaft	170	1370	987.5	870	577.5	330	576	800	98'846	323'593	1'600	-349	6.5E+09	0.9
8-12 RT84C short crankshaft	170	1370	987.5	870	577.5	330	576	800	80'324	323'593	1'600	-349	6.5E+09	0.9
6-7 RT96C / C-B	210	1460	870	990	615	295	620	840	68'503	434'348	1'800	-314	5.0E+09	1.0
8-12 RT96C / C-B	210	1460	870	990	615	295	620	840	43'743	434'348	1'800	-342	5.0E+09	1.0

Subject:

This GUIDELINE provides information on the basic principles of the ENGINE ALIGNMENT PROCEDURE for direct-coupled Sulzer RT marine propulsion engines to the responsible parties.

Contents:

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1 General

This guideline refers to the last steps made before the resin chocks are poured and the engine is fixed.

It depends on the ship building practice to perform alignment work at different stages of building progress. Essential is that the alignment meets the tolerances in all normal ship service conditions.

Individual aspects of engine alignment are described in the text below. In practice, all items are treated simultaneously by a mutual process due to their strong interrelationship.

2 Pre-requisites

The following conditions should be provided:

a) Major ship hull manufacture is completed.
b) Engine erection is completed.
c) Propulsion shaft line is aligned according to calculation and shipyard practice.

3 Influences

Influences affecting alignment should be reduced to lowest possible extent and/or appropriately considered (if unavoidable):

a) Actual ship draught.
b) Heavy load shifts (e.g. ballasting, bunkering) are to be avoided during alignment.
c) Uneven temperature distribution (e.g. direct sunshine) influences alignment measurements and should be considered.

4 Engine alignment towards propulsion shaft line

The crankshaft drive end flange is aligned in relation to foremost intermediate shaft flange by gap & sag, according to engine and shaft alignment calculation.

- Gap tolerance: ±0.10mm
- Sag tolerance: ±0.10mm

5 Engine alignment towards foundation

Engine alignment towards engine foundation is verified by measurements of
a) crank web deflections and
b) bedplate top surface.

5.1 Longitudinal twist

The engine forward end has to be parallel to aft end.

Relevant measurements refer to the outer corners of machined bedplate top surface:

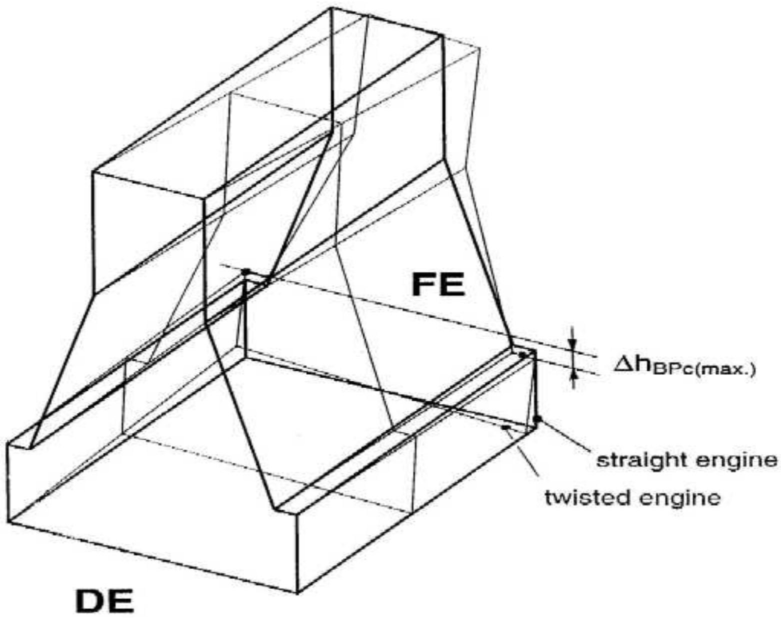

Fig.1: Parallelism of engine drive end (DE) to engine free end (FE)

The tolerance for parallelism $\Delta h_{BPc(max.)}$:

Table 1	Parallelism of engine free end to drive end for alignment		
	RT48T, RT52	RT58T, RT60C, RT62, RT68T, RT72	RT84C, RT84T, RT96C
$\Delta h_{BPc(max.)}$	0.2mm	0.25mm	0.3mm

Note: The a.m. limits include a tolerance for measurement of 0.1mm.

5.2 Sideways bend

The tolerance for horizontal crank web deflections are given in Appendix 2.

The sideways bend (around a vertical axis) is verified by measuring the horizontal crank web deflection.

5.3 Up / downward bend (hog / sag)

5.3.1 Straight alignment for short engines

Short engines (5-8 cylinders) should be aligned straight or just slightly pre-sagged.

A pre-sag of 0.0 mm (tolerance to –0.2 mm) is recommended.

5.3.2 Pre-sagged alignment for long engines

Long engines (9 and more cylinders) should be aligned pre-sagged.

Recommended values for engine pre-sag are provided in Appendix 1.

5.3.3 Adjustment of pre-sag

A pre-sag is adjusted by shifting support point load from the middle section of engine to the outer corners. Use of wedges and hydraulic jacks for pre-sagged alignment is essential to take up the resulting increasing support point load at both engine ends.

Jacking screws are considered as being unsuitable for pre-sag adjustment.

The pre-sag must not be forced by applying additional downward loads or forces onto the engine.

5.3.4 Measurement of engine sag

The sag curve is verified by the shape of bedplate top surface by measuring the heights of bedplate along port and starboard side.

Several methods can be applied:

- Piano wire
- Optical tools

5.3.4.1 Tolerances:

The sag curve of the bedplate should be as smooth as possible. The given tolerance of ±0.1 mm in Appendix 1 is only applied on the absolute pre-sag value measured in the middle of the engine.

Two tolerance values apply for verifying the results of measuring longitudinal bedplate top surface:

a) 0.1mm/m tolerance for local measurements
b) 0.2mm max. deviation between recorded bending lines of starboard versus port side.

6 Finishing alignment

6.1 Alignment checks in un-coupled condition

The following items have to be checked and recorded for being within the limits:

a) gap & sag towards forward intermediate shaft flange,
b) all crank web deflections (for reference),
c) bedplate top surface (optional, also possible in coupled condition).

If tolerances found to be in excess of given limits and cannot be improved, forward actual data records to engine builder or Wärtsilä Switzerland Ltd. directly for assistance.

If the tolerances are within given limits, proceed with next step.

6.2 Alignment checks in coupled condition

Pre-requisites:

- propulsion shaft line coupled to the engine
- all temporary supports disengaged

The following items have to be checked and recorded for being within the limits:

a) No bottom clearance in engine main bearings (check by feeler gauge at least aft most bearings).

b) Record crank web deflections.

c) Perform jack-up tests of all accessible propulsion shaft line bearings and aftmost 3 engine main bearings. This jack-up test can be omitted in case
   - the shipyard has accumulated sufficient experience on relevant ship type
   - a jack-up test of aftmost 3 engine main bearings is specified during sea trial.

If the experience of responsible party deviates from the above mentioned or in case that tolerances are found to be in excess of given limits and cannot be improved please contact engine builder or Wärtsilä Switzerland Ltd. directly for assistance and include actual data records.

6.2.1 Jack-up test for main bearings

The jack load is determined by means of a plot of jack pressures (or load) and deflections. The longitudinal offset between bearing centre and jack / dial gauge position is compensated by a jack correction factor:

main bearing load = jack load · jack correction factor

The following jack / dial gauge positions and approximate correction factors apply for the main bearings:

Table 2	Jack-up test for engine main bearings	
	mb1 (aftmost)	**mb2 to (n)**
Jack and dial gauge position	at flywheel	at adjacent crank (close to relevant mb)
Jack correction factor	1.3	0.9

6.3 Final steps

If the tolerances are within given limits proceed with pouring the resin chocks.

Appendix 1: Bedplate sag curves

The following tables give the recommended pre-sag value measured in the middle of the engine and the offset values for each centre of main bearings. Both represents the absolute values measured from the bedplate top surface in relation to a straight line. A negative value means that the measured position is below the straight line.

For engines with 8 or lower cylinder numbers a pre-sag at alignment of 0.0 mm (tolerance to –0.2 mm) is recommended.

The measurement of the actual sag curve can be done either by optical or by piano wire method.

Calculated pre-sag offsets for reference
Absolute values related to straight base line

RT_2/U/U-B RT_8T/T-B RT60C	Pre-sag Tol.: ±10	vertical offsets in 1/100mm at main bearing nos.									
		mb 2	Mb 3	mb 4	mb 5	mb 6	mb 7	mb 8	mb 9	mb 10	mb 11
5 cyl.	-10	0	-6	-10	-10	-6	0				
6 cyl.	-10	0	-6	-9	-10	-9	-6	0			
7 cyl.	-10	0	-5	-8	-10	-10	-8	-5	0		
8 cyl.	-10	0	-4	-8	-9	-10	-9	-8	-4	0	

Calculated pre-sag offsets for reference
Absolute values related to straight base line

RTA84T / T-B / T-D	Pre-sag Tol.: ±10	vertical offsets in 1/100mm at main bearing nos.													
		mb 2	mb 3	mb 4	mb 5	Mb 6	mb 7	mb 8	mb 9	mb 10	mb 11	mb 12	mb 13	mb 14	mb 15
5 cyl.	-10	0	-6	-10	-10	-6	0								
6 cyl.	-10	0	-6	-9	-10	-9	-6	0							
7 cyl.	-10	0	-5	-8	-10	-10	-8	-5	0						
8 cyl.	-10	0	-4	-7	-9	-10	-10	-9	-7	-4	0				
9 cyl.	-30	0	-11	-20	-26	-29	-30	-29	-26	-20	-11	0			

continued →

Calculated pre-sag offsets for reference Absolute values related to straight base line															
RTA84C / C-U	**Pre-sag Tol.: ±10**	**vertical offsets in 1/100mm at main bearing nos.**													
		mb 2	**mb 3**	**mb 4**	**mb 5**	**mb 6**	**mb 7**	**mb 8**	**mb 9**	**mb 10**	**mb 11**	**mb 12**	**mb 13**	**mb 14**	**mb 15**
6 cyl.	**-10**	0	-6	-9	-10	-9	-6	0							
7 cyl.	**-10**	0	-5	-8	-10	-10	-8	-5	0						
8 cyl.	**-10**	0	-4	-7	-9	-10	-10	-9	-7	-4	0				
9 cyl.	**-30**	0	-11	-20	-26	-29	-30	-29	-26	-20	-11	0			
10 cyl.	**-40**	0	-14	-24	-32	-38	-39	-40	-38	-32	-24	-14	0		
11 cyl.	**-45**	0	-14	-26	-34	-41	-44	-45	-44	-41	-34	-26	-14	0	
12 cyl.	**-55**	0	-16	-29	-40	-48	-53	-55	-55	-53	-48	-40	-29	-16	0

Calculated pre-sag offsets for reference Absolute values related to straight base line															
RTA96C / C-B	**pre-sag tol.: ±10**	**vertical offsets in 1/100mm at main bearing nos.**													
		mb 2	**mb 3**	**mb 4**	**mb 5**	**mb 6**	**mb 7**	**mb 8**	**mb 9**	**mb 10**	**mb 11**	**mb 12**	**mb 13**	**mb 14**	**mb 15**
6 cyl.	**-10**	0	-6	-9	-10	-9	-6	0							
7 cyl.	**-10**	0	-5	-8	-10	-10	-8	-5	0						
8 cyl.	**-10**	0	-4	-7	-9	-10	-10	-9	-7	-4	0				
9 cyl.	**-35**	0	-13	-23	-30	-33	-35	-34	-30	-23	-13	0			
10 cyl.	**-40**	0	-14	-25	-33	-38	-39	-40	-38	-33	-25	-14	0		
11 cyl.	**-50**	0	-16	-29	-38	-45	-49	-50	-49	-45	-38	-29	-16	0	
12 cyl.	**-60**	0	-18	-32	-44	-52	-58	-60	-60	-58	-52	-44	-32	-18	0

Appendix 2: Vertical and horizontal crankshaft deflection limits at alignment

Crank web deflection limits for alignment			
	vertical $\Delta a_{max.(vert.)}$		horizontal $\Delta a_{max.(hor.)}$
	inner cylinders 2 to (n-1)	aftmost cylinder 1 foremost cylinder (n)	all cylinders 1 to (n)
RT52 / U / U-B	± 0.14	+ 0.14 - 0.18	± 0.05
RT62 / U / U-B	± 0.16	+ 0.16 - 0.21	± 0.06
RT72 / U / U-B	± 0.19	+ 0.19 - 0.25	± 0.08
RT48T / T-B	± 0.16	+ 0.16 - 0.20	± 0.06
RT58T / T-B	± 0.19	+ 0.19 - 0.24	± 0.07
RT68T-B	± 0.22	+ 0.22 - 0.28	± 0.09
RT84T / T-B / T-D	± 0.20	+ 0.20 - 0.26	± 0.08
RT60C	± 0.15	+ 0.15 - 0.20	± 0.06
RT84C	± 0.15	+ 0.15 - 0.20	± 0.06
RT96C/C-B	± 0.17	+ 0.17 - 0.21	± 0.07