Grasso

Refrigeration Division

Reciprocating Compressors for industrial refrigeration Series Grasso 10

Product information (ED)

Legal Notice

This publication has been written in good faith. However, **Grasso** cannot be held responsible, neither for any errors occurring in this publication nor for their consequences.

GEA Grasso

Refrigeration Division

Table of Contents

Grasso
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Preface

This preface gives a survey of the types of documentation and software available for this Grasso compressor series.

All Grasso documentation and Grasso selection software is available on CD-Roms (Consult Grasso).

1) Grasso Refrigeration Equipment Catalogue (REC)

Contents

This catalogue contains all Product Information (engineering data) and all brochures of the reciprocating compressors, screw compressors, air purgers, chillers, packages, etc. This catalogue also includes the CD-Rom ´Grasso Software´ and the CD-ROM ´Documentation Navigator´.

User group

Project engineers, applications engineers, sales managers and product managers for both end-users and contractors.

Distribution

Sales Department of Grasso.

2) Grasso CD-ROM ´Grasso Software´

Contents

COMSEL programme (the Grasso COMpressor SELection programme), PURGER programme (to calculate energy savings and pay-back time) and REVALCO software (to select Revalco valves, check valves, Revalco parts etc.).

User group

Project engineers, application engineers, sales managers, product managers for both end-users and contractors.

Distribution

Sales Department of Grasso.

3) Grasso CD-ROM ´Documentation Navigator´

Contents

All Grasso documentation including a user friendly navigation system.

With this CD-rom it is possible to re-use all text, graphics, tables, etc. for various purposes (presentations, reports, ...)

User group

Project engineers, application engineers, sales managers, product managers for both end-users and contractors.

Distribution

Sales Department of Grasso.

4) Product Information (Engineering Data Sheets; ED)

Contents

All product information (engineering data) for this series compressor and the corresponding recommended accessories. It is meant to be a guide to the selection of these components.

User group

Project engineers, application engineers, sales managers, product managers for both end-users and contractors.

Distribution

Sales Department of Grasso.

5) Installation and maintenance manual (IMM)

Contents

This manual will provide information on how to transport, install, start-up and maintain the compressor (package). It also contains a number of "Product Information Sheets" and the current "Parts List"

User group

To be used in the field by qualified personnel for both end-user and contractor.

Distribution

Supplied together with the compressor.

6) Instructions for Accessories (IFA)

Contents

All the relevant mounting and installation instructions and spare parts information for those accessories supplied with the compressor.

User group

To be used in the field by qualified personnel for both end-user and contractor.

Distribution

Supplied together with the compressor.

7) Parts list (PL)

Contents

All current parts of the compressor and accessories together with the design changes applicable to previous supplied components ("History").

User group

Service and parts department for both end-user and contractor.

Distribution

Service and Parts Department of Grasso.

8) Service & Maintenance Schedules (SMS)

Contents

Complete set of service and maintenance schedules for 100 operating hours up to 48000 operating hours (inspection, renewal, measuring, cleaning, ...) of the bare shaft compressor.

User group

Service and parts department and in the field by qualified personnel for both end-user and contractor.

Distribution

Service and Parts Department of Grasso.

9) Service and Maintenance Manual (SIM)

Contents

Description of (re)assembling, inspection, repair and part or total overhaul of the bare shaft compressor. This manual should be used together with the 'Installation and Maintenance Manual'.

User group

To be used in the field by qualified personnel of refrigeration installers or contractors.

Distribution

Service and Parts Department of Grasso.

10) Miscellaneous

Typographic signs:

Indicates a caution, note or procedure to which you should pay special attention.
READ IT CAREFULLY!

Indicates a WARNING. READ IT CAREFULLY!

Indicates an IMPORTANT note or procedure to which you should pay special attention.

Indicates a HINT.

Values between []

Values between [ ] are read-outs of Grasso's electronic control device Monitron CR.

Release Notes ED Grasso 10

	Description	Date M-YY	Ref.
001	Evaluation copy	10-00	KK
002	Initial version	10-00	KK
003	1. Translation and lay-out checked by Grasso UK 2. Oil table; R507/R404 added; separate table for recommended oils(Table 1.5-2) 3. Direct drive speeds 50 Hz 1328 and 1475 rpm; graphic E, L and D values(Fig. 2.3-4) 4. Text for interstage cooling systems() 5. Stop valves and flanges; standard DN connections changed(Section 2.7.1) 6. Oil selection table (Section 2.5.1.1Table 2.5-2)	12-00	KK
004	Height packages (Section 2.4.1.1) Capacity control cylinders 310/410 (Table 2.1-1) Sound data (Table 1.3-4) Tcmax R134a(Fig. 1.4-4) Dimensions interstage coolers A/B (Section 2.8.2.1) Free Forces and Moments(Section 1.3.7.1) Starting torques (Section 1.3.6.1)	03-01	KK
005	Oil equalizing connection (Section 2.5.4) Section moved (Section 2.8.2.1) Minimum pressure ratio 1.1 (was 1.5)(Table 1.4-1) Packages dimension H (Section 2.4.1.1) Max. pressure ration NH3 (Table 1.4-1)	Sep-01	KK

Booster or single-stage operation

Booster operation applies if condensing temperature <5 °C.
Single stage operation applies if condensing temperature =>5°C.

Cylinder numbering of Grasso reciprocating compressors

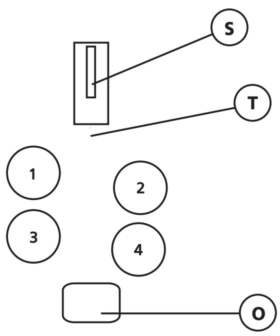


Fig. 1 Cylinder numbering Grasso reciprocating compressors

Legend	
1, 2, 3, ...	Cylinder numbers
T	Top view of compressor
S	Shaft-end of compressor

Legend	
O	Oil pump of compressor

1. DESCRIPTION AND SELECTION OF COMPRESSOR

1.1 INTRODUCTION AND SCOPE

1.1.1 OUTLINE

Grasso10 is the designation of a series of open, single- acting, reciprocating refrigeration compressors with trunk-type pistons and with 2 up to 8 cylinders in V- and Line-arrangement.
The series consist of 9 types, 5 single-stage and 4 integral two-stage (compound) compressors. The single-stage types can also be used as booster compressors.

1.1.2 TYPE DESIGNATION

The following examples will explain the type designation:

6-cylinder single-stage compressor type
(K, M) Grasso610:
- **K** (Lloyds-approval),
- **M** (Marine application)
- **6** Number of cylinders
- **10** Series indication

8-cylinder two-stage compressor type
(K, M) Grasso6210
- **K** (Lloyds-approval),
- **M** (Marine application)
- **6** Number of LP cylinders
- **2** Number of HP cylinders
- **10** Series indication

1.1.3 APPLICATION

- Industrial (heavy duty) operation.
- Evaporating temp. between -68 and +33 °C.
- Refrigerants: amongst others NH_3, R134a, R22, R404A, R507.
- For particular applications (cascade systems, chemical processes, etc.) consult Grasso.

1.1.4 DRIVE SYSTEM

- Electric motor: direct or V-belt.
- Max. speed 1500 min^{-1}
- Rotation normally counter-clockwise when facing shaft end of compressor.

1.1.5 SELECTION COMPRESSOR AND ACCESSOIRIES

- Consult Grasso's software program COMSEL (COMpressor SELection) in combination with Engineering Data Sheets to select compressor and/or accessories. The software program COMSEL can be downloaded from our homepage "www.grasso.nl" or “www.grasso.de”

1.1.6 PRESSURE TESTS

- Test pressure 37.5 bar(e).
- Design pressure 26.0 bar(a).
- Test run with air.

1.1.7 ACCEPTANCE TEST

- Acceptance test under design conditions, acc. to ISO 917, witnessed by the customer possible on request.

1.1.8 STANDARD SCOPE OF SUPPLY

- Standard bare compressor:
  - ⇨ painting hammertone blue
  - ⇨ oil and suction filters
  - ⇨ Filled with nitrogen
  - ⇨ Mating flanges suction and discharge connections
  - ⇨ Purge valve(s) on discharge line(s)

Supplied loose:

- Suction filter element, including sealings (running-in filter is factory mounted)
- Oil discharge filter for first oil change, including seals (running-in filter is factory mounted)
- Swivel coupling for oil return connection
- Installation and Maintenance Manual.(IMM)

Not included:

- oil charge.

1.1.9 OPTIONS

- Lloyds approval (other approvals on request),
- Accessoiries as mentioned in next chapter.
- Heavy duty oil discharge filter.
- Back pressure independent relief valves, 26.0 bar acc. to DIN 8975. One or two relief valves are required depending on type of compressor.
- Oil differential pressure indicator on oil discharge filter.

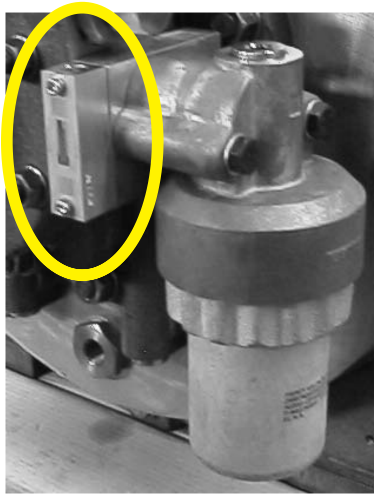


Fig. 1.1-1 Option; Oil differential pressure indicator on oil discharge filter

On request:

- Different painting
- Extra purge and evacuating stop valve(s) on suction line(s)
- Thermometers in suction and discharge lines
- Explosion proof acc. to EEX-dIIC-T5
- Check valves discharge lines
- Clockwise direction of rotation

1.2 GRASSO 10 GRAPHICS

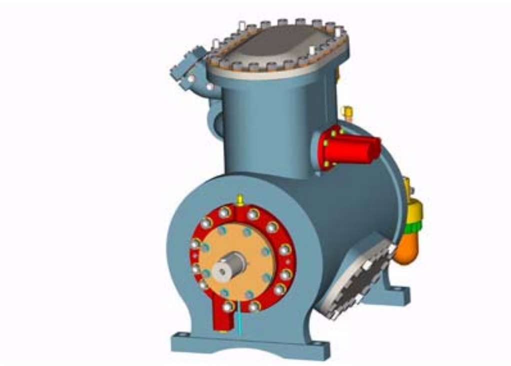


Fig. 1.2-1 Grasso 210

Fig. 1.2-2 Grasso 210

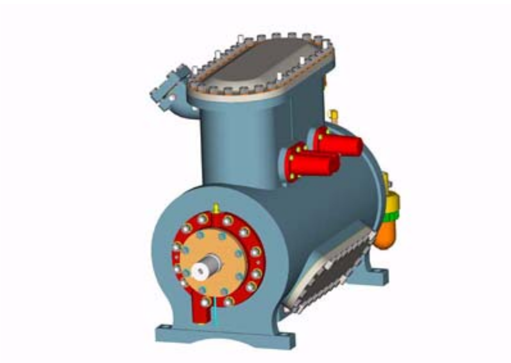


Fig. 1.2-3 Grasso 310

Fig. 1.2-4 Grasso 310

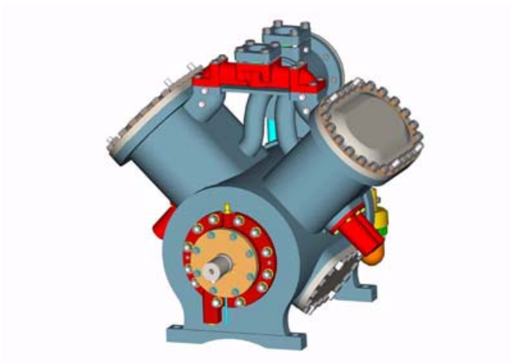


Fig. 1.2-5 Grasso 410

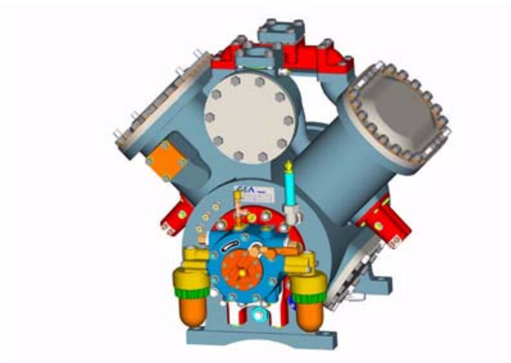


Fig. 1.2-6 Grasso 410

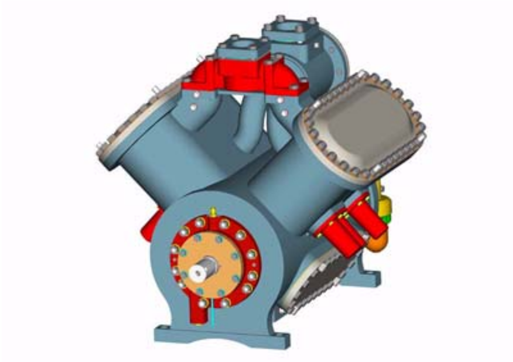


Fig. 1.2-7 Grasso 610

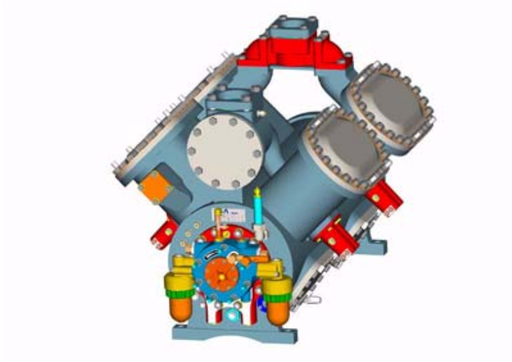


Fig. 1.2-10 Grasso 810

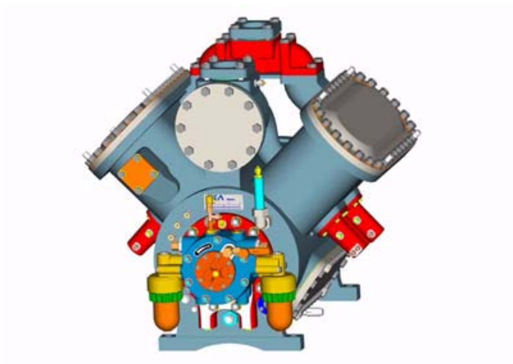


Fig. 1.2-8 Grasso 610

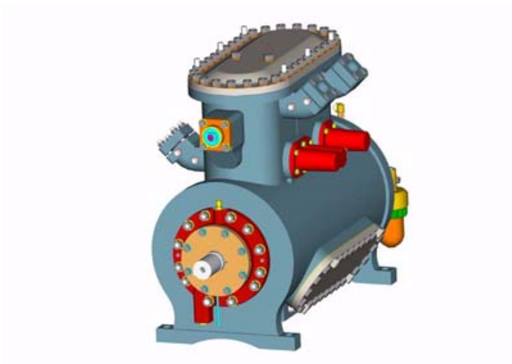


Fig. 1.2-11 Grasso 2110

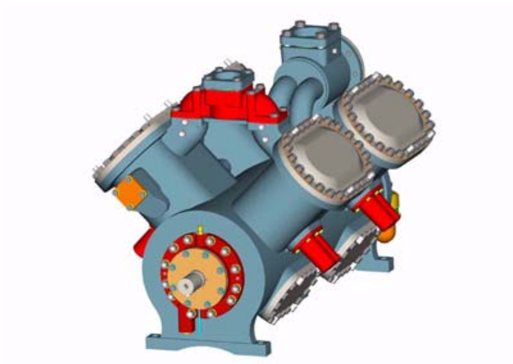


Fig. 1.2-9 Grasso 810

Fig. 1.2-12 Grasso 2110

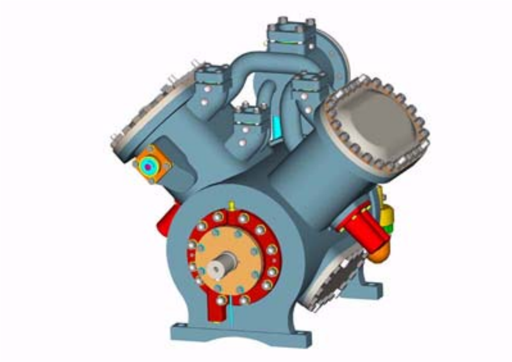


Fig. 1.2-13 Grasso 3110

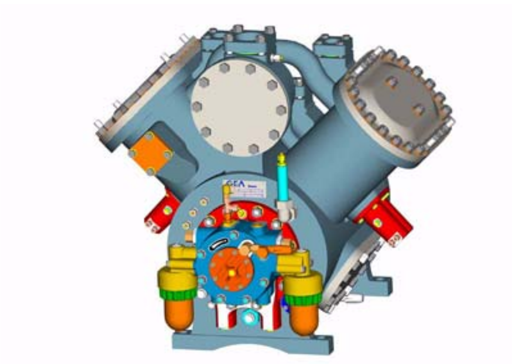


Fig. 1.2-14 Grasso 3110

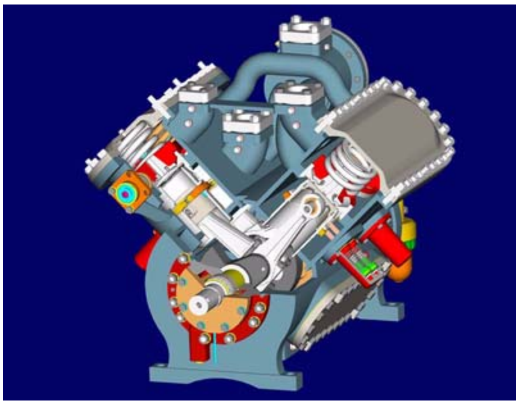


Fig. 1.2-15 Grasso 4210

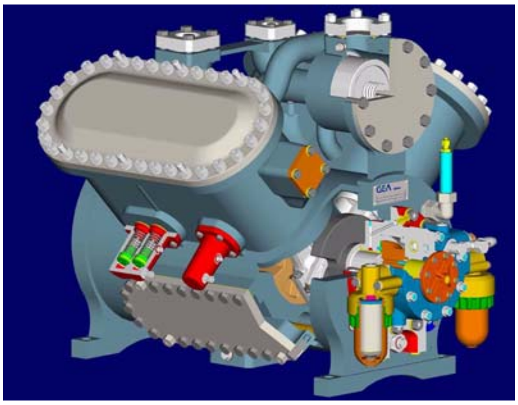


Fig. 1.2-16 Grasso 4210

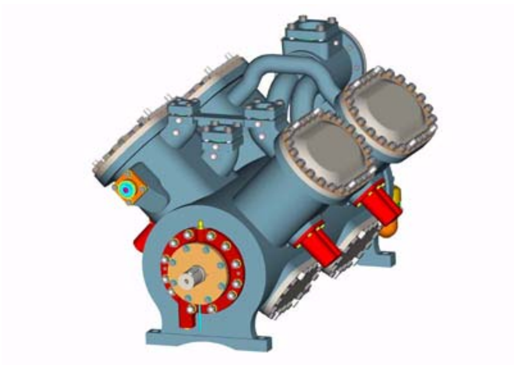


Fig. 1.2-17 Grasso 6210

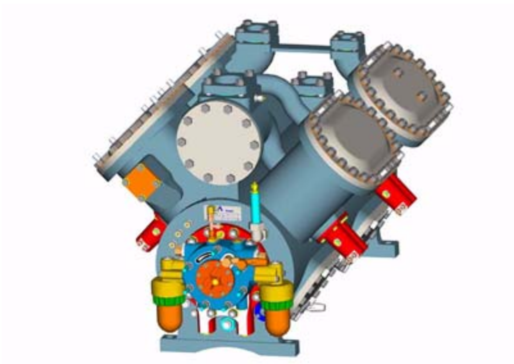


Fig. 1.2-18 Grasso 6210

1.3 GENERAL DATA

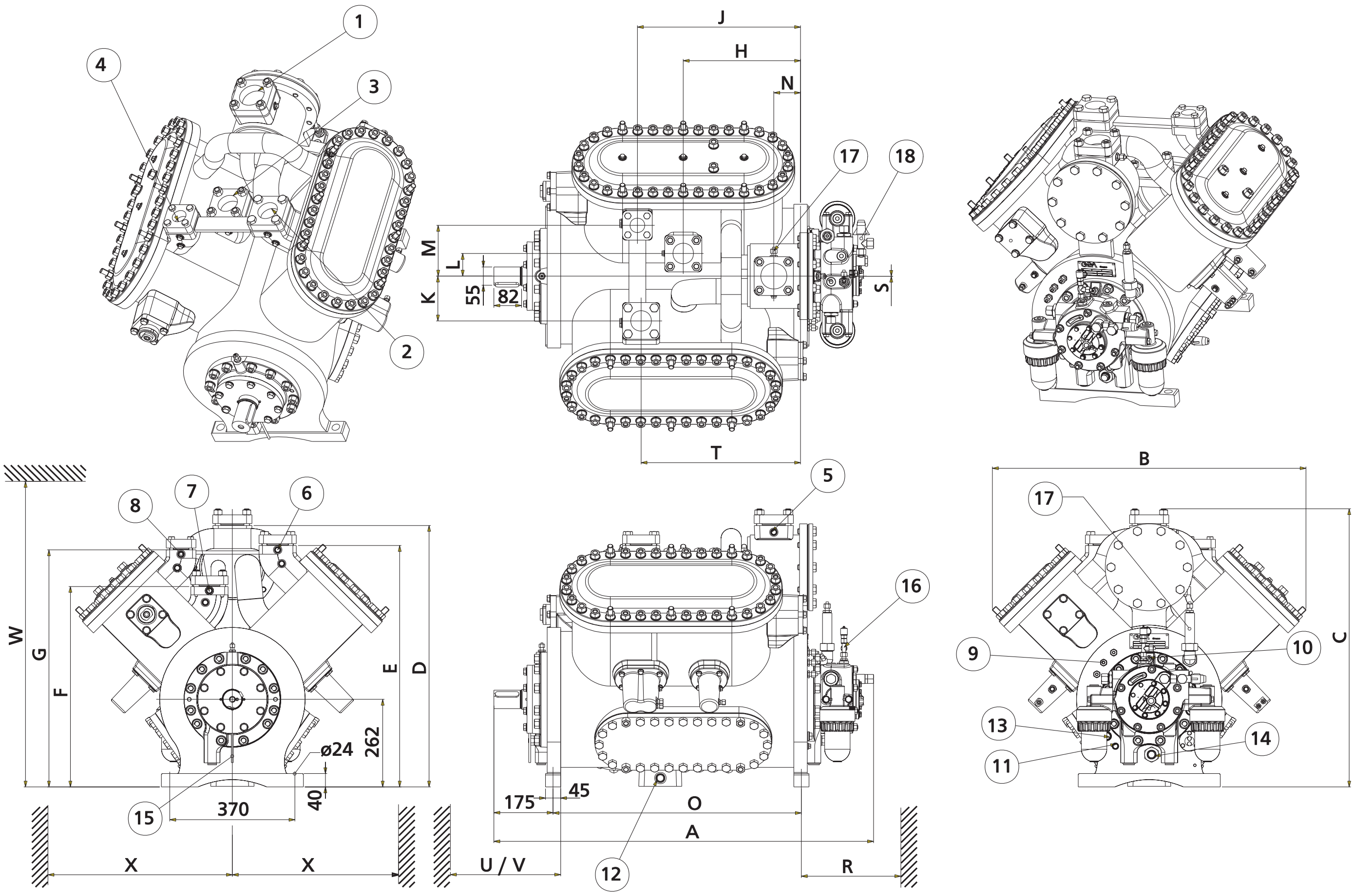
1.3.1 TECHNICAL DATA

Table 1.3-1 Technical Data of Grasso 10 compressors

COMPRESSOR TYPE Grasso				Single-stage					Two-stage			
				210	310	410	610	810	2110	3110	4210	6210
Number of cylinders			z_L	2	3	4	6	8	2	3	4	6
			z_H						1	1	2	2
Cylinder arrangement				1xL	1xL	2xV	2xV	4xV	1xL	2xV	2xV	4xV
Cylinder bore		D	mm	110								
Piston stroke		S	mm	85								
Swept volume at full-load and:	n=1500 min^{-1}	V_s	m^3/h	145	217	290	435	580	145	217	290	435
Standard direction of rotation				counter-clockwise when facing shaft end								
Standard compressor speeds (with V-belt drive) at motor speed:	1475 min^{-1} (50 Hz)	n	min^{-1}	1475-1328-1180-1047-929-826-738-661-625								
	1775 min^{-1} (60 Hz)	n	min^{-1}	1416-1257-1115-991-885-793-750-708-637								
Standard steps of capacity control (expressed in % of full-load swept volume):	manual and electric control:		%	100-50	100-67-33	100-75-50	100-83-67-50-33	100-87-75-62-50-37-25	100	100-67	100-75-50	100-83-67-50-33
	incl. Fast Pull Down(FPD)[a]		%	-					100-50	100-67 33	100-75(1.5)-75(3.0)-50(1.0)-50(2.0)-25	100-83-67-50(1.5)-50(3.0)-33(1.0)-33(2.0)
Mass of bare compressor (without flywheel and other accessories)			kg	510	585	610	725	990	590	615	730	998
Shipping mass (approx.)			kg	560	635	660	775	1040	640	665	780	1048
Shipping volume			m^3	0.3	0.4	0.7	0.8	1.1	0.4	0.7	0.8	1.1
Oil charge in crankcase and oil circuit (centre line of sight glass)			dm^3	9.5	12	9.5	12	16.5	12	9.5	12	16.5
Mass moment of inertia of crank mechanism (without flywheel)		I_d	kg.m^2	0.0776	0.1491	0.0776	0.1491	0.1673	0.1491	0.0776	0.1491	0.1673

a. Volume ratio between brackets

1.3.2 MAIN DIMENSIONS AND SPACE REQUIREMENTS

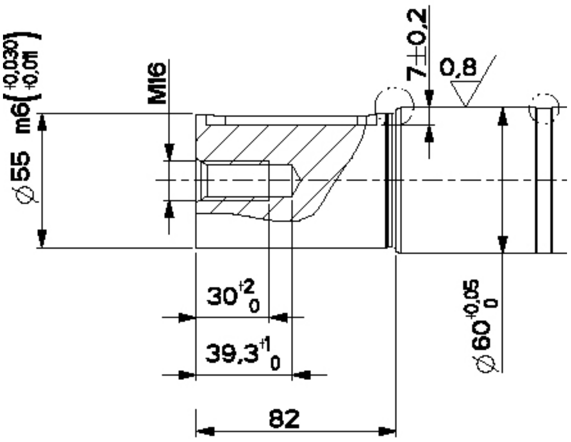


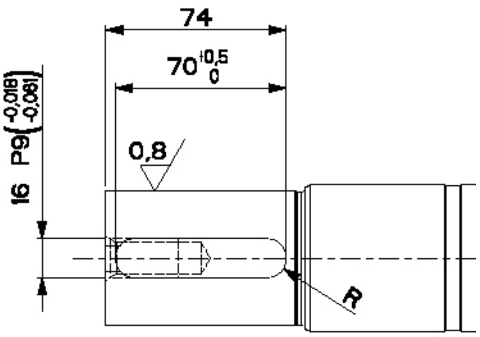
COMPRESSOR TYPE Grasso		210	310	410	610	810	2110	3110	4210	6210
Length	A	925	1105	925	1105	1455	1105	925	1105	1455
Width	B	536	536	888	888	888	536	888	888	888
Height	C	765	765	815	815	815	765	815	815	815
	D	579	579	782	777	782	577	782	782	777
	E	-	-	-	-	-	685	709	722	722
	F	-	-	-	-	-	513	595	600	600
	G	-	-	787	824	824	709	709	709	709
	H	-	516	-	-	-	516	315	345	735
	J	343	402	301	372	821	519	315	481	845
	K	-	-	-	-	-	152	152	134	134
	L	-	-	-	-	-	30	38	68	68
	M	152	134	0	0	0	152	152	152	152
	N	68	68	77	100	98	70	77	77	98
	O	555	735	555	735	1085	735	555	735	1085
	R	240	240	240	240	240	240	240	240	240

COMPRESSOR TYPE Grasso		210	310	410	610	810	2110	3110	4210	6210
	S	211	211	0	0	0	210	0	0	0
MINIMUM REQUIRED FREE SPACE for removal of:										
	T	-	-	-	-	-	519	326	470	860
flywheel[a]	U	335	355	335	335	335	335	335	335	335
crankshaft[a]	V	750	925	750	925	1270	925	750	925	1270
piston and cylinder liner[a]	W[b]	1000	1000	790	790	790	1000	790	790	790
	X	300	300	530	530	530	300	530	530	530
LOCATION OF CENTRE OF GRAVITY										
length	Y	on request								
width	Z									
MAIN CONNECTIONS DN (mm)[c]										
(LP) suction	1	50	65	65	80	100	50	65	65	80
LP dicharge/HP suction	2/3	-					32	32	50	50
(HP) discharge	4	32	50	50	65	80	32	32	32	32
AUXILIARY CONNECTIONS										
Temperature	5	1/4" BSP								
LP discharge pressure/ temperature	6									
HP suction pressure/ temperature	7									
HP dicharge pressure/ temperature	8									
Crankcase	9									
Oil lubrication pressure	10									
Oil temperature	11									
Oil drain	12	1/2' BSP								
Oil return oil separator	13									
Crankcase heater	14									
Oil leakage drain of rotary shaft seal	15	clamp coupling provided width Ø6 x 1.5 mm steel precision tube								
Oil control pressure	16	1/2" BSP								
Crankcase pressure equalizing	17	1/4" BSP								
Oil charge valve	18	1/2' bsp (TAH 8)								

a. Minimum required free space
b. Minimum required free space for interstage cooling system A or B refer to Section 2.8.2.1.
c. connection 45 degr. for Grasso 210, 2110 and 310.

1.3.3 SHAFT END COMPRESSOR





1.3.4 SOUND RATING

General

In the following pages the sound characteristics are stated in:

SWL (= sound power level)

- Average sound power level of the compressor block.

SPL (= sound pressure level)

- The values are based on an average sound pressure in free field above a reflecting plane at a distance of 1 metre from a fictional frame around the unit.
- Values are based on compressor + electric motor IP23 + oil separator

Both values SWL and SPL are applicable for for next conditions of operation:

- All cylinders in operation (full-load)
- All refrigerants
- Discharge pressure 13.5 bar(a)

For different discharge pressures from 13.5 bar (a) the indicated sound power level values have to be corrected by adding: C (pdis - 13.5) dB, where pdis is the discharge pressure in bar(a) and C is a constant which can be taken from the correction factor table.

Conversion to sound pressure level

Provided so-called "free field" conditions may be assumed (i.e. flat concrete floor and sound reflecting surfaces sufficiently far away), both the octave band and overall sound power level L_w can be converted to the corresponding sound pressure level L_p, appearing at a distance R from the compressor centre, so on the surface of a imaginary hemisphere with radius R. See figure below. The conversion formula reads as follows:

$L_p = L_w - 8 - 20\log R$
where: - L_p = sound pressure level in dB, re $2x10^{-5}$ N/m^2
- L_w = sound power level in dB, re 10^{-12} W
- R = distance (radius) in m (≥1.5).

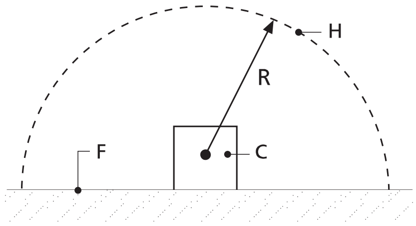


Fig. 1.3-1 Hemisphere

Legend	
H	hemisphere
F	floor
C	compressor
R	radius

Sound power-frequency characteristics

The data below shows the sound power level (S.W.L. or Lw , expressed in dB, re 10^{-12}W) as a function of the octave band centre frequency for all compressor types (number of cylinders) at different speeds and at a discharge pressure of 13.5 bar(a). The data represent the sound power emitted by the compressor (body) only, so excluding the influence of the electric motor and (V-belt) drive. Each dB-value is the direct or derived result of accurate laboratory measurements according to ISO 9614-1 and carried out by means of the latest sound intensity analysing system, make Difa measuring systems, type DSA 220C, software version D-TAC200 3.30, together with a Microtech intensity probe SIS90 and Microtech microphones MK290.

1.3.4.1 SOUND DATA Grasso 10

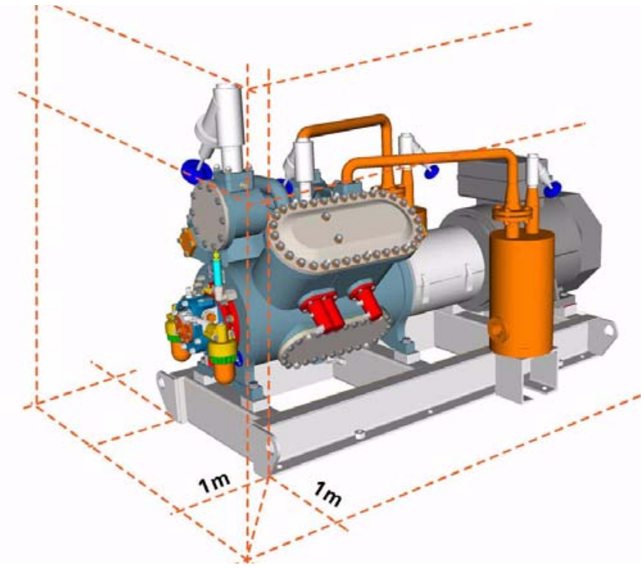


Fig. 1.3-2 Fictional frame

Table 1.3-2 Sound levels (Pdis=13.5 bar(a))

Qty Cylinders	SWL				SPL			
	speed (min-1)							
	700	1000	1250	1500	700	1000	1250	1500
2	78	78	85	86	63	63	70	71
3	81	81	88	88	66	66	73	73
4	84	85	90	90	69	70	75	75
6	86	89	93	92	71	74	78	77
8	89	92	96	96	73	76	80	80

Table 1.3-3 Correction factor

Speed (min^{-1})	<=1000	1250	1500
C(-)	0.5	0.58	0.62

Table 1.3-4 Sound power levels at discharge pressure 13.5 bar(a)

speed	Number of cylinders	Sound power level (S.W.L. or Lw) in dB, re 10^{-12}W, Pdis = 13.5 Bar(a)								
		Octave bands								
		63	125	250	500	1000	2000	4000	8000	RMS
min^{-1}	-	dB								dB(A)
700	2	71	70	78	76	78	73	70	62	78
	3	72	71	80	80	80	75	72	64	81
	4	73	73	82	83	83	77	75	67	84
	6	74	74	85	87	85	79	77	69	86
	8	73	76	87	91	88	81	79	72	89
1000	2	74	75	80	80	74	73	71	65	78
	3	75	76	82	84	76	75	73	68	81
	4	76	78	84	87	79	77	75	70	85
	6	77	79	86	91	86	79	78	73	89
	8	76	81	88	95	84	81	80	76	92
1250	2	80	82	86	83	85	76	72	68	85
	3	81	83	88	86	87	78	74	71	88
	4	82	85	90	90	90	80	77	73	90
	6	83	86	92	94	92	82	79	76	93
	8	82	88	95	98	95	83	82	78	96
1500	2	78	86	87	88	83	80	77	72	86
	3	79	88	89	90	85	82	79	73	88
	4	80	89	91	91	87	84	81	75	90
	6	81	91	94	93	90	85	83	77	92
	8	82	93	97	98	93	88	85	80	96

1.3.5 PART-LOAD POWER CONSUMPTION

General

To determine the allowed partload steps for the design conditons and the corresponding partload power consumption refer to software program Comsel.

1.3.6 STARTING TORQUE

The electric motor driving the compressor sometimes has to be checked for proper starting, especially in the case of two-stage compressors. For that purpose the "torque - speed characteristic" of the compressor at fully unloaded starting (suction valves of all cylinders lifted) is needed. This torque M_a, the trend of which is shown in the figure overleaf, is built up of the following components:

$\mathbf{M_l}$ = pull-out torque (or break-away torque), required to initiate the movement of the crankshaft after a period of compressor standstill. This torque, only occurring at compressor speed zero, is a constant for each compresor type.

$\mathbf{M_w}$ = friction torque, resulting from the purely mechanial losses in the crank mechanism. This torque, acting during the entire starting period at a constant value, only depends on the compressor type and the oil temperature.

$\mathbf{M_p}$ = pumping torque, due to the flow resistance in the lifted suction valves. This torque is zero at zero speed and increases continuously with speed during the starting period, its magnitude being dependent on the refrigerant, the number of cylinders and the suction pressure according to the formulas:

for single-stage compressors:
$\mathbf{M_{ps}} = 1.62 \times 10^{-6} (A\ p_o + B) z\ n^2$ (N.m)
for two-stage compressors:
$\mathbf{M_{pt}} = 1.62 \times 10^{-6} [A(z_L\ po + z_H\ p_m) + B\ z] n^2$ (N.m)

$\mathbf{M_d}$ = pressure torque, only valid for two-stage compressors to counterbalance the pressure difference across the HP-pistons. This torque, only occurring at zero compressor speed and depending on the number of HP-cylinders and their disposition relative to each other, can be written as follows:
$\mathbf{M_d} = C(p_m - p_o)$ (N.m)

Meaning of symbols used:

z = total number of cylinders
z_L = number of LP-cylinders
z_H = number of HP-cylinders
A and B = pumping torque factors, only dependent on the refrigerant
C (N.m/bar) = pressure torque factor, only dependent on (two-stage) compressor type
p_o (bar(a)) = suction pressure during compressor starting
p_m (bar(a)) = intermediate pressure during compressor starting
n (min^{-1}) = compressor speed, increasing from zero to the chosen nominal operating speed.

The total M_a-curve as a function of the speed n is derived from the components in table below.

The M_a-curve, thus obtained, has to be compared with the corresponding torque - speed characteristic of the selected electric drive motor, as supplied by the motor manufacturer and after being converted to the compressor shaft by multiplying with the transmission ratio D/d, where D and d are the nominal diameters of the flywheel and the motor pulley respectively.
In the normal case of a squirrel cage motor with star-delta starter, two torque - speed characteristics M_m (Y) and M_m (Δ) have to be considered as shown in the figure below.

The difference between M_m and M_a at any speed (shaded area) represents the torque available for accelerating the combination motor - compressor. The intersection points **I** and **II** indicate respectively the theoretical switch-over speed from star to delta and the final unloaded compressor speed.

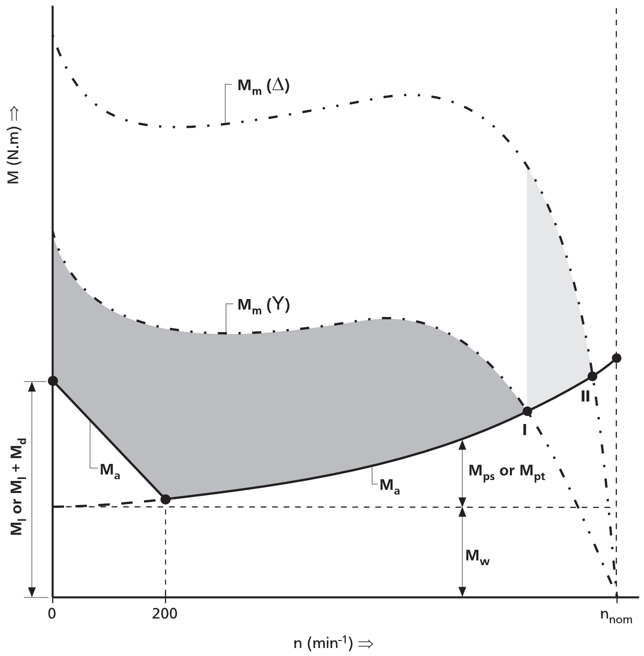


Fig. 1.3-3 Compressor torque and electric motor torque - speed characteristics

Speed interval	n = 0	n ≥ 200/min	0 ≤ n ≤ 200/min
Single-stage compressors	$M_a = M_l$	$M_a = M_w + M_{ps}$	M_a is linear from M_l to $M_w + M_{ps}$
Two-stage compressors	$M_a = M_l + M_d$	$M_a = M_w + M_{pt}$	M_a is linear from $M_l + M_d$ to $M_w + M_{pt}$

1.3.6.1 TORQUES GRASSO 10

Compr. type Grasso		Total number of cylinders	Number of LP and HP cylinders		Pull-out torque	Friction torque at 55 °C oil temp.	Pumping torque factors										Pressure torque factor
							A					B					
		Z	Z_L	Z_H	M_l (N.m)	M_w (N.m)	NH_3	R134a	R22	R404A	R507	NH_3	R134a	R22	R404A	R507	C (N.m/bar)
SINGLE-STAGE	210	2	-	-	19	17											-
	310	3	-	-	23	19											-
	410	4	-	-	24	21	0.762	4.875	4.193	5.100	5.209	0.155	0.500	0.511	0.300	0.178	-
	610	6	-	-	36	25											-
	810	8	-	-	50	30											-
TWO-STAGE	2110	3	2	1	23	19											41
	3110	4	3	1	24	21	0.762		4.193			0.155		0.511			41
	4210	6	4	2	36	25											41
	6210	8	6	2	50	30											57

1.3.7 FREE FORCES AND MOMENTS

Free forces and moments are inertia forces and their resulting moments, generated by not fully balanced masses of the compressor main moving parts (crankshaft, connecting rods, pistons).
As indicated in the adjacent figure there can be distinguished horizontal and vertical free forces, called H and V respectively, both acting in a vertical plane I, which is perpendicular to the crankshaft centre line at a distance L from the vertical centre plane of the compressor foot on drive end.

Likewise, there are horizontal and vertical free moments, called Mh and Mv and respectively acting in a horizontal plane II and a vertical plane III, which both pass through the crankshaft centre line.
Each free force and moment consists of a "primary" component (see table below for the different compressor types) with a frequency equal to the compressor speed and a "secondary" component with a frequency of double the compressor speed.

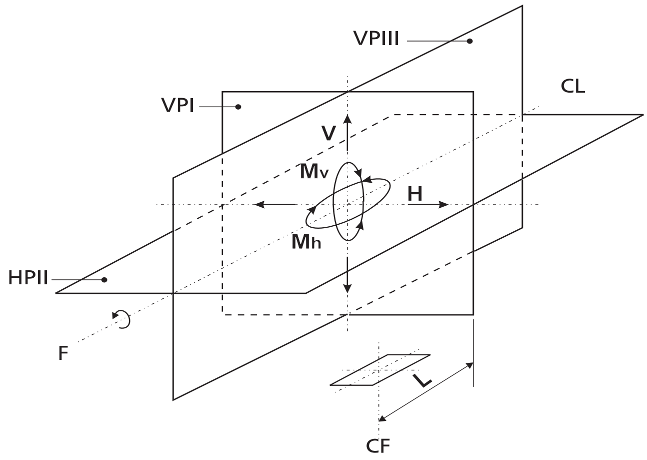


Fig. 1.3-4 Planes

Legend	
VPI	vertical plane I
VPIII	vertical plane III
HPII	horizontal plane II
F	flywheel end of compressor
CF	centre line of compressor foot
CL	center line crankshaft
L	distance VPI and centre line compressor foot

1.3.7.1 FORCES AND MOMENTS

Compr. type Grasso	**Free forces and moments Forces H (horizontal) and V (vertical) in (N); Moments M_h (horizontal) and M_v (vertical) in (N.m)[a]**				**L (mm)**
			Primary	**Secundary**	
			1500 rpm[b]	**1500 rpm**	
210	Forces	H	0	0	on request
		V	0	617	
	Moments	M_h	162	0	
		M_v	162	12	
310/2110	Forces	H	0	0	
		V	0	0	
	Moments	M_h	281	0	
		M_v	281	101	
410/3110	Forces	H	0	916	
		V	0	0	
	Moments	M_h	0	0	
		M_v	0	17	
610/4210	Forces	H	0	0	
		V	0	0	
	Moments	M_h	0	143	
		M_v	0	0	
810/6210	Forces	H	0	0	
		V	0	0	
	Moments	M_h	0	0	
		M_v	0	0	

a. 1 N = 0.102 kgf = 0.225 lbf; 1 N.m = 0.102 kgf.m = 0.738 lbf.ft.
b. For different speed n (min-1), all forces and moments have to be multiplied by $(n/1500)^2$

1.4 LIMITS OF OPERATION AND FIELDS OF APPLICATION

1.4.1 GENERAL LIMITS AND FIELDS OF OPERATION

When operating the compressor, none of the limits of operation as stated in the table below must be exceeded.[1]

The diagrams overleaf represent the overall fields of application in which the individual operation limits are taken into account.

Table 1.4-1 General limits and fields of operation

1. In practice, it is not so much the individual operation limits as combinations of them that are decisive for the conditions under which a compressor may operate. To check the various possibilities in this respect, use should be made of the "fields of application").

REFRIGERANT					NH_3	R22	R134a	R404A	R507
Compressor speed		n	min^{-1}	min.	600				
				max.	1500				
Suction pressure = evaporating pressure =crankcase pressure	a	p_o	bar(a)	min.	0.3				
				max.	8.5				
Intermediate pressure		p_m	bar(a)	min.	0.3				
				max.	8.5				
Evaporating temperature = saturation temperature at suction pressure		t_o	°C	min.	-55	-63	-50	-68	-68
				max.	19	17	33	10	10
Actual suction temperature		t_a	°C	min.	-50				
Discharge pressure = condensing pressure	b	p_c	bar(a)	max.	26.0				
Condensing temperature = saturation temperature at discharge pressure		t_c	°C	max.	60	63	79	55	54
Discharge temperature	c	t_e	°C	max.	+170				
Pressure ratio per stage (p_c/p_o or p_c/p_m or p_m/p_o)	d	j	-	min.	1.1				
				max.	7.0	10.0			
Pressure difference	e	Δp	bar	max.	25.0				
Oil temperature in crankcase	f	t_{oil}	°C	min.	+20	+30			
				max.	depending on type of oil (Required oil viscosity > 10 cSt)				

a. 1 bar = 10^5 N/m^2 = 100 kPa = 1.02 kgf/cm^2 = 14.5 psi.
b. This pressure is also the maximum allowable pre-set value of the HP safety switch. CAUTION!: When adjusting the HP and/or LP safety switch, care should be taken that the pressure difference $\Delta p=(P_C-p_o)$ never exceeds 25.0 bar.
c. This is the actual discharge temperature, measured directly in the gas flow just before the discharge connection. The given value also applies to the LP stage of two-stage compressors.
d. Pressure ratio limits are not absolute but arbitrary values based on practical considerations.
e. The standard built-in overflow safety valve(s) between suction and discharge side has been factory-set to 25.0 >1.0 bar to prevent advanced opening during normal operation at $\Delta p = (p_c - p_o) \leq 25.0$ bar.
f. Indicated minimum value is the lowest oil temperature at which the compressor is allowed to be started. The maximum oil temperature depends on the operating conditions of the compressor, the oil type used and (for halocarbon refrigerants only) the solubility of the refrigerant in the oil. A minimum actual oil viscosity of 10 cSt is always required.

1.4.2 FIELDS OF APPLICATION SINGLE-STAGE AND BOOSTER

General

Application of part-load operation for a long period of time and/or superheat > 0 K results into higher discharge temperatures. Consequently the fields of application for single-stage and booster compressors will be reduced. So line $t_{e\text{-}max}$ will shift downwards for NH_3.

Symbols used in diagrams

t_o = evaporating temperature
p_o = evaporating pressure
t_c = condensing temperature
p_c = condensing pressure
Δt_o = suction superheat
j = pressure ratio = (p_c / p_o)
Δp = pressure difference = $(p_c - p_o)$
$t_{e,max}$ = maximum discharge temperature
$\downarrow$ = Line shift downwards for Δt_o > 0 K and/or part-load operation

Procedure and data

- Diagrams in Section 1.4.2 are based on continuous full-load operation, suction superheat = 0K.
- For continuous minimum part-load (i.e. more than 30 minutes) consult Grasso.

1.4.2.1 DIAGRAMS Grasso 10

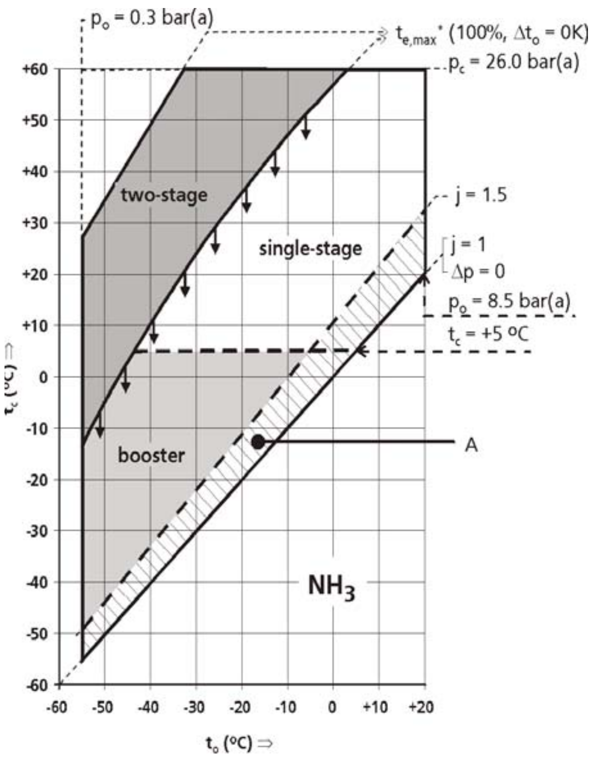


Fig. 1.4-1 Field of application NH_3

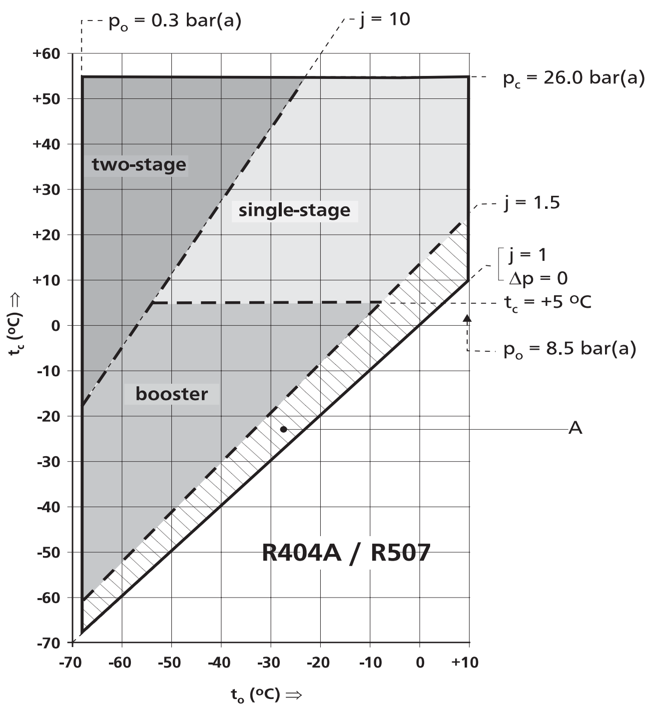


Fig. 1.4-2 Field of application R404A/R507

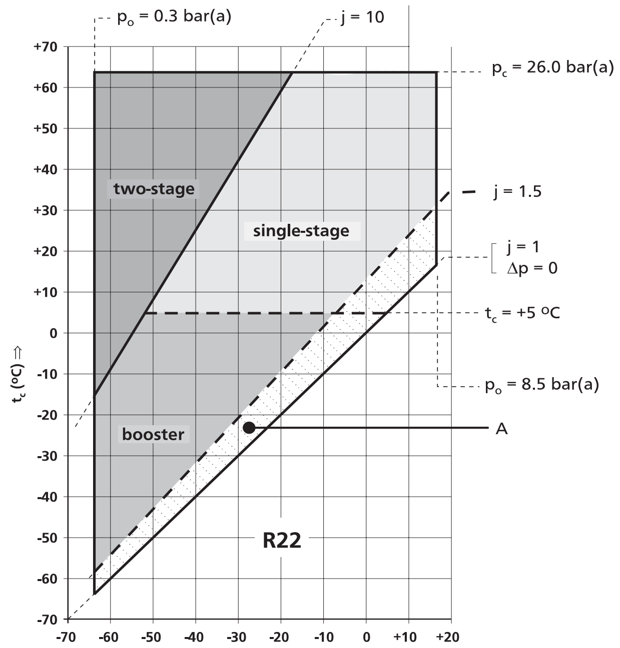


Fig. 1.4-3 Field of application R22

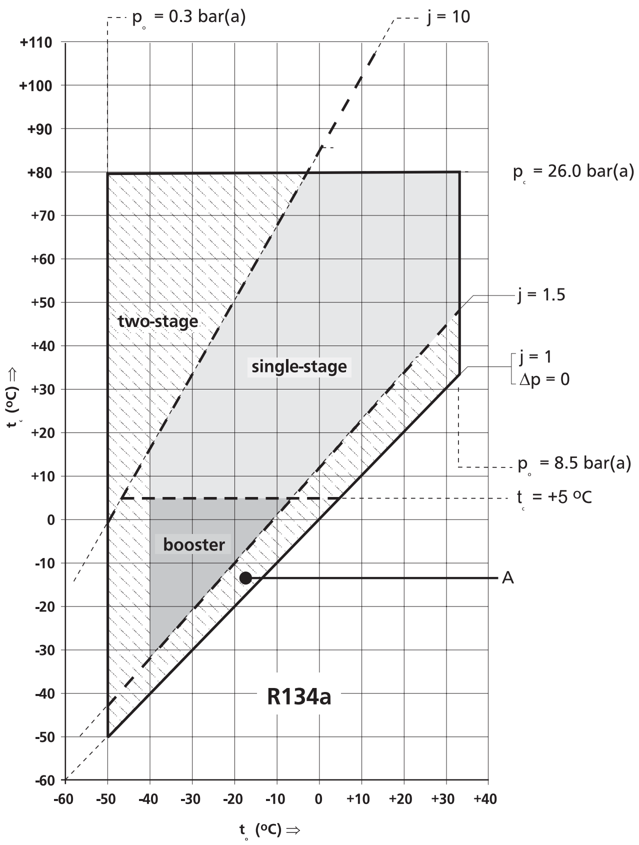


Fig. 1.4-4 Field of application R134a

1.4.3 FIELDS OF APPLICATION TWO STAGE

General

The fields of application for two stage compressors are (besides superheat and part-load operation) very dependant on φ(ratio LP/HP swept volume; full-load and part-load can have different values). Because each capacity control step can have a different φ, it is very important to check for every control step (especially during starting up!) that the compressor will run with-in its limits of operation.

Refer to Starting Up Procedure and Limitations of Partload Operation

Symbols used in diagrams

t_o = evaporating temperature
p_o = evaporating pressure
t_c = condensing temperature
p_c = condensing pressure
t_m = saturation intermediate temperature
j = pressure ratio = (p_c / p_o, p_c / p_m or p_m / p_o)
Δp = pressure difference = (p_c - p_o)
$t_{e,max}$ = maximum discharge temperature
$t_{eH,max}$ = maximum discharge temperature HP
φ = ratio LP/HP swept volume (full-load and part-load can have different values)
↓ = Line shift downwards for Δt_o > 0 K and/or part-load operation

Procedure and Data

- Two stage fields of application are not valid for all types of compressors and/or all part-load steps.
  All compressor types are included within the total field of application.
- Diagrams overleaf are based on LP and HP suction superheat 0K resp. 10K.

For continous part-load (i.e. more than 30 minutes) consult Grasso.

- The Dummy diagram shows field of application for different φ's.
- Shaded areas are fields of single-stage operation (used and allowed only during starting up compressor).
- Each φ has its own field of application (Example; see dummy diagram φ= X area)
- φ = 1 is "Fast Pull Down" capacity control step (option), to be used during starting up compressor only. Refer to starting up procedure

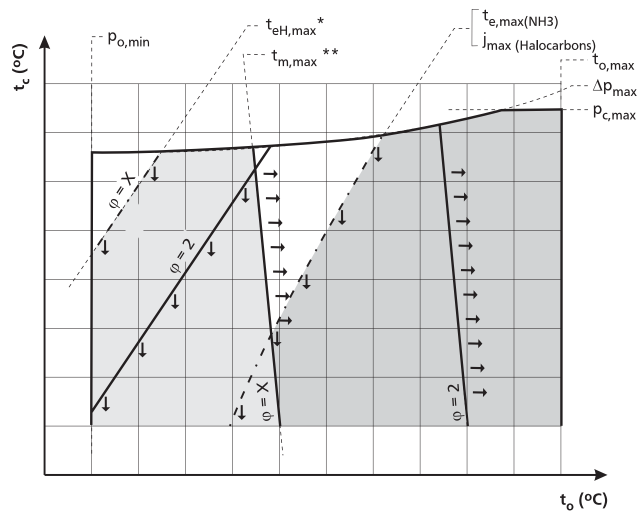


Fig. 1.4-5 Dummy diagram

Table 1.4-2 Dummy Diagram; Explanation two stage field of application

Legend	
J_{max} / $t_{e,max}$	Area on the right side of this line indicates the single stage field of operation (starting up). This line shifts down in case of continuous part-load operation and/or (intermediate) superheat. Superheat also results in limited part-load operation.
$t_{eH,max}$* / $t_{e,max}$	Maximum HP-discharge temperature (not applicable for halocarbons). This line shifts down in case of continuous part-load operation and/or (intermediate) superheat. Superheat also results in limited part-load operation.
φ	Each φ (phi) has its own field of appication. The higher this value, the lower possible evaporating temperature. For each capacity control step field of application must be verified in relation with φ.
$P_{o,min}$	Minimum suction pressure (evaporating)
$t_{m,max}$	Maximum intermediate pressure.

1.4.3.1 FIELDS OF APPLICATION DIAGRAMS GRASSO 10

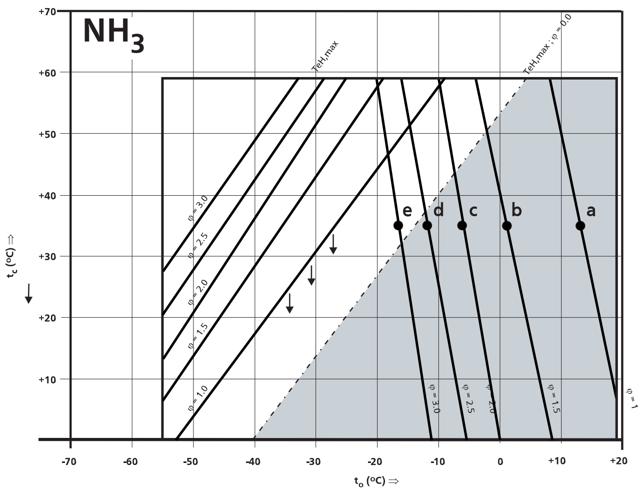


Fig. 1.4-6 Field of application two-stage NH_3

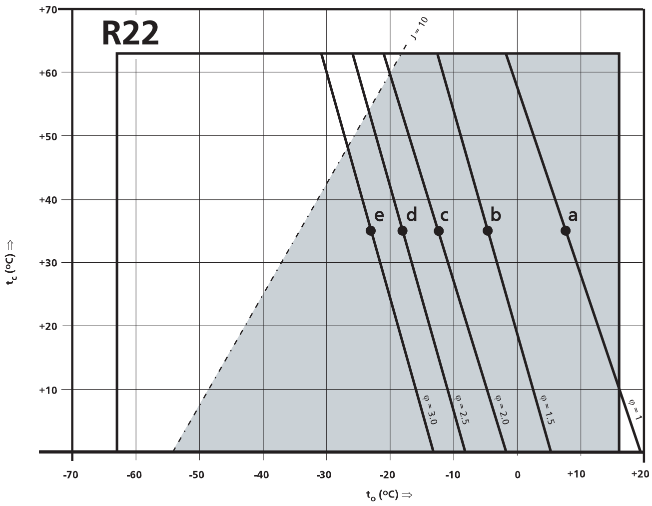


Fig. 1.4-8 Field of application two-stage R22

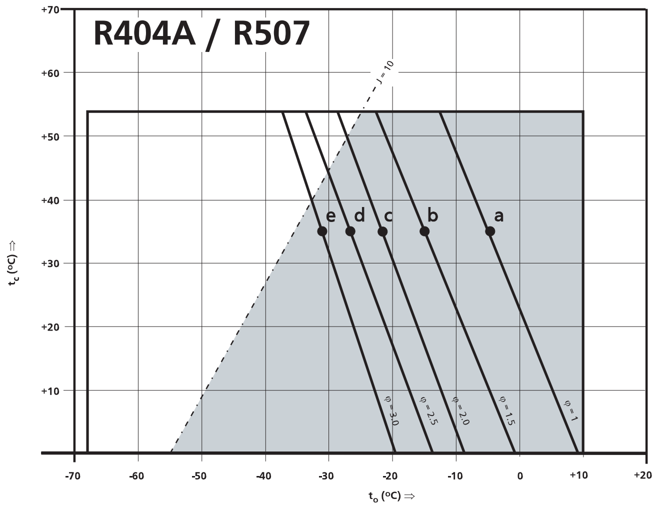


Fig. 1.4-7 Field of application two-stage R404A and R507

1.4.4 LIMITATIONS OF PART-LOAD OPERATION

General

The Monitron CR will control automatically all full-load and part-load limitations (motor current, optimum φ etc.) for booster, single- and two-stage compressors.

Limitations of part-load operation for single-stage compressors

In the case of *continuous* single-stage part-load operation of Grasso compressors with the refrigerant NH_3, not all standard capacity control steps can be used under all operating conditions. There is a limitation with respect to minimum capacity, which, depending on the amount of suction superheat, is determined by the maximum discharge temperature of 170 °C. This means that the full-load field of application as shown in the NH_3- diagram, is reduced at top-left for part-load operation in a way as indicated by the arrows in the the relevant diagram.
This part-load restriction cannot be eliminated by applying a cooling system on the cylinder head.

When, on the contrary, the refrigerants R134a, R22, R404A and R507 are used for *continuous* single-stage part-load operation of all standard capacity control steps, the same operating conditions are allowed as for full-load operation with all cylinders energized. In other words, the full-load fields of application, also remain valid for

part-load operation down to and including the standard minimum capacity step.
Only under very extreme conditions with respect to ambient temperature (e.g. above approx. +40 °C) and/or suction superheat (e.g. more than approx. 30 K) the situation may occur that during part-load operation the maximum discharge temperature of 170 °C and/or the maximum oil temperature are/is exeeded, which implies that in these cases it is not permitted to switch off cylinders down to the standard minimum capacity.
In such a case the oil temperature is the decisive factor, the limitation mentioned before can be avoided by applying an oil cooler. For these special cases, always consult Grasso.

In general the rule is that, irrespective of refrigerant and conditions of operation, it is never allowed to run a compressor during a prolonged period of time fully unloaded, i.e. with all cylinders switched off.

When using a Grasso compressor equipped with a standard capacity control such a situation is impossible because then, apart from the starting period, always one or more cylinders are permanently connected to the control oil pressure.

Limitations of part-load operation for two-stage compressors

From the diagrams, it appears that for two-stage compressors the field of application depends not only on the kind of refrigerant but also on the ratio φ of L.P. and H.P. swept volume.
This involves (since the standard capacity control steps of the individual two-stage types have not always the same φ-value) that for the successive capacity control steps of a certain compressor type different fields of application may be valid. If this is the case, the situation may occur that, when cylinders are switched on or off under constant (design) conditions of operation, the corresponding working point (= combination of condensing temperature t_c and evaporating temperature t_o) lies outside one or more of the relevant fields of application.
This implies that it is not allowed to use the part load steps concerned, either on account of too high a H.P. discharge temperature in case of NH_3 only (working point lies to the left of the field of application), or on account of too high a saturation intermediate temperature / intermediate pressure (working point to the right of the field of application). In the case of electrical capacity control, such disallowed part-load steps can easily be avoided in actual practice for once and forever by adapting accordingly the wiring diagram for energizing the three-way solenoid valves.

Should hand-operated capacity control be applied, however, the operator in the engine room has to be well informed about the part-load steps that are not allowed to be used and consequently about the positions of the oil distributor handle that must be avoided. It will be clear that ignorance and/or negligence in this respect may easily lead to failures and/or breakdowns. This is one of the reasons that for two-stage compressors hand-operated capacity control is forbidden.

Apart from the above-mentioned inadmissibility of certain standard part-load control steps, care should always be taken to ensure that the capacity of two-stage compressors is never reduced to such an extent that only H.P. cylinders remain operative.

For then the compressor would operate as a single-stage machine, but under two-stage conditions, which would result, in particular for NH_3, in an unacceptably high discharge temperature. This restriction means that the three-way solenoid valves should be wired so that, when the compressor is running under design conditions, at least one solenoid valve remains energized. Here again the undesirability of hand-operated capacity control becomes evident, for it would mean that, as long as the compressor in running, one has to be sure that the handle of the oil distributor is never set to (starting) position 1.

1.4.5 STARTING UP OF TWO-STAGE COMPRESSORS

General

The Monitron CR will control automatically all full-load and part-load limitations (motor current, optimum φ etc.) for booster, single- and two-stage compressors.

Procedure for starting from compressor standstill

In the case of two-stage compressors it is very important that immediately after the period of automatic fully unloaded start (ensured by the corresponding three-way solenoid valve in the control pressure supply line from the oil pump; only one or more H.P. cylinders become operative, viz. only those cylinders of which the suction valve lifting mechanism is directly and permanently connected to the control pressure supply of the oil pump via the starting solenoid valve mentioned. This means that during starting none of the three-way solenoid valves for the capacity control are allowed to be energized.

Procedure to move on to two-stage operation and to increase capacity.

Once properly started, as indicated in the previous paragraph, the compressor has to be switched over to two-stage operation with minimum capacity, followed, if and when required, by gradual stepping up to maximum capacity.
The procedure thereby to be applied depends on the installation operating conditions during starting which give rise to two distinct possibilities, viz.:

1. *The compressor is started at low evaporating temperatures,* this being approx. the (design) value during normal (full-load) operation.
   This situation occurs after the compressor has been stopped for a certain period of time because of low capacity requirements of the installation. Under these circumstances it is permitted to switch over to the two-stage part-load step of minimum capacity immediately after proper starting with H.P. cylinders in operation.
   In the case of NH_3, this is even a necessity, for otherwise the compressor would be running in single-stage under two-stage conditions, resulting in too high a discharge temperature.
2. *The compressor is started at a relatively high evaporating temperature,* that is to say much higher than under design conditions and in any case not suitable for two-stage operation.
   Such a situation may occur after a prolonged period of compressor standstill or when the compressor operates on a batch type freezing tunnel, just loaded with warm products. Under these circumstances it is not permitted to switch over to two-stage operation with minimum capacity until the H.P. cylinders already in operation have lowered (in single-stage) the evaporating temperature to so much that the corresponding working point at the condensing temperature t_c, lies inside the field of application of the two-stage minimum part-load step concerned. Only then, after this step has been energized, the saturation intermediate temperature t_m will be below its maximum value. Consequently, the maximum value of t_o at which it is allowed to switch over to two-stage operation, is determined by the intersection of the near-vertical line which represents the right hand limitation of the relevant field of application and the horizontal line which represents the condensing temperature t_c.
   Likewise, during further stepping up to maximum capacity, the evaporating temperature has to be pulled down by each intermediate part-load step so far that the corresponding working point at given condensing temperature lies each time just inside the field of application of the next part-load step of higher capacity, before that step is energized.

Fast pull-down part-load control steps

When using the standard capacity control steps of the two-stage compressor types, the pull-down procedure to achieve full-load operation at design conditions, as described in the previous paragraph, is rather often very time consuming. This is due to the fact that all compressor types are always started with only one HP cylinder in operation and that the minimum LP/HP swept volume ratio for any part-load step is $\varphi = 2$.
Therefore, for all Grasso two-stage types a fast pull-down electric capacity control system has been developed, which allows the compressors to be started with two or more HP cylinders in operation and which includes one or more part-load steps with volume ratio $\varphi = 1$.

1.5 LUBRICATING OILS (choice and recommendations)

For lubrication of refrigeration compressors, several brands and types of specially developed lubricating oils are on the market. The choice of oil depends not only on its good lubrication properties (viscosity) and chemical stability at the operating conditions of the compressor, but also on the operating conditions of the refrigerating plant (solidifying and floc point, solubility).

Grasso has tested and approved for use in its reciprocating-compressors the brands and types of oil as listed in Table 1.5-2.
The choice of the viscosity of the lubricating oil depends on the operating conditions of the compressor.
The oil viscosity should always be more than 10 cSt (based on bearing construction requirements of the compressor). For the selection of the oil viscosity grade number, refer to Table 1.5-1 below.
A higher viscosity should be chosen, when a high oil temperature is expected, due to arduous operating condition such as:

- high evaporating temperature;
- large superheat of the refrigerant suction vapour;
- prolonged part-load operation with a large number of cylinders cut-out;
- a high surrounding temperature;
- large pressure ratio.

Remark

For the oil types mentioned below, applied with the refrigerants R22, NH_3 and R134a, the minimum requirement of the actual oil viscosity of 10 cSt is fulfilled, but only when the maximum oil temperature as mentioned in the Table 1.5-1 below is not exceeded.

Table 1.5-1 Oil selection table

		Max. allowable evaporating temperature $t_{o,max}$ (°C)	Maximum allowable crankcase oil temperature[a]		
			ISO VG-number		
			46	68	100
Refrigerant used[b]	NH_3	-	73	80[c]	88
	R22	-64	72	80[c]	88
		-30	69	78[c]	86
		-20	67	76[c]	84[c]
		-10	65	74[c]	82[c]
		0	60	71	78[c]
		+10	52	65	74[c]
	R134a, R507, R404A	-50	-	88[c]	94
		-30	-	85[c]	92
		-20	-	83[c]	91
		-10	-	81[c]	90[c]
		0	-	76	87[c]
		+10	-	68	84[c]

a. Data based on minimum oil viscosity of 10 cSt at the bearing surfaces, which is derived from the oil type, solubility of the regrigerant in the oil (halocarbon refrigerants only) and operating conditions. Assumed is that the oil temperature at the bearing surfaces = 6 K above crankcase oil temperature.
b. In case of other refrigerants always contact the oil supplier in advance for advise
c. Recommended ISO VG-numbered oil.

Example: R22, $t_{o,max}$ = 0°C): recommended oil type is ISO VG100. NH_3 under normal operating conditions, oil type with ISO VG68 is recommended.

Table 1.5-2 Recommended oil types for Grasso reciprocating compressors - NH_3

Refrigerant used	Brand	Type designation	ISO VG number[a]
NH_3	CPI	CP-1009-68[b]	100-68
	PETRO CANADA	Reflo 68a[b] Reflo 68A[b]	68

a. Viscosity grade number designation according to ISO Standard 3448.
b. For NH3 only! Strongly recommended for NH_3 with discharge temp. > 120 °C

Some of the oil types listed in this table may be marketed under other names and/or designations; these oils can also be used, provided their identity can be proved beyond any doubt. Application of other oils is not permitted without the written consent of Grasso.

Table 1.5-3 Accepted oil types for Grasso reciprocating compressors

Refrigerant used	Brand	Type designation	ISO VG number[a]
NH_3 and R22	AVIA	Avilub FC 46/68	b
	BP	Energol LPT-F 46	46
		Energol LPT-F 68	68
	CASTROL	Icematic 299	b
	CPI Recommeded!	CP-1009-68[c]	b(NH_3 only!)
	ELF	Elfrima FR 68	b
	ESSO	Zerice 46	46
		Zerice 68	68
		Zerice 46	46
		Zerice 68	68
	FINA	Purfrigol MP 68	68
	FUCHS	KC 46	46
		KC 68	68
	KROON OIL	Carsinus FC 46/68	b
	MOBIL	Arctic oil 300	b
	PETRO CANADA Recommended!	Reflo 68a[b]	(NH_3 only!)
		Reflo 68A[b]	
	Q 8	StravinksyB	b
		Stravinsky C	b
	SHELL	Clavus 46	46
		Clavus 68	68
		Clavus G 46	46
		Clavus G 68	68
		Clavus G 100	100
	SUN-OIL	Suniso 3.5 GS	b
		Suniso 4 GS	b
		Suniso 5 GS	b
		Suniso 4 SA	b(NH_3 only!)
	TEXACO	Capella WF 68	68
	TOTAL	Lunaria S 46/68	b

Refrigerant used	Brand	Type designation	ISO VG number[a]
R134a/R404A/R507	CASTROL	Icematic SW 68	68
		Icematic SW 100	100
	CPI	Solest 68	b
		Solest 120	b
	DEA	Triton SE 55	b
		Triton SE 80	b
		Triton SE 120	b
	ELF	Planetelf ACD 68	b
		Planetelf ACD 100	b
	FINA	Purfrigol ST VG 68	b
		Purfrigol ST VG 100	b
	FUCHS	Reniso E 68	68
		Reniso E 100	100
	ICI	Emkarte RL 685	b
		Emkarte RL 100S	b
	MOBIL	EAL Arctic 68	b
		EAL Arctic 100	b
	SHELL	Clavus R68	b
		Clavus R100	b
	SUN-OIL	Suniso Excel	b
	TEXACO	Capella HFC 68	68
		Capella HFC 100	100

a. Viscosity grade number designation according to ISO Standard 3448.
b. Consult your oil supplier to determine the maximum allowable oil temperature at an oil viscosity of 10 cSt, under prevailing operating conditions and refrigerant used.
c. For NH3 only! Strongly recommended for NH_3 with discharge temp. > 120 °C

Some of the oil types listed in this table may be marketed under other names and/or designations; these oils can also be used, provided their identity can be proved beyond any doubt. Application of other oils is not permitted without the written consent of Grasso.

1.6 DESIGN DETAILS OF COMPRESSOR

1.6.1 COMPRESSOR HOUSING (Fig. 1.6-1 and Fig. 1.6-2)

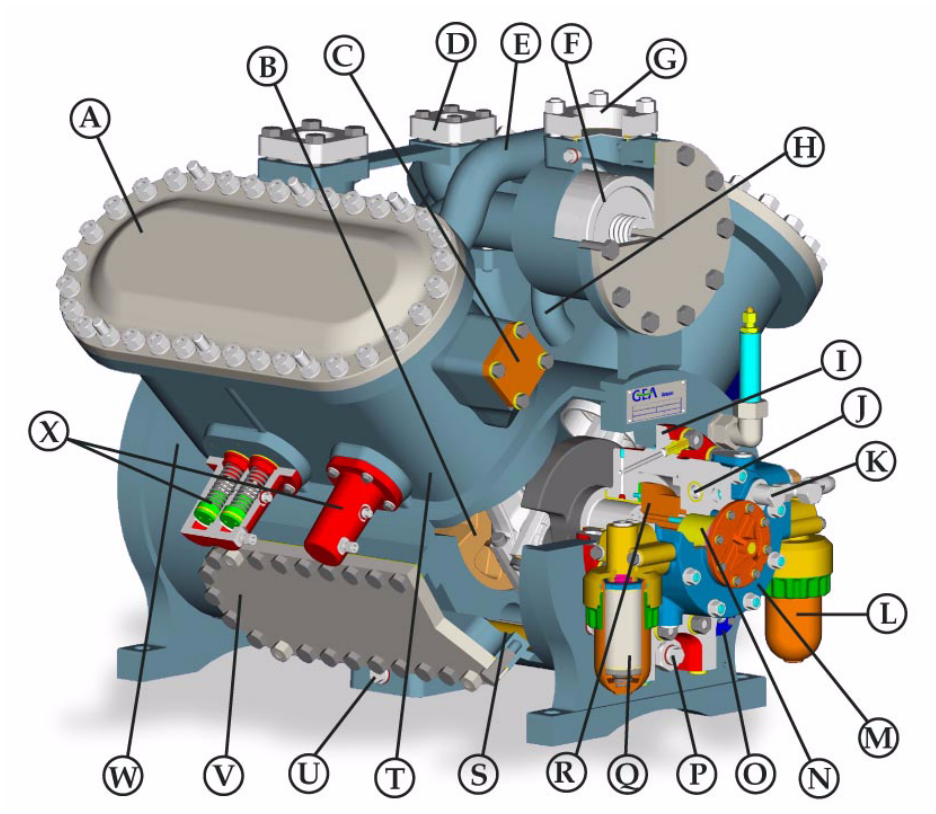


Fig. 1.6-1 Design of bare compressor (Grasso 4210)

Legend	
A	Cylinder head cover
B	Intermediate bearing
C	Relief valve
D	HP discharge connection
E	Discharge line
F	Suction gas filter
G	Suction connection
H	Suction line
I	Bearing cover
J	Control oil pressure regulator
K	Oil charge valve
L	Oil discharge filter
M	Oil pump housing

Legend	
N	Oil pump
O	Oil sight glass
P	Plugged off connection for crankcase heater
Q	Oil suction filter
R	Thrust bearing
S	Sleeve for crankcase heater
T	Cylinder jacket
U	Oil drain connection
V	Service cover
W	Crankcase
X	Control cylinder valve lifting mechanism

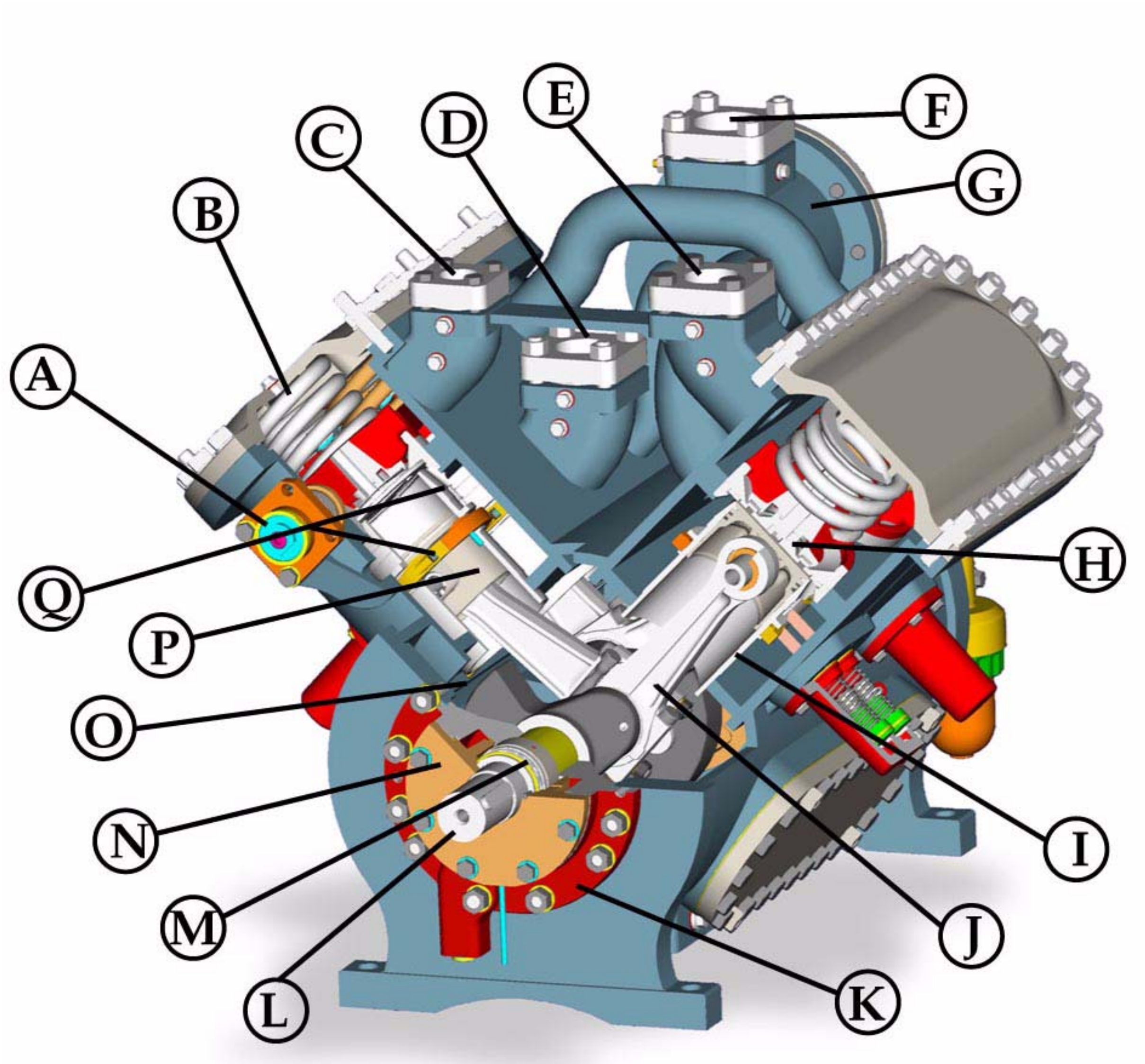


Fig. 1.6-2 Design of bare compressor (Grasso 4210)

Legend	
A	Relief valve
B	Buffer spring
C	HP discharge connection
D	HP Suction connection
E	LP Discharge connection
F	Suction connection
G	Suction gas filter housing
H	Suction and discharge valve assembly
I	Cylinder liner
J	Connecting rod
K	Bearing cover

Legend	
L	Crank shaft
M	Rotary shaft seal
N	Shaft seal housing
O	Plug (oil return orifice)
P	Piston
Q	Valve lifting mechanism

The compressor housing is of welded steel construction and comprises the crankcase and the cylinder jackets. In the lower part of each cylinder jacket, an interchangeable cylinder liner is provided. The annular space between cylinder liner and jacket serves as suction chamber. The discharge chamber is formed by the upper part of the cylinder jacket shut off by the cylinder head cover.

The crankshaft runs in bearings at either end of the crankcase. The covers also carry the rotary shaft seal housing and the oil pump housing. In the case of compressors whose crankshaft is provided with intermediate bearings, one or more supports for the bearing blocks are welded to the crankcase.

A certain level of oil is always contained in the crankcase for lubrication purposes.
To determine the oil level, a sight glass is located on oil pump side of the compressor.
All compressors are fitted with a crankcase heater connection.

The oil which is separated in the suction chamber from the refrigerant vapour can flow back to the crankcase via a small orifice inside a plug. This plug is fitted between suction chamber and crankcase in the lower supporting ring of the cylinder liner. The plugs fitted in the HP-cylinders of two-stage compressors are not provided with an orifice.

The crankcase interior is accessible via one or more service covers provided on both sides of the crankcase.

1.6.2 CYLINDERS AND MOVING PARTS

The cylinders are formed by interchangeable, centrifugally cast iron cylinder liners pressed into the cylinder jackets. The collar on top of the cylinder liner is provided with openings and acts as a seat for the suction valve ring.
In the cylinder liners light metal pistons are located, on which compression rings and 1 oil scraper ring are fitted.

The connecting rods have a split-type big end, in which precision bearing shells are positioned.
To provide bearing for the gudgeon pin, a bush, or, in the case of HP cylinders of two-stage compressors, two needle bearings are pressed into the small end bore.

The nodular cast iron crankshaft is mounted in slide bearings consisting of interchangeable, one-piece bushes pressed into the bearing covers.
Intermediate bearings are built up of split-type bearing shells located in bearing blocks.

The axial crankshaft thrust is taken up by a special heavy duty thrust bearing on the oil pump end, consisting of a rotational steel disc, fitted onto the crankshaft, and a stationary steel ring. The sliding surface of this ring is coated with a wear-resistant layer and has separately fed oil chambers.

The crankshaft is dynamically balanced. The shaft end with key, for taking up flywheel or coupling, is carried by the bearing and maintained gastight by the shaft seal.

1.6.3 ROTARY SHAFT SEAL

In order to maintain gastightness, the compressor is provided with a special rotary shaft seal, the parts of which are retained in a housing mounted against the bearing cover on the driving end.

The seal between rotating and stationary parts is effected by the sliding surface between a stationary ring fitted in the shaft seal housing and a rotating slip ring fitted on the crankshaft.
For this purpose the sliding surface of both slip rings is ground to extreme finish and lapped.

The slip ring is carried by the slip ring holder and forms an integral part of the rotary seal assembly. This assembly consists of the slip ring holder with insert, a metal bellows and a drive collar.

O-rings are provided to ensure the sealing between the rotary seal assembly and shaft seal housing and between the counter-slip ring and crankshaft.

To remove frictional heat developed by the slip rings, the shaft seal is incorporated in the relatively cool main stream of the lubricating oil circuit.

1.6.3.1 ROTARY SHAFT SEAL DIAGRAM

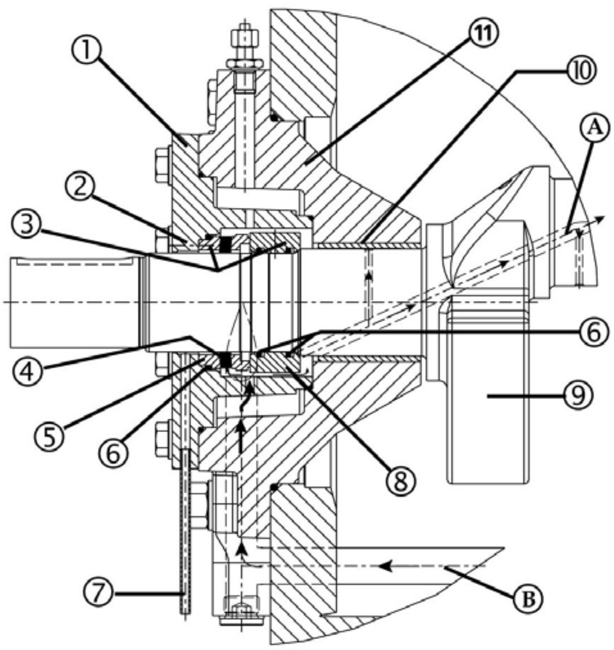


Fig. 1.6-3 Rotary shaft seal

Table 1.6-1

Legend	
1	Shaft seal housing
2	Screw
3	Rotary seal assembly
4	Metal bellows
5	Stationary counterslip ring
6	O-ring
7	Oil leakage drain of rotary shaft seal
8	Drive collar
9	Crankshaft
10	Bearing bush
11	Bearing cover
A	Internal lubricating system
B	Clean lubricating oil, direct from oil pump

1.6.4 SUCTION AND DISCHARGE VALVES

The suction and discharge valves of the compressor are of the ring type. They contain valve rings kept in closed position under spring tension. The lift of the valve rings is limited by the stroke limitor.

The suction valve consists of one synthetic valve ring with sinusoidal spring(s) mounted, between the collar of the cylinder liner and the stroke limitor.

The stroke limitor of the suction valve is centred by the collar of the cylinder liner.

The discharge valve consists of a valve seat and a stroke limitor fixed together by means of a central bolt and between which valve ring(s), with sinusoidal spring(s), are placed concentrically. The whole assembly is pressed onto the collar of the cylinder liner by a powerful buffer spring. This buffer spring prevents serious damage to the compressor due to any incidental slight liquid hammer.

1.6.4.1 SUCTION AND DISCHARGE VALVES DIAGRAM

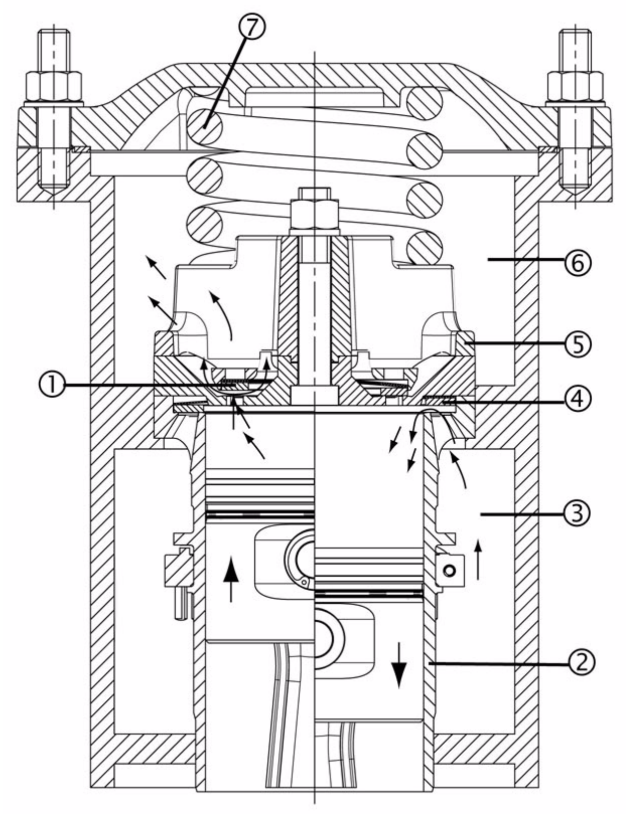


Fig. 1.6-4 Suction and discharge valve assembly

	Left side of picture = compression, Right side = suction
1	Discharge valve ring
2	Cylinder liner/suction valve seat
3	Suction chamber
4	Suction valve ring with sinusoidal spring
5	Discharge valve/stroke limitor/spring cup
6	Discharge chamber
7	Buffer spring

1.6.5 VALVE-LIFTING MECHANISM

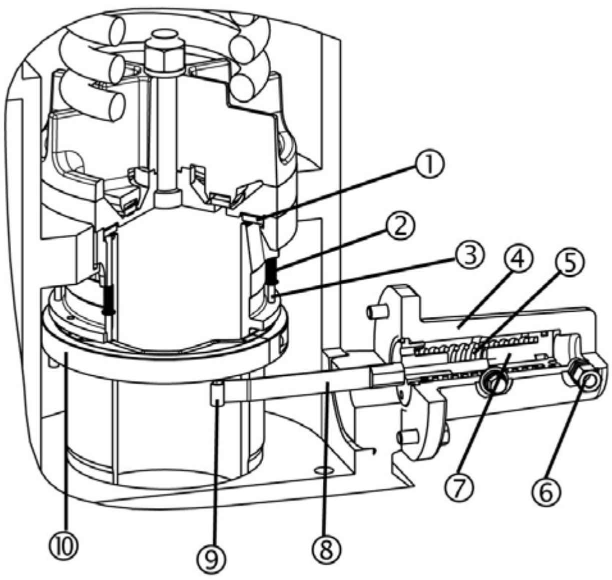


Fig. 1.6-5 Valve-lifting mechanism

Picture shows cylinder not in operation (suction valve ring lifted)

1	Suction valve ring
2	Spring
3	Push pin
4	Piston housing
5	Spring
6	Control oil pressure
7	Piston
8	Flexible shaft
9	Guide pin
10	Cam ring

In order to enable the compressor to start fully unloaded, all cylinders are put out of action mechanically by suction valve ring lifting. The cylinder liner is provided with push pins capable of lifting the suction valve ring from its seat via openings in the collar of the cylinder liner. A cam ring is provided in each cylinder, which can turn around the cylinder liner.

By turning the cam ring the push pins can move upwards (against spring tension) or downwards. The cam ring is is connected to a spring loaded control piston via a flexible shaft.
The cam ring can rotate by means of an axial guide pin which in turn is driven by the piston in a hydraulic cylinder on the outside of the cylinder jacket. The piston can be moved inwards against spring tension by the oil pressure from the oil pump.
At compressor standstill there is no oil pressure and the control piston is forced outwards by the spring tension and turns the cam ring in a position which causes the push pins to lift the suction valve ring.

After the compressor has been started, oil pressure energizes the control piston which moves the piston inward and rotates the cam ring via the flexible shaft so that the push pins move downwards by spring tension.
The suction valve ring then descends on to its seat and the cylinder is in operation.

The valve-lifting mechanism is also used for capacity control by succesively cutting in or out cylinders or cylinder groups, which is controlled either manually or electrically.

Because there is only oil pressure after the compressor has been started, fully unloaded starting of the compressor is ensured, i.e. ALL suction valves rings are lifted.

1.6.6 PRINCIPAL CONNECTIONS, GAS SUCTION FILTER AND PRESSURE EQUALIZING

The suction and discharge chambers of the cylinders are connected into a single suction and discharge connection with flange, with which the compressor is coupled to the refrigerating plant.
The (LP) suction connection is located on the suction filter housing on the oil pump side of the compressor, in which one removable suction filter is provided for filtering the intake refrigerant gas. In the case of two-stage compressors, an extra LP discharge and HP suction connection is provided, which can be interconnected via an interstage cooler.
The HP suction connection requires an externally mounted suction gas filter (available as an accessory from Grasso).

Between suction filter housing and crankcase an equalizing line is provided in order to prevent the crankcase pressure from rising due to piston leakage. Consequently, the crankcase pressure is equal to suction pressure for single-stage as well as for two-stage compressors. All principal connections have nipples for connecting the lines of pressure gauges and pressure safety switches or in case of an electronic control device (Monitron CR) for connecting the lines of pressure and temperature sensor elements.

1.6.7 RELIEF VALVES

In order to prevent excessive pressure difference in the compressor, one or more relief valves (dependent on compressor type) are provided.

In case of single-stage compressors these counter pressure dependent type of relief valves act on the difference between discharge and suction pressure.

In case of two-stage compressors counter pressure dependent type of relief valves act on the difference between intermediate and suction pressure (LP-stage). For the HP-stage always a counter pressure independent type of relief valve will be applied

To comply with certain regulations a counter pressure independent type of relief valve is available (optional).

The valves are fitted externally against the crankcase housing. The relief valves are spring-loaded valves adjusted at the works.

1.6.8 OIL PUMP AND FILTERS

The direct-driven oil pump is fitted on the bearing cover opposite the compressor driving end. The oil pump housing accommodates the pump element and two adjustable oil pressure regulators.
The oil pump supplies, besides the lubricating oil pressure, a separate control oil pressure for actuating the valve-lifting mechanisms, mounted on each cylinder to obtain unloaded starting and for capacity control.

The oil suction and discharge filters are fitted externally to the oil pump housing. The oil suction and oil discharge filter elements are spring-mounted inside their housings. In case the pressure difference over the filter element exceeds the maximum value, the filter element will be lifted from its seat against spring pressure and the oil by-passes the filter element.

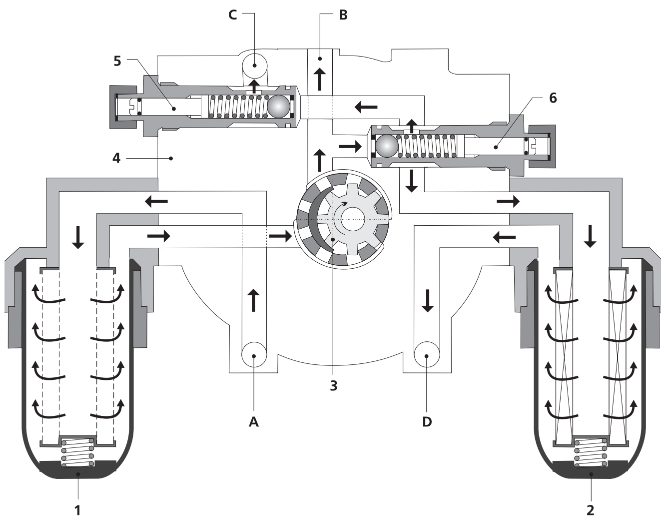
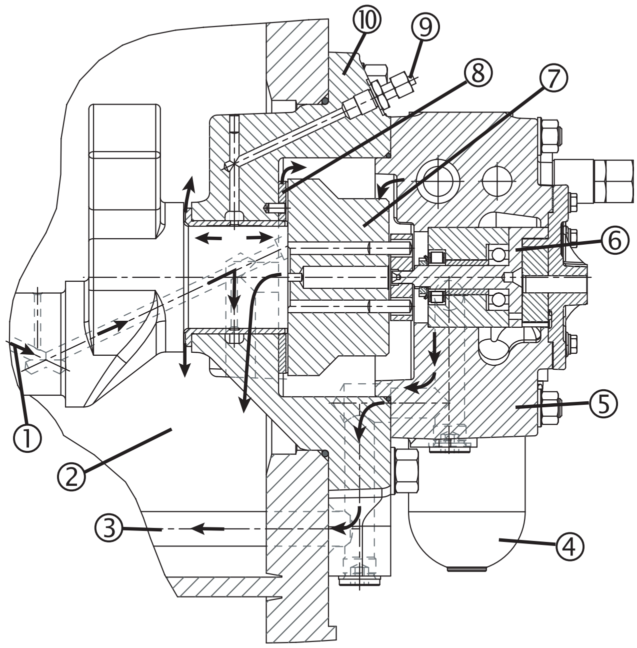


Fig. 1.6-6 Oil pump, oil filters and oil pressure regulators

Legend	
1	Oil suction filter
2	Oil discharge filter
3	Pump element
4	Oil pump housing and bearing cover
5	Lubricating oil pressure regulator
6	Control oil pressure regulator
A	Oil suction from crankcase
B	Control oil pressure to valve lifting mechanisms for unloaded starting and capacity control
C	Return of excess oil to crankcase
D	Oil discharge to shaft seal and lubrication system via internal line

1.6.8.1 OIL PUMP AND FILTERS DIAGRAM



Legend	
1	From lubricating system
2	Return of excess oil to crankcase via internal bore
3	Internal line for oil supply to shaft seal and lubrication system
4	Oil discharge filter housing
5	Oil pump housing
6	Oil pump element
7	Steel disk
8	Stationary trust bearing ring
9	Measure point of oil pressure
10	Bearing cover

1.6.9 CONTROL AND LUBRICATION OIL SYSTEM (Fig. 1.6-6 and Fig. 1.6-7)

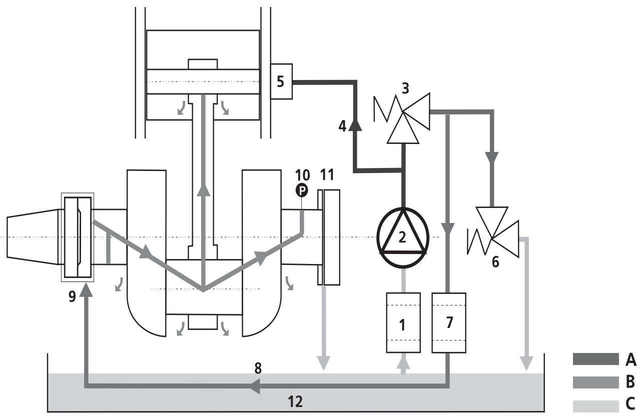


Fig. 1.6-7 Control and lubricating oil system

1	Oil suction filter
2	Oil pump
3	Control oil pressure regulator
4	External oil pressure line(s) to valve lifting mechanism(s)
5	Piston housing of valve lifting mechanism
6	Lubricating oil pressure regulator
7	Oil discharge filter
8	Internal oil pressure line for oil supply to shaft seal and lubrication system
9	Shaft seal housing
10	Measure point of oil pressure at the end of lubrication system
11	Thrust bearing
12	Oil sump
A	Control oil pressure
B	Oil lubricating pressure
C	Crankase pressure

The oil is drawn from the crankcase via the oil suction filter. The pressures delivered by the pump are controlled by a control oil pressure regulator together with a lubricating oil pressure regulator at the beginning of the lubrication system just before the oil discharge filter.
The pump discharge pressure, which is the control pressure is determined by the built-in control oil pressure regulator; excess oil flows to the lubricating oil pressure regulator. This regulator acts as relief valve from which excess oil is returned to the crankcase.

The oil available between the control oil pressure regulator and lubricating oil pressure regulator flows to the lubrication system via the oil discharge filter. The lubrication of the compressor is effected under pressure. The pump delivers the oil via a discharge filter and an internal oil supply line to the shaft seal housing.
From this housing the oil flows into the crankshaft, in which a continuous oil channel has been drilled, provided with radially drilled oilways in the bearings.

The connecting rods also have an internal oil channel through which the oil is supplied to the small end bearings. Sufficient lubrication of the cylinder walls is ensured by splash lubrication.

The thrust bearing at the oil pump end of the crankshaft is also lubricated.

As well as its lubricating function, the oil has a cooling function, especially for the rotary shaft seal, the amount of circulating oil is considerably more than that required for lubrication. This excess is fed back into the crankcase via four oil ways in the stationary thrust bearing ring and a separate bore inside the bearing cover.
A connection for measuring the lubricating oil pressure at the end of lubrication oil system is located at the outside of the bearing cover just above the oil pump housing.

2. DESCRIPTION AND SELECTION OF ACCESSORIES

2.1 CAPACITY CONTROL SYSTEMS

2.1.1 SURVEY CAPACITY CONTROL SYSTEMS AND UNLOADED START

General

Capacity control of the compressor will be enabled by lifting the suction valves, by means of the control oil pressure from the oil pump. One of the options mentioned below is compulsory.

One of the options must be applied;

- Electric (compulsory for two-stage compressors);
  - Standard (recommended for single-stage and booster compressors)
  - 'Fast pull down' (FPD); obligatory for R404A and R507 applications; recommended for all two-stage compressors
- Manual (Not allowed for two-stage compressors)

In case manual or electric capacity control is applied, fully unloaded starting of the compressor is ensured.

Unloaded start

Fully unloaded compressor starting is enabled by energizing the solenoid valve for unloaded starting, which is an Normally Open valve in contrast with the solenoid valves for capacity control which are Normally Closed.
This NO-solenoid valve has to be energized when starting the electric motor and has to be De-energized when the compressor is running and the specified lubricating oil pressure is reached, by means of the star delta switch of electric motor when electric motor switches from star to delta or by means of an auxiliary time relay.

Time relay and/or star-delta switch are not included (time relay is built-in in Monitron CR).

After fully unloaded compressor starting, this solenoid valve must be DE-engergized allowing control oil pressure to the control pistons of these cylinders and causing these cylinders to become operative automatically.
In the case of single-stage compressors, they are at the same time the minimum number of cylinders that must always remain energized during continuous operation.
For two-stage compressors only HP cylinders are involved, which, however, do not at the same time represent the minimum capacity.
The other cylinders can be energized or de-energized in one or more steps in a standard sequence for each type of compressor.

Summary wiring logic NO-unloaded start solenoid:

- If compressor is NOT running then NO-solenoid is not energized.
- If compressor starts then NO-solenoid is energized until star-delta switch switches from star to delta or by means of an auxiliary time relay.

De-energize NO-solenoid after the specified lubricating pressure is reached, OR a maximum of 30 seconds after starting the compressor.

- If compressor is running then NO-solenoid is NOT energized.

2.1.2 ELECTRIC CAPACITY CONTROL AND FAST PULL DOWN (FPD)

General

Electric capacity control is compulsory if Monitron CR is applied and is included in the standard scope of supply for two stage compressors.

Procedure and data

- Refer to diagrams and figures below.
- The possible control steps and the number of solenoid valves depends on type of compressor

Standard scope of supply

- One NO-solenoid valve (with LED indicator) for unloaded starting (mounted).
- A number of NC- solenoid valves (each with LED indicator; mounted).
- Oil pressure lines (mounted).

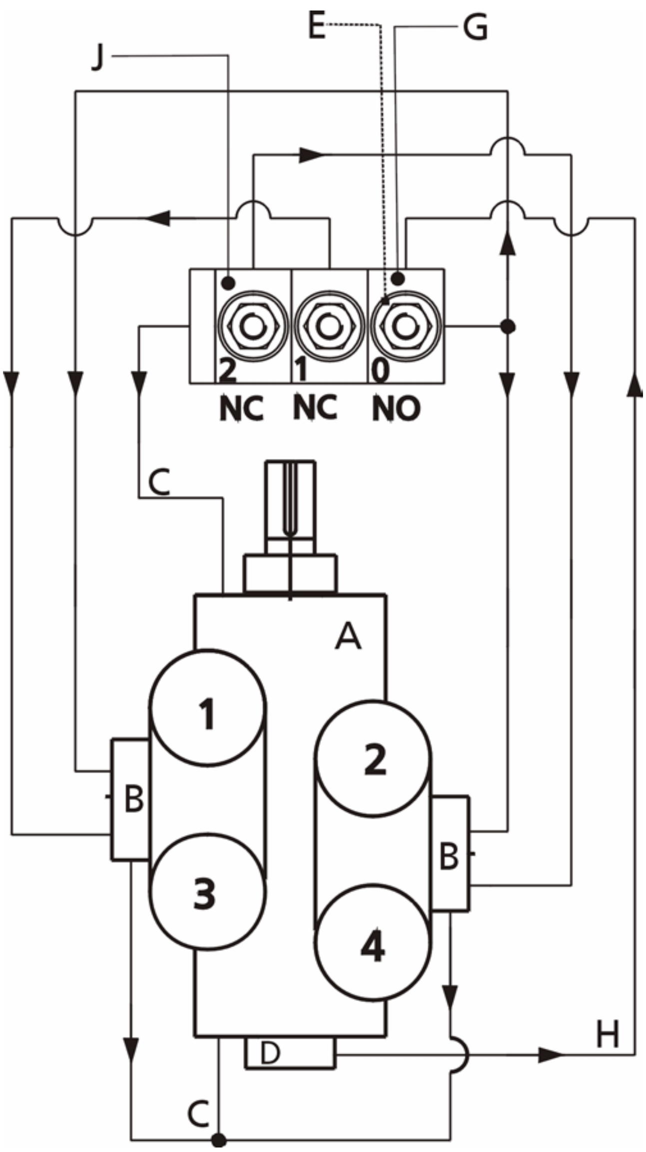
Options (for two-stage compressors only)

- Fast Pull Down control system

FPD is compulsory for R404A and R507.

The standard starting procedure which is contained in the standard electrical capacity control, is only suitable if the compressor is being started at design evaporating temperature.
In case the compressor has to start frequently with high evaporating temperatