BAB V
PENUTUP

5.1. Kesimpulan

Berdasarkan perhitungan yang telah dilakukan pada bab-bab sebelumnya untuk kapal ikan 370 BRT dengan ukuran utama sebagai berikut :

LOA : 33,15 M
LWL : 30,60 M
LPP : 30,00 M
B : 9,40 M
H : 4,66 M
T : 3,80 M
C_b : 0,55
V_s : 11 knots
Radius Pelayaran : 2100 sea miles
Klasifikasi : B K I

diperoleh besarnya Daya Continous Rating yang diperlukan agar kapal dapat mencapai 11 knot adalah 1000 HP.

Untuk memenuhi kebutuhan tersebut dengan berbagai pertimbangan maka ditetapkan motor penggerak utama kapal dengan data-data sebagai berikut :

Merk : MAN, B&W
Model : L20/27
Daya : 815 HP (600 kW)
Rpm : 1000
Bore : 200 mm
Stroke : 270 mm
Ukuran : panjang x lebar x tinggi
3000 mm x 1350 mm x 1900 mm
Berat mesin total : 5,9 ton
Jumlah : 1 unit
Posisi mesin penggerak : di belakang

Untuk memenuhi kebutuhan listrik di kapal disuplai oleh Main Generator dan Generator Darurat dengan data-data :

Main Generator :

Merk : YANMAR
Type : G HAL2 - N
Daya Motor : 135 kW (183 PS)
Rpm : 1800
Frekuensi : 50 Hz
Jumlah Silinder : 4
Jumlah : 2 units

Generator Darurat :

Merk : YANMAR
Type : YMGH 100
Daya Motor : 100 kW (135 PS)
Rpm : 1800
Frekuensi : 50 H_z
Jumlah Silinder : 4
Jumlah : 1 units

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LAMPIRAN

Tabel 1. Pemakaian Tenaga Listrik

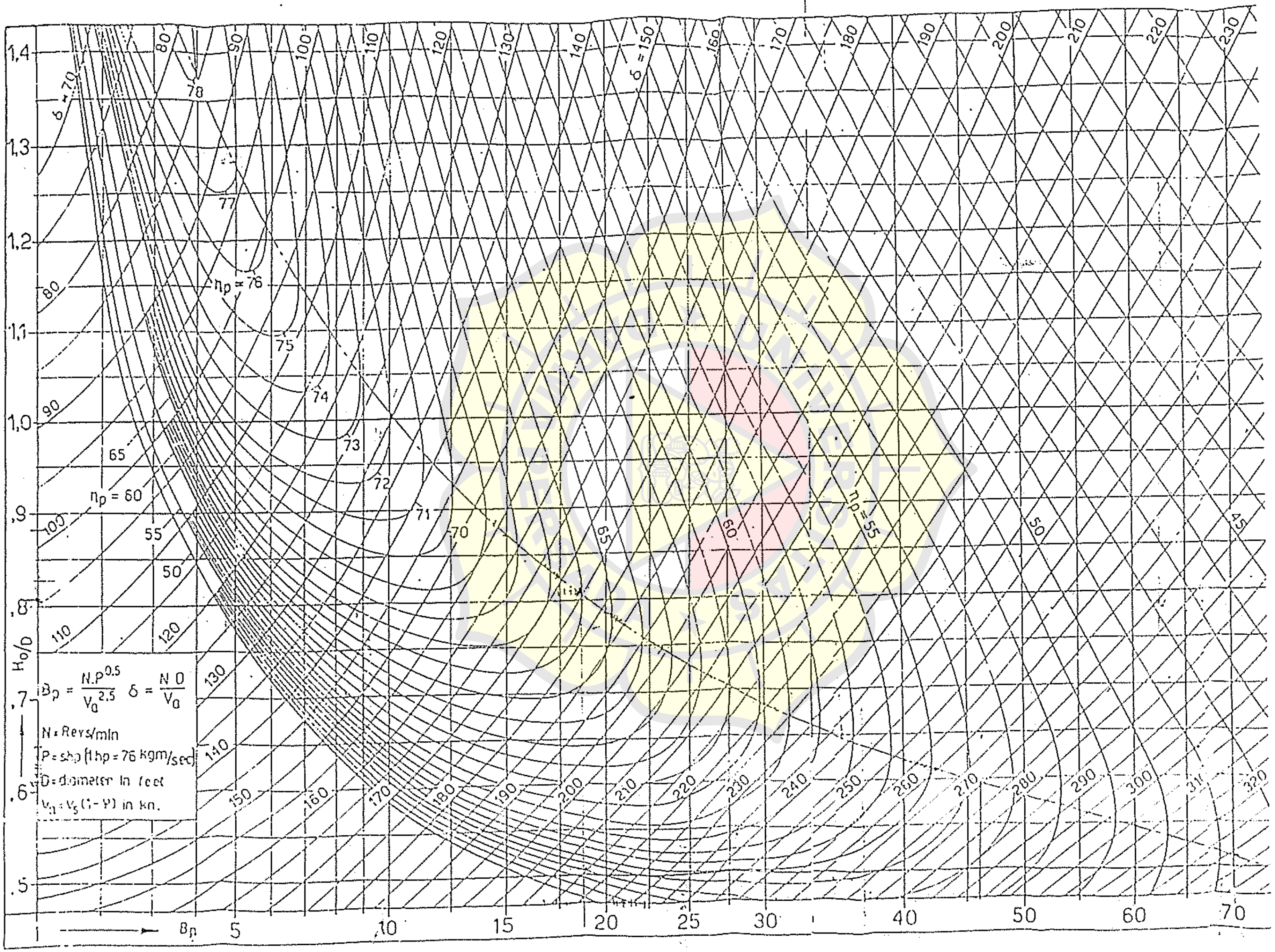
No	Peralatan Listrik	kW	Qty	Total	Berlayar		Olah Gerak		Sandar	
					LF	kW	LF	kW	LF	kW
	Engine Room :									
1	Main Air Compressor	5.000	2	10.000	0.20	2.000	0.40	4.000	0.40	4.000
2	Aux. Start. Air Compressor	5.000	1	5.000	0.20	1.000	0.20	1.000	0.20	1.000
3	MDO Transfer Pump	4.000	2	8.000	0.10	0.800	0	0.000	0.20	1.600
4	LO Transfer Pump	2.650	1	2.650	0.20	0.530	0.30	0.795	0.35	0.928
5	Sea Cooling Water Pump	8.096	2	16.192	1.00	16.192	1.00	16.192	0.00	0.000
6	Bilga Pump	10.110	2	20.220	0.20	4.044	0.20	4.044	0.10	2.022
7	Ballast Pump	10.110	2	20.220	0.10	2.022	0	0.000	0.50	10.110
8	Fresh Water Pump	5.500	2	11.000	0.50	5.500	0.50	5.500	0.60	6.600
9	Sea Water Pump	10.200	3	30.600	0.50	15.300	0.50	15.300	0.50	15.300
10	Fire & GS Pump	12.000	3	36.000	0.10	3.600	0.05	1.800	0	0
11	Sewage Pump	1.500	2	3.000	0.30	0.900	0	0	0	0
12	Gear Oil Pump	4.200	4	16.800	1.00	16.800	1.00	16.800	0	0
13	Hydrophore Pump	5.500	2	11.000	0.50	5.500	0.20	2.200	0.20	2.200
14	Sludge Pump	2.900	1	2.900	0.30	0.870	0.30	0.870	0.30	0.870
15	Dirty Oil Pump	2.900	1	2.900	0.30	0.870	0.30	0.870	0.30	0.870
16	E/R Fan	1.000	8	8.000	1.00	8.000	1.00	8.000	1.00	8.000
17	CO2 Room Fan	0.360	2	0.720	1.00	0.720	10.00	7.200	1.00	0.720
18	AC Room	0.650	8	5.200	1.00	5.200	1.00	5.200	1.00	5.200
19	Fan Room	0.080	6	0.480	1.00	0.480	1.00	0.480	1.00	0.480
20	Electric Welder	5.500	1	5.500	0	0	0	0.000	0	0
21	Grinder	0.350	1	0.350	0	0	0	0.000	0	0
22	Cold Storage Compressor	1.500	1	1.500	1	1.500	1	1.500	1	1.500
23	Fish Hold Compressor	16.000	2	32.000	1.00	32.000	1.00	32.000	0	0
24	Steering Gear	13.000	2	26.000	0.30	7.800	1.00	26.000	0	0

	Main Deck :					0.000		0.000		
25	Windlass	11.203	2	22.406	0	0.000	0.20	4.481	0	0
26	Trawl Winch	50.000	1	50.000	1.00	50.000	1.00	50.000	0	0
27	Capstan	4.000	4	16.000	0	0	0.05	0.800	0.10	1.600
28	Pantry/Galley	0.500	1	0.500	0.30	0.150	0.30	0.150	0.30	0.150
	Upper Deck :									
29	Radar dan Radio	0.300	1	0.300	1.00	0.300	0.40	0.120	0	0
30	Navigation Light	0.060	6	0.360	1.00	0.360	1.00	0.360	0	0
	Lighting :									
31	Gangway	0.040	8	0.320	1.00	0.320	1.00	0.320	1.00	0.320
32	Ruang Kapten	0.030	3	0.090	1.00	0.090	1.00	0.090	0.50	0.045
33	Ruang Markonis	0.030	2	0.060	0.25	0.015	1.00	0.060	0.50	0.030
34	Store	0.030	2	0.060	0.10	0.006	0.05	0.003	0.10	0.006
35	Ruang Pompa Cuci Deck	0.040	1	0.040	0.10	0.004	1.00	0.040	1.00	0.040
36	Cold Storage	0.030	2	0.060	1.00	0.060	1.00	0.060	1.00	0.060
37	Messroom	0.040	2	0.080	1.00	0.080	1.00	0.080	1.00	0.080
38	Ruang KKM	0.030	3	0.090	1.00	0.090	1.00	0.090	1.00	0.090
39	WC/KM	0.030	4	0.120	0.10	0.012	0.10	0.012	0.10	0.012
40	Ruang ABK	0.030	6	0.180	1.00	0.180	1.00	0.180	1.00	0.180
41	Ruang Olie Mesin Deck	0.040	1	0.040	1.00	0.040	1.00	0.040	0.00	0.000
42	Mate Spare	0.030	2	0.060	1.00	0.060	1.00	0.060	0	0.000
43	Engine Room	0.050	12	0.600	1.00	0.600	1.00	0.600	1.00	0.600
	TOTAL					183.995		207.297		64.613

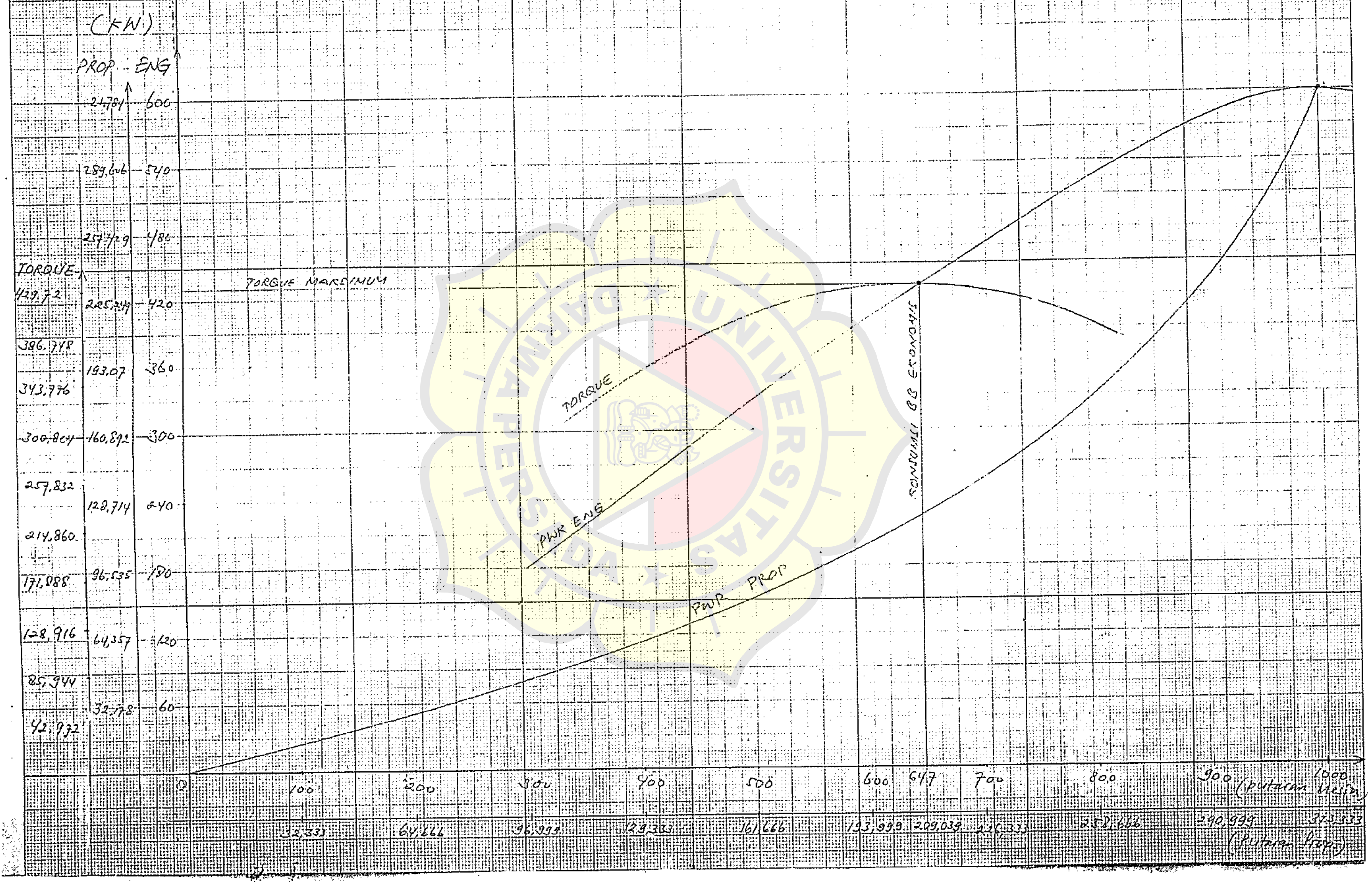
LAMPIRAN

Tabel 2. Kapasitas Udara Tiap Ruangan

No	Nama Ruangan	l (m)	b (m)	h (m)	Volume (m3)	Kandungan CO2 (lt/m3)	Kap.Udara Qch (m3/jam)	Jenis Mesin Penyegar Udara	Daya Listrik (kW)
1	*Ruang Kapten*	3.50	2.20	2.20	16.94	0.1540	3.7268	A.C	0.750
2	*Ruang Markonis*	3.50	2.20	2.20	16.94	0.0478	1.1568	A.C	0.370
3	*Store*	3.50	2.20	11.50	88.55	0.0375	4.7438	FAN	0.274
4	*Ruang Pompa Cuci Deck*	1.00	2.35	2.30	5.41	0.0844	0.6523	FAN	0.023
5	*Galley*	3.50	2.50	2.00	17.50	0.0600	1.5000	FAN	0.073
6	*Messroom*	2.50	2.50	2.00	12.50	0.4020	7.1786	A.C	2.200
7	*Ruang KKM*	2.00	2.50	2.00	10.00	0.1540	2.2000	A.C	0.750
8	*WC/KM Perwira*	1.00	2.00	2.00	4.00	0.1050	0.6000	FAN	0.020
9	*Ruang ABK 1*	2.00	2.00	2.00	8.00	0.0470	0.5371	A.C	0.250
10	*Ruang Olie Mesin Deck*	2.50	2.50	2.00	12.50	0.0375	0.6696	FAN	0.053
11	*Mate Spare*	2.00	2.75	2.00	11.00	0.0478	0.7511	A.C	0.250
12	*Ruang ABK 2*	3.00	2.75	2.00	16.50	0.0470	1.1079	A.C	0.370
13	*Ruang ABK 3*	2.00	2.00	2.00	8.00	0.0470	0.5371	A.C	0.250
14	*WC/KM ABK*	1.00	1.50	2.00	3.00	0.1050	0.4500	FAN	0.020
								Total	5.653


$B_p = \frac{N.P^{0.5}}{V_a^{2.5}}$ $\delta = \frac{N\,D}{V_a}$
N = Revs/min
P = shp (1 hp = 76 kgm/sec)
D = diameter in feet
$V_a = V_s(1-\psi)$ in kn.
H_o/D
1,4
1,3
1,2
1,1
1,0
,9
,8
,7
,6
,5
B_p
5
10
15
20
25
30
40
50
60
70
δ = 70
80
90
100
110
120
130
140
δ = 150
160
170
180
190
200
210
220
230
240
250
260
270
280
290
300
310
320
$n_p = 76$
78
77
75
74
73
72
71
70
65
$n_p = 60$
$n_p = 55$
50
45

KURVA MATCHING DAYA, PUTARAN DAN TORSI



LAMPIRAN

MAN B&W Diesel AG
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D-86135 Augsburg
Telephone (08 21) 32 20
Telex 53 796-0 man d
Telefax (08 21) 322 3382

Status: August 1996

Four-stroke
Diesel engine programme

MAN
B&W

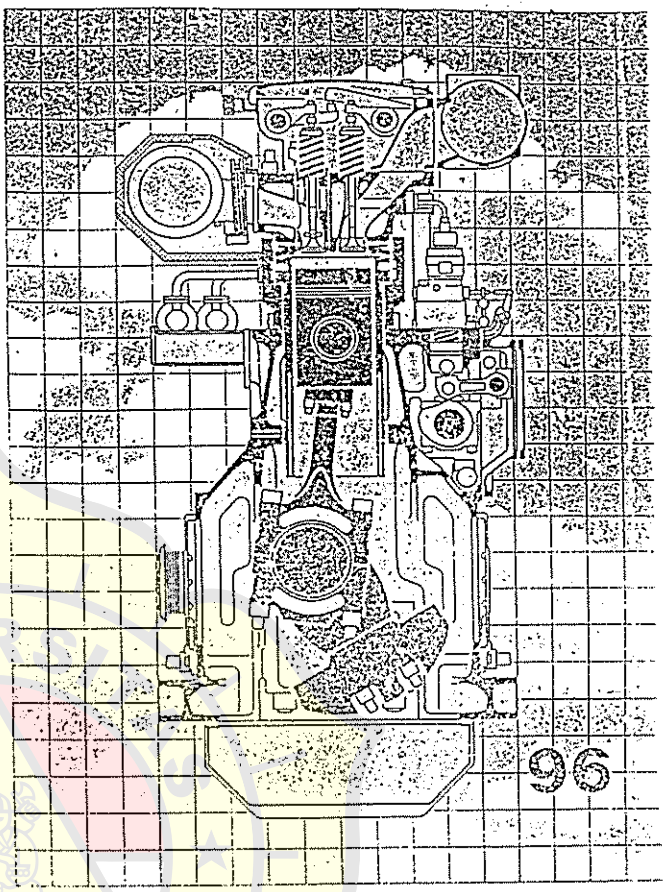

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Table of contents

Type	Power range kW	Speed range 1/min	Page
Definitions			4/5
Diesel engines			
L-V 20/27	450– 1800	900–1000	6
L-V 32/40	2200– 7920	720– 750	7
L 40/54	4200– 6480	500– 550	8
L-V 48/60	6300–18900	500– 514	9
L 58/64	7600–12510	400– 428	10
Dual fuel engines			
L-V 20/27 DG	405– 1520	900–1000	11
L-V 32/40 DG	2400– 7200	720– 750	12
L-V 48/60 DG	5400–16200	500– 514	13
Holeby Genset			
L 16/24	450– 900	1000–1200	14
L 23/30 H	530– 1280	720– 900	15
L-V 28/32 H	880– 3960	720– 750	16
L 32/40	2200– 3960	720– 750	17
Spark-fired gas engines			
L-V 28/32 SI	1000– 3600	720– 750	18
Alpha Diesel propulsion systems			
L-V 23/30 A-KV/VO	800– 1920	800– 900	19
L-V 28/32 A-VO	1470– 3920	775	20
Standard rating values generating sets with gas- and dual-fuel engines			21
Standard rating values Diesel generating sets			22/23
Fuel cost savings			24/25

Engine power ranges of marine propulsion engines

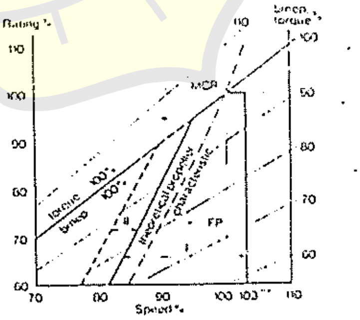

Fig. 1: Marine propulsion engine with fixed-pitch propeller

MCR = maximum continuous rating (fuel stop power)
I = operating range for continuous service
II = operating range temporarily admissible, e.g. during acceleration, manoeuvring (torque limit)
FP = design range for fixed-pitch propeller (Fig. 1)
VP = design range for controllable-pitch propeller with combinator (Fig. 2)

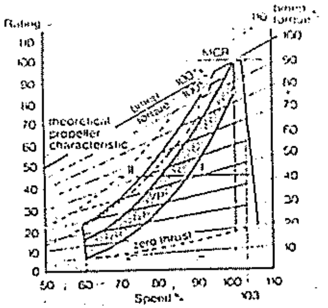

Fig. 2: Marine propulsion engine with controllable-pitch propeller

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L 20/27
V 20/27

No. of cyl.	Continuous rating P MCR kW/HP diesel and heavy fuel operation n (1/min) 1000	900	Dimensions mm L1/L2	W	H	Weight** tons
5 L	500 680	450 610	2700 1710	1350	1900	5.0
6 L	600 815	540 730	3000 2000	1350	1900	5.9
7 L	700 950	630 855	3300 2450	1350	1950	6.6
8 L	800 1090	720 980	3560 2730	1350	2150	7.4
9 L	900 1225	810 1100	3809 3010	1350	2150	8.0
12 V	1200 1630	1060 1470	3600 3400	1510	2600	10.6
14 V	1400 1900	1260 1715	3950 3200	1510	2750	11.8
16 V	1600 2180	1440 1960	4300 4150	1510	2750	13.1
18 V	1800 2450	1620 2200	4650 4500	1510	2750	14.4

Bore (mm)	Stroke (mm)		n (1/min)	kW/cyl. (HP/cyl.)	pe (bar)	cm (m/s)
200	270	MCR	1000	100 (136)	14.15	9.0
			900	90 (122)		8.1

Fuel consumption (to ISO conditions):*					
		100 % P		85 % P	
L 20/27	MCR	200 g/kWh	147 g/HPh	200 g/kWh	147 g/HPh
V 20/27		199 g/kWh	146 g/HPh	199 g/kWh	146 g/HPh

Lube oil consumption: approx. 1.2 g/kWh 0.9 g/HPh

L 32/40
V 32/40

No. of cyl.	Continuous rating P MCR kW/HP diesel and heavy fuel operation n (1/min) 750	720	Dimensions mm L1/L2	W	H	Weight** tons
5 L	2200 3000	2200 3000	5095 3500	2100	3890	33
6 L	2640 3600	2640 3600	5625 4480	2100	3890	38
7 L	3080 4200	3080 4200	6155 5010	2570	4410	42
8 L	3520 4800	3520 4800	6685 5540	2570	4410	47
9 L	3960 5400	3960 5400	7215 6070	2570	4410	52
12 V	5280 7200	5280 7200	6250 5100	3100	3900	61
14 V	6160 8400	6160 8400	7100 5750	3100	4200	70
16 V	7040 9600	7040 9600	7750 6400	3100	4200	79
18 V	7920 10800	7920 10800	8400 7000	3100	4200	86

Bore (mm)	Stroke (mm)		n (1/min)	kW/cyl. (HP/cyl.)	pe (bar)	cm (m/s)
320	400	MCR	750	440 (600)	21.9	10.0
			720	440 (600)	22.8	9.6

Fuel consumption (to ISO conditions):*					
		100 % P		85 % P	
L 32/40	MCR	182 g/kWh	134 g/HPh	179 g/kWh	132 g/HPh
V 32/40		181 g/kWh	133 g/HPh	178 g/kWh	131 g/HPh

Lube oil consumption: approx. 1,0 g/kWh 0,7 g/HPh

Definitions

General definiton of Diesel engine ratings (acc. to ISO 3046/I)

P = Continuous rating

10% overload capacity for 1 hour within 12 operating hours

Reference conditions:
Air temperature [illegible]
Air pressure 1 bar
Cooling water
temperature upstream of
charge air cooler [illegible]

Marine auxiliary engines

P = Continuous Rating

10% overload capacity for 1 hour within 12 operating hours

Reference conditions:
Air temperature: 318 K (45° C)
Air pressure: 1 bar
Cooling water
temperature upstream of
charge air cooler: 305 K (32° C)

[illegible] engines

Definitions

n	Rated engine speed
pe	Mean effective pressure
cm	Mean piston speed
L1	Overall engine length
L2	Length at crankshaft centreline
W	Overall engine width
H	Overall engine height
Weight	Dry weight without fly wheel (tolerance 5%)

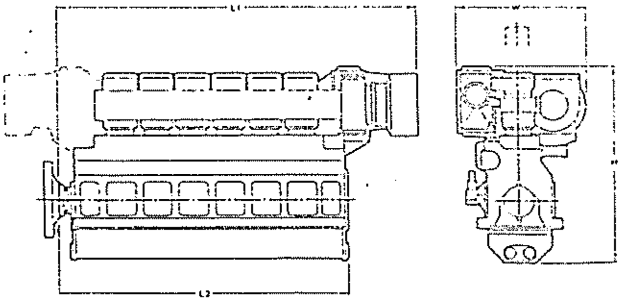
Key to engine type designations

e.g. L or V 20/27

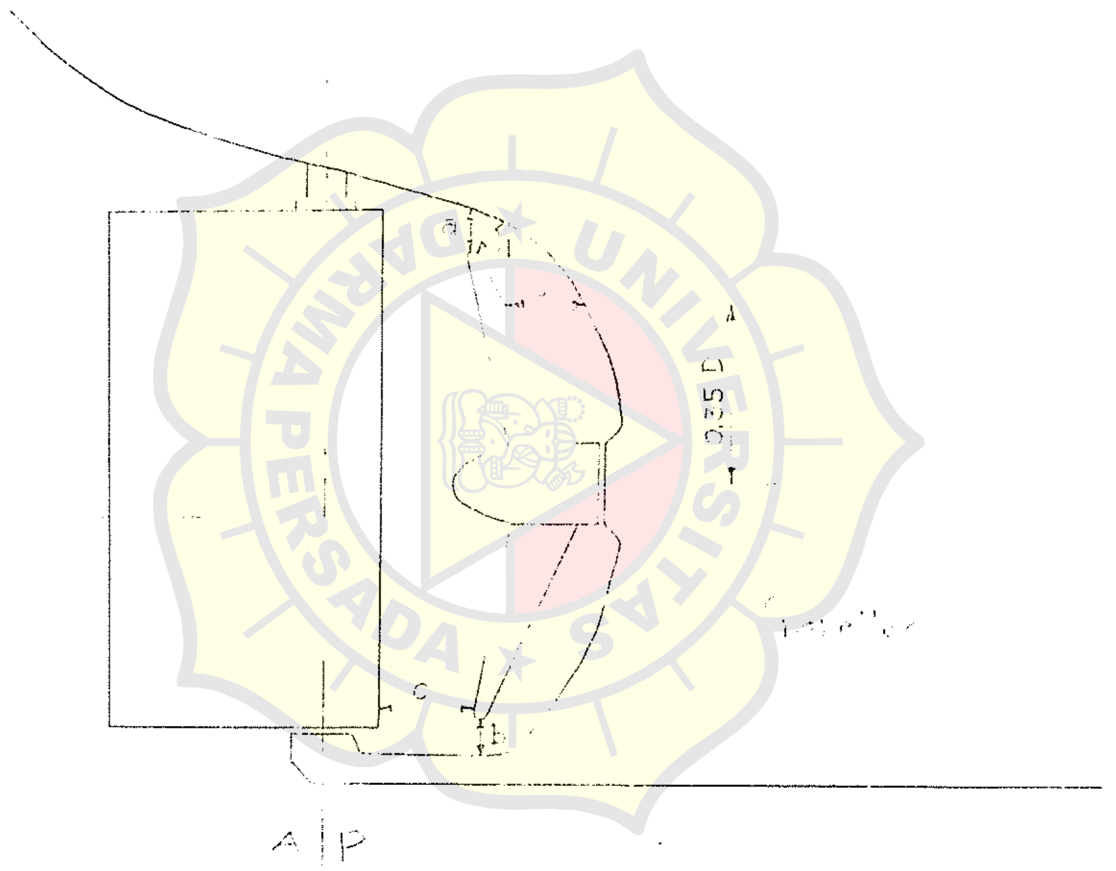
L	= in-line engine
V	= V-engine
20	= bore in cm
27	= stroke in cm

e.g. L 28/32A–VO

VO, KV	= designation for complete propulsion system



The fuel consumption rates are based on ISO conditions (25° C ambient temperature, 25° C cooling water temperature upstream of charge air cooler, 1 bar barometric pressure) and a net calorific value of the fuel of 42,700 kJ/kg. Tolerance + 3%


a
0.25 D
c
b
A P

1.2.3 For engines with a power of up to 600 kW relaxations may be agreed with the Society.

2. Auxiliary engines

2.1 As a minimum requirement, the following indicating instruments are to be mounted in a logical manner on the engine:

- Tachometer
- Pressure gauge for lubricating oil pressure
- Pressure gauge for fuel pressure
- Pressure gauge for cooling water pressure
- Thermometer for cooling water
- Thermometer for fuel (only for engines running on heavy fuel oil)

2.2 Engines of over 50 kW power are to be equipped with an engine alarm system responding to the lubricating oil pressure and to the pressure or flow-rate of the cooling water.

K. Auxiliary Systems

1. Lubricating oil system

1.1. General requirements relating to lubricating oil systems and to the cleaning, cooling etc. of the lubricating oil are contained in Section 11, H., for filters, see G.3.

1.1.1 Engines whose sumps serve as oil reservoirs must be so equipped that the oil level can be established and, if necessary, topped up during operation. Means must be provided for completely draining the oil sump.

1.1.2 The combination of the oil drainage lines from the crankcases of two or more engines is not allowed

1.2 The equipment of engines fitted with lubricating oil pumps is subject to Section 11, H.3.

1.2.1 Main lubricating oil pumps driven by the engine are to be designed to maintain the supply of lubricating oil over the entire operating range.

1.2.2 Main engines which drive main lubricating oil pumps are to be equipped with independently driven stand-by pumps or with means for connecting the lubricating oil system to independently driven stand-by pumps.

1.2.3 In installations comprising more than one main engine and with separate lubricating oil systems approval may be given for the carriage on board of reserve pumps ready for mounting provided that the arrangement of the main lubricating oil pumps enables the change to be made with the means available on board.

2. Cooling system

2.1 For the equipment of engines with cooling water pumps and for the design of cooling water systems, see Section 11, J. and K.

2.2.1 Main cooling water pumps driven by the engine are to be designed to maintain the supply of cooling water over the entire operating range.

2.2.2 Main engines which drive main cooling water pumps are to be equipped with independently driven stand-by pumps or with means for connecting the cooling water system to independently driven stand-by pumps.

2.2.3 In installations comprising more than one main engine and with separate fresh cooling water systems approval may be given for the carriage on board of reserve pumps ready for mounting provided that the arrangement of the main fresh cooling water pumps enables the change to be made with the means available on board. Shutoff valves must be provided enabling the main pumps to be isolated from the fresh cooling water system.

2.3 If cooling air is drawn from the engine room, the design of the cooling system is to be based on a room temperature of at least 45 °C.

The exhaust air of air-cooled engines may not cause any unacceptable heating of the spaces in which the plant is installed. The exhaust air is normally to be led to the open air through special ducts.

2.4 Where engines are installed in spaces in which oil-firing equipment is operated, Section 9, A.5 is also to be complied with.

3. Charge air system

3.1 Exhaust gas turbocharger

3.1.1 The construction and testing of exhaust gas turbocharger are subject to Section 3/II (Gas Turbines).

3.1.2 Exhaust gas turbocharger may exhibit no critical speed ranges over the entire operating range of the engine.

3.1.3 The lubricating oil supply must also be ensured during start-up and run-down of the exhaust gas turbocharger.

3.1.4 Even at low engine speeds, main engines must be supplied with charge air in a manner to ensure reliable operation.

Appendix to Section 2

Part C :

Approximate Calculation of the Starting Air Supply

1. Starting air for installations with reversible engines

Assuming an initial pressure of 30 bar and a final pressure of 9 bar in the starting air receivers, the preliminary calculation of the starting air supply for a reversible main engine may be performed as follows:

$$J = a \bullet \sqrt[3]{\frac{H}{D}} \bullet (z + b \bullet p_{e,e} \bullet n_A + 0{,}9) \bullet V_h \bullet c \qquad (13)$$

where

J	[dm^3]	total capacity of the starting air receivers
D	[mm]	cylinder bore
H	[mm]	stroke
V_h	[dm^3]	swept volume of one cylinder (in the case of double-acting engines, the swept volume of the upper portion of the cylinder)
$P_{c,perm}$	[bar]	maximum permissible working pressure of the starting air receiver
z	[-]	number of cylinders
P_{cc}	[bar]	mean effective working pressure in cylinder at rated power

The following values of "a" are to be used:

- for two-stroke engines: a = 0,4714
- for four-stroke engines: a = 0,4190

The following values of "b" are to be used:

- for two-stroke engines: b = 0,059
- for four-stroke engines: b = 0.056

The following values of "c" are to be used:

c = 1, where $P_{c,perm}$ = 30 bar

$$c = \frac{0{,}0584}{1 - e^{(0{,}11 - 0{,}05 \bullet 1_a \bullet p_{c,perm})}}$$

where $p_{c,perm} \neq 30$ bar, if no pressure-reducing valve is fitted.

e [-] Euler's number (2,718....)

If a pressure-reducing valve is fitted, which reduces the pressure $p_{c,perm}$ to the starting pressure P_A, then the value of "c" shown in Fig. 2.14 is to be used.

The following values of n_A are to be applied:

$n_A = 0{,}06 \cdot n_o + 14$ where $n_o \leq 1000$

$n_A = 0{,}25 \cdot n_o - 176$ where $n_o > 1000$

n_o [Rpm] = rated speed

2. Starting air for installations with non reversible engines

For each non-reversible main engine driving a controllable pitch propeller or where starting without torque resistance is possible the calculated starting air supply may be reduced to 0,5 . J though not less than that needed for six start-up operations.

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Section 4

Main Shafting

A. General

1. Scope

The following Rules apply to standard and established types of main shafting. Novel designs require the Society's special approval.

In the case of ships with ice classes, the strengthening factors given in Section 13 are to be complied with. The Society reserves the right to call for propeller shaft dimensions in excess of those specified in this Section if the propeller arrangement results in increased bending stresses.

2. Documents for approval

General drawings of the entire shafting, from the main engine coupling flange to the propeller and detail drawings of the shafts, couplings and other component parts transmitting the propelling engine torque, are each to be submitted to the Society in triplicate[1]) for approval. The drawings must contain all the data necessary to enable the stresses to be evaluated.

B. Materials

1. Approved materials

Propeller, intermediate and thrust shafts together with flange and clamp couplings are to be made of forged steel; where appropriate, couplings may be made of cast steel. Rolled round steel may be used for plain, flangeless shafts.

In general, the tensile strength of steels used for shafting shall be between 400 N/mm² and 800 N/mm². However, the value of Rm used for calculation the material factor Cw in accordance with formula (2) for propeller shafts shall not be greater than 600 N/mm².

Where in special cases wrought copper alloys resistant to seawater are to be used for the shafting, the consent of BKI shall be obtained.

2. Testing of materials

All component parts of the shafting which assist in transmitting the torque from the ship's propulsion plant are subject to the Society's Rules for Materials and must be tested. This requirement also covers metal propeller shaft liners. Where propeller shafts running in seawater are protected against seawater penetration not by a metal liner but by plastic coatings, the coating technique used must be approved by the Society.

C. Shaft Dimensions

1. General

All parts of the shafting are to be dimensioned in accordance with the following formulae in compliance with the requirements relating to torsional vibrations set out in Section 16. The dimensions of the shafting shall be based on the total rated installed power. Where the geometry of a part is such that it cannot be dimensioned in accordance with these formulae, special evidence of the mechanical strength of the part or parts concerned is to be furnished to the Society.

2. Minimum diameter

The minimum shaft diameter is to be determined by applying formula (1).

$$d \ge F \cdot k \cdot \sqrt[3]{\frac{P_w}{n \cdot \left[1 - \left(\frac{d_i}{d_a}\right)^4\right]}} \cdot C_w \le d_a \qquad (1)$$

d [mm] required outside diameter of shaft

d_i [mm] diameter of shaft bore, where present. If the bore in the shaft is ≤ 0,4 · d_a, the expression

$$1 - \left(\frac{d_i}{d_a}\right)^4 = 1{,}0 \text{ may be applied}$$

d_a [mm] actual shaft diameter

P_w [kW] rated power transmitted by shaft

---

[1] For ships flying Indonesian flag in quadruplicate, one of which is intended for [illegible] Indonesian Government [illegible]

n [Rpm] rated shaft speed

F [-] factor for the type of propulsion installation

a) Intermediate and thrust shafts
= 95
for turbine installations, engine installations with slip couplings and electric propulsion installations

= 100
for all other propulsion installations

b) Propeller shafts
= 100
for all types of installations

C_w [-] material factor

$$= \frac{560}{R_m + 160} \qquad (2)$$

R_m [N/mm²] Tensile strength of the shaft material (see also B.1)

k [-] Factor for the type of shaft

k = 1,0 for **intermediate shafts** with integral forged coupling flanges or with shrink-fitted keyless coupling flanges

k =1,10 for **intermediate shafts** where the coupling flanges are mounted on the ends of the shaft with the aid of keys. At a distance of at least 0,2 . d from the end of the keyway, such shafts can be reduced to a diameter corresponding to k = 1,0.

k =1,10 for **intermediate shafts** with radial holes whose diameter is not greater than 0,3 · d.

k =1,10 for **thrust shafts** near the plain bearings on either side or the thrust collar, or near the axial bearings where an antifriction bearing design is used.

k =1,15 for **intermediate shafts designed** as multi-splined shafts where d is the outside diameter of the splined shaft. Outside the splined section, the shafts can be reduced to a diameter corresponding to k = 1,0

k =1,20 for **intermediate shafts** with longitudinal slots where the length and width of the slot do not exceed 1,17 · d and 0,25 · d respectively.

k =1,22 for **propeller shafts** from the area of the aft stern tube or shaft bracket bearing to the forward load-bearing face of the propeller boss subject to a minimum [illegible] propeller is shrink fitted, without key, on to the tapered end of the propeller shaft using a method approved by the Society, or if the propeller is bolted to a flange forged on the propeller shaft, the propeller shaft runs in oil.

k =1,26 for **propeller shafts** in the area specified for k= 1,22, if the propeller is keyed to the tapered propeller shaft and the propeller shaft runs in oil, and also for water-lubricated propeller shafts which are protected against the penetration of seawater in accordance with D.3.2.

k =1,40 for **propeller shafts in** the area specified for k = 1,22, if the shaft inside the stern tube is lubricated with grease.

k =1,15 for **propeller shafts** forward portion of shafts to where they emerge from the stern tube. The portion of the propeller shaft located forward of the stern tube can be reduced to the size of the line shaft.

D. Design

1. General

Changes in diameter are to be effected by tapering or ample radiusing. For intermediate shafts, the radius at forged flanges is to be at least 0,08 ·d, that at the aft propeller shaft flange at least 0,125 ·d.

2. Shaft tapers and propeller nut threads

Keyways in the shaft taper for the propeller should be so designed that the forward end of the groove makes a gradual transition to the full shaft section. In addition, the forward end of the keyway should be spoon-shaped. The edges of the keyway at the surface of the shaft taper for the propeller may not be sharp. The forward end of the keyway must lie well within the seating of the propeller boss. Threaded holes to accommodate the securing screws for propeller keys should be located only in the aft half of the keyway (see Fig. 4.1).

In general, tapers for securing flange couplings should have a conicity of between 1: 10 and 1: 20. In the case of shaft tapers for propellers, the conicity must be between 1:10 and 1:15. Where the oil [illegible] at the propeller [illegible]

1.8 For the double bottom structure of bulk carriers, see Section 23, B.4.

1.9 For bottom strengthening forward see Section 6, E.

1.10 For the material factor k see Section 2, B.2. For the corrosion allowance t_K see Section 3, K.1.

2. Centre girder

2.1 Lightening holes

Lightening holes in the centre girder are generally permitted only outside 0,75 L amidships. Their depth is not to exceed half the depth of the centre girder and their lengths are not to exceed half the frame spacing.

2.2 Scantlings

Depth h and thickness t of the centre girder are not to be less than:

.1 $h = 350 + 45 \cdot B$ [mm]

$h_{min} = 600$ mm

Where longitudinal wing bulkheads are fitted, the distance between the bulkheads may be inserted in lieu of B, however, not less than 0,8 B.

.2 within 0,7 L amidships:

$$t = \left[\frac{h}{100} - 1{,}0\right]\sqrt{k} \quad [\text{mm}]$$

for $h \le 1200$ [mm]

$$t = \left[\frac{h}{120} - 3{,}0\right]\sqrt{k} \quad [\text{mm}]$$

for $h > 1200$ [mm].

The thickness may be reduced by 10 per cent for 0,15 L at the ends.

.3 Where the actual depth of the centre girder exceeds the rule depth h according to .1, the thickness t may be reduced accordingly, provided sufficient buckling and shear strength is maintained.

3. Side girders

3.1 Arrangement

At least one side girder shall be fitted in the engine room and in way of 0,25 L aft of F.P. In the other parts of the double bottom, one side girder shall be fitted where the horizontal distance between ship's side and centre girder exceeds 4,5 m. Two side girders shall be fitted where the distance exceeds 8 m, and three side girders where it exceeds 10,5 m. The distance of the side girders from each other and from centre girder and ship's side respectively shall not be greater than:

1,8 m	in the engine room within the breadth of engine seatings,
4,5 m	where one side girder is fitted in the other parts of double bottom,
4,0 m	where two side girders are fitted in the other parts of double bottom,
3,5 m	where three side girders are fitted in the other parts of double bottom.

3.2 Scantlings

3.2.1 The thickness of the side girders is not to be less than:

$$t = \frac{h}{120}\sqrt{k} \quad [\text{mm}]$$

h = depth of the centre girder in [mm] according to 2.2.1.

Proof of adequate buckling strength of the side girders may be required where deemed necessary. For strengthenings under the engine seating, see C.2.3.

3.2.2 The scantlings of watertight and oil tight side girders are also to be in accordance with the requirements given under 6.3.

3.2.3 Lightening holes in the side girders are to be of such size as to leave a remainder of web plate around the hole not less than 0,2 of the height of side girder or of frame spacing. Where the holes are fitted with flat bars, the above value may be reduced to 0,15.

4. Inner bottom

4.1 The thickness of the inner bottom plating is not to be less than:

$t = 1{,}1 \cdot a\sqrt{[illegible]} + t_K$ [mm]

p = design pressure [kN/m²]

4.2.2 An additional stringer may be required in the after ship outside the afterpeak where frames are inclined considerably and not fitted vertically to the shell.

5. Strengthenings in fore- and aft body

5.1 General

As far as practicable and possible, tiers of beams or web frames and stringers are to be fitted in the fore- and afterpeak.

5.2 Tiers of beams

5.2.1 Forward of the collision bulkhead, tiers of beams (beams at every other frame) generally spaced not more than 2,6 m apart, measured vertically, are to be arranged below the lowest deck within the forepeak. Stringer plates are to be fitted on the tiers of beams which are to be connected by continuous welding to the shell plating and by a bracket to each frame. The scantlings of the stringer plates are to be determined from the following formulae:

width $b = 75\ \sqrt{L}$ [mm]

thickness $t = 6{,}0 + L/40$ [mm].

5.2.2 The cross sectional area of each beam is to be determined according to Section 10, C.2 for a load

$P = A \cdot p$ [kN]

A = load area of a beam in [m^2]

p = p_S or p_e, whichever is applicable.

5.2.3 In the afterpeak, tiers of beams with stringer plates generally spaced 2,6 m apart measured vertically, are to be arranged as required under 5.2.1, as far as practicable with regard to the ship's shape.

5.2.4 [illegible] stringers in the [illegible] scalloping at the shell [illegible] holes required for welding [illegible]

5.2.5 [illegible] as tanks, stringer [illegible] are to be fitted at [illegible] effectively fitted [illegible] inner edges [illegible] forces can be properly [illegible]

5.2.6 Wh[illegible] instead of [illegible] be [illegible] as [illegible]

for wash bulkheads according to Section 12, G. The requirements regarding cross sectional area stipulated in 5.2.2 are, however, to be complied with.

5.3 Web frames and stringers

5.3.1 Where web frames and supporting stringers are fitted instead of tiers of beams, their scantlings are to be determined as follows:

.1 Section modulus:

$$W = 0{,}6 \cdot e \cdot \ell^2 \cdot p_S \cdot n \cdot k\ [\text{cm}^3]$$

.2 Web sectional area at the supports:

$$A_w = 0{,}061 \cdot e \cdot \ell_1 \cdot p_S \cdot k\ \ [\text{cm}^2]$$

ℓ = unsupported span in [m], without consideration of cross ties, if any

ℓ_1 = similar to ℓ, however, considering cross ties, if any

n = coefficient according to the following Table 9.1.

Table 9.1

Number of cross ties	n
0	1,0
1	0,5
2	0,3
≥ 3	0,2

5.3.2 Vertical transverses are to be interconnected by cross ties the cross sectional area of which is to be determined according to 5.2.2.

5.4 Web frames and stringers in 'tween decks and superstructure decks

Where the speed of the ship exceeds $v_0 = 1{,}6\ \sqrt{L}$ [kn] or in ships with a considerable bow flare respectively, stringers and transverses according to 5.3 are to be fitted within 0.2 L from forward perpendicular in 'tween deck spaces and superstructures.

5.5 Tripping brackets

5.5.1 Between the point of greatest breadth [illegible] ship at maximum draft and the collision [illegible] tripping brackets spaced not more than [illegible] sured vertically, according to Fig. [illegible]

1.5.2 A combination of a non-return valve without shut-off mechanism and a shut-off valve may be recognized as equivalent with the Society's approval.

1.6 Pipe connections

1.6.1 To prevent the penetration of ballast and seawater into the ship through the bilge system, two means of reverse-flow protection are to be fitted in the bilge connections, one of which is to be a screw-down non-return valve.

One of such means of protection is to be fitted in each suction line.

1.6.2 For bilge connections outside machinery spaces, a combination of a non-return valve without shut-off and a remote-controlled shut-off valve may be recognized as equivalent.

1.6.3 The direct bilge suction and the emergency injection need only have one means of reverse-flow protection as specified in 1.5.1.

1.6.4 Where a direct seawater connection is arranged for attached bilge pumps to protect them against running dry, the bilge suction are also to be fitted with two screw-down non-return valves.

1.6.5 The discharge lines of oily water separators are to be fitted with a non-return valve at the ship's side.

2. Calculation of pipe diameters

2.1 The calculated values according to formulae (4) to (6) are to be rounded up to the next higher nominal diameter.

2.2 Dry cargo and passenger ships

a) main bilge pipes

$$d_H = 1{,}68 \cdot \sqrt{(B + H) \cdot L} + 25 \ [mm] \qquad (4)$$

b) branch bilge pipes

$$d_z = 2{,}15 \cdot \sqrt{(B + H) \cdot l} + 25 \ [mm]$$

where

d_H	[mm]	calculated inside diameter of main bilge pipe
d_z	[mm]	calculated inside diameter of branch bilge pipe
L	[m]	length of ship between perpendiculars
B	[m]	moulded breadth of ship
H	[m]	depth of ship to the bulkhead deck
l	[m]	length of the watertight compartment

2.3 Tankers

The diameter of the main bilge pipe in the engine rooms of tankers and bulk cargo/oil carriers is calculated using the formula:

$$d_H = 3{,}0 \cdot \sqrt{(B + H) \cdot l_1} + 35 \ [mm] \qquad (6)$$

where:

l_1	[m]	total length of spaces between cofferdam or pump-room bulkhead and stern tube bulkhead

Other terms as in formulae (4) and (5).

Branch bilge pipes are to be dimensioned in accordance with 2.2 b). For bilge installations for spaces in the cargo area of tankers and bulk cargo/oil carriers see Section 15.

2.4 Minimum diameter

The inside diameter of main and branch bilge pipes is not to be less than 50 mm. For ships under 25 m length, the diameter may be reduced to 40 mm.

2.5 Maximum diameter

The diameter of the main bilge line calculated according to 2.2 a) need not exceed ND 200.

2.6 Deviations

Where in individual cases formula (5) requires a greater bilge pipe diameter than that determined by formula (4), a greater pipe diameter than that according to formula (4) is not necessary.

3. Bilge pumps

3.1 Capacity of bilge pumps

Each bilge pump must be capable of delivering:

$$Q = 5{,}75 \cdot 10 \qquad (7)$$

where:

Q	[m³/h]	minimum capacity
d_H	[mm]	calculated inside diameter of main bilge pipe

Section 14

Rudder and Manoeuvring Arrangement

A. General

1. Manoeuvring arrangement

1.1 Each ship is to be provided with a manoeuvring arrangement which will guarantee sufficient manoeuvring capability.

1.2 The manoeuvring arrangement includes all parts from the rudder and steering gear to the steering position necessary for steering the ship.

1.3 Rudder stock, rudder coupling, rudder bearings and the rudder body are dealt with in this Section. The steering gear is to comply with Volume III, Section 14.

1.4 The steering gear compartment shall be readily accessible and, as far as practicable, separated from the machinery space. (See also Chapter II-1, Reg. 29.13 of SOLAS 74.)

Guidance

Concerning the use of non-magnetic material in the wheel house in way of a magnetic compass, the requirements of the national Administration concerned are to be observed.

1.5 For ice-strengthening see Section 15.

2. Structural details

2.1 Effective means are to be provided for supporting the weight of the rudder body without excessive bearing pressure, e.g. by a rudder carrier attached to the upper part of the rudder stock. The hull structure in way of the rudder carrier is to be suitably strengthened.

2.2 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.3 The rudder stock is to be carried through the hull either enclosed in a watertight trunk, or glands are to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided.

3. Size of rudder area

In order to achieve sufficient manoeuvring capability the size of the movable rudder area A is recommended to be not less than obtained from the following formula:

$$A = c_1 \cdot c_2 \cdot c_3 \cdot c_4 \cdot \frac{1{,}75 \cdot L \cdot T}{100} \quad [m^2]$$

c_1 = factor for the ship type:

= 1,0 in general

= 0,9 for bulk carriers and tankers having a displacement of more than 50.000 ton

= 1,7 for tugs and trawlers

c_2 = factor for the rudder type:

= 1,0 in general

= 0,9 for semi-spade rudders

= 0,8 for double rudders (per rudder)

= 0,7 for high lift rudders

c_3 = factor for the rudder profile:

= 1,0 for NACA-profiles and plate rudder

= 0,8 for hollow profiles

c_4 = factor for the rudder arrangement:

= 1,0 for rudders in the propeller jet

= 1,5 for rudders outside the propeller jet

For semi-spade rudder 50% of the projected area of the rudder horn may be included into the rudder area A.

4. Materials

4.1 For materials for rudder stock, pintles, coupling bolts etc. see Rules for Material Volume V. Special material requirements are to be observed for the ice notations ES3 and ES4 as well as for the arctic ice notations Arc 1- Arc 4.

4.2 In general materials having a minimum nominal upper yield point R_{eH} of less than 200 N/mm^2 and a minimum tensile strength of less than 400 N/mm^2 or more than 900 N/mm^2 shall not be used for rudder stocks, pintles, keys and bolts. The requirements of this Section are based on a material's minimum nominal upper yield point R_{eH} of 235 N/mm^2. If material is used having a R_{eH} differing from 235 N/mm^2, the material factor k_r is to be determined as follows:

$$k_r = \left[\frac{235}{R_{eH}}\right]^{0,75} \quad \text{for } R_{eH} > 235\ N/mm^2$$

$$k_r = \frac{235}{R_{eH}} \quad \text{for } R_{eH} < 235\ N/mm^2$$

R_{eH} = minimum nominal upper yield point of material used in $[N/mm^2]$. R_{eH} is not to be taken greater than $0,7 \cdot R_m$ or 450 N/mm^2, whichever is less. R_m = tensile strength of the material used.

4.3 Before significant reductions in rudder stock diameter due to the application of steels with R_{eH} exceeding 235 N/mm^2 are granted, the Society may require the evaluation of the elastic rudder stock deflections. Large deflections should be avoided in order to avoid excessive edge pressures in way of bearings.

4.4 The permissible stresses given in E.1. are applicable for ordinary hull structural steel. When higher tensile steels are used, higher values may be used which will be fixed in each individual case.

5. Definitions

C_R = rudder force in [N]

Q_R = rudder torque in [Nm]

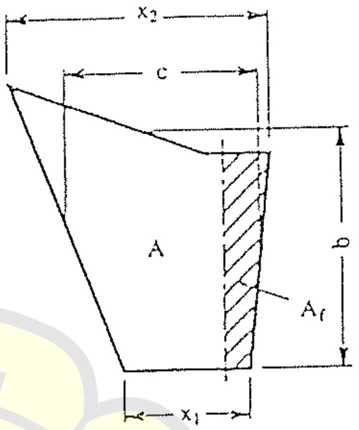
A = total movable area of the rudder in $[m^2]$
For nozzle rudders, A is not to be taken less than 1,35 times the projected area of the nozzle;

A_t = A + area of a rudder horn, if any, in $[m^2]$

A_f = portion of rudder area located ahead of the rudder stock axis in $[m^2]$

b = mean height of rudder area in [m]

c = mean breadth of rudder area in [m] (see Fig. 14.1)



$$c = \frac{x_1 + x_2}{2} \qquad b = \frac{A}{c}$$

Fig. 14.1

Λ = aspect ratio of rudder area A_t

$\Lambda = b^2/A_t$

v_0 = ahead speed of ship in [kn] as defined in Section 1, H.5. if this speed is less than 10 kn, v_0 is to be taken as

$$v_{min} = (v_0 + 20)/3 \ [kn]$$

v_a = astern speed of ship in [kn]; if the astern speed $v_a \leq 0,4 \cdot v_0$ or 6 kn, whichever is less, determination of rudder force and torque for astern condition is not required. For greater astern speeds special evaluation of rudder force and torque as a function of the rudder angle may be required. If no limitations for the rudder angle at astern condition is stipulated, the factor κ_2 is not to be taken less than given in Table 14.1 for astern condition.

k = material factor according to Section 2, B.2.

B. Rudder Force and Torque

1. Rudder force and torque for normal rudders

1.1 The rudder force is to be determined according to the following formula:

C_R = $132 \cdot A \cdot v^2 \cdot \kappa_1 \cdot \kappa_2 \cdot \kappa_3 \cdot \kappa_t$ [N]

v = v_0 for ahead condition

v = v_a for astern condition

κ_1 = coefficient, depending on the aspect ratio Λ

κ_1 = $(\Lambda + 2)/3$, where Λ need not be taken greater than 2

κ_2 = coefficient, depending on the type of the rudder and the rudder profile according to Table 14.1.

κ_3 = coefficient, depending on the location of the rudder

κ_3 = 0,8 for rudders outside the propeller jet

κ_3 = 1,15 for rudders aft of the propeller nozzle

κ_3 = 1,0 elsewhere, including also rudders within the propeller jet

κ_t = coefficient depending on the thrust coefficient c_t

κ_t = 1,0 normally

In special cases for thrust coefficients $c_t > 1,0$ determination of κ_t according to the following formula may be required:

$$\kappa_t = \frac{C_R\,(c_t)}{C_R\,(c_t = 1,0)}$$

Table 14.1

Profile/ type of rudder	κ_2	
	ahead	astern
NACA-00 series Göttinger profiles	1,1	1,4
flat side profiles	1,1	1,4
hollow profiles	1,35	1,4
high lift rudders	1,7	to be specially considered; if not known: 1,7

1.2 The rudder torque is to be determined by the following formula:

Q_R = $C_R \cdot r$ [Nm]

r = $c\,(\alpha - k_b)$ [m]

α = 0,33 for ahead condition

α = 0,66 for astern condition (general)

α = 0,75 for astern condition (hollow profiles)

For parts of a rudder behind a fixed structure such as a rudder horn:

α = 0,25 for ahead condition

α = 0,55 for astern condition.

For high lift rudders α is to be specially considered. If not known, $\alpha = 0,4$ may be used for the ahead condition

k_b = balance factor as follows:

k_b = A_f/A

k_b = 0,08 for unbalanced rudders

r_{min} = $0,1 \cdot c$ [m] for ahead condition.

2. Rudder force and torque for rudder blades with cut-outs (semi-spade rudders)

2.1 The total rudder force C_R is to be calculated according to 1.1. The pressure distribution over the rudder area, upon which the determination of rudder torque and rudder blade strength is to be based, is to be derived as follows:

The rudder area may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2 (see Fig. 14.2).

The resulting force of each part may be taken as:

$$C_{R1} = C_R\,\frac{A_1}{A}\ [\text{N}]$$

$$C_{R2} = C_R\,\frac{A_2}{A}\ [\text{N}]$$

2.2 The resulting torque of each part may be taken as:

Q_{R1} = $C_{R1} \cdot r_1$ [Nm]

Q_{R2} = $C_{R2} \cdot r_2$ [Nm]

r_1 = $c_1\,(\alpha - k_{b1})$ [m]

r_2 = $c_2\,(\alpha - k_{b2})$ [m]

k_{b1} = A_{1f}/A_1

k_{b2} = A_{2f}/A_2

A_{1f}, A_{2f} see Fig. 14.2

C_1 = A_1/b_1

$C_2 = A_2/b_2$

b_1, b_2 = mean heights of the partial rudder areas A_1 and A_2 (see Fig. 14.2).

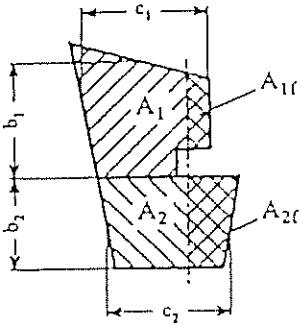


Fig. 14.2

2.3 The total rudder torque is to be determined according to the following formulae:

$Q_R = Q_{R1} + Q_{R2}$ [Nm] or

$Q_{Rmin} = C_R \cdot r_{1,2min}$ [Nm].

$r_{1,2min} = \frac{0,1}{A}(c_1 \cdot A_1 + c_2 \cdot A_2)$ [m]

for ahead condition

The greater value is to be taken.

C. Scantlings of the Rudder Stock

1. Rudder stock diameter

1.1 The diameter of the rudder stock for transmitting the torsional moment is not to be less than:

$$D_t = 4,2 \sqrt[3]{Q_R \cdot k_r} \quad [\text{mm}]$$

Q_R see B. 1.2 and B. 2.2 - 2.3.

The related torsional stress is:

$$\tau_t = \frac{68}{k_r} \quad [\text{N/mm}^2]$$

k_r see A.4.2.

1.2 The diameter of the rudder stock determined according to 1.1 is decisive for the steering gear, the stoppers and the locking device.

1.3 In case of mechanical steering gear the diameter of the rudder stock in its upper part which is only intended for transmission of the torsional moment from the auxiliary steering gear may be 0,9 D_t. The length of the edge of the quadrangle for the auxiliary tiller must not be less than 0,77 D_t and the height not less than 0,8 D_t.

1.4 The rudder stock is to be secured against axial sliding. The degree of the permissible axial clearance depends on the construction of the steering engine and on the bearing.

2. Strengthening of rudder stock

2.1 If the rudder is so arranged that additional bending stresses occur in the rudder stock, the stock diameter has to be suitably increased. The increased diameter is, where applicable, decisive for the scantlings of the coupling.

For the increased rudder stock diameter the equivalent stress of bending and torsion is not to exceed the following value:

$$\sigma_v = \sqrt{\sigma_b^2 + 3\,\tau^2} \leq 118/k_r \quad [\text{N/mm}^2]$$

Bending stress:

$$\sigma_b = \frac{10,2 \cdot M_b}{D_1^3} \quad [\text{N/mm}^2]$$

M_b = bending moment at the neck bearing in [Nm]

Torsional stress:

$$\tau = \frac{5,1 \cdot Q_R}{D_1^3} \quad [\text{N/mm}^2]$$

D_1 = increased rudder stock diameter in [cm]

The increased rudder stock diameter may be determined by the following formula:

$$D_1 = D_t \sqrt[6]{1 + \frac{4}{3}\left[\frac{M_b}{Q_R}\right]^2}$$

Q_R see B.1.2 and B.2.2 - 2.3

D_t see 1.1.

Guidance

Where a double-piston steering gear is fitted, additional bending moments may be transmitted from the steering gear into the rudder stock. These additional bending moments are to be taken into account for determining the rudder stock diameter.

$$Z = D^{2/3} + 2\,h\,B + \frac{A}{10}$$

D = moulded displacement in [ton] (in sea water having a density of 1,025 t/m^3) to the summer load waterline

h = effective height from the summer load waterline to the top of the uppermost house

$h = f_b + \sum h'$

f_b = freeboard in [m], from the summer load waterline amidships

A = area in [m^2], in profile view of the hull, superstructures and houses, having a breadth greater then B/4, above the summer load waterline within the length **L** and up to the height h

$\sum h'$ = sum of height in [m] of superstructures and deckhouses, on the centreline of each tier having a breadth greater than B/4. Deck sheer, if any, is to be ignored. For the lowest tier, "h" is to be measured at centreline from the upper deck or from a notional deck line where there is local discontinuity in the upper deck.

Where a deckhouse having a breadth greater than B/4 is located above a deckhouse having a breadth of B/4 or less, the wide house is to be included and the narrow house ignored.

Screens of bulwarks 1,5 m or more in height are to be regarded as parts of houses when determining h and A, e.g. the area shown in Fig. 18.1 as A_1 is to be included in A. The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining h and A.

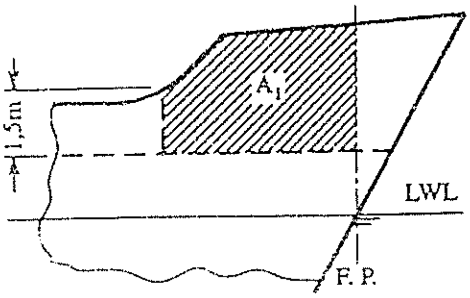


Fig. 18.1

[illegible]

[illegible]

connected to their chain cables and positioned on board ready for use. Where in column 3 of table 18.2 three bower anchors are required the third anchor is intended as a spare bower anchor. Installation of the spare bower anchor on board is not required. Upon agreement by the owner the spare anchor may even be dispensed with.

Guidance

National regulations concerning the provision of a spare anchor may need to be observed.

2. Anchors must be of approved design. The mass of the heads of patent (ordinary stockless) anchors, including puns and fittings, is not to be less than 60 percent of the total mass of the anchor.

3. For stock anchors, the total mass of the anchor, including the stock, shall comply with the values in Table 18.2. The mass of the stock shall be 20 percent of this total mass.

4. The mass of each individual bower anchor may vary by up to 7 per cent above or below the required individual mass provided that the total mass of all the bower anchors is not less than the sum of the required individual masses.

5. Where special anchors approved as "High Holding Power Anchors" are used, the anchor mass may be 75 per cent of the anchor mass as per Table 18.2.

"High Holding Power Anchors" are anchors which are suitable for ship's use at any time and which do not require prior adjustment or special placement on the sea bed.

For approval as a "High Holding Power Anchor", satisfactory tests are to be made on various types of bottom and the anchor is to have a holding power at least twice that of a patent anchor ("Admiralty Standard Stockless") of the same mass. The weights of anchors to be tested should be representative of the full range of sizes intended to be manufactured. The tests are to be carried out on at least two sizes of anchors in association with the chain cables appropriate to the weight. The anchors to be tested and the standard stockless anchors should be of approx. the same mass.

The chain length used in the tests should be appr[illegible] times the depth of water.

3.2 The weld quality grade of welded joints without proof by calculation (see 1.1) depends on the significance of the welded joint for the total structure and on its location in the structural element (location to the main stress direction) and on its stressing. For details concerning the type, scope and manner of testing, see Rules for Welding Volume VI, Section 9, B. Where proof of fatigue strength is required, the details listed in Section 20 apply.

B. Design

1. General design principles

1.1 During the design stage welded joints are to be planned such as to be accessible during fabrication, to be located in the best possible position for welding and to permit the proper welding sequence to be followed.

1.2 Both the welded joints and the sequence of welding involved are to be so planned as to enable residual welding stresses to be kept to a minimum in order that no excessive deformation occurs. Welded joints should not be overdimensioned, see also 3.3.3.

1.3 When planning welded joints, it must first be established that the type and grade of weld envisaged, such as full root weld penetration in the case of HV or DHV (K) weld seams, can in fact be perfectly executed under the conditions set by the limitations of the manufacturing process involved. If this is not the case, a simpler type of weld seam shall be selected and its possibly lower load bearing capacity taken into account when dimensioning the component.

1.4 Highly stressed welded joints - which, therefore are generally subject to examination are to be so designed that the most suitable method of testing for [illegible] can be used (radiography, ultrasonic, surface [illegible] testing methods) in order that a reliable examination may be carried out.

1.5 [illegible] characteristics peculiar to the mate- [illegible] strength [illegible] of rolled ma- [illegible] 25.1 [illegible] [illegible] as a result of wel[illegible] [illegible] the [illegible]

mainly filled weld connections are used).

1.6 In cases where different types of material are paired and operate in sea water or any other electrolytic medium, for example welded joints made between unalloyed carbon steels and stainless steels in the wear-resistant cladding in rudder nozzles or in the cladding of rudder shafts, the resulting differences in potential greatly increase the susceptibility to corrosion and must therefore be given special attention. Where possible, such welds are to be positioned in locations less subject to the risk of corrosion (such as on the outside of tanks) or special protective counter-measures are to be taken (such as the provision of a protective coating or cathodic protection).

2. Design details

2.1 Stress flow, transitions

2.1.1 All welded joints on primary supporting members shall be designed to provide as smooth a stress profile as possible with no major internal or external notches, no discontinuities in rigidity and no obstructions to strains (cf Section 3, H.).

2.1.2 This applies in analogous manner to the welding of subordinate components on to primary supporting members whose exposed plate or flange edges should, as far as possible, be kept from notch effects due to welded attachments. Regarding the inadmissibility of weldments to the upper edge of the sheer strake, see Section 6, C.3.4. This applies similarly to weldments to the upper edge of continuous hatchway side coamings.

2.1.3 Butt joints in long or extensive continuous structures such as bilge keels, fenders, slop coamings, etc. attached to primary structural members are therefore to be welded over their entire crosssection.

2.1.4 Wherever possible, joints (especially site joints) in girders and sections shall not be located in areas of high bending stress. Joints at the knuckle of flanges are to be avoided.

2.1.5 The transition between differing component dimensions shall be smooth and gradual. Where the [illegible] differs, the flanges [illegible] bevelled and the web slit and [illegible] equalize the depths of [illegible] transition should be at [illegible]

Table 28.1

Anchors, Chain Cables and Ropes of Fishing Vessels

No for Reg	Equipment Numeral Z	Stockless Bower Anchors		Stud Link Chain Cables [1]) for Bower Anchors				Recommended Mooring Ropes		
		Number	Weight p. Anchor	Total Length	diameter			Number	Length	Br. Load
					dd_1	d_2	d_3			
			kg	m	mm	mm	mm		m	kN
1	2	3	4	6	7	8	9	14	15	16
101	up to 30	2	70	137.5	11	11	11	2	40	28
102	30 - 40	2	80	165	11	11	11	2	50	30
103	40 - 50	2	100	192.5	11	11	11	2	60	30
104	50 - 60	2	120	192.5	12.5	12.5	12.5	2	60	30
105	60 - 70	2	140	192.5	12.5	12.5	12.5	2	80	30
106	70 - 80	2	160	220	14	12.5	12.5	2	100	35
107	80 - 90	2	180	220	14	12.5	12.5	2	100	35
108	90 - 100	2	210	220	16	14	14	2	110	35
109	100 - 110	2	240	220	16	14	14	2	110	40
110	110 - 120	2	270	247.5	17.5	16	16	2	110	40
111	120 - 130	2	300	247.5	17.5	16	16	2	110	45
112	130 - 140	2	340	275	19	17.5	17.5	2	120	45
113	140 - 150	2	390	275	19	17.5	17.5	2	120	50
114	150 - 175	2	480	275	22	19	19	2	120	55
115	175 - 205	2	570	302.5	24	20.5	20.5	2	120	60
116	205 - 240	2	660	302.5	26	22	20.5	2	120	65
117	240 - 280	2	780	330	28	24	22	3	120	70
118	280 - 320	2	900	357.5	30	26	24	3	140	80
119	320 - 360	2	1020	357.5	32	28	24	3	140	85
120	360 - 400	2	1140	385	34	30	26	3	140	95
121	400 - 450	2	1290	385	36	32	28	3	140	100
122	450 - 500	2	1440	412.5	38	34	30	3	140	110
123	500 - 550	2	1590	412.5	40	34	30	4	160	120
124	550 - 600	2	1740	440	42	36	32	4	160	130
125	600 - 660	2	1920	440	44	38	34	4	160	145
126	660 - 720	2	2100	440	46	40	36	4	160	160

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Additions to the volume

2%   for double bottom tanks
1 ... 2% for top tanks and deep tanks
2%   for thermal expansion, i.e. 98% filled only.

Diesel oil

used for auxiliary engines and for the main engine during estuary trading.

$$w_{diesel} = (0.1 \ldots 0.2) \cdot w_{heavy\ fuel\ oil}$$

specific weight $\gamma_{diesel} = 0.85\ t/m^3$

Volume: $$V_{diesel} = \frac{w_{diesel}}{\gamma_{diesel}} \quad [m^3]$$

additions see fuel oil!

Lubrication oil

In general ships have about 30 ... 50 t lubrication oil, because otherwise the tanks will get too small. (According to owner's desire!).

$$w_{lubr.} = P_{Bme} \cdot b_{me} \cdot \frac{S}{V_{serv}} + \text{addition}$$

b = 0.8 ... 1.2 [g/KW·h] diesel engine two stroke
b = 1.2 ... 1.6 [g/KW·h] diesel engine four stroke
b = 0.14   [g/KW·h] turbines and gearboxes

specific weight $\gamma_{lubr} = 0.90\ t/m^3$; $V = \frac{w}{\gamma}\ (m^3)$

Fresh water

- drinking water   10 ... 20 kg/pers · day
- washing water   60 kg/pers · day without bathing room
  up to 200 kg/pers · day with bathing room
- boiler feed water 0.14 kg/KW·h plus first filling

additions to the tank volume: 3 ... 4% for special coatings in case of fresh water

Fresh water tanks have to be separated from all other tanks by cofferdams.

of gravity are not yet exactly known in the early project stage. If the model does not accomplish the required speed the designer has to alter the hull. This alteration, however, is possible in the early project stage only. If the trial speed in ballast condition corresponds to the model trial speed in ballast, it can be assumed that service speed in loaded condition is attained, too.

Service speed of a ship is smaller than trial speed because of:

- increase of resistance by wind more than Beaufort 2
- increase of resistance by seaway
- increase of resistance by fouling on shell plating.

In general

$$V_{trial} \approx 1.06 \cdot V_{service}$$ (this corresponds to a power margin of about 20 - 25%).

The propeller is designed for 85% ... 90% of the driving power, at 100% of revolutions.

Consumables and tanks

There are some more special requirements in ship design: Capacities of

- consumables
- provisions
- ballast.

a) consumables are (depending on type of engine plant, time for one round trip, number of crew members):

- fuel oil

$$w_{fuel\ oil}\ [t] = P_{Bme} \cdot b_{me} + P_{ae} \cdot b_{ae} \cdot \frac{S}{V_{serv}} \cdot 10^{-6} \cdot [1.3 \ldots 1.5]$$

last brackets for reserve:

- fuel rests in tanks
- seaway
- wind
- waiting time

(- according to owner's desire).

Rumus yang sederhana dan praktis untuk perencanaan baling-baling adalah :

Rumus TAYLOR

Untuk Wake fraction : Kapal berbaling2 tunggal;

$$w = -0,05 + 0,5\ C_b$$

Kapal berbaling2 ganda;

$$w = -0,20 + 0,55\ C_b$$

Untuk Thrust deduction factor :

Kapal berbaling2 tunggal; $t \approx w$

Kapal berbaling2 ganda; $t \quad w$

dimana harga k adalah sebagai berikut :

Streamline rudder $k = 0,55 - 0,70$

Rudder tipis $k = 0,50$

Rudder tebal $k = 0,70$

Untuk menghitung harga wake yang lebih teliti adalah memakai diagram yang dibuat oleh Harvald. Untuk dapat membuat diagram tersebut Harvald telah menggunakan 200 model kapal untuk percobaan2-nya di tangki percobaan dinegeri Belanda. Adapun parameter yang ia pilih untuk menentukan besarnya aliran wake adalah :

- Block coefficient C_b.
- Bentuk dari penampang-penampang melintang kapal bagian belakang.
- Diameter baling-baling D.
- Panjang kapal L dan harga perbandingan D/L.
- Rake dari daun baling-baling dan celah antara baling-baling dengan stern frame.

Block coeff. C_b mempunyai pengaruh kepada aliran wake. Percobaan Harvald memakai model kapal yg. mempunyai beban indentik tetapi diadakan beberapa perubahan-perubahan pada bagian muka badan kapal.

Ternyata bagian muka badan kapal juga mempunyai pengaruh terhadap besarnya aliran wake. Dari percobaan ini dapatlah diketahui bahwa harga w tidak hanya dipengaruhi oleh C_b badan kapal bagian belakang, tetapi oleh C_b dari keseluruhan badan kapal.

Adapun coefficient prismatic C_p tidak dipakai sebagai salah satu parameter berhubung percobaan

		kJ/kg		kJ/kg · K		L/kg	
t, °C	P, kPa	h_f	h_g	s_f	s_g	v_f	v_g
-60	37,48	134,763	379,114	0,73254	1,87886	0,68208	537,152
-55	49,47	139,830	381,529	0,75599	1,86389	0,68856	414,827
-50	64,39	144,959	383,921	0,77919	1,85000	0,69526	324,557
-45	82,71	150,153	386,282	0,80216	1,83708	0,70219	256,990
-40	104,95	155,414	388,609	0,82490	1,82504	0,70936	205,745
-35	131,68	160,742	390,896	0,84743	1,81380	0,71680	166,400
-30	163,48	166,140	393,138	0,86976	1,80329	0,72452	135,844
-28	177,76	168,318	394,021	0,87864	1,79927	0,72769	125,563
-26	192,99	170,507	394,896	0,88748	1,79535	0,73092	116,214
-24	209,22	172,708	395,762	0,89630	1,79152	0,73420	107,701
-22	226,48	174,919	396,619	0,90509	1,78779	0,73753	99,9362
-20	244,83	177,142	397,467	0,91386	1,78415	0,74091	92,8432
-18	264,29	179,376	398,305	0,92259	1,78059	0,74436	86,3546
-16	284,93	181,622	399,133	0,93129	1,77711	0,74786	80,4103
-14	306,78	183,878	399,951	0,93997	1,77371	0,75143	74,9572
-12	329,89	186,147	400,759	0,94862	1,77039	0,75506	69,9478
-10	354,30	188,426	401,555	0,95725	1,76713	0,75876	65,3399
-9	367,01	189,571	401,949	0,96155	1,76553	0,76063	63,1746
-8	380,06	190,718	402,341	0,06585	1,76394	0,76253	61,0958
-7	393,47	191,868	402,729	0,97014	1,76237	0,76444	59,0996
-6	407,23	193,021	403,114	0,97442	1,76082	0,76636	57,1820
-5	421,35	194,176	403,496	0,97870	1,75928	0,76831	55,3394
-4	435,84	195,335	403,876	0,98297	1,75775	0,77028	53,5682
-3	450,70	196,497	404,252	0,98724	1,75624	0,77226	51,8653
-2	465,94	197,662	404,626	0,99150	1,75475	0,77427	50,2274
-1	481,57	198,828	404,994	0,99575	1,75326	0,77629	48,6517
0	497,59	200,000	405,361	1,00000	1,75279	0,77834	47,1354
1	514,01	201,174	405,724	1,00424	1,75034	0,78041	45,6757
2	530,83	202,351	406,084	1,00848	1,74889	0,78249	44,2702
3	548,06	203,530	406,440	1,01271	1,74746	0,78460	42,9166
4	565,71	204,713	406,793	1,01694	1,74604	0,78673	41,6124
5	583,78	205,899	407,143	1,02116	1,74463	0,78889	40,3556
6	602,28	207,089	407,489	1,02537	1,74324	0,79107	39,1441
7	621,22	208,281	407,831	1,02958	1,74185	0,79327	37,9759
8	640,59	209,477	408,169	1,03379	1,74047	0,79549	36,8493
9	660,42	210,675	408,504	1,03799	1,73911	0,79775	35,7624
10	680,70	211,877	408,835	1,04218	1,73775	0,80002	34,7136
11	701,44	213,083	409,162	1,04637	1,73640	0,80232	33,7013
12	722,65	214,291	409,485	1,05056	1,73506	0,80465	32,7239
13	744,33	215,503	409,804	1,05474	1,73373	0,80701	31,7801
14	766,50	216,719	410,119	1,05892	1,73241	0,80939	30,8683
15	789,15	217,937	410,430	1,06309	1,73109	0,81180	29,9874
16	812,29	219,160	410,736	1,06726	1,72978	0,81424	29,1361
17	835,93	220,386	411,038	1,07142	1,72848	0,81671	28,3131
18	860,08	221,615	411,336	1,07559	1,72719	0,81922	27,5173
19	884,75	222,848	411,629	1,07974	1,72590	0,82175	26,7477
20	909,93	224,084	411,918	1,08390	1,72462	0,82431	26,0032
21	935,64	225,324	412,202	1,08805	1,72334	0,82691	25,2829
22	961,89	226,568	412,481	1,09220	1,72206	0,82954	24,5857
23	988,67	227,816	412,755	1,09634	1,72080	0,83221	23,9107
24	1016,0	229,068	413,025	1,10048	1,71953	0,83491	23,2572
25	1043,9	230,324	413,289	1,10462	1,71827	0,83765	22,6242
26	1072,3	231,583	413,548	1,10876	1,71701	0,84043	22,0111
27	1101,4	232,847	413,802	1,11290	1,71576	0,84324	21,4169
28	1130,9	234,115	414,050	1,11703	1,71450	0,84610	20,8411
29	1161,1	235,387	414,293	1,12116	1,71325	0,84899	20,2829
30	1191,9	236,664	414,530	1,12530	1,71200	0,85193	19,7417
31	1223,2	237,944	414,762	1,12943	1,71075	0,85491	19,2168
32	1255,2	239,230	414,987	1,13355	1,70950	0,85793	18,7076
33	1287,8	240,520	415,207	1,13768	1,70826	0,86101	18,2135
34	1321,0	241,814	415,420	1,14182	1,70701	0,86412	17,7341
35	1354,8	243,114	415,627	1,14594	1,70576	0,86729	17,2686
36	1389,2	244,418	415,828	1,15007	1,70450	0,87051	16,8168
37	1424,3	245,727	416,021	1,15420	1,70325	0,87378	16,3779
38	1460,1	247,041	416,208	1,15833	1,70199	0,87710	15,9517
39	1496,5	248,361	416,388	1,16246	1,70073	0,88048	15,5375
40	1533,5	249,686	416,561	1,16659	1,69946	0,88393	15,1351
41	1571,2	251,015	416,726	1,17073	1,69819	0,88741	14,7439
42	1609,6	252,352	416,883	1,17486	1,69692	0,89097	14,3636
43	1648,7	253,694	417,033	1,17900	1,69564	0,89459	13,9938
44	1688,5	255,042	417,174	1,18315	1,69435	0,89828	13,6341
45	1729,0	256,396	417,308	1,18730	1,69305	0,90203	13,2841
46	1770,2	257,756	417,432	1,19145	1,69174	0,90586	12,9436
47	1812,1	259,123	417,548	1,19560	1,69043	0,90976	12,6122
48	1854,8	260,497	417,655	1,19977	1,68911	0,91374	12,2895
49	1898,2	261,877	417,752	1,20393	1,68777	0,91779	11,9753
50	1942,3	263,264	417,838	1,20811	1,68643	0,92193	11,6693
52	2032,8	266,062	417,983	1,21648	1,68370	0,93047	11,0806
54	2126,5	268,891	418,083	1,22489	1,68091	0,93939	10,5214
56	2223,2	271,754	418,137	1,23333	1,67805	0,94872	9,98952
58	2323,2	274,654	418,141	1,24183	1,67511	0,95850	9,48319
60	2426,6	277,594	418,089	1,25038	1,67208	0,96878	9,00062
62	2533,3	280,577	417,978	1,25899	1,66895	0,97960	8,54016
64	2643,5	283,607	417,802	1,26768	1,66570	0,99104	8,10023
66	2757,3	286,690	417,553	1,27647	1,66231	1,00317	7,67934
68	2874,7	289,832	417,226	1,28531	1,65876	1,01608	7,27605
70	2995,9	293,058	416,809	1,29436	1,65504	1,02987	6,88399
75	3316,1	301,399	415,299	1,31758	1,64472	1,06916	5,98334
80	3662,3	310,424	412,898	1,34223	1,63239	1,11810	5,14862
85	4036,8	320,505	409,101	1,36936	1,61673	1,18328	4,35815
90	4442,5	332,616	402,653	1,40155	1,59440	1,28230	3,56440
95	4883,5	351,757	386,708	1,45222	1,54712	1,52064	2,55133

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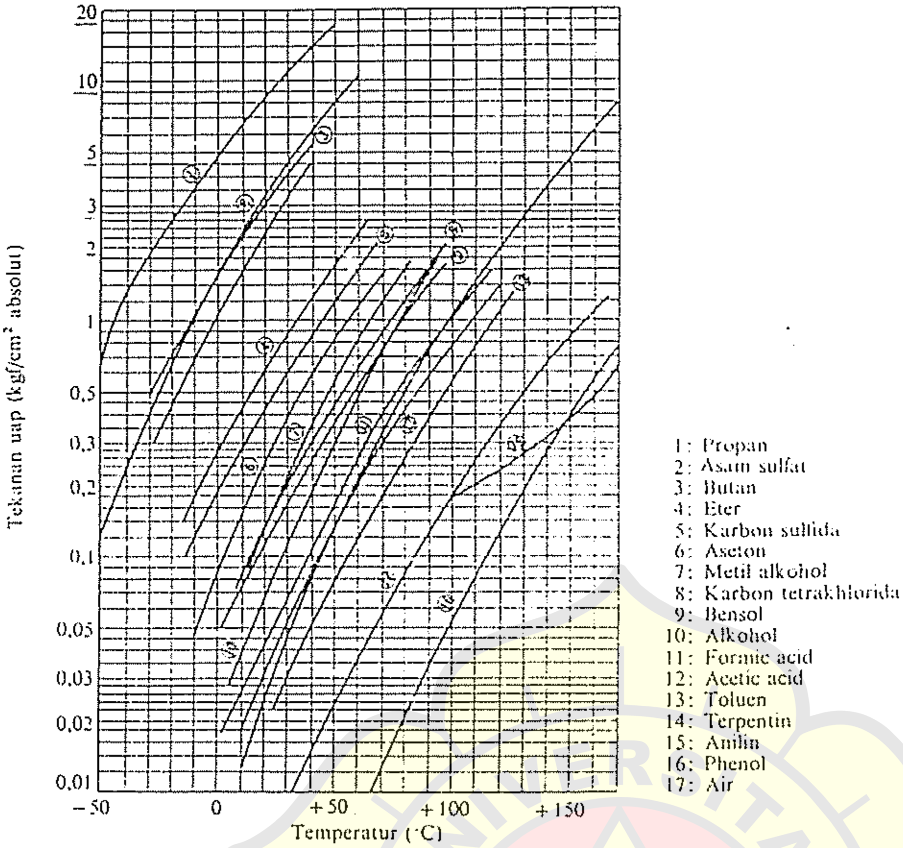
Tabel A-7 Refrigeran 22: sifat-sifat uap gas panas lanjut[5]

t, °C	v, L/kg	h, kJ/kg	s, kJ/kg · K	v, L/kg	h, kJ/kg	s, kJ/kg · K	v, L/kg	h, kJ/kg	s, kJ/kg · K
	Suhu jenuh, −20°C			Suhu jenuh, −10°C			Suhu jenuh, 0°C		
-20	92,8432	397,467	1,7841						
-15	95,1474	400,737	1,7969						
-10	97,4256	404,017	1,8095	65,2399	401,555	1,7671			
-5	99,6808	407,307	1,8219	67,0081	404,983	1,7800			
0	101,915	410,610	1,8341	68,6524	408,412	1,7927	47,1354	405,361	1,7518
5	104,130	413,926	1,8461	70,7751	411,845	1,8052	48,3899	408,959	1,7649
10	106,328	417,258	1,8580	71,8785	415,283	1,8174	49,6215	412,567	1,7777
15	108,510	420,606	1,8697	73,4644	418,730	1,8295	50,8328	416,159	1,7903
20	110,678	423,970	1,8813	75,0346	422,186	1,8414	52,0259	419,649	1,8026
25	112,832	426,353	1,8928	76,5904	425,653	1,8531	53,2028	423,339	1,8148
	Suhu jenuh, 5°C			Suhu jenuh, 10°C			Suhu jenuh, 15°C		
5	40,3556	407,143	1,7446						
10	41,4580	410,851	1,7578	34,7136	408,835	1,7377			
15	42,5379	414,542	1,7708	35,6907	412,651	1,7511	29,9874	410,430	1,7311
20	43,5979	418,222	1,7834	36,6454	416,442	1,7642	30,8606	414,362	1,7556
25	44,6401	421,894	1,7958	37,5804	420,215	1,7769	31,7114	418,260	1,7578
30	45,6665	425,562	1,8080	38,4981	423,974	1,7894	32,5427	422,133	1,7707
35	46,6786	429,229	1,8200	39,4002	427,724	1,8017	33,3568	425,985	1,7833
40	47,6779	432,897	1,8319	40,2834	431,469	1,8137	34,1556	429,823	1,7956
45	48,6656	436,569	1,8435	41,1642	435,211	1,8256	34,9409	433,650	1,8078
50	49,6427	440,247	1,8550	42,0286	438,954	1,8373	35,7139	437,470	1,8197

Tabel A-7 (lanjutan)

	Suhu jenuh, 20°C			Suhu jenuh, 25°C			Suhu jenuh, 30°C		
20	26,0032	411,918	1,7246						
25	26,7900	415,977	1,7383	22,6242	413,289	1,7183			
30	27,5542	419,991	1,7517	23,3389	417,487	1,7322	19,7417	414,530	1,7120
35	28,2989	423,970	1,7646	24,0306	421,627	1,7458	20,3962	418,881	1,7262
40	29,0264	427,922	1,7774	24,7027	425,721	1,7590	21,0272	423,159	1,7400
45	29,7369	431,852	1,7899	25,3575	429,779	1,7718	21,6381	427,378	1,7534
50	30,4379	435,766	1,8021	25,9974	433,807	1,7844	22,2316	431,549	1,7664
55	31,1250	439,668	1,8141	26,6239	437,813	1,7967	22,8101	435,683	1,7791
60	31,8012	443,561	1,8258	27,2386	441,801	1,8087	23,3733	439,787	1,7915
65	32,4678	447,450	1,8374	27,8427	445,777	1,8206	23,9288	443,867	1,8036
	Suhu jenuh, 32°C			Suhu jenuh, 34°C			Suhu jenuh, 36°C		
35	19,0907	417,648	1,7182	17,8590	416,325	1,7099			
40	19,7093	422,014	1,7322	18,4675	420,792	1,7243	17,2953	419,453	1,7162
45	20,3062	426,310	1,7458	19,0526	425,174	1,7382	17,8708	423,961	1,7304
50	20,8847	430,549	1,7591	19,6178	429,487	1,7517	18,4247	428,358	1,7442
55	21,4471	434,743	1,7719	20,1660	433,747	1,7647	18,9603	432,690	1,7575
60	21,9956	438,900	1,7845	20,6994	437,963	1,7775	19,4802	436,970	1,7704
65	22,5318	443,028	1,7968	21,2199	442,143	1,7899	19,9865	441,207	1,7830
70	23,0571	447,133	1,8089	21,7289	446,294	1,8021	20,4867	445,410	1,7954
75	23,5726	451,219	1,8207	22,2278	450,424	1,8141	20,9643	449,586	1,8074
80	24,0794	455,292	1,8323	22,7176	454,535	1,8258	21,4385	453,739	1,8193



(b) Tekanan uap berbagai zat cair
(*Catatan*: 1 kgf/cm² = 0,1 M Pa)

Gb. 2.1 Sifat-sifat fisik berbagai zat cair.

2.4 Head

2.4.1 Head Total Pompa

Head total pompa yang harus disediakan untuk mengalirkan jumlah air seperti direncanakan, dapat ditentukan dari kondisi instalasi yang akan dilayani oleh pompa. Seperti diperlihatkan dalam Gb. 2.2, head total pompa dapat ditulis sebagai berikut:

$$H = h_a + \Delta h_p + h_l + \frac{v_d^2}{2g} \tag{2.6}$$

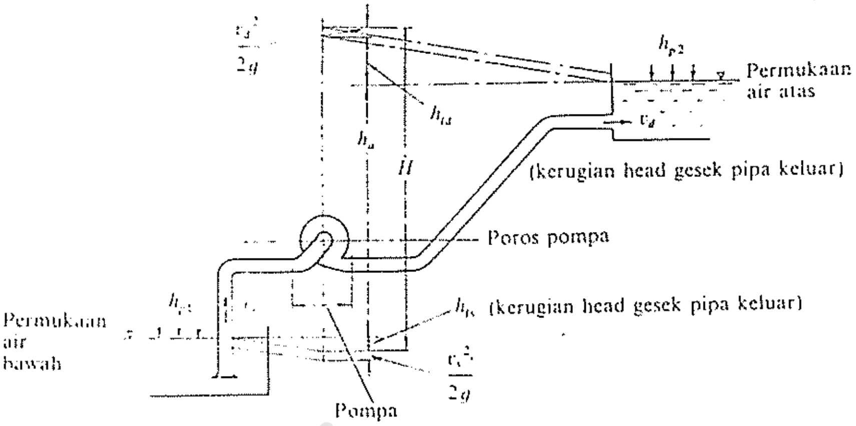
di mana H: Head total pompa (m)

h_a: Head statis total (m)
Head ini adalah perbedaan tinggi antara muka air di sisi keluar dan di sisi isap; tanda positip (+) dipakai apabila muka air di sisi ke luar lebih tinggi dari pada sisi isap.

Δh_p: Perbedaan head tekanan yang bekerja pada kedua permukaan air (m),

$$\Delta h_p = h_{p_2} - h_{p_1},$$

h_l: Berbagai kerugian head di pipa, katup, belokan, sambungan, dll (m),



Gb. 2.2 Head pompa (1).

$$h_l = h_{ld} + h_{ls}$$

$v^2/2g$: Head kecepatan keluar (m)
g: Percepatan gravitasi (= 9,8 m/s²)

Dalam hal pompa menerima energi dari aliran yang masuk ke sisi isapnya, seperti pada pompa penguat (pompa booster), maka head total pompa dapat dihitung dengan rumus berikut:

$$H = h_a + \Delta h_p + h_l + \frac{1}{2g}(v_d^2 - v_s^2) \tag{2.7}$$

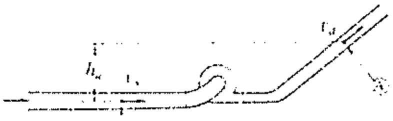
di mana h_a: Perbedaan tinggi antara titik sebarang Ⓐ di pipa keluar, dan sembarang titik Ⓑ di pipa isap (m) (Lihat Gb. 2.3).
Δh_p: Perbedaan tekanan statis antara titik Ⓐ dan titik Ⓑ (m)
h_l: Berbagai kerugian head di pipa, katup, belokan dll, antara titik Ⓐ dan titik Ⓑ (m)
v_d: Kecepatan aliran rata-rata di titik Ⓐ (m/s)
v_s: Kecepatan aliran rata-rata di titik Ⓑ (m/s)

Untuk pompa tegak yang tidak mempunyai pipa isap, $h_l = h_{ld}$.

Apabila permukaan air berubah-ubah dengan perbedaan besar, head statis total harus ditentukan dengan mempertimbangkan karakteristik pompa, besarnya selisih perubahan permukaan air, dan dasar yang dipakai untuk menentukan jumlah air yang harus dipompa.

Adapun hubungan antara tekanan dan head tekanan dapat diperoleh dari rumus berikut:

$$h_p = 10 \times \frac{p}{\gamma} \tag{2.8}$$



Gb. 2.3 Head pompa (2).

di mana h_p: Head tekanan (m)

p: Tekanan (kgf/cm^2)

γ: Berat per satuan volume zat cair yang dipompa (kgf/l)

Apabila tekanan diberikan dalam kPa, dapat dipakai rumus berikut:

$$h_p = \frac{1}{9{,}8}\,\frac{p'}{\rho} \tag{2.9}$$

di mana p': Tekanan (Pa)

ρ: Rapat masa (kg/l)

Menurut ISO, energi spesifik Y (J/kg) kadang-kadang dipakai sebagai pengganti head H (m). Adapun hubungannya adalah sebagai berikut:

$$Y = gH \tag{2.10}$$

Sebagaimana diutarakan di atas, untuk menentukan head total yang harus disediakan pompa, perlu dihitung lebih dahulu head kerugian h_l. Di bawah ini akan diuraikan cara menghitung kerugian head tersebut.

2.4.2 Head Kerugian

Head kerugian (yaitu head untuk mengatasi kerugian-kerugian) terdiri atas head kerugian gesek di dalam pipa-pipa, dan head kerugian di dalam belokan-belokan, reduser, katup-katup, dsb. Di bawah ini akan diberikan cara menghitungnya, satu per satu.

(1) Head kerugian gesek dalam pipa

Untuk menghitung kerugian gesek di dalam pipa dapat dipakai salah satu dari dua rumus berikut ini:

$$v = CR^pS^q \tag{2.11}$$

$$h_f = \lambda\frac{L}{D}\,\frac{v^2}{2g} \tag{2.12}$$

di mana v: Kecepatan rata-rata aliran di dalam pipa (m/s)

C, p, q: Koefisien-koefisien

R: Jari-jari hidrolik (m)

$$R = \frac{\text{Luas penampang pipa, tegak lurus aliran (m}^2\text{)}}{\text{Keliling pipa atau saluran yang dibasahi (m)}}$$

S: Gradien hidrolik

$$S = \frac{h_f}{L}$$

h_f: Head kerugian gesek dalam pipa (m)

λ: Koefisien kerugian gesek

g: Percepatan gravitasi (9,8 m/s^2)

L: Panjang pipa (m)

D: Diameter dalam pipa (m)

Selanjutnya, untuk aliran yang laminer dan yang turbulen, terdapat rumus yang berbeda. Sebagai patokan apakah suatu aliran itu laminer atau turbulen, dipakai bilangan Reynolds:

$$Re = \frac{vD}{\nu} \tag{2.13}$$

LAMPIRAN

di mana Re: Bilangan Reynolds (tak berdimensi)
v: Kecepatan rata-rata aliran di dalam pipa (m/s)
D: Diameter dalam pipa (m)
ν: Viskositas kinematik zat cair (m^2/s)

Pada $Re < 2300$, aliran bersifat laminer.
Pada $Re > 4000$, aliran bersifat turbulen.
Pada $Re = 2300 - 4000$ terdapat daerah transisi, di mana aliran dapat bersifat laminer atau turbulen tergantung pada kondisi pipa dan aliran.

(I) Aliran laminer

Dalam hal aliran laminer, koefisien kerugian gesek untuk pipa (λ) dalam pers. (2.12) dapat dinyatakan dengan

$$\lambda = \frac{64}{Re} \tag{2.14}$$

(II) Aliran turbulen

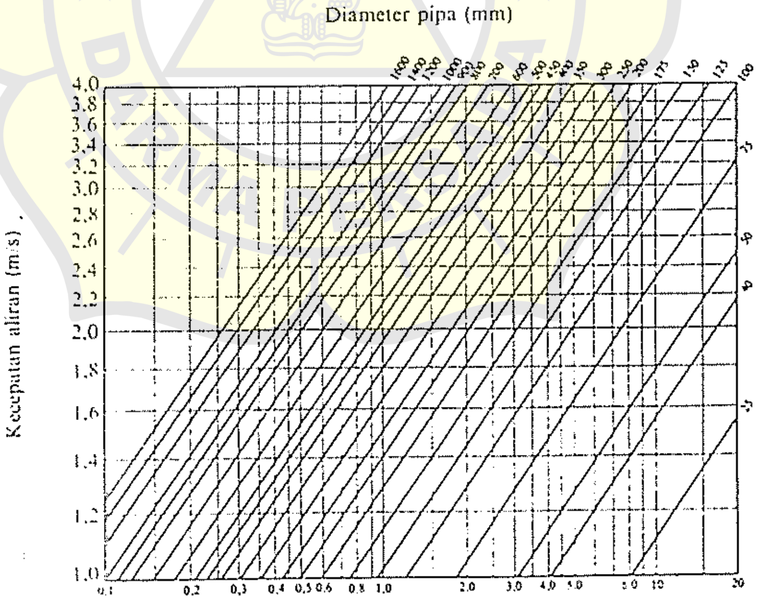
Untuk menghitung kerugian gesek dalam pipa pada aliran turbulen terdapat berbagai rumus empiris. Di bawah ini akan diberikan cara perhitungan dengan rumus Darcy dan Hazen-Williams.

1) Formula Darcy

Dengan cara Darcy, koefisien kerugian gesek λ dari Pers. (2.12) dihitung menurut rumus

$$\lambda = 0{,}020 + \frac{0{,}0005}{D} \tag{2.15}$$

di mana D adalah diameter dalam pipa (m). Rumus ini berlaku untuk pipa baru dari besi cor. Jika pipa telah dipakai selama bertahun-tahun, harga λ akan menjadi 1,5



Gb. 2.4 Kerugian gesek pada pipa lurus
(rumus Darcy).

LAMPIRAN

Tabel 2.21 Panjang pipa lurus ekivalen, L_f.

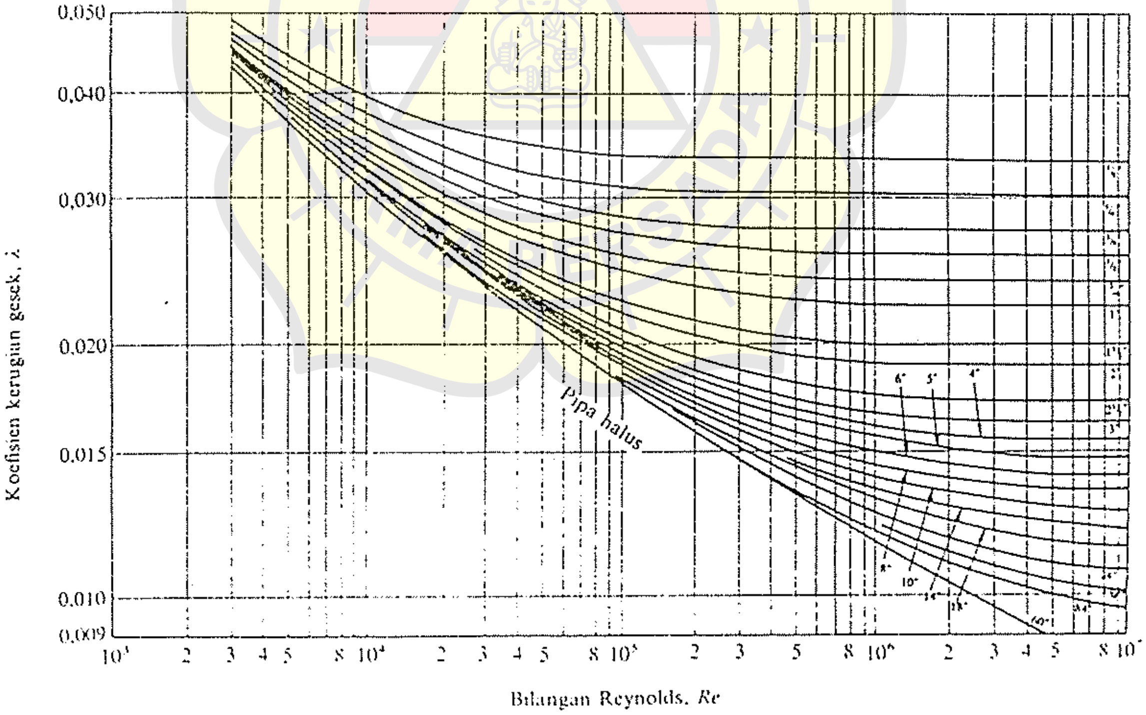
Nama peralatan pipa	Panjang pipa lurus ekivalen L_f
Belokan 45 (1" - 3")	15 - 20 d
Belokan 90 (jari-jari lengkung standar)	32 D
Belokan ($R/D = 3$) 90 ($R/D = 4$)	24 D 10 D
Belokan 180	75 D
Sambungan silang Sambungan -T	50 D 40 - 80 D
Meteran air jenis toras	600DD

Nama peralatan pipa	Panjang pipa lurus ekivalen L_f
Meteran air: Jenis cakram jenis turbin Katup sorong: terbuka penuh " 3/4 " 1/2 " 1/4	135 - 400 D 200 - 300 D 0 - 7 D 10 - 40 D 100 - 200 D 800 D
Katup bola 1" – 2½" 3" – 6" 7" – 10"	45 D 60 D 75 D

pipa lurus. Harga-harga L_f untuk berbagai peralatan pipa yang umum, diberikan dalam Tabel 2.21.

(5) Head kerugian gesek untuk zat cair istimewa

Untuk menghitung kerugian head pada pipa yang mengalirkan zat cair bukan air, dapat dilakukan sebagai berikut. Mula-mula harus dihitung bilangan Reynolds Re dari aliran. Kemudian kerugian head ditentukan dengan cara seperti pada air di mana koefisien kerugian gesek diambil untuk bilangan Reynolds yang bersangkutan.

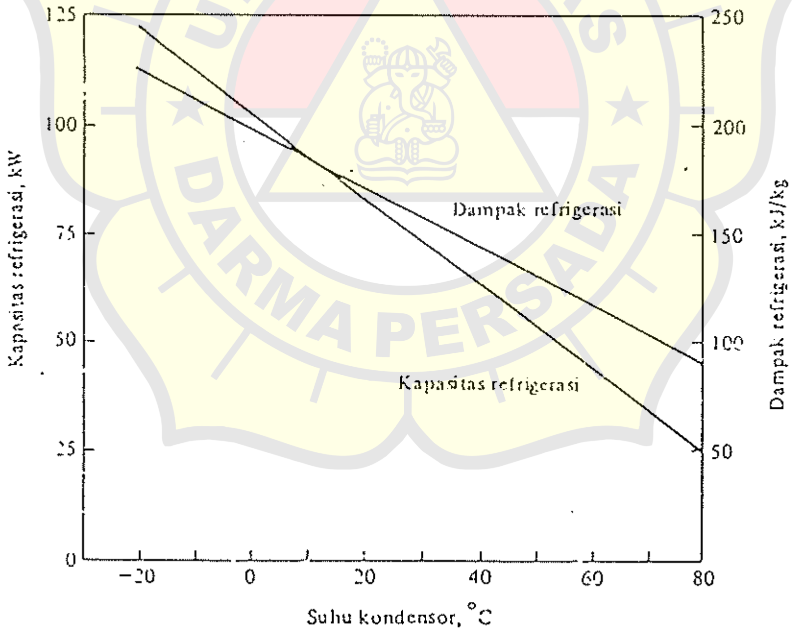


Gb. 2.17 Bilangan Reynolds dan koefisien gesek.
(angka-angka menunjukkan diameter dalam pipa).

si volumetrik yang mempengaruhi laju alir massa, yang menunjukkan suatu penurunan akibat naiknya suhu kondensor. Gambar 11-10 menunjukkan penurunan tersebut yang progresif. Kapasitas refrigerasi adalah hasil kali antara dampak refrigerasi dan laju aliran massa, yang keduanya akan turun bila suhu kondensor naik. Jadi kapasitas refrigerasi turun agak lebih cepat karena naiknya suhu kondensor.

Karakteristik yang penting lagi adalah daya – yang diperlihatkan dalam Gambar 11-11. Daya kompresor adalah hasil perkalian antara kerja kompresi yang bersatuan kilojoule per-kilogram dan laju alir massa. Bila suhu kondensor naik, maka kerja kompresi dan laju alir massa menurun, sehingga daya naik mencapai puncak dan kemudian mulai turun. Sifat yang sama dengan daya ini, yaitu sebagai fungsi dari suhu evaporator, ditunjukkan dalam Gambar 11-6.

Beberapa penjelasan tentang arti dan sifat-sifat yang terdapat di dalam Gambar 11-9 hingga 11-11 adalah sebagai berikut: pencapaian puncak-puncak daya dapat terjadi dalam kompresor-kompresor nyata seperti juga pada kompresor ideal, tetapi hanya terjadi bila dilakukan pemompaan dari suhu-suhu rendah evaporator. Kompresi satu tingkat dari suhu penguapan −20°C hingga suhu pengembunan 60°C yang menghasilkan puncak seperti pada Gambar 11-11, tidaklah umum. Dengan perbedaan suhu yang lebih sedikit antara kondensor dan evaporator, diperkirakan bila suhu kondensor naik, akan ada kenaikan daya pada kompresor, walaupun kenaikan tersebut mungkin hanya sedikit. Kapasitas refrigerasi selalu turun bila suhu kondensor naik. Karakteristik lain yang penting, tidak digambarkan dalam grafik, adalah *koefisien prestasi* (coefficient of performance), yang turun secara monoton bila suhu kondensor naik.



Gambar 11-10 Dampak refrigerasi dan kapasitas refrigerasi untuk kompresor ideal dengan refrigeran 22, volume sisa 4,5 persen, laju volume langkah 50 L/det, dan suhu evaporator −20°C.

Bertitik tolak dari daya dan efisiensi, diinginkan suhu kondensor yang rendah, jadi kondensor tersebut harus menggunakan udara atau air yang terdingin yang tersedia, mengalir secara maksimum dan ekonomis, serta permukaannya harus dijaga tetap bersih. Udara atau gas-gas yang tak dapat mengembun di dalam kondensor juga mengakibatkan tingginya tekanan kondensor tersebut.

Table 42

Compartment	Number of air renewals per hour for	
	Plenum ventilation	Exhaust ventilation
Passengers', officers' and crew accommodations	10 to 15	—
Public rooms (staterooms, dining-saloons, etc.)	15 to 20	10 to 15
Smoking rooms	—	15 to 20
Gymnasiums	15	20
Swimming pools	15	20
Russian baths	—	10 to 20
Galleys	5 to 10	40 to 60
Provision rooms without cooling facilities	5 to 10	10 to 15
Bathrooms, toilets and laundries	5	15 to 20
Sick bays	5 to 10	10 to 20
Baggage rooms	—	20
Deck refreshment bars	10 to 15	25 to 30
Upper deck passageways	—	6
Middle deck passageways	—	7
Lower deck passageways	—	8
Engine and boiler rooms	30	35

$p_{st}=760$ mm Hg, relative humidity of $\varphi_{st}=50$ per cent and density $\gamma_{st}=1.2$ kg per cu m. The capacity of the fan determined for air in a given state, having a pressure p_a, volume Q_a and temperature t_a, can be converted to the standard air capacity by using formula (276) which is derived from the equation

$$\frac{p_{st}Q_{st}}{1+\alpha t_{st}}=\frac{p_aQ_a}{1+\alpha t_a}$$

whence

$$Q_{st}=\frac{(1+\alpha t_{st})\,p_aQ_a}{p_{st}(1+\alpha t_a)}=Q_a\frac{\left(1+\frac{1}{273}\,20\right)}{\left(1+\frac{1}{273}\,t_a\right)}\frac{p_a}{760}=$$

$$=Q_a\frac{293}{273+t_a}\,\frac{p_a}{760}\ \text{cu m per hour} \qquad (276)$$

The theoretical head developed by the fan is expressed in mm of water column:

$$H_{t\infty}=\frac{1}{g}(c_{2u}u_2-c_{1u}u_1)=\frac{1{,}000}{g}\frac{\gamma_{air}}{\gamma_{wat}}(c_{2u}u_2-c_{1u}u_1)=$$
$$=\rho(c_{2u}u_2-c_{1u}u_1)\ \mathrm{mmH_2O} \qquad (277)$$

where γ_{air} = density of air, kg per cu m

$\gamma_{wat}=1{,}000$ = density of water, kg per cu m

ρ = mass density of air, kg-sec^2 per m^4.

Upon radial entry of the air onto the fan impeller vanes

$$H_{t\infty}=\rho c_{2u}u_2\ \mathrm{mmH_2O}$$

Taking into account the effect of having a finite number of impeller vanes on the developed head by the factor σ and for the losses of head in the fan by the hydraulic efficiency η_h we obtain the actual head

$$H=H_{t\infty}\sigma\eta_h=\sigma\rho c_{2u}u_2\eta_h=\sigma\rho\frac{c_{2u}}{u_2}u_2u_2\eta_h=$$
$$=\sigma\rho\varphi_h u_2^2\eta_h=\rho\psi_h u_2^2\ \mathrm{mmH_2O} \qquad (278)$$

where $\varphi_h=\frac{c_{2u}}{u_2}$ = eddy current factor

$\psi_h=\sigma\varphi_h\eta_h$ = head factor taken equal to: 0.8 to 1.1 for forward-curved vanes; 0.6 to 0.8 for radial, or straight, vanes; 0.5 to 0.7 for backward-curved vanes.

The fan head required to accommodate a given ventilating system depends upon the resistance and characteristic curves of the latter.

The permissible maximum peripheral speeds (tip speeds) of an impeller, based upon fan design and strength considerations, are listed in Table 43. The table also lists the most widely used inlet and outlet angles of the vanes.

Table 43

Type of fan	Peripheral speed, m per sec	Inlet angle	Outlet angle
Low-pressure	30 to 40	95 to 105	15 to 25
Medium-pressure . . .	40 to 50	125 to 130	30 to 35
High-pressure	50 to 90	140 to 145	40 to 45

Backward curved vanes are rarely employed and then only for low-pressure fans. The number of vanes is usually assigned so as to facilitate laying out and may be equal to 4, 6, 8, 12, 16, 24, 32 or 48.

The power required to drive a fan is found from the formula

$$N_m = \frac{Q_a H}{75\eta_f 3{,}600}\ \text{hp}$$

The overall efficiency of a fan is made up of the following efficiencies:

1. Hydraulic efficiency, which takes into consideration the loss of head in the fan

$$\eta_h = \frac{H}{H+\Delta H} = \frac{H}{H_t} = 0.7\ \text{to}\ 0.85$$

where ΔH=loss of head in the fan.

2. Hydraulic friction efficiency which takes into account the losses due to the friction of the impeller shrouds against the fluid being transferred

$$\eta_{fr} = \frac{N_{fr}}{N_a} = \frac{\beta 10^{-6}\rho D_2^2 u_2^3}{N_a}$$

where N_{fr}=power lost in overcoming fluid friction

$\beta=(5\ \text{to}\ 15)\left(1+5\frac{b_2}{D_2}\right)$=coefficient obtained from data compiled by the Central Institute of Aero- and Hydrodynamics

b_2=width of the impeller at air outlet

D_2=impeller diameter at air outlet

For backward-curved vanes—$\eta_{fr} \simeq 0.6$ to 0.75

For forward-curved vanes—$\eta_r \simeq 0.75$ to 0.9.

3. Mechanical efficiency which takes into account the losses due to mechanical friction

$$\eta_m = \frac{N_a - \Delta N_{mf}}{N_a} \approx 0.95\ \text{to}\ 0.99$$

where ΔN_{mf}=power lost in overcoming mechanical friction. The overall efficiency of a fan is thus

$$\eta_f = \eta_h \eta_{fr} \eta_m = 0.4\ \text{to}\ 0.75 \tag{279}$$

The overall efficiency of an axial fan may reach $\eta_f \approx 0.84$.

2-2. Design and Selection of Fans

Strictly aerodynamical calculations in fan design do not, as a rule, ensure results in subsequent tests that comply with the initial design data.

More accurate results may be achieved by designing a fan similar to one which has already been built, tested and modified to obtain the most favourable aerodynamic and design features.

expressed in rpm, as n_{rs}, then the torque developed on the steering engine shaft and its speed, n_m rpm, will be

$$M_m = \frac{M_{rs}}{i_{sg}\eta_{sg}} \text{ kg-m} \qquad (312)$$

$$n_m = i_{sg} n_{rs} \text{ rpm} \qquad (313)$$

where n_m = 100 to 350 rpm for steam engines
n_m = 300 to 1,800 rpm for electric motors.

The angular velocity of rotation ω_{rs} of the rudder stock can be calculated from the following formulas:

$$\omega_{rs} = \frac{\pi n_{rs}}{30} \text{ 1/sec} \qquad (314)$$

$$\omega_{rs} = \frac{2\alpha^\circ}{\tau}\frac{\pi}{180^\circ} \text{ 1/sec} \qquad (315)$$

where α° = maximum rudder angle from the middle-line plane.

It follows from formula (314) that

$$n_{rs} = \frac{30\omega_{rs}}{\pi} \text{ rpm} \qquad (316)$$

Combining equations (315) and (316) we obtain

$$n_{rs} = \frac{30}{\pi}\frac{2\alpha^\circ}{\tau}\frac{\pi}{180} = \frac{1}{3}\frac{\alpha^\circ}{\tau} \text{ rpm} \qquad (317)$$

Combining equations (313) and (317) we can write

$$i_{sg} = \frac{n_m}{n_{rs}} = \frac{n_m}{\frac{1}{3}\frac{\alpha^\circ}{\tau}} = 3n_m\frac{\tau}{\alpha^\circ} \qquad (318)$$

Taking equations (314) and (315) into consideration, the power developed on the rudder stock is

$$N_{rs} = \frac{M_{rs}\omega_{rs}}{75} = \frac{M_{rs}}{75}\frac{2\alpha^\circ}{\tau}\frac{\pi}{180^\circ} = 4.65\frac{M_{rs}}{10^4}\frac{\alpha^\circ}{\tau} \text{ metric hp} \qquad (319)$$

$$N_{rs} = \frac{M_{rs}\omega_{rs}}{75} = \frac{M_{rs}}{75}\frac{\pi n_{rs}}{30} = 1.395\frac{M_{rs}n_{rs}}{10^3} \approx 1.4\frac{M_{rs}n_{rs}}{10^3} \text{ metric hp} \qquad (320)$$

The shaft horse power of the steering engine motive unit will be

$$N_m = \frac{N_{rs}}{\eta_{sg}} = 4.65\frac{M_{rs}}{10^4\eta_{sg}}\frac{\alpha^\circ}{\tau} \text{ metric hp} \qquad (321)$$

$$\boxed{N_m = \frac{N_{rs}}{\eta_{sg}} = 1.4\frac{M_{rs}}{10^3\eta_{sg}}n_{rs}} \text{ metric hp} \qquad (322)$$

The shaft horse power can also be determined from the shaft torque

5-3. Determining the Principal Dimensions of Anchoring and Warping Machinery

The initial data used to determine the principal dimensions of anchoring machinery are the required pull of the cable lifter and the speed at which the anchor is weighed from the anchorage depth, which is equal to the distance from the hawse hole to the bottom.

It is advisable to determine the pull on the cable lifter so as to ensure that one anchor will be brought in at a speed of at least 12 m per min from the anchorage depth which is taken equal to:

80 m if each anchor weighs 1,000 kg or less
90 m if the anchor weighs from 1,500 to 3,000 kg
100 m if the anchor weighs from 3,000 to 6,000 kg.

The following notation will be used to derive the formulas for determining the pull on the cable lifter:

G_a = weight of the anchor, kg
p_a = weight per running metre of the chain cable, kg
L_a = length of the suspended cable, m
γ_a = 7,750 = density of the material of the anchor, kg per cu m
γ_w = 1,025 = density of sea water, kg per cu m
f_h = 1.28 to 1.35 = a factor taking into account the friction losses in the hawse hole and stopper.

The required pull of the cable lifter to hoist two anchors is

$$T_{cl} = 2f_h(G_a + p_aL_a)\left(1 - \frac{\gamma_w}{\gamma_a}\right) = 2 \times 1.35\,(G_a + p_aL_a)\left(1 - \frac{1,025}{7,750}\right) = 2.35\,(G_a + p_aL_a) \quad \text{kg} \tag{383}$$

In hoisting one anchor

$$T_{cl} = 1.175\,(G_a + p_aL_a) \quad \text{kg}$$

The following empirical formulas can be derived from a comparison of the weights of anchors and the size of their chains as stipulated by the U.S.S.R. Shipping Register, as well as the U.S.S.R. Standard on anchor chain:

The chain bar size $d_c \approx \sqrt{G_a}$ mm. The weight per running metre of anchor chain is

$$\left.\begin{aligned} &(a)\ p_{ao} = 0.023\,d_c^2 \quad \text{kg for open-link chain} \\ &(b)\ p_{as} = 0.0218\,d_c^2 \quad \text{kg for stud-link chain} \end{aligned}\right\} \tag{384}$$

According to the U.S.S.R. Shipping Register the aft anchoring arrangement, usually consisting of a capstan, must break away the anchor and heave it in at a speed of at least 9 m per min.*

---

* In breaking away one anchor from the bottom

$$T_{cl} = 2G_a + 1.175\,(G_a + p_aL_a) \quad \text{kg}$$

1. Semua data diacukan pada daerah (lingkup) model, dan tahanan model (R_{Tm}) ditentukan sebagai fungsi kecepatan.
2. Koefisien tahanan total spesifik model (C_{Tm}) ditentukan :

$$C_{Tm} = \frac{R_{Tm}}{\frac{1}{2}\rho V_m^2 S_m} \qquad (5.5.5)$$

ρ adalah massa jenis, V_m kecepatan model, S_m permukaan basah model (= panjang garis sisi rata-rata × panjang garis air).

3. Koefisien tahanan sisa spesifik ditentukan dari

$$C_R = C_{Tm} - C_{Fm} \qquad (5.5.6)$$

C_{Fm} adalah koefisien tahanan gesek spesifik. "Garis korelasi model – kapal ITTC 1957" dipakai untuk menentukan koefisien tahanan gesek.

$$C_F = \frac{0{,}075}{(\log_{10} R_n - 2)^2} \qquad (5.5.7)$$

R_n adalah angka Reynolds (VL/ν, ν adalah koefisien viskositas kinematik dan L panjang garis air). Dalam Gb. 5.5.4 diberikan kontur C_F untuk berbagai harga V dan F_n. Koordinat horizontal menunjukkan panjang model L. Diagram tersebut untuk $\nu = 1{,}139 \times 10^{-6}$ m s^{-1}, $\rho = 1000$ t/m^3, dan $T = 15$°C. Karena itu untuk memakai diagram tersebut dengan kondisi yang lain, yaitu massa jenis dan suhu yang lain, panjang kapal harus diubah dulu sebelum memakai diagram tersebut sebagai berikut

$$L_1 = \frac{1{,}139}{10^6 \nu} L \qquad (5.5.8)$$

4. C_R dinyatakan sebagai fungsi angka Froude

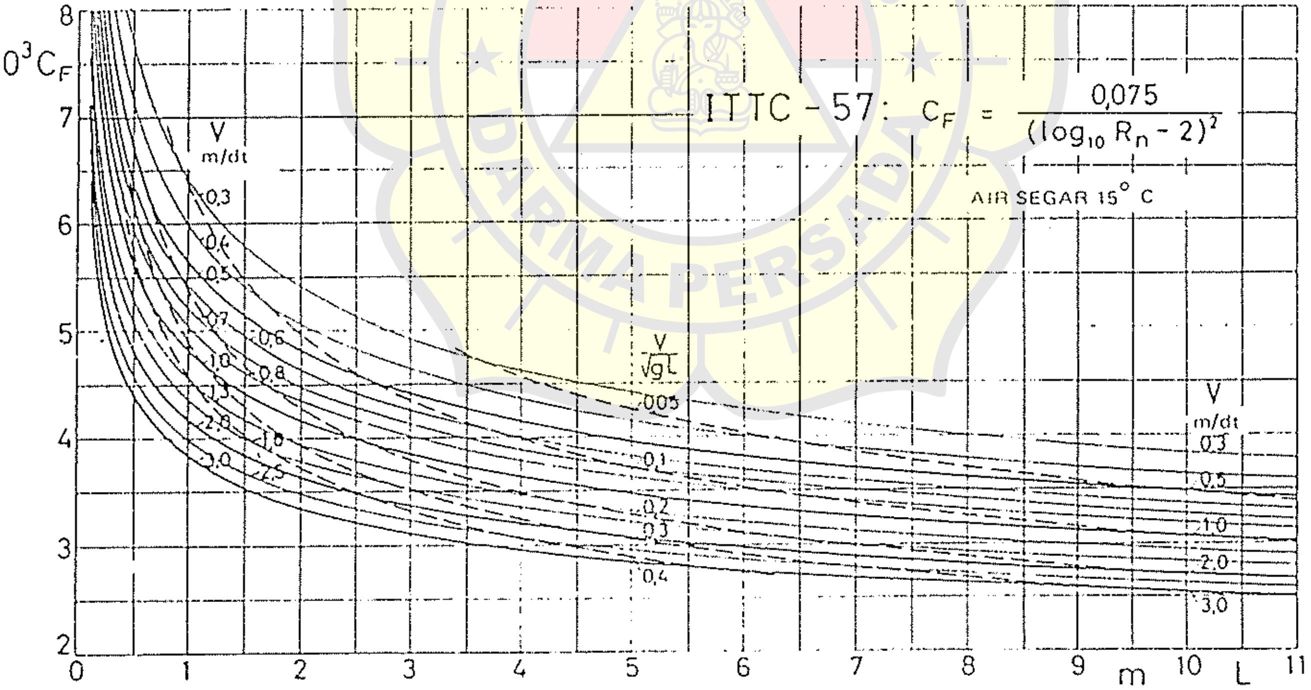
$$F_n = \frac{V}{\sqrt{gL}} \qquad (5.5.9)$$

(rasio kecepatan – panjang $V/\sqrt{L}$, dalam hal ini V diukur dalam knot dan L dalam kaki, didapat dari subskala dalam diagram C_R).

5. Hasilnya dikelompokkan menurut rasio panjang – displasemen $L/\nabla^{1/3}$ dan koefisien prismatik φ model. ∇ adalah volume displasemen dan

$$\varphi = \frac{\nabla}{LBT\beta} \qquad (5.5.10)$$

B adalah lebar, T sarat, dan β koefisien penampang melintang tengah kapal.



Gambar 5.5.4. Koefisien tahanan gesek C_F (menurut ITTC 1957) sebagai fungsi dari panjang model kapal L dan kecepatan V.

6. Diagram utama digambarkan untuk menyatakan kurva rata-rata C_R untuk rasio lebar – sarat $B/T = 2{,}5$. Diagram tersebut ditunjukkan di Gb. 5.5.5 – 5.5.13.

Dalam diagram tersebut kurva yang digambar dengan garis terputus-putus menunjukkan bahwa kurva tersebut didasarkan pada hasil percobaan yang sedikit jumlahnya atau diperoleh secara ekstrapolasi. Karena itu keraguan hasil di daerah kurva itu cukup besar. Selain itu, perlu diperhatikan pula bahwa di dan di dekat daerah kurva yang mempunyai punuk (tonjolan) yang menyolok, terutama jika kemiringannya menjadi negatif, tingkat ketidak pastiannya juga tinggi. Perubahan yang kecil saja dari bentuk badan kapal di dalam daerah tersebut dapat mempunyai pengaruh yang berarti pada harga C_R.

Perlu pula disebutkan di sini bahwa kurva tahanan tersebut berlaku untuk kapal yang mempunyai bentuk standar, yaitu letak titik benamnya standar, harga B/T nya standar, bentuk penampangnya normal, buritannya merupakan buritan sendok (cruiser stern) yang moderat, dan linggi haluannya merupakan linggi haluan condong (raked stem).

Tahanan R dan daya efektif P_E untuk kapal baru dapat dihitung dengan memakai

$$R = C_T(\tfrac{1}{2}\rho V^2 S) \quad (\text{N}) \qquad (5.5.11)$$

$$P_E = RV \quad (\text{kW}) \qquad (5.5.12)$$

Dalam hal ini koefisien tahanan totalnya adalah

$$C_T = C_R + C_F + C_A \qquad (5.5.13)$$

C_R = koefisien tahanan sisa. Untuk bentuk kapal yang "standar" dapat diambil dari diagram (Gb. 5.5.5 – 5.5.13)

C_F = koefisien tahanan gesek dan dapat dihitung dengan memakai

$$C_F = \frac{0{,}075}{(\log_{10} R_n - 2)^2} \qquad (5.5.14)$$

atau dapat diambil dari Gb. 5.5.14. Dalam gambar ini kontur C_F diberikan untuk berbagai harga V yang berbeda. Koordinat L horizontalnya adalah panjang kapal. Diagram tersebut berlaku untuk $\nu = 1{,}188 \times 10^{-6}$ m.s^{-1}, $\rho = 1{,}025$ t/m^3, dan $t = 15$°C. Untuk kondisi yang lain, yaitu massa jenis dan suhu yang lain, sebelum memakai diagram tersebut panjang kapal harus diubah dulu sebagai berikut :

$$L_1 = \frac{1{,}188}{10^6 \nu} L \qquad (5.5.15)$$

C_A = koefisien tahanan tambahan, yaitu koefisien kekasaran permukaan dan pengaruh skala pada hasil percobaan model. Dalam hal ini maka C_A akan tergantung pada cara penentuan C_R dan C_F.

Untuk kapal penarik, R harus diganti dengan $R + F$. Dalam hal ini F adalah gaya tarik tali penarik (tow rope pull).

Karena kapal pada umumnya berbeda dengan standar dengan tingkat perbedaan tertentu, lebih besar atau lebih kecil, maka harus dilakukan koreksi sebagai berikut.

B/T

Karena diagram tersebut dibuat berdasarkan rasio lebar – sarat

$$B/T = 2{,}5 \qquad (5.5.16)$$

maka harga C_R untuk kapal yang mempunyai rasio lebar – sarat lebih besar atau lebih kecil daripada harga tersebut harus dikoreksi.

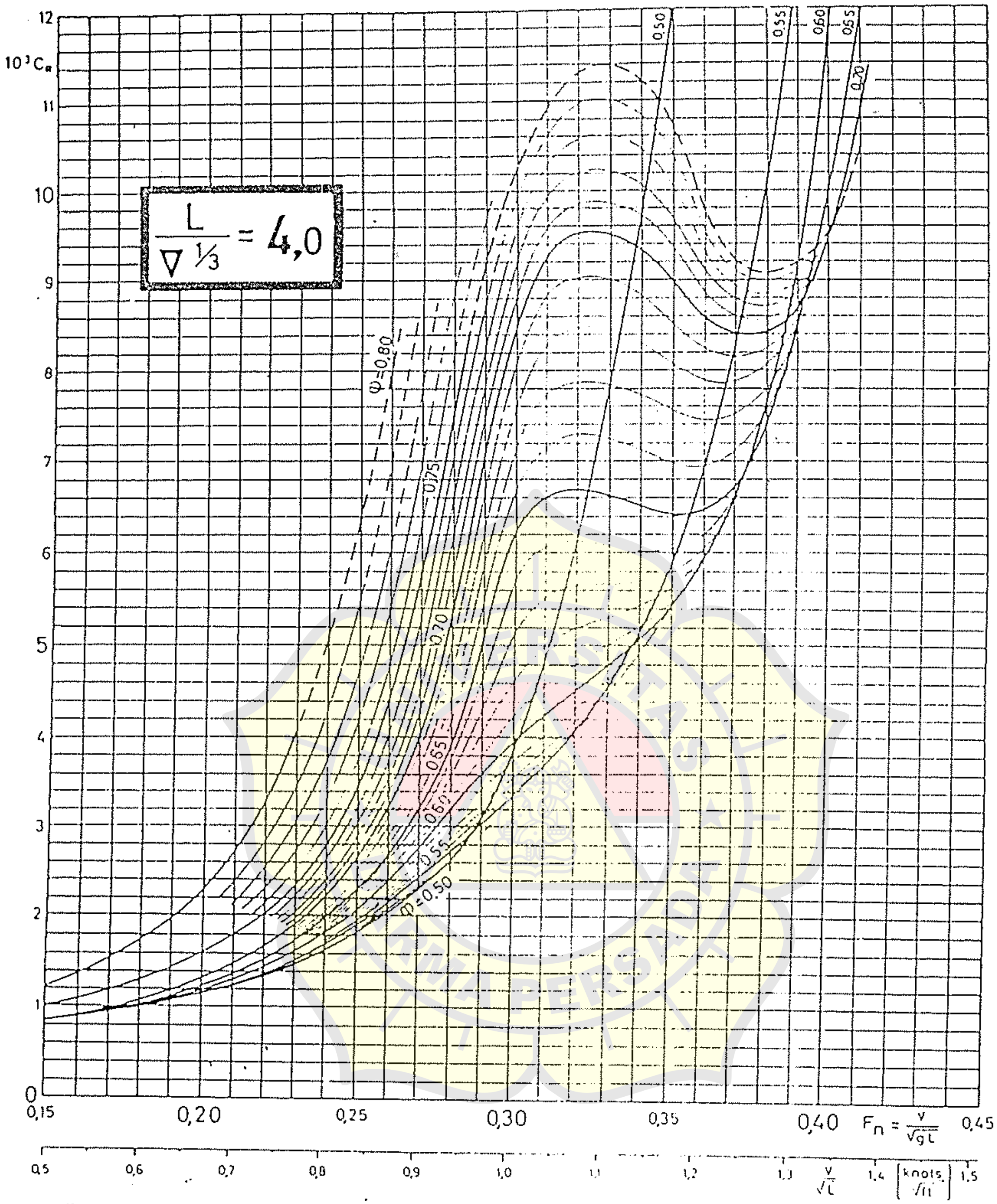
Berdasarkan hasil pemeriksaan materi pengujian yang ada saat ini maka disarankan untuk memakai rumus koreksi berikut ini :

$$10^3 C_R = 10^3 C_{R(B/T=2{,}5)} + 0{,}16(B/T - 2{,}5) \qquad (5.5.17)$$

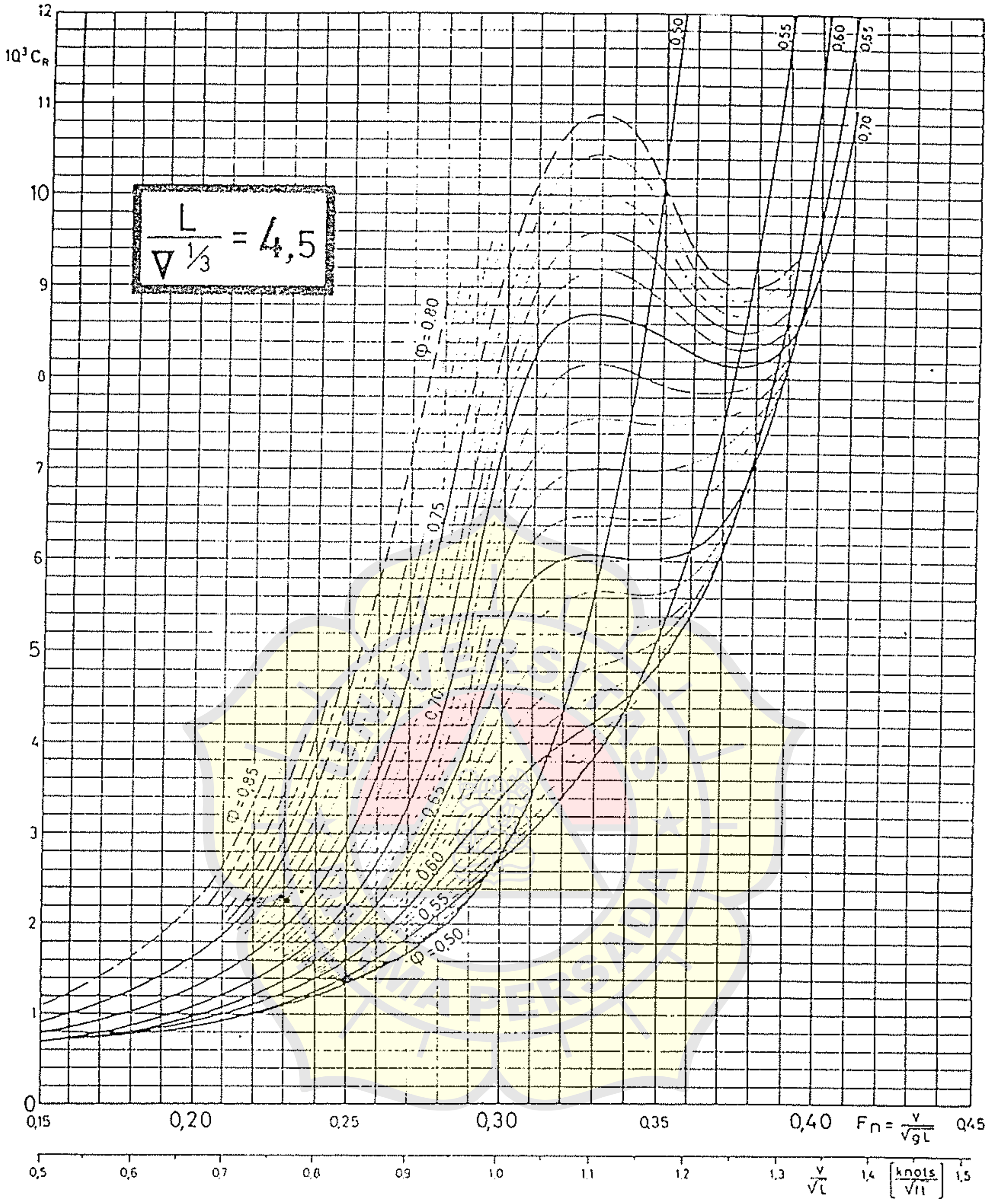
Koreksi ini dapat mempunyai harga yang negatif atau positif.

LCB

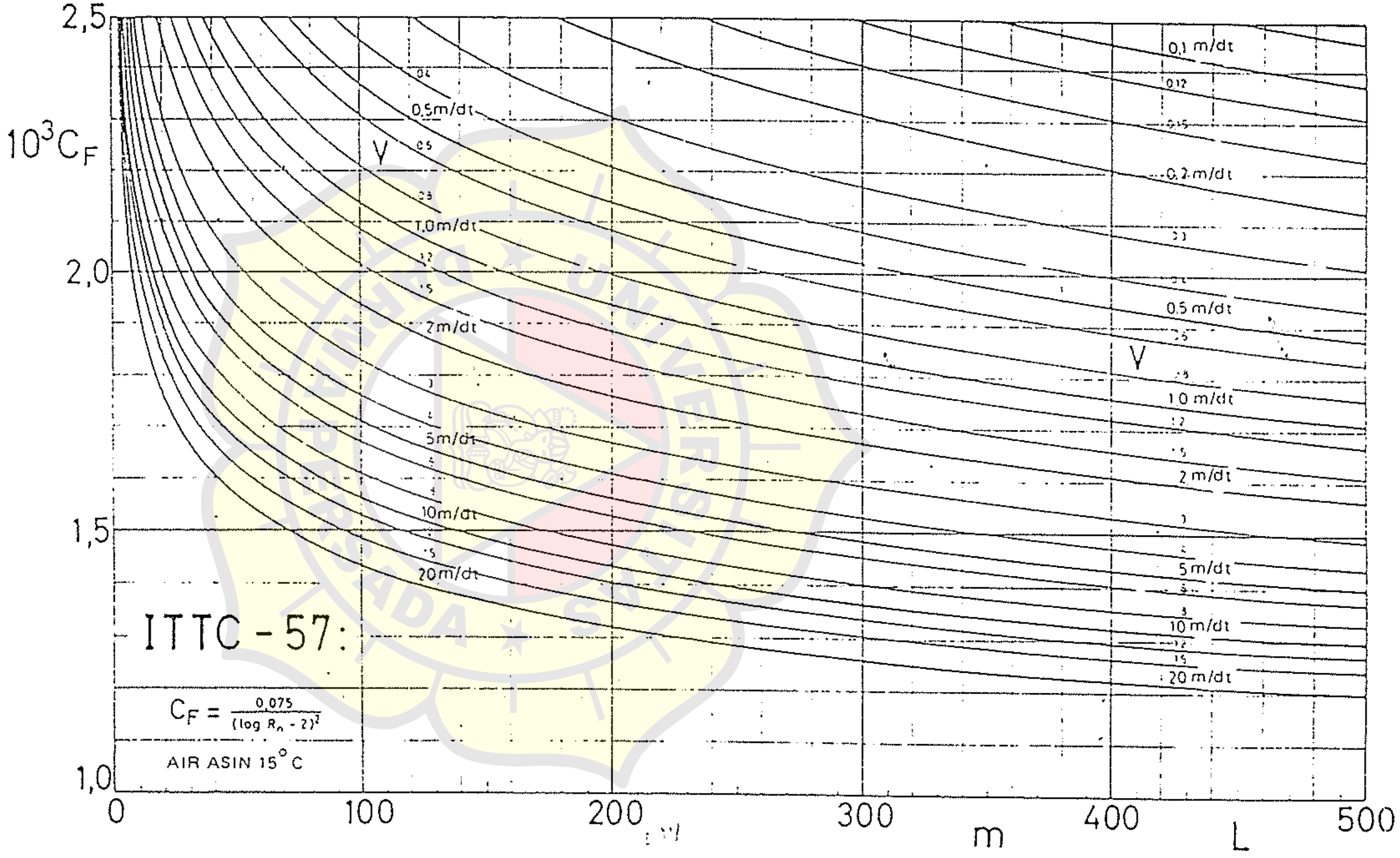
Semua kurva C_R tersebut dimaksudkan untuk kapal yang letak titik benam longitudinalnya dekat dengan letak yang dewasa ini dipandang sebagai letak yang terbaik yang memungkinkan. Letak LCB yang optimum merupakan kuantitas yang masih agak meragukan, dan semua kepustakaan yang ada menunjukkan pendapat yang berbeda-beda sehingga memberikan gambaran yang agak membingungkan. Namun demikian, ketergantungan tahanan kapal pada LCB nampak jelas pada kecepatan yang tinggi. Sebagai upaya untuk mengatasi kerancuan tersebut maka semua informasi yang ada dikumpulkan dan diringkas pada Gb. 5.5.15. Namun ini harus dipandang sebagai LCB standar untuk metode itu saja.



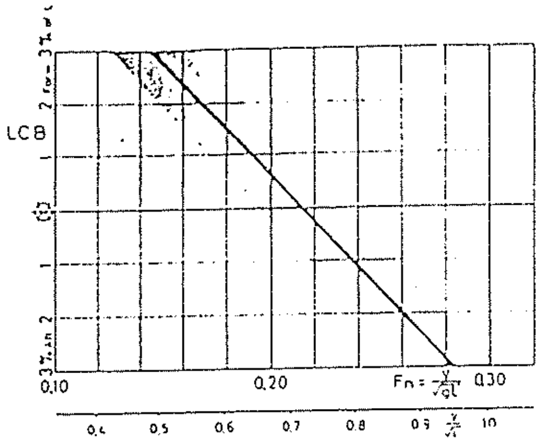
Gambar 5.5.5. Koefisien tahanan sisa terhadap rasio kecepatan panjang untuk harga koefisien prismatik longitudinal yang berbeda-beda. $L/\nabla^{1/3} = 4,0$.



Gambar 5.5.6. Koefisien tahanan sisa terhadap rasio kecepatan-panjang untuk harga koefisien prismatik longitudinal yang berbeda-beda. $L/\nabla^{1/3} = 4,5$.



Gambar 5.5.14. Koefisien tahanan gesek C_F (menurut ITTC 1957) sebagai fungsi panjang kapal L dan kecepatan V.



Gambar 5.5.15. LCB standar. Letak longitudinal titik benam yang dipandang terbaik.

Dalam hal ini, LCB standar tersebut didefinisikan sebagai fungsi linier angka Froude F_n. Karena tidak adanya ketergantungan yang pasti pada parameter lainnya yang tercatat maka LCB standar tersebut disajikan sebagai garis tunggal. Daerah yang diberi warna gelap di sekitar garis ini menunjukkan lingkup materi yang dikaji.

Sebagaimana disebutkan sebelumnya, karena letak LCB standar dianggap merupakan letak yang memberikan tahanan yang paling kecil maka letak yang lain pada prinsipnya akan memberikan tahanan yang lebih besar. Penambahan tahanan tersebut harus dicari dengan jalan mengalikan penyimpangan LCB dari standar, yaitu

$$\Delta\text{LCB} = \text{LCB} - \text{LCB}_{\text{standar}} (\text{LCB dalam } \% L) \qquad (5.5.18)$$

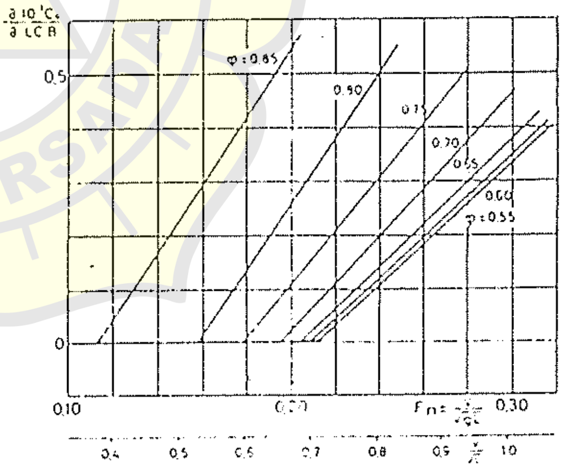
dengan faktor $\partial 10^3 C_R / \partial \text{LCB}$. Harga faktor ini dapat diperoleh dari Gb. 5.5.16, dan ini hanya berlaku untuk LCB yang berada di depan $\text{LCB}_{\text{standar}}$. Mengenai LCB yang berada di belakang $\text{LCB}_{\text{standar}}$, semua sumber yang ada mempunyai pendapat yang saling bertentangan. Namun demikian, karena kecenderungan terjadinya letak demikian itu sangat kecil maka pengabaian koreksi dalam hal itu tidak akan memberikan kesalahan yang berarti.

Dengan demikian maka koefisien tahanan sisa dengan koreksi tersebut untuk kapal yang mempunyai LCB di depan LCB standar adalah :

$$10^3 C_R = 10^3 C_{R(\text{standar})} + \frac{\partial 10^3 C_R}{\partial \text{LCB}} |\Delta\text{LCB}| \qquad (5.5.19)$$

Bentuk badan kapal yang dilingkup dalam *Ship Resistance* adalah bentuk badan yang umum untuk jenis kapal niaga di sekitar tahun 1960 an, yaitu sampai dengan waktu diterbitkannya publikasi Guldhammer dan Harvald (1974). Bentuk badan kapal tersebut mempunyai burjitan yang diletakkan tegak lurus di (berimpit dengan) sumbu tongkat kemudi (rudder stock) dan haluan yang tegak lurus di ujung depan garis air perancangan. Sejak tahun 1960 bentuk badan kapal telah mengalami pengembangan lebih lanjut, dan lebih bervariasi, misalnya berbagai bentuk haluan gembung yang telah dipakai secara luas. Rumus perhitungan tahanan yang diberikan di sini dapat dipakai baik untuk bentuk gembung modern atau yang lebih bervariasi maupun untuk bentuk tradisional, tetapi *L* dan LCB harus mengikuti definisi yang lebih sesuai berikut ini. Panjang perhitungan *L* didefinisikan sebagai panjang antara batas depan dan batas belakang displasemen, yaitu panjang terbesar dari bagian badan kapal yang berada di dalam air, dan ini adalah L_{OS} menurut standar ITTC. Untuk kapal dengan bentuk tradisional tanpa gembung, panjang tersebut adalah panjang garis air.

LCB didefinisikan sebagai letak longitudinal titik benam, yaitu jarak antara titik ini dengan penampang tengah kapal, dan positif di belakang penampang tersebut. Midship section (penampang melintang tengah kapal, atau penampang tengah kapal, atau bidang tengah kapal, atau bidang tengah kapal) didefinisikan sebagai penampang melintang yang terletak sejauh 48,5%*L* dari batas depan displasemen. *L* adalah



Gambar 5.5.16. Koreksi koefisien tahanan sisa untuk LCB 1% di depan standar. Dengan demikian maka koreksi ini adalah $(\partial 10^3 C_R / \partial \text{LCB}) |\Delta\text{LCB}|$. ΔLCB adalah jarak longitudinal antara LCB yang sebenarnya dengan LCB standar dalam persen *L*. Tidak ada koreki untuk LCB yang terletak di belakang standar. Koreksi tersebut selalu positif.

panjang perhitungan menurut definisi tadi. Dengan demikian maka penampang tengah kapal menurut definisi ini adalah pertengahan antara kedua garis tegak bantu (auxuliary perpendiculars), $AP_1 - FP_1$; bandingkan di Gb. 5.5.17. Untuk bentuk normal, $AP_1 - FP_1$ ini akan sama dengan kedua garis tegak yang umum didefinisikan, $AP - FP$.

BENTUK BADAN KAPAL (BENTUK PENAMPANG MELINTANG DAN HALUAN)

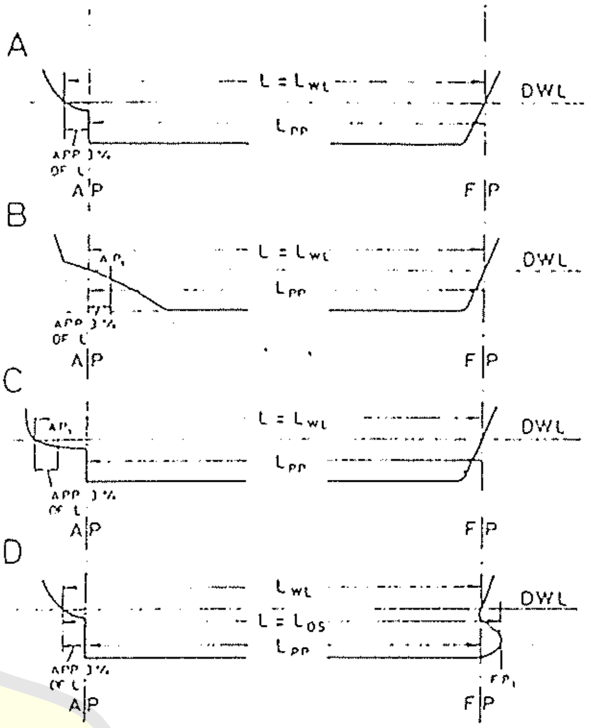
Sebagaimana disebutkan sebelumnya, kurva tahanan (yang diperoleh berdasarkan Gb. 5.5.5 – 5.5.13) dianggap berlaku untuk yang mempunyai bentuk "standar", yaitu penampangnya bukan yang benar-benar berbentuk U ataupun V. Karena itu, dalam menghitung daya efektif untuk perancangan awal umumnya tidak diperlukan koreksi untuk bentuk penampang badan kapal. Jika penampang tersebut merupakan penampang U atau V yang ekstrem maka harga $10^3 C_R$ dapat dikoreksi sebagai berikut : Koreksi $10^3 C_R$ untuk bentuk dari penampang

badan depan	ekstrem U – 0,1	ekstrem V + 0,1
badan belakang	ekstrem U + 0,1	ekstrem V – 0,1

(5.5.20)

Koreksi ini berlaku untuk kecepatan $V/\sqrt{gL}$ dalam rentang 0,20 – 0,25. Selain itu, bentuk "standar" harus dipandang sebagai bentuk yang mempunyai garis yang dirancang dengan baik. Jika garis perancangan tersebut harus diubah untuk menyesuaikan kebutuhan operasional kapal, atau besarnya daya harus diberikan kelonggaran, maka disarankan agar C_R dinaikkan sebesar 10% dan, untuk garis perancangan yang tidak optimal, mungkin sebesar 20% atau lebih.

Mengenai haluan, bentuk standar tersebut harus dipandang sebagai bentuk haluan kuno tanpa gembung. Untuk kapal dengan haluan gembung yang mempunyai harga $A_{BT}/A_X \geqq 0{,}10$ (A_{BT} adalah luas penampang haluan gembung di garis tegak depan dan A_X adalah luas penampang tengah kapal) maka disarankan agar $10^3 C_R$ diberikan koreksi sebagai berikut :



Gambar 5.5.17. Definisi L dan LCB. (a) Bentuk normal. Panjang buritan pada garis air umumnya 3% L. (b) Badan kapal tanpa linggi buritan (sternpost). AP umumnya diletakkan di ujung belakang DWL. Untuk koreksi LCB dipakai AP_1 3% L di depan ujung belakang garis air. (c) Badan kapal dengan panjang buritan yang ekstrem. Untuk koreksi LCB dipakai AP_1 3% L di depan ujung akhir garis air. FP_1 adalah batas depan displasemen.

Jika $A_{BT}/A_X = 0{,}10$ maka bentuk haluan gembung akan tampak lebih menyolok. Koreksi untuk $0 < A_{BT}/A_X < 0{,}10$ dianggap berbanding lurus dengan ukuran gembung.

Koreksi ini hanya berlaku untuk kapal dalam kondisi bermuatan saja. Untuk kondisi balas maka koreksi karena adanya haluan gembung akan memberikan gambaran yang sebaliknya. Bentuk penuh ($\varphi > 0{,}70$) akan menunjukkan penurunan tahanan yang menyolok, harga koreksinya dua hingga tiga kali harga koreksi tersebut, sedangkan tahanan untuk bentuk ramping ($\varphi < 0{,}60$) umumnya akan cenderung naik.

$F_n = 0{,}15$	0,18	0,21	0,24	0,27	0,30	0,33	0,36	φ
		+ 0,2	0	– 0,2	– 0,4	– 0,4	– 0,4	0,50
		+ 0,2	0	– 0,2	– 0,3	– 0,3		0,60
	+ 0,2	0	– 0,2	– 0,3	– 0,3			0,70
+ 0,1	0	– 0,2						0,80

(5.5.21)

ANGGOTA BADAN KAPAL

Daun kemudi	Tidak ada koreksi bentuk standar sudah mencakup daun kemudi.	
Lunas bilga (lunas sayap)	Tidak ada koreksi	
Bos baling-baling	Untuk kapal penuh C_R dinaikkan sebesar 3 – 5%	(5.5.22)
Braket dan poros baling-baling	Untuk kapal ramping C_R dinaikkan sebesar 5 – 8%	

TAHANAN TAMBAHAN

Pemberian koreksi pada C_{FS} untuk kapal merupakan cara yang umum dilakukan dalam praktek dan sudah bertahun-tahun lamanya diterapkan untuk memperhitungkan pengaruh kekasaran permukaan kapal mengingat bahwa permukaan kapal tidak akan pernah semulus permukaan model, sekalipun kapal itu benar-benar baru dan catnyapun masih segar. Koefisien penambahan tahanan untuk korelasi model – kapal umumnya ditentukan sebesar $C_A = 0{,}0004$. Namun demikian, pengalaman lebih lanjut menunjukkan bahwa cara demikian itu tidak selalu benar. Karena itu, diusulkan koreksi untuk pengaruh kekasaran dan pengaruh sebagai berikut untuk kondisi pelayaran percobaan :

$$
\begin{array}{lrl}
\text{Untuk kapal dengan } L \leqq 100\text{ m}, & 10^3 C_A = & 0{,}4 \\
= 150\text{ m} & = & 0{,}2 \\
= 200\text{ m} & = & 0 \\
= 250\text{ m} & = & -0{,}2 \\
\geqq 300\text{ m} & = & -0{,}3
\end{array}
\tag{5.5.23}
$$

Beberapa pihak berpendapat bahwa koreksi yang diberikan di Bab 5, 5.2.4 lebih sesuai, yaitu,

$$
\begin{array}{rrl}
\multicolumn{3}{c}{\textbf{Displasemen}} \\
\hline
1.000\text{ t} & C_A = & 0{,}6 \times 10^{-3} \\
10.000\text{ t} & = & 0{,}4 \times 10^{-3} \\
100.000\text{ t} & = & 0 \\
1.000.000\text{ t} & = & -0{,}6 \times 10^{-3}
\end{array}
\tag{5.5.24}
$$

Perlu disebutkan di sini bahwa koreksi untuk koefisien tahanan gesek ini masih agak meragukan.

ANGGOTA BADAN KAPAL

Koreksi C_F untuk anggota badan kapal hanya dilakukan dengan jalan menaikkan C_F sebanding dengan luas permukaan basah anggota badan begitu saja. Jadi,

$$C_F' = C_F \frac{S_1}{S} \tag{5.5.25}$$

S adalah luas permukaan basah badan kapal dan S_1 adalah permukaan basah badan dan anggota badan kapal.

TAHANAN UDARA DAN TAHANAN KEMUDI

Tahanan udara dapat ditentukan dengan memakai data mengenai struktur yang berada di atas air dan data udara. Namun demikian, besarnya tahanan udara umumnya tidak terlalu penting, dan upaya yang harus dilakukan untuk mendapatkan hasil perhitungan yang tepat mungkin tidak memadai dengan pentingnya pengaruh udara tersebut. Karena itu, jika data mengenai angin dalam perancangan kapal tidak diketahui maka disarankan untuk mengoreksi $10^3 C_R$ sebagai berikut :

$$10^3 C_{AA} = 0{,}07 \tag{5.5.26}$$

Koreksi untuk tahanan kemudi mungkin sekitar

$$10^3 C_{AS} = 0{,}04 \tag{5.5.27}$$

tetapi tentu saja untuk kapal yang stabil dalam kondisi yang wajar koreksi tersebut dapat diabaikan.

Terlihat bahwa kedua koreksi tersebut kecil dan dalam perancangan awal koreksi ini umumnya sudah tercakup dalam tahanan tambahan.

KONDISI PELAYARAN DINAS

Tahanan dan daya efektif yang dihitung dengan memakai diagram yang diberikan di sini berlaku untuk kapal dalam kondisi pelayaran percobaan, yaitu, untuk kondisi ideal dari segi angin, gelombang, kedalaman air, dan kemulusan badan kapal. Untuk kondisi rata-rata pelayaran dinas harus diberikan kelonggaran tambahan pada tahanan dan daya efektif yang disebabkan oleh angin, laut, erosi, dan fouling pada badan kapal.

Tambahan kelonggaran ini sangat tergantung pada jalur pelayaran. Kelonggaran rata-rata untuk pelayaran dinas (kadang-kadang disebut sea margin atau service margin) untuk tahanan atau daya efektif diusulkan sebagai berikut :

Jalur pelayaran Atlantik Utara, ke Timur, untuk musim panas 15% dan musim dingin 20%

Jalur pelayaran Atlantik Utara, ke Barat, untuk musim panas 20% dan musim dingin 30% (5.5.28)

Jalur pelayaran Pasifik, 15 – 30%
Jalur pelayaran Atlantik Selatan dan Autralia, 12 – 18%

Jalur pelayaran Asia Timur, 15 – 20%

Tahanan total harus dihitung dengan memakai rumus

$$R_T = C_T(\tfrac{1}{2}\rho V^2 S) \qquad (5.5.29)$$

S adalah luas permukaan basah badan kapal.

Banyak sekali metode untuk memperkirakan S. Dianjurkan untuk memakai salah satu dari dua metode berikut ini :

1. Publikasi FORMDATA I – V (Guldhammer, 1962, 1963, 1967, 1969, 1973) memuat data hidrostatik dari suatu seri yang sangat baik yang terdiri dari sejumlah bentuk kapal yang divariasikan secara sistematik. Permukaan basah semua bentuk memakai koefisien

   $$\boxed{S} = \frac{S}{L(B + 2{,}5T)} \qquad (5.5.30)$$

   Jika dari perancangan awal kapal bentuk badan kapal yang sebenarnya hampir sama dengan salah satu bentuk yang diberikan dalam FORMDATA tersebut maka akan diperoleh S dengan kesalahan kurang dari 1%.
2. Permukaan basah untuk kapal niaga yang normal dapat dihitung dengan memakai rumus berikut ini (versi rumus Mumford) :

   $$S = 1{,}025 L_{pp}(\delta_{pp} B + 1{,}7T) \qquad (5.5.31)$$

Semua diagram $\boxed{S}$ dan rumus yang disertakan dalam FORMDATA berlaku untuk bentuk kapal yang buritan dan haluannya masing-masing terletak pada garis tegak belakang dan garis tegak depan. Hampir semua kapal mempunyai luas permukaan basah yang sesuai dengan asumsi tersebut, karena luas yang kurang dan luas yang lebih akan saling berimbang. Untuk kapal yang mempunyai juntaian (= bagian yang menggantung = overhang), atau lekukan (= bagian yang masuk = cutout), di dalam air yang besar maka hal tersebut harus diperhitungkan (diberikan kelonggaran).

Perhitungan tahanan dan daya efektif dapat dilakukan dengan prosedur seperti yang ditunjukkan dalam Contoh Formulir untuk Menghitung Daya Efektif (lihat halaman 132). Perhitungan dapat dilakukan dengan memakai komputer mini. Kini banyak arsitek kapal yang mempunyai program untuk perhitungan demikian itu.

Dalam tahap perancangan pertanyaan utama yang harus dituntaskan adalah jenis dan ukuran mesin (misalnya banyaknya dan ukuran silinder, jika memakai mesin disel). Tahanan harus ditentukan dengan tingkat kepastian yang memadai sehingga, atas dasar daya efektif P_E, daya poros akan dapat ditentukan dengan tingkat ketepatan yang cukup untuk dapat menjawab dengan aman pertanyaan vital tadi.

Di lain pihak, upaya untuk mencapai ketepatan yang melebihi dari yang diperlukan untuk menyelesaikan masalah tahanan tidak mempunyai arti yang besar. Tingkat ketidakpastian dalam faktor yang terlibat cukup tinggi, dan pembaca diingatkan untuk tidak membuang waktu untuk memburu ketepatan yang tersisa dengan perhitungan yang sifatnya hanya pendekatan.

Untuk kapal yang bertenaga mesin disel, merubah jumlah silinder, katakanlah dari 6 menjadi 7, atau dari 11 menjadi 12, akan berarti merubah daya masing-masing sebesar sekitar 17% atau 8%. Dengan memodifikasi tekanan efektif rata-rata dan jumlah kisaran maka akan dapat merubah luaran menerus (continuous output) sebesar sekitar 10%.

Mesin turbin mempunyai tingkatan menurut jenisnya.

Atas dasar pertimbangan tersebut barangkali tingkat ketepatan yang diperlukan dalam penentuan P_E untuk perancangan awal kapal dapat ditentukan sebesar 1 hingga 5%. Ketepatan ini dapat dengan mudah diperoleh dengan memakai diagram dan formulir Perhitungan yang diberikan di sini.

Diagram dan rumus tersebut dapat pula dipakai dengan cara sebagai berikut. Setiap hasil yang diperoleh dari percobaan yang dilakukan sendiri oleh si arsitek kapal di tangki percobaan dicocokkan dengan diagram. Data ini kemudian dikoreksi dengan memakai rumus dan diagram tadi dan selanjutnya dipakai sebagai dasar materi untuk menentukan tahanan kapal baru yang akan diajukan dalam usulan. Sering bahwa dengan prosedur demikian ini dapat diperoleh hasil yang sangat baik.

Tabel A.1. Satuan dan Faktor Konversi

To Convert	From	To	Multiply by*
Length	inch (in.)	metre	0.0254
	foot (ft)	metre	0.3048
Area (A)	ft²	m²	0.0929
	in.²	cm²	6.4516
Volume (V)	ft³	m³	0.0283
	gallon (U.S.)	m³	0.003785
	gallon (U.S.)	L	3.785
Volume flow rate (V)	ft³/min (cfm)	m³/s	0.000472
	gpm	m³/s	0.00006309
	gpm	L/s	0.06309
Mass (m)	lb	kg	0.45359
Mass flow rate (m)	lb/min	g/s	7.55987
Specific volume (v)	ft³/lb	m³/kg	0.062428
	ft³/lb	cm³/g	62.428
Density (ρ)	lb/ft³	kg/m³	16.0185
Velocity (v)	ft/min (fpm)	m/s	0.00508
	ft/sec (fps)	m/s	0.3048
	mph	m/s	0.447040
Pressure (p)	psi	Pa (N/m²)	6894.76
	psf	Pa	47.8803
	mm Hg	Pa	133.322
	in. Hg (0°C)	Pa	3,386.[illegible]
	in. H₂O (4°C)	Pa	249.0
	ft H₂O (4°C)	Pa	2988.[illegible]
	m H₂O (4°C)	Pa	9806.65
	kPa	m H₂O	0.102
	bar	Pa	100,000
	1 atmosphere (std)	Pa	101,325
	kg/cm²	kPa	98.067
Force (F)	lb	N	4.44822
Work and energy (w)	ft-lb	J	1.355818
	Btu	J	1055.06
	Btu	ft-lb	778
Power (P)	hp	W (J/s)	745.69[illegible]
	Btu/hr	W	0.293071
	ton (ref)	W	3516.8
Specific heat (c) or entropy (s)	Btu/lb °F	J/g K	4.18682
Enthalpy (h)	Btu/lb	J/g	[illegible]
Conductivity (k)	(Btu)(in.)/(hr)(ft²)(°F)	W/(m)(K)	[illegible]
Conductance (C) or coefficient of heat transfer (U)	Btu/(hr)(ft²)(°F)	W/(m²)(K)	[illegible]

* To convert in the opposite direction, divide by the factor in this column.

LAMPIRAN

Tabel B.1. Harga Konduktivitas Thermal Beberapa Material

Material	Description	Thermal Conductivity (k) W/m K	Thermal Conductance (C) W/m² K
Masonry	Brick, common	0.72	
	Brick, face	1.30	
	Concrete, mortar or plaster	0.72	
	Concrete, sand aggregate	1.7[illegible]	
	Concrete block		
	Sand aggregate 100 mm		7.95
	Sand aggregate 200 mm		5.11
	Sand aggregate 300 mm		4.43
	Cinder aggregate 100 mm		5.11
	Cinder aggregate 200 mm		3.29
	Cinder aggregate 300 mm		3.01
	Gypsum plaster 13 mm		17.72
	Tile, hollow clay 100 mm		5.11
	Tile, hollow clay 150 mm		3.75
	Tile, hollow clay 200 mm		3.07
Woods	Maple, oak, similar hardwoods	0.15	
	Fir, pine, similar softwoods	0.12	
	Plywood 13 mm		9.09
	Plywood 19 mm		6.08
Roofing	Asphalt roll roofing		36.91
	Built-up roofing 9 mm		17.03
Insulating materials	Blanket or batt, mineral or glass fiber	0.039	
	Board or slab		
	Cellular glass	0.055	
	Corkboard	0.043	
	Glass fiber	0.035	
	Expanded polystyrene (smooth)	0.029	
	Expanded polystyrene (cut cell)	0.036	
	Expanded polyurethane	0.025	
	Loose fill		
	Milled paper or wood pulp	0.039	
	Sawdust or shavings	0.065	
	Mineral wool (rock, glass, slag)	0.039	
	Redwood bark	0.037	
	Wood fiber (soft woods)	0.043	
Surface conductance (convection coefficient)	Still air		9.37
	Moving air (3.35 m/s or 12 km/h)		22.70
	Moving air (6.7 m/s or 24 km/h)		34.10
Glass	Single pane		6.42
	Two pane		2.81
	Three pane		1.8[illegible]
	Four pane		[illegible]

Adapted from [illegible]
Society of Heati[illegible]

TABEL B.2 THERMAL CONDUCTIVITIES, SPECIFIC HEATS, SPECIFIC GRAVITIES OF METALS AND ALLOYS

k = Btu/(hr)(ft²)(°F/ft)

Substance	Temp, °F	k*	Specific heat,† Btu/(lb)(°F)	Specific gravity
Aluminum	32	117	0.183	2.55–7.8
Aluminum	212	119	0.1824	
Aluminum	932	155	0.1872	
Antimony	32	10.6	0.0493	
Antimony	212	9.7	0.0508	
Bismuth	64	4.7	0.0294	9.8
Bismuth	212	3.9	0.0304	
Brass (70–30)	32	56	0.1315‡	8.4–8.7
Brass	212	60	0.1488‡	
Brass	752	67	0.2015‡	
Copper	32	224	0.1487	8.8–8.95
Copper	212	218	0.1712	
Copper	932	207	0.2634	
Cadmium	64	53.7	0.0550	8.65
Cadmium	212	52.2	0.0567	
Gold	64	169.0	0.030	19.25–19.35
Gold	212	170.8	0.031	
Iron, cast	32	32	0.1064	7.03–7.13
Iron, cast	212	30	0.1178	
Iron, cast	752	25	0.1519	
Iron, wrought	64	34.6	See Iron	7.6–7.9
Iron, wrought	212	27.6	See Iron	
Lead	32	20	0.0306	11.34
Lead	212	19	0.0315	
Lead	572	18	0.0335	
Magnesium	32–212	92	0.245	1.74
Mercury	32	4.8	0.0329	13.6
Nickel	32	35	0.1050	8.9
Nickel	212	34	0.1170	
Nickel	572	32	0.1408	
Silver	32	242	0.0557	10.4–10.6
Silver	212	239	0.0571	
Steel	32	26	See Iron	7.83
Steel	212	26	See Iron	
Steel	1112	21	See Iron	
Tantalum	64	32	0.0342	16.6
Zinc	32	65	0.0917	6.9–7.2
Zinc	212	64	0.0958	
Zinc	752	54	0.1032	

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* From L. S. Marks, "Mechanical Engineers' Handbook," McGraw-Hill Book Company, Inc., New York, 1941.

† From K. K. Kelley, *U.S. Bur. Mines Bull.* 371 (1939).

‡ Weighted value for copper and zinc.

LAMPIRAN

bel C.1. Sifat Cairan dan Gas Jenuh Refrigeran 134a

TEMP °C	PRES bar	VOLUME dm³/kg		DENSITY kg/dm³		ENTHALPY kJ/kg			ENTROPY kJ/kg K		TEMP °C
		LIQUID v_f	VAPOR v_g	LIQUID $1/v_f$	VAPOR $1/v_g$	LIQUID h_f	LATENT h_{fg}	VAPOR h_g	LIQUID s_f	VAPOR s_g	
0	4.9757	0.77834	47.1354	1.28479	0.02122	200.000	205.361	405.361	1.00000	1.75179	0
1	5.1401	0.78041	45.6757	1.28139	0.02189	201.174	204.530	405.704	1.00424	1.75034	1
2	5.3085	0.78249	44.2702	1.27797	0.02259	202.351	203.703	406.054	1.00848	1.74883	2
3	5.4806	0.78460	42.9166	1.27453	0.02330	203.530	202.910	406.440	1.01271	1.74744	3
4	5.6571	0.78673	41.6124	1.27108	0.02403	204.713	202.060	406.773	1.01694	1.74604	4
5	5.8378	0.78889	40.3556	1.26760	0.02478	205.899	201.243	407.142	1.02116	1.74463	5
6	6.0225	0.79107	39.1441	1.26412	0.02555	207.089	200.400	407.489	1.02537	1.74324	6
7	6.2122	0.79327	37.9759	1.26061	0.02633	208.281	199.550	407.831	1.02958	1.74181	7
8	6.4059	0.79549	36.8493	1.25708	0.02714	209.477	198.693	408.169	1.03379	1.74047	8
9	6.6042	0.79775	35.7624	1.25353	0.02796	210.675	197.829	408.504	1.03799	1.73911	9
10	6.8070	0.80002	34.7136	1.24997	0.02881	211.877	196.958	408.835	1.04218	1.73775	10
11	7.0144	0.80232	33.7013	1.24638	0.02967	213.083	196.079	409.162	1.04637	1.73640	11
12	7.2265	0.80465	32.7239	1.24277	0.03056	214.291	195.194	409.485	1.05056	1.73506	12
13	7.4433	0.80701	31.7801	1.23915	0.03147	215.503	194.301	409.804	1.05474	1.73372	13
14	7.6650	0.80939	30.8683	1.23550	0.03240	216.719	193.400	410.119	1.05892	1.73241	14
15	7.8915	0.81180	29.9874	1.23185	0.03335	217.937	192.492	410.430	1.06305	1.73109	15
16	8.1229	0.81424	29.1361	1.22810	0.03432	219.160	191.577	410.736	1.06726	1.72979	16
17	8.3593	0.81671	28.3134	1.22442	0.03532	220.385	190.653	411.038	1.07142	1.72846	17
18	8.6006	0.81922	27.5172	1.22066	0.03634	221.615	189.721	411.336	1.07559	1.72719	18
19	8.8475	0.82175	26.7477	1.21692	0.03739	222.847	188.782	411.629	1.07974	1.72590	19
20	9.0993	0.82431	26.0032	1.21313	0.03846	224.084	187.834	411.918	1.08390	1.72462	20
21	9.3564	0.82691	25.2829	1.20932	0.03955	225.324	186.877	412.202	1.08805	1.72334	21
22	9.6189	0.82954	24.5857	1.20548	0.04067	226.568	185.913	412.481	1.09220	1.72206	22
23	9.8857	0.83221	23.9107	1.20163	0.04182	227.816	184.939	412.755	1.09634	1.72080	23
24	10.150	0.83491	23.2572	1.19773	0.04300	229.068	183.957	413.025	1.10048	1.71952	24
25	10.433	0.83765	22.6242	1.19382	0.04420	230.324	182.965	413.289	1.10462	1.71827	25
26	10.723	0.84043	22.0111	1.18987	0.04543	231.583	181.965	413.548	1.10876	1.71701	26
27	11.014	0.84324	21.4169	1.18590	0.04669	232.847	180.955	413.802	1.11290	1.71576	27
28	11.309	0.84610	20.8411	1.18190	0.04798	234.115	179.935	414.050	1.11703	1.71450	28
29	11.611	0.84899	20.2829	1.17787	0.04930	235.387	178.906	414.293	1.12116	1.71325	29
30	11.919	0.85193	19.7417	1.17381	0.05065	236.664	177.867	414.530	1.12530	1.71200	30
31	12.232	0.85491	19.2168	1.16971	0.05204	237.945	176.817	414.762	1.12943	1.71075	31
32	12.552	0.85793	18.7076	1.16559	0.05345	239.230	175.758	414.987	1.13355	1.70950	32
33	12.878	0.86101	18.2135	1.16143	0.05490	240.520	174.687	415.207	1.13768	1.70825	33
34	13.210	0.86412	17.7341	1.15724	0.05639	241.814	173.606	415.420	1.14181	1.70701	34
35	13.548	0.86729	17.2686	1.15303	0.05791	243.114	172.513	415.627	1.14594	1.70576	35
36	13.892	0.87051	16.8168	1.14875	0.05946	244.418	171.410	415.828	1.15007	1.70450	36
37	14.243	0.87378	16.3779	1.14445	0.06106	245.727	170.294	416.021	1.15420	1.70325	37
38	14.601	0.87710	15.9517	1.14012	0.06269	247.041	169.167	416.208	1.15833	1.70199	38
39	14.965	0.88048	15.5375	1.13574	0.06436	248.361	168.027	416.388	1.16246	1.70073	39
40	15.335	0.88392	15.1351	1.13133	0.06607	249.686	166.875	416.561	1.16659	1.69946	40
41	15.712	0.88741	14.7439	1.12687	0.06782	251.016	165.710	416.726	1.17072	1.69819	41
42	16.096	0.89097	14.3636	1.12237	0.06962	252.352	164.531	416.883	1.17485	1.69692	42
43	16.487	0.89459	13.9939	1.11783	0.07146	253.693	163.339	417.032	1.17900	1.69564	43
44	16.885	0.89828	13.6344	1.11324	0.07334	255.042	162.133	417.174	1.18315	1.69435	44
45	17.290	0.90203	13.2841	1.10861	0.07527	256.396	160.912	417.308	1.18727	1.69305	45
46	17.702	0.90585	12.9436	1.10393	0.07726	257.756	159.676	417.432	1.19141	1.69175	46
47	18.121	0.90975	12.6122	1.09919	0.07929	259.123	158.425	417.548	[illegible]	[illegible]	47
48	18.548	0.91374	12.2895	1.09441	0.08137	260.497	157.156	417.653	[illegible]	[illegible]	48
49	18.982	0.91779	11.9753	1.08957	0.08351	261.877	155.875	417.752	[illegible]	[illegible]	49

Courtesy E.I. du Pont de Nemours & Co., Inc.

LAMPIRAN

Lanjutan Tabel C.1. Sifat Cairan dan Gas Jenuh Refrigeran 134a

TEMP °C	PRES bar	VOLUME m³/kg·10³		DENSITY kg/m³·10⁻³		ENTHALPY kJ/kg			ENTROPY kJ/kg·K		TEMP °C
		LIQUID v_f	VAPOR v_g	LIQUID $1/v_f$	VAPOR $1/v_g$	LIQUID h_f	LATENT h_{fg}	VAPOR h_g	LIQUID s_f	VAPOR s_g	
-50	0.6439	0.69536	324.557	1.43811	0.00308	144.959	238.962	383.921	0.77919	1.85000	-50
-49	0.6776	0.69663	309.466	1.43549	0.00323	145.992	238.403	384.395	0.78380	1.84734	-49
-48	0.7128	0.69800	295.211	1.43266	0.00339	147.029	237.840	384.869	0.78841	1.84472	-48
-47	0.7494	0.69939	281.753	1.42982	0.00355	148.067	237.274	385.341	0.79302	1.84214	-47
-46	0.7875	0.70078	269.021	1.42698	0.00372	149.109	236.704	385.813	0.79756	1.83959	-46
-45	0.8271	0.70219	256.926	1.42412	0.00389	150.153	236.129	386.282	0.80216	1.83709	-45
-44	0.8682	0.70360	245.600	1.42125	0.00407	151.200	235.551	386.751	0.80672	1.83460	-44
-43	0.9110	0.70502	234.917	1.41839	0.00426	152.249	234.968	387.217	0.81128	1.83216	-43
-42	0.9555	0.70646	224.503	1.41551	0.00445	153.301	234.381	387.682	0.81582	1.82976	-42
-41	1.0016	0.70790	214.923	1.41262	0.00465	154.356	233.790	388.146	0.82035	1.82739	-41
-40	1.0495	0.70936	205.745	1.40972	0.00486	155.414	233.195	388.609	0.82490	1.82504	-40
-39	1.0992	0.71082	197.040	1.40682	0.00508	156.474	232.596	389.070	0.82942	1.82273	-39
-38	1.1507	0.71230	188.772	1.40390	0.00530	157.537	231.992	389.529	0.83393	1.82045	-38
-37	1.2041	0.71378	180.830	1.40097	0.00553	158.603	231.383	389.986	0.83844	1.81821	-37
-36	1.2594	0.71529	173.482	1.39804	0.00576	159.671	230.771	390.442	0.84294	1.81599	-36
-35	1.3168	0.71680	165.400	1.39509	0.00605	160.742	230.153	390.895	0.84743	1.81380	-35
-34	1.3761	0.71832	159.804	1.39214	0.00626	161.816	229.532	391.348	0.85191	1.81164	-34
-33	1.4375	0.71985	153.264	1.38918	0.00652	162.893	228.905	391.798	0.85635	1.80951	-33
-32	1.5011	0.72139	147.140	1.38622	0.00679	163.972	228.274	392.246	0.86085	1.80741	-32
-31	1.5668	0.72295	141.369	1.38322	0.00707	165.055	227.639	392.694	0.86534	1.80534	-31
-30	1.6348	0.72452	135.844	1.38022	0.00736	166.140	226.998	393.138	0.86976	1.80329	-30
-29	1.7050	0.72610	130.520	1.37722	0.00766	167.227	226.352	393.579	0.87420	1.80126	-29
-28	1.7776	0.72769	125.560	1.37420	0.00796	168.318	225.700	394.018	0.87861	1.79927	-28
-27	1.8525	0.72930	120.775	1.37118	0.00828	169.411	225.040	394.451	0.88306	1.79730	-27
-26	1.9299	0.73092	116.244	1.36814	0.00860	170.507	224.388	394.895	0.88748	1.79535	-26
-25	2.0098	0.73255	111.859	1.36509	0.00894	171.606	223.724	395.330	0.89190	1.79342	-25
-24	2.0922	0.73420	107.707	1.36203	0.00928	172.708	223.054	395.762	0.89630	1.79152	-24
-23	2.1772	0.73585	103.739	1.35895	0.00964	173.812	222.379	396.191	0.90070	1.78965	-23
-22	2.2646	0.73752	99.9022	1.35590	0.01001	174.919	221.700	396.619	0.90509	1.78779	-22
-21	2.3557	0.73921	96.2101	1.35279	0.01039	176.029	221.015	397.044	0.90948	1.78595	-21
-20	2.4483	0.74091	92.8432	1.34969	0.01077	177.142	220.325	397.467	0.91386	1.78412	-20
-19	2.5442	0.74263	89.5770	1.34657	0.01117	178.258	219.629	397.887	0.91824	1.78239	-19
-18	2.6429	0.74436	86.2545	1.34344	0.01159	179.376	218.927	398.303	0.92259	1.78059	-18
-17	2.7446	0.74610	83.3479	1.34030	0.01200	180.498	218.223	398.721	0.92695	1.77884	-17
-16	2.8493	0.74786	80.4103	1.33715	0.01244	181.622	217.512	399.134	0.93129	1.77712	-16
-15	2.9570	0.74964	77.6254	1.33397	0.01288	182.749	216.795	399.544	0.93564	1.77540	-15
-14	3.0678	0.75143	74.9572	1.33079	0.01334	183.879	216.072	399.951	0.93997	1.77371	-14
-13	3.1817	0.75324	72.3997	1.32760	0.01381	185.011	215.345	400.356	0.94430	1.77204	-13
-12	3.2989	0.75506	69.9978	1.32439	0.01429	186.147	214.612	400.759	0.94862	1.77039	-12
-11	3.4193	0.75690	67.5951	1.32118	0.01479	187.285	213.873	401.158	0.95294	1.76875	-11
-10	3.5430	0.75876	65.3339	1.31794	0.01530	188.426	213.129	401.555	0.95725	1.76713	-10
-9	3.6701	0.76063	63.1746	1.31469	0.01583	189.571	212.379	401.949	0.96155	1.76553	-9
-8	3.8006	0.76253	61.1958	1.31143	0.01634	190.718	211.623	402.341	0.96585	1.76394	-8
-7	3.9342	0.76444	59.0955	1.30815	0.01692	191.868	210.861	402.729	0.97014	1.76237	-7
-6	4.0723	0.76637	57.1820	1.30486	0.01749	193.021	210.094	403.115	0.97442	1.76082	-6
-5	4.2135	0.76831	55.3394	1.30155	0.01807	194.176	209.320	403.496	0.97870	1.75928	-5
-4	4.3584	0.77028	53.5602	1.29823	0.01867	195.335	208.540	403.875	0.98297	1.75775	-4
-3	4.5070	0.77226	51.8653	1.29490	0.01928	196.497	207.755	404.252	0.98724	1.75624	-3
-2	4.6594	0.77427	50.2274	1.29154	0.01991	197.662	206.963	404.625	0.99150	1.75475	-2
-1	4.8157	0.77629	48.6517	1.28817	0.02055	198.829	206.165	404.994	0.99575	1.75326	-1

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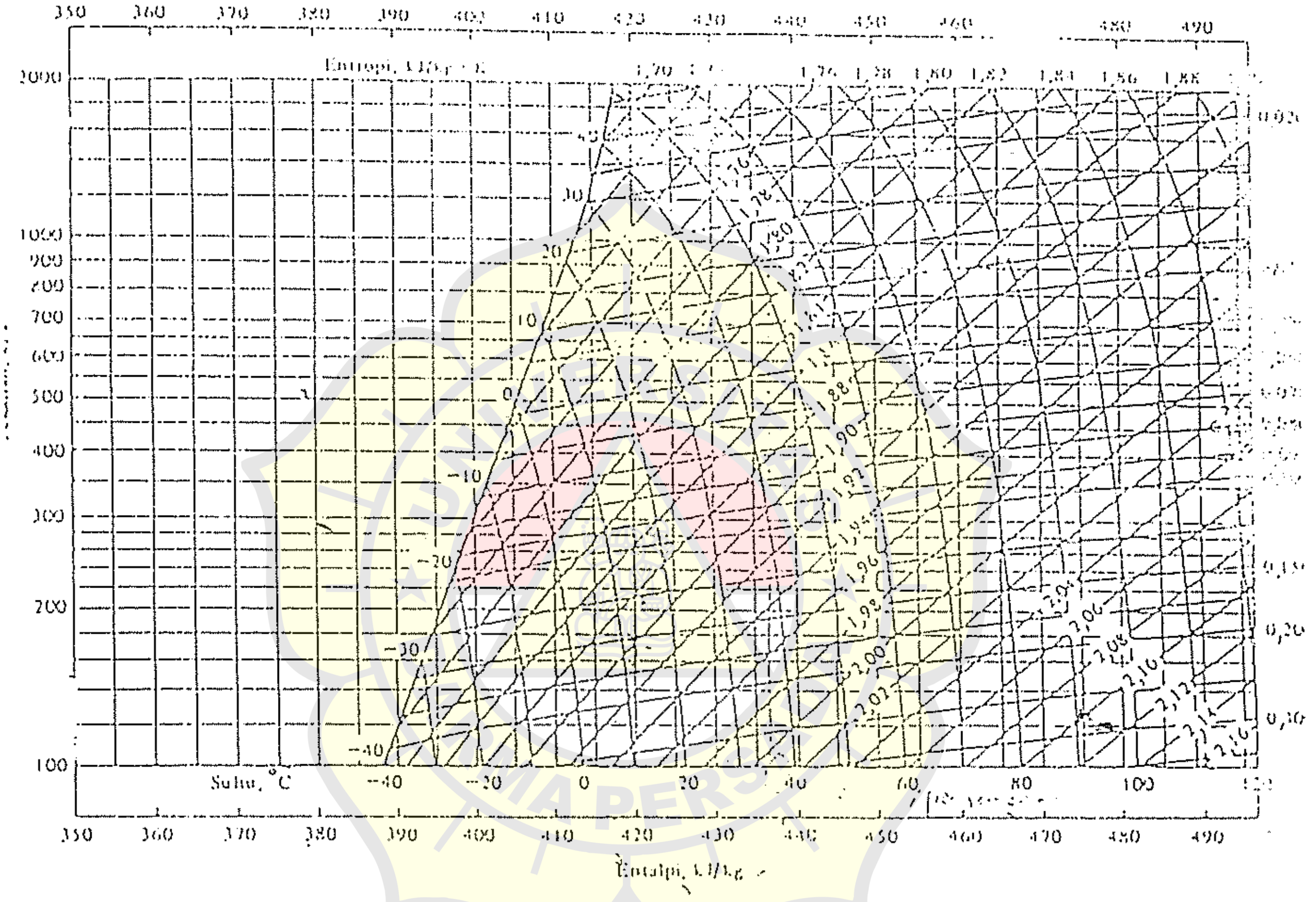
Gambar C.1. Diagram Tekanan – Entalphi Panas Lanjut Refrigeran 134a



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Tabel C.2. Perbandingan Sifat Refrigeran

Refrigerant	ASA B9 Safety Code Group Classification	NBFU Fire Underwriters Group Number	Toxicity Lethal or Serious Injury[3]					Flammable or Explosive Limits of Concentration in Air
			Refrigerant in Air			Products of Decomposition by Flame		
			Duration of Exposure (hr)	% by Vol	lb/1000 cu ft	Duration of Exposure (min)	% by Vol[4]	% by Vol
Methane	3[1]	4-5						4.9-15.0
R-14	1[1]	6[1]						Nonflam.
Ethylene	3[1]	4-5						3.0-25.0
Nitrous oxide			8	0.0025				Nonflam.
R-13	1[1]	6[1]						Nonflam.
Ethane	3	5	2	33.4-51.7				3.3-10.6
Carbon dioxide	2	5	½ to 1	29-30	33.2-34.3			Nonflam.
Kulene-131	1	6[1]						Nonflam.
Propane	3	5	2	37.5-51.7	42.4-58.5			2.3-7.3
R-22	1	5A				16	3.0	Nonflam.[2]
Ammonia	2	2	½	0.5-0.6	0.251-0.256			16.0-25.0
Carrene-7	1	5A	2	19.3-20.3	50.2-52.2	25	1.1	Nonflam.
R-12	1	6	2	28.5-30.4	89.6-95.7	20	1.0	Nonflam.
Methyl chloride	2	4	2	2-2.5	2.62-3.28	30	2.4	8.1-17.2
Isobutane	3	4-5						1.8-8.4
Sulfur dioxide	2	1	1/12	0.7	1.165			Nonflam.
Butane	3	5	2	37.5-51.7				1.6-6.5
R-114	1	6	2	20.1-21.5	90.5-96.6	15	1.0	Nonflam.
R-21	1		1	10.2	22.1			Nonflam.
Ethyl chloride	2	4	1	4.0	6.72	18	2.0	3.7-12.0
R-11	1	5	2	10	35.7	5	1.0	Nonflam.
Methyl formate	2	3	1	2-2.5	3.12-3.9			4.5-20.0
Methylene chloride	1	4A	1	5.1-5.3	11.35-11.7	20	1.0	Nonflam.
R-113	1	4	1	4.8-5.2	23.3-25.2	16	1.2	Nonflam.
Dichlorethylene	2	4	1	2-2.5	5.04-6.3	5	2.1	5.6-11.4

[1] Unofficial.
[2] Very slightly flammable, but for practical purposes considered nonflammable.
[3] To guinea pigs.
[4] Initial concentration.

From the *ASRE Data Book* Design Volume, 1957-58 Edition, by permission of the American Society of Heating Refrigerating, and Air-Conditioning Engineers.

Tabel D.1. Volume Udara Infiltrasi

Air Infiltration into Cold Storage Rooms

Average Air Changes Per 24 Hours for Storage Rooms Above 32°F Due to Door Opening and Infiltrationᵃ

Volume Cu Ft	Air Changes Per 24 Hr	Volume Cu Ft	Air Changes Per 24 Hr	Volume Cu Ft	Air Changes Per 24 Hr	Volume Cu Ft	Air Changes Per 24 Hr
200	44.0	800	20.0	5000	7.2	25 000	3.0
250	38.0	1000	17.5	6000	6.5	30 000	2.7
300	34.5	1500	14.0	8000	5.5	40 000	2.3
400	29.5	2000	12.0	10 000	4.9	50 000	2.0
500	26.0	3000	9.5	15 000	3.9	75 000	1.6
600	23.0	4000	8.2	20 000	3.5	100 000	1.4
						150 000	1.1
						200 000	0.9

Average Air Changes Per 24 Hours for Storage Rooms Below 32°F Due to Door Opening and Infiltrationᵇ

Volume Cu Ft	Air Changes Per 24 Hr	Volume Cu Ft	Air Changes Per 24 Hr	Volume Cu Ft	Air Changes Per 24 Hr	Volume Cu Ft	Air Changes Per 24 Hr
200	33.5	800	15.3	5000	5.6	25 000	2.3
250	29.0	1000	13.5	6000	5.0	30 000	2.1
300	26.2	1500	11.0	8000	4.3	40 000	1.8
400	22.5	2000	9.3	10 000	3.8	50 000	1.6
500	20.0	3000	7.4	15 000	3.0	75 000	1.3
600	18.0	4000	6.3	20 000	2.6	100 000	1.1
						150 000	1.0
						200 000	0.9

ᵃFor heavy usage multiply the above values by a service factor of 2. For long storage multiply the above values by 0.6

ᵇFor heavy usage multiply the above values by a service factor of 2. For long storage multiply the above values by 0.6. [illegible] two open doors [illegible]

ᶜExtrapolated

Courtesy Dunham-Bush, Inc.

Tabel D.2. Beban Panas Udara Infiltrasi

Heat Removed in Cooling Air to Storage Room Conditions (Btu per Cu Ft)

Storage Room Temperature °F	Temperature of Outside Air, °F: 85		90		95		100	
	Relative Humidity, %: 50	60	50	60	50	60	50	60
65	0.65	0.85	0.93	1.17	1.24	1.54	1.58	1.95
60	0.85	1.03	1.13	1.37	1.44	1.74	1.78	2.15
55	1.12	1.34	1.41	1.66	1.72	2.01	2.06	2.44
50	1.32	1.54	1.62	1.87	1.93	2.22	2.28	2.65
45	1.50	1.73	1.80	2.06	2.12	2.42	2.47	2.85
40	1.69	1.92	2.00	2.26	2.31	2.62	2.67	3.06
35	1.86	2.09	2.17	2.43	2.49	2.79	2.85	3.24
30	2.00	2.24	2.26	2.53	2.64	2.94	2.95	3.35

Storage Room Temperature °F	Temperature of Outside Air, °F: 40		50		90		100	
	Relative Humidity, %: 70	80	70	80	50	60	50	60
30	0.24	0.29	0.58	0.66	2.26	2.53	2.94	[illegible]
25	0.41	0.45	0.75	0.83	2.44	2.71	3.1	[illegible]
20	0.56	0.61	0.91	0.99	2.62	2.90	3.33	[illegible]
15	0.71	0.75	1.06	1.14	2.80	3.07	3.51	[illegible]
10	0.85	0.89	1.19	1.27	2.93	3.20	3.54	[illegible]
5	0.98	1.03	1.34	1.42	3.12	3.40	3.84	[illegible]
0	1.12	1.17	1.48	1.56	3.28	3.56	4.01	[illegible]
-5	1.23	1.28	1.59	1.67	3.41	3.69	4.15	[illegible]
-10	1.35	1.41	1.73	1.81	3.54	3.85	4.31	4.74
-15	1.50	1.53	1.85	1.92	3.67	3.95	4.42	4.91
-20	1.63	1.68	2.01	2.09	3.83	4.18	4.66	5.10
-25	1.77	1.80	2.12	2.21	4.00	4.30	4.76	5.21
-30	1.90	1.95	2.29	2.38	4.21	4.51	4.90	5.44

Courtesy Dunham-Bush, Inc.

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Tabel G.1. Sifat Produk dan Kebutuhan Pendinginan

Storage Requirements and Properties of Perishable Products

Commodity (Alphabetical Listing)	Storage Conditions			Water Content, %	Highest Freezing Point, °F	Specific Heat Above Freezing, Btu/lb °F	Specific Heat Below Freezing, Btu/lb °F	Latent Heat of Fusion, Btu/lb
	Storage Temperature, °F	Relative Humidity, %	Approximate Storage Life*					
Apples	30–40	90	3–8 months	84.1	29.3	0.87	0.45	121
Apricots	31–32	90	1–2 weeks	85.4	30.1	0.88	0.46	122
Artichokes (globe)	31–32	95	2 weeks	83.7	29.9	0.87	0.45	120
Asparagus	32–36	95	2–3 weeks	93.0	30.9	0.94	0.48	134
Avocados	45–55	85–90	2–4 weeks	65.4	31.5	0.72	0.40	94
Bananas		85–95	—	74.8	30.6	0.80	0.42	108
Beans (green or snap)	40–45	90–95	7–10 days	88.9	30.7	0.91	0.47	128
Lima	32–40	90	1 week	66.5	31.0	0.73	0.40	94
Beer, keg	35–40	—	3–8 weeks	90.2	28.0	0.92	—	129
bottles, cans	35–40	65 or below	3–6 months	90.2	—	—	—	—
Beets, topped	32	95–100	4–6 months	87.6	30.1	0.90	0.46	126
Blackberries	31–32	95	3 days	84.8	30.5	0.88	0.46	122
Blueberries	31–32	90–95	2 weeks	82.3	29.7	0.86	0.45	118
Bread, baked	0	—	1–3 months	32–37	16–20	0.70	0.34	46–53
Dough	35–40	85–90	3–72 hours	58.5	—	0.75	—	—
Broccoli, sprouting	32	95	10–14 days	89.9	30.9	0.92	0.47	130
Brussels sprouts	32	95	3–5 weeks	84.9	30.5	0.88	0.46	122
Cabbage, late	32	95–100	3–4 months	92.4	30.4	0.94	0.47	132
Carrots, topped, mature	32	98–100	5–9 months	88.2	29.5	0.90	0.46	126
Cauliflower	32	95	2–4 weeks	91.7	30.6	0.93	0.47	132
Celery	32	95	1–2 months	93.7	31.1	0.95	0.48	135
Cherries, sour	31–32	90–95	3–7 days	83.7	29.0	0.87	0.45	120
Sweet	30–31	90–95	2–3 weeks	80.4	28.8	0.84	—	115
Chocolate (coating)	50–65	40–50	2–3 months	55.0	95–85	0.30	0.55	40
Cocoa	32–40	50–70	1 year plus	—	—	—	—	—
Coconuts	32–35	80–85	1–2 months	46.9	30.4	0.58	0.34	67
Coffee (green)	35–37	80–85	2–4 months	10–15	—	0.30	0.24	14–21
Collards	32	95	10–14 days	86.9	30.6	0.90	—	—
Corn, sweet (fresh)	32	95	4–8 days	73.9	30.9	0.79	0.42	106
Cranberries	36–40	90–95	2–4 months	87.4	30.4	0.90	0.46	124
Cucumbers	50–55	90–95	10–14 days	96.1	31.1	0.97	0.49	137
Currants	31–32	90–95	10–14 days	84.7	30.2	0.88	0.45	120
Dairy products								
Cheddar cheese	40	65–70	6 months	37.5	8.0	0.50	0.31	53
Processed cheese	40	65–70	12 months	39.0	19.0	0.50	0.31	56
Butter	40	75–85	1 month	16.0	−4 to 31	0.50	0.25	23
Cream	35–40	—	2–3 weeks	55–75	31.0	0.66–0.80	0.36–0.42	79–107
Ice cream	−20 to −15	—	3–12 months	58–63	21.0	0.66–0.70	0.37–0.39	86
Milk, fluid whole								
Pasteurized, Grade A	32–34	—	2–4 months	87.0	31.0	0.93	0.46	125
Condensed, sweetened	40	—	15 months	28.0	5.0	0.42	0.28	40
Evaporated	40	—	24 months	74.0	29.5	0.79	0.42	106
Dates (dried)	0 or 32	75 or less	6–12 months	20.0	3.7	0.36	0.26	29
Dewberries	31–32	90–95	3 days	84.5	29.7	0.88	—	—
Dried fruits	32	50–60	9–12 months	14.0–26.0	—	0.31–0.41	0.26	20–37
Eggplant	45–50	90–95	7–10 days	92.7	30.6	0.94	0.48	132
Eggs, shell	29–31	80–85	5–6 months	66.0	28.0	0.73	0.40	96
Shell, farm cooler	50–55	70–75	2–3 weeks	66.0	28.0	0.73	0.40	96
Frozen, whole	0 or below	—	1 year plus	74.0	28.0	0.73	0.42	106
Endive (escarole)	32	95	2–3 weeks	93.3	31.9	0.94	0.48	132
Figs, dried	32–40	50–60	9–12 months	23.0	—	0.39	0.27	34
Fresh	31–32	85–90	7–10 days	78.0	27.6	0.82	0.43	112
Fish, fresh	31–35	90–95	5–15 days	62–85	28.0	0.70–0.86	0.38–0.45	89–122
Smoked	40–50	50–60	6–8 months	—	—	0.70	0.39	92
Shellfish, fresh	30–33	85–95	3–7 days	80–87	28.0	0.83–0.90	0.44–0.46	113–125
Furs and fabrics	34–40	45–55	several years	—	—	—	—	—

Physical Properties of HFC-134a

Physical Properties	Units	HFC-134a
Chemical Name	–	Ethane, 1,1,1,2-Tetrafluoro
Chemical Formula	–	CH_2FCF_3
Molecular Weight	–	102.03
Boiling Point at 1 atm (101.3 kPa or 1.013 bar)	°C °F	-26.1 -14.9
Freezing Point	°C °F	-103.0 -153.9
Critical Temperature	°C °F	101.1 213.9
Critical Pressure	kPa lb/in^2 abs	4060 588.9
Critical Volume	m^3/kg ft^3/lb	1.94×10^{-3} 0.0311
Critical Density	kg/m^3 lb/ft^3	515.3 32.17
Density (Liquid) at 25°C(77°F)	kg/m^3 lb/ft^3	1206 75.28
Density (Saturated Vapor) at Boiling Point	kg/m^3 lb/ft^3	5.26 0.328
Heat Capacity (Liquid) at 25°C(77°F)	kJ/kg.K or Btu/(lb)(°F)	1.44 0.340
Heat Capacity (Vapor at Constant Pressure) at 25°C (77°F) and 1 atm (101.3 kPa or 1.013 bar)	~~kJ/kg.K~~ or Btu/(lb)(°F)	0.852 0.204
Vapor Pressure at 25°C(77°F)	kPa bar	666.1 6.661
Heat of Vaporization at Boiling Point	kJ/kg Btu/lb	217.1 93.4
Thermal Conductivity at 25°C(77°F) Liquid	W/m·K Btu/hr·ft°F	0.0824 0.0478
Vapor at 1 atm (101.3 kPa or 1.013 bar)	W/m·K Btu/hr·ft°F	0.0145 0.00836
Viscosity at 25°C(77°F) Liquid	mPa·s(cP)	0.202
Vapor at 1 atm(101.3 kPa or 1.013 bar)	mPa·s(cP)	0.012
Solubility of HFC-134a in Water at 25°C(77°F) and 1 atm (101.3 kPa or 1.013 bar)	wt%	0.15
Solubility of Water in HFC-134a at 25°C(77°F)	wt%	0.11
Flammability Limits in Air at 1 atm (101.3 kPa or .012 bar)	vol%	None
Autoignition Temperature	°C °F	770 1418
Ozone Depletion Potential	–	0
Halocarbon Global Warming Potential (HGWP) (For CFC-11, HGWP=1)	–	0.28
Global Warming Potential (GWP) (100yr ITH for CO_2, GWP=1)	--	1200
SCA Inventory Status	--	Reported/Included
oxicity AEL* (8- and 12-hr TWA)	ppm(v/v)	1000

Tabel H.1

LAMPIRAN

Bitzer **R134a**

Leistungswerte

bezogen auf Sauggastemperatur 25° (20)°C, ohne Flüssigkeitsunterkühlung, Motordrehzahl = 1450 min-1 (50 Hz)

Performance data

relating to 25° (20)°C suction gas temperature, without liquid subcooling, motor speed = 1450 min-1 (50 Hz)

Données de puissance

à une température de gaz aspiré de 25° (20)°C se référant, sans sous-refroidissement de liquide, moteur = 1450 min-1 (50 Hz)

Kälteleistung / Refrigerating capacity / Pulssance frigorifique Q_o [Watt]

Leistungsaufnahme / Power consumption / Puissance absorbée P_e [kW]

Verdichter Typ Compressor type Compresseur type	Verfl. Temp Cond. temp. Temp. de cond. °C	↓	Verdampfungstemperatur °C Evaporating temperature °C Température d'évaporation °C 12,5	10	7,5	5	0	-5	-10	-15	-20	-25	-30
4P-15.2Y	50	Q	34350	31200	28300	25600	20750	16610	13090	10110	7620		
		P	8,83	8,52	8,22	7,90	7,26	6,60	5,92	5,23	4,54		
	60	Q	29400	26700	24150	21800	17620	14030	10970	8390	6240		
		P	9,64	9,26	8,87	8,48	7,69	6,89	6,08	5,28	4,48		
	70	Q	24600	22250	20100	18130	14570	11520	8940	6760	4950		
		P	10,21	9,76	9,31	8,85	7,94	7,03	6,13	5,24	4,37		
4N-12.2Y	30	Q	52300	47600	43250	39200	32000	25800	20550	16130	12410	9320	6770
		P	8,43	8,37	8,26	8,12	7,75	7,29	6,76	6,18	5,56	4,89	4,18
	40	Q	45900	41800	37900	34350	28000	22550	17900	13970	10680	7940	5680
		P	10,00	9,68	9,35	9,02	8,35	7,66	6,95	6,23	5,50	4,75	3,98
	50	Q	40000	36400	33000	29900	24300	19500	15420	11970	9080	6680	4700
		P	11,37	10,91	10,46	10,01	9,11	8,21	7,32	6,44	5,57	4,70	3,85
4N-20.2Y	50	Q	40000	36400	33000	29900	24300	19500	15420	11970	9080		
		P	11,26	10,81	10,36	9,92	9,03	8,15	7,27	6,40	5,54		
	60	Q	34300	31200	28250	25550	20700	16540	13010	10030	7530		
		P	12,33	11,77	11,22	10,67	9,60	8,54	7,51	6,61	5,54		
	70	Q	28750	26100	23600	21300	17200	13690	10700	8180	6070		
		P	13,09	12,45	11,81	11,19	9,97	8,78	7,64	6,54	5,49		
4J-13.2Y	30	Q	59800	54300	49250	44550	36150	29000	22950	17860	13620	10110	7260
		P	8,93	8,66	8,39	8,12	7,57	7,00	6,39	5,76	5,10	4,43	3,75
	40	Q	53100	48150	43600	39400	31950	25550	20150	15600	11800	8670	6100
		P	10,70	10,25	9,83	9,43	8,63	7,84	7,04	6,23	5,42	4,60	3,78
	50	Q	46600	42300	38300	34600	27950	22300	17510	13460	10080	7280	4990
		P	12,31	11,72	11,16	10,62	9,58	8,58	7,58	6,59	5,62	4,66	3,72
4J-22.2Y	50	Q	46600	42300	38300	34600	27950	22300	17510	13460	10080		
		P	11,95	11,39	10,86	10,35	9,37	8,43	7,51	6,60	5,69		
	60	Q	40450	36700	33200	23950	24200	19210	14990	11420	8430		
		P	12,86	12,22	11,60	11,00	9,84	8,73	7,67	6,64	5,63		
	70	Q	34400	31200	28250	25500	20500	16250	12590	9490	6880		
		P	13,73	13,03	12,33	11,65	10,33	9,08	7,87	6,71	5,56		
4H-15.2Y	30	Q	69100	62800	57000	51600	41950	33700	26700	20850	15920	11840	8500
		P	10,41	10,07	9,74	9,41	8,75	8,08	7,39	6,68	5,95	5,20	4,43
	40	Q	61300	55700	50400	45600	37000	29600	23350	18090	13690	10050	7080
		P	12,42	11,88	11,37	10,88	9,94	9,02	8,11	7,21	6,29	5,37	4,44
	50	Q	54100	49050	44400	40100	32400	25800	20250	15570	11660	8430	5800
		P	14,33	13,61	12,93	12,28	11,05	9,87	8,74	7,63	6,53	5,44	4,36
4H-25.2Y	50	Q	54100	49050	44400	40100	32400	25800	20250	15570	11660		
		P	13,86	13,21	12,59	11,99	10,85	9,76	8,69	7,64	6,59		
	60	Q	47100	42700	38600	34800	28000	22200	17320	13190	9760		
		P	14,98	14,22	13,48	12,77	11,40	10,10	8,86	7,67	6,52		
	70	Q	40250	36450	32900	29600	23750	18740	14500	10940	7980		
		P	16,08	15,21	14,36	13,53	11,95	10,46	9,06	7,74	6,46		
4G-20.2Y	30	Q	78500	71400	64800	58600	47700	38350	30450	23800	18190	13560	9770
		P	12,46	12,14	11,82	11,49	10,79	10,02	9,17	8,26	7,30	6,31	5,29
	40	Q	69700	63300	57400	51900	42100	33750	26650	20700	15700	11570	8190
		P	14,60	14,08	13,57	13,05	12,01	10,94	9,84	8,72	7,58	6,44	5,28
	50	Q	61500	55800	50500	45650	36950	29500	23200	17870	13430	9760	6770
		P	16,74	15,99	15,25	14,52	13,09	11,69	10,32	8,98	7,67	6,38	5,10
4G-30.2Y	50	Q	61500	55800	50500	45650	36950	29500	23200	17870	13430		
		P	16,18	15,50	14,83	14,16	12,84	11,53	10,24	8,96	7,69		
	60	Q	53700	48650	44000	39700	32000	25450	19890	15210	11300		
		P	17,59	16,72	15,89	15,08	13,50	11,97	10,48	9,01	7,58		
	70	Q	45900	41600	37600	33850	27200	21550	16720	12680	9320		
		P	19,22	18,17	17,15	16,16	14,26	12,46	10,75	9,12	7,56		
J-22.2Y	30	Q	89800	81500	73900	66800	54200	43500	34400	26800	20400	15170	10880
		P	13,39	12,98	12,58	12,18	11,36	10,50	9,59	8,64	7,65	6,64	5,62
	40	Q	79600	72200	65400	59100	47900	38350	30200	23400	17700	13000	9160
		P	16,04	15,38	14,75	14,14	12,95	11,76	10,56	9,35	8,12	6,90	5,67
	50	Q	69900	63400	57400	51900	41950	33450	26250	20200	15110	10920	7490
		P	18,46	17,57	16,73	15,93	14,37	12,86	11,37	9,88	8,42	6,99	5,58
J-33.2Y	50	Q	69900	63400	57400	51900	41950	33450	26250	20200	15110		
		P	17,93	17,09	16,29	15,52	14,05	12,64	11,26	9,90	8,54		
	60	Q	60600	55000	49800	44950	36250	28800	22500	17130	12640		
		P	19,29	18,33	17,40	16,49	14,75	13,09	11,50	9,96	8,44		
	70	Q	51600	46850	42400	38200	30800	24350	18890	14240	10320		
		P	20,59	19,54	18,50	17,48	15,50	13,61	11,81	10,06	8,34		
H-25.2Y	30	Q	103800	94300	85600	77400	63000	50600	40100	31300	23900	17780	12760
		P	15,62	15,12	14,62	14,13	13,14	12,13	11,10	10,03	8,94	7,81	6,65
	40	Q	92000	83600	75700	68500	55500	44450	35100	27150	20550	15100	10630
		P	18,65	17,84	17,07	16,33	14,92	13,54	12,18	10,82	9,45	8,07	6,66
	50	Q	81100	73600	66600	60200	48600	38800	30400	23400	17510	12660	8710
		P	21,51	20,43	19,41	18,43	16,58	14,82	13,12	11,45	9,80	8,17	6,54
H-35.2Y	50	Q	81100	73600	66600	60200	48600	38800	30400	23400	17510		
		P	20,81	19,83	18,90	18,00	16,29	14,65	13,05	11,46	9,89		
	60	Q	70700	64100	57900	52200	42050	33400	26000	19810	14650		
		P	22,50	21,35	20,25	19,17	17,11	15,16	13,31	11,52	9,78		
	70	Q	60400	54700	49400	44450	35650	28150	21750	16420	11980		
		P	24,15	22,84	21,56	20,31	17,94	15,71	13,61	11,61	9,69		
G-30.2Y	30	Q	117900	107100	97200	88000	71600	57600	45700	35700	27300	20350	14650
		P	18,70	18,22	17,74	17,24	16,19	15,03	13,76	12,40	10,96	9,47	7,95
	40	Q	104600	95000	86100	77900	63200	50700	40000	31050	23550	17360	12280
		P	21,90	21,13	20,36	19,59	18,02	16,41	14,77	13,09	11,38	9,66	7,92
	50	Q	92300	83700	75800	68500	55400	44300	34800	26800	20150	14650	10160
		P	25,11	23,99	22,89	21,79	19,64	17,54	15,49	13,48	11,50	9,57	7,65

2 Vorläufige Werte — Tentative data — Valeurs provisoires

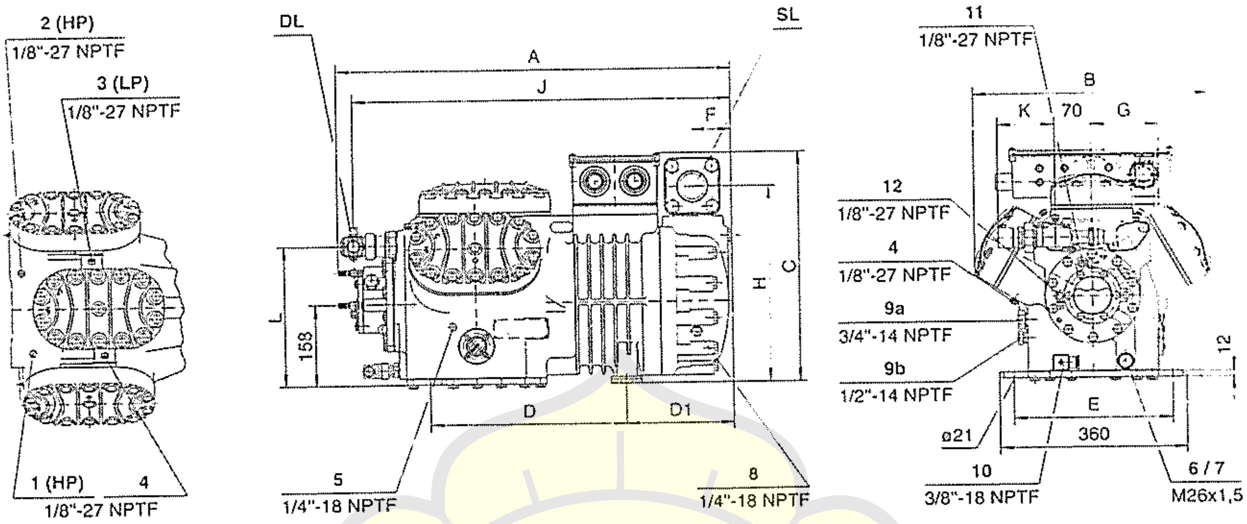
Technische Daten Technical data Caractéristiques techniques

Verdichter Typ Compressor type Compresseur type	Motor PS/kW Nominal ① Motor HP/kW Nominal ① Moteur CV/kW Nominal ①	Motor Version Motor Version Version moteur	Hubvolumen bei 1450 min^{-1} Displacement with 1450 min^{-1} Volume balayé à 1450 min^{-1} m^3/h	Anzahl der Zylinder Number of cylinder Nombre de cylindres	Öl-füllung Oil-charge Charge d'huile dm^3	Gewicht Weight Poids kg	Rohranschlüsse DL Druckleitung mm Pipe connections DL Discharge line mm Raccords DL Conduite de ref. mm	Zoll inch pouce	SL Saugleitung mm SL Suction line mm SL Conduite d'aspiration mm	Zoll inch pouce	CR –Stufen – CR – Steps – CR – Etages – %②	Elektrische Daten Stromart Electrical Data electrical supply Caractéristiques électriques Genre de courant Volt③	max. Betriebsstrom Max. working current Courant de service max. Amp.④	max. Leistungsaufnahme max. power consumption Puissance absorbée max. kW①	Anlaufstrom (Rotor blockiert) Starting current (locked rotor) Courant de démarrage (Rotor bloqué) Amp.⑤
2KC-05.2(Y)	0,5/0,37	1 + 2	4,06	2	1,0	43	12	$^1/_2$	12	$^1/_2$	–		4,6/2,7	1,5	20,8/12
2JC-07.2(Y)	0,75/0,55	1 + 2	5,21	2	1,0	43	12	$^1/_2$	12	$^1/_2$	–		6,0/3,5	1,9	26/14,8
2HC-1.2(Y)	1/0,7	2	6,51	2	1,0	44	12	$^1/_2$	16	$^5/_8$	–		6,1/3,5	2,0	28,9/16,7
2HC-2.2(Y)	1,5/1,1	1			1,0	45							7,4/4,3	2,4	39/22,5
2GC-2.2(Y)	1,5/1,1	1 + 2	7,58	2	1,0	45	12	$^1/_2$	16	$^5/_8$	–		8,1/4,7	2,7	39/22,5
2FC-2.2(Y)	1,5/1,1	2	9,54	2	1,0	45	12	$^1/_2$	16	$^5/_8$	–		8,5/4,9	2,8	39/22,5
2FC-3.2(Y)	1,8/1,3	1			1,0	47							10,0/5,8	3,4	44/25,3
2EC-2.2(Y)	2/1,5	2	11,36	2	1,5	67,5	16	$^5/_8$	22	$^7/_8$	–	Δ / Y	9,9/5,7	3,3	45/26
2EC-3.2(Y	3/2,2	1			1,5	70,5							12,0/6,9	4,0	60,6/35
2DC-2.2(Y)	2/1,5	2	13,42	2	1,5	67,5	16	$^5/_8$	22	$^7/_8$	–	220..240 Δ/	11,9/6,9	3,9	50,2/29
2DC-3.2(Y)	3/2,2	1			1,5	70,5						380..420Y/3/50	13,5/7,8	4,5	60,6/35
2CC-3.2(Y)	3/2,2	2	16,24	2	1,5	70	16	$^5/_8$	22	$^7/_8$	–	265..290 Δ/	14,8/8,5	5,0	60,6/35
2CC-4.2(Y)	4/3	1			1,5	70						440..480Y/3/60	16,4/9,4	5,6	72,7/42
4FC-3.2(Y)	3/2,2	2	18,05	4	2,0	82	16	$^5/_8$	22	$^7/_8$			15,9/9,2	5,4	74/42,5
4FC-5.2(Y)	5,5/4	1			2,0	86							18,7/10,8	6,2	109/63
4EC-4.2(Y)	4/3	2	22,72	4	2,0	84	16	$^5/_8$	28	$1^1/_8$	50		18,5/10,7	6,4	81,4/47
4EC-6.2(Y)	5,5/4	1			2,0	86							22,9/13,2	7,9	109/63
4DC-5.2(Y)	5.5/4	2	26,84	4	2,0	85,5	22	$^7/_8$	28	$1^1/_8$			23,4/13,5	8,0	109/63
4DC-7.2(Y)	7,5/5,5	1			2,0	88,5							27,5/15,9	9,0	128/74
4CC-6.2 (Y)	7,5/5,5	2	32,48	4	2,0	90,5	22	$^7/_8$	28	$1^1/_8$			27,5/15,9	9,0	128/74
Z-5.2(Y)	5,5/4	2	28,11	4	3,0	135	22	$^7/_8$	28	$1^1/_8$			14	6,9	39/68
Z-8.2(Y)	7,5/5,5	1				140							17	9,7	49/81
V-6.2(Y)	5,5/4	2	33,07	4	3,0	135	22	$^7/_8$	28	$1^1/_8$			14	8,1	39/68
V-10.2(Y)	10/7,5	1				142							21	11,3	59/99
T-8.2(Y)	7,5/5,5	2	39,36	4	3,0	138	28	$1^1/_8$	35	$1^3/_8$		PW	17	9,4	49/81
T-12.2(Y)	12,5/9,2	1				146							24	13,8	69/113
P-10.2(Y)	10/7,5	2	47,14	4	3,0	145	28	$1^1/_8$	35	$1^3/_8$	50	④	21	11,7	59/99
P-15.2(Y)	15/11	1				152							31	16,3	81/132
N-12.2(Y)	12,5/9.2	2	56,1	4	3,0	147	28	$1^1/_8$	42	$1^5/_8$		380..420YY/3/50	24	14,1	69/113
N-20.2(Y)	20/15	1				155						440..480YY/3/60	37	19,5	97/158
J-13.2(Y)	13/9,5	2	63,5	4	4,0	179	28	$1^1/_8$	42	$1^5/_8$			27	15,7	81/132
J-22.2(Y)	22/16	1				190							39	21,5	97/158
H-15.2(Y)	15/11	2	73,6	4	4,0	183	28	$1^1/_8$	42	$1^5/_8$			31	18,1	81/132
H-25.2(Y)	25/18,5	1			4,5	203			54	$2^1/_8$			45	24,9	116/193
G-20.2(Y)	20/15	2	84,5	4	4,5	192	28	$1^1/_8$	54	$2^1/_8$			37	21,5	97/158
G-30.2(Y)	30/22	1				206							53	30,1	135/220
J-22.2(Y)	22/16	2	95,3	6		213	35	$1^3/_8$	54	$2^1/_8$		④ 380..420YY/3/50 440..480 YY/3/60	39	23.5	116/193
J-33.2(Y)	33/24	1			4,75	213							60	32.2	147/262
H-25.2(Y)	25/18,5	2	110,5	6		224	35	$1^3/_8$	54	$2^1/_8$	33 altern. 66		45	27.2	116/193
H-35.2(Y)	35/26	1			4,75	235							61	37.4	147/262
G-30.2(Y)	30/22	2	126.8	6		228	35	$1^3/_8$	54	$2^1/_8$		PW	53	31.9	[illegible]
G-40.2(Y)	40/30	1			4.75	238							78	45.1	[illegible]
F-40.2(Y)	40/30	2	151,6	6		239	42	$1^5/_8$	54	$2^1/_8$			78	38.6	[illegible]
F-50.2(Y)	50/37	1			4,75	241						380..400YY/3/50 440..460YY/3/60	92	53.2	[illegible]

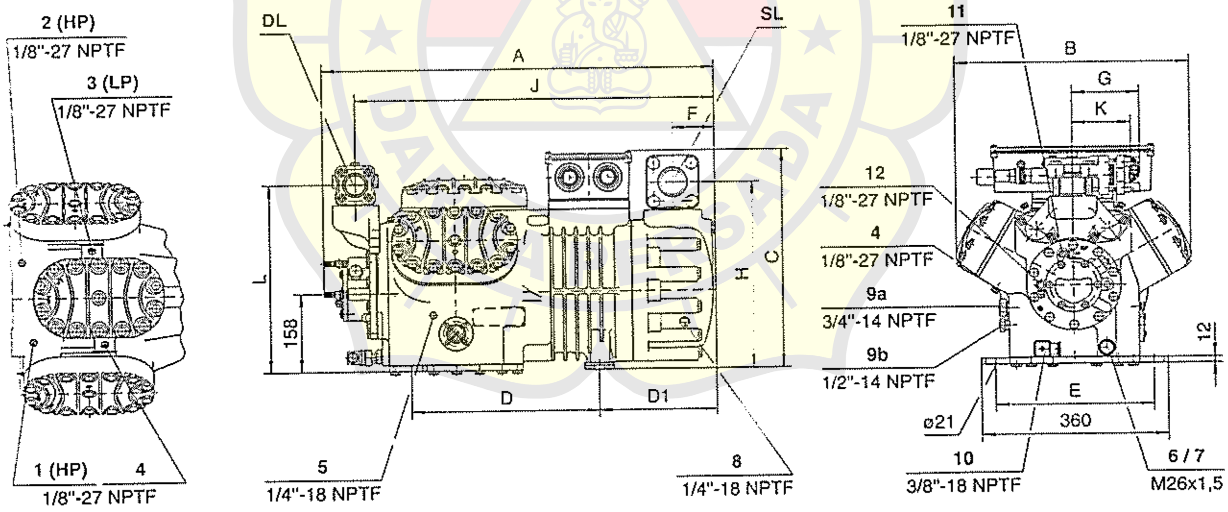
Tabel H.1

Maßzeichnungen Dimensional drawings Croquis cotés

6J-22.2(Y) .. 6G-40.2(Y)



6F-40.2(Y) / 6F-50.2(Y)



	A mm	B mm	C mm	D mm	D1 mm	E mm	F mm	G mm	H mm	J mm	K mm	L mm	L1 mm
6J-22.2(Y)	763	460	441	381	212	305	77	125	380	734	70	271	110
6J-33.2(Y)	792	460	441	381	242	305	87	125	380	764	70	271	110
6H-25.2(Y)	763	460	441	381	212	305	77	125	380	734	70	271	110
6H-35.2(Y)	792	460	441	381	242	305	87	125	380	764	70	271	110
6G-30.2(Y)	763	460	441	381	212	305	77	125	380	734	70	271	110
6G-40.2(Y)	792	460	441	381	242	305	87	125	380	764	70	271	110
6F-40.2(Y)	783	460	441	381	242	305	87	125	380	730	110	381	–
6F-50.2(Y)	783	460	441	381	242	305	87	125	380	730	110	381	

Legende für Anschlüsse siehe Seite 31 Legend for connections see page 31 Légende pour les raccordements voir page 31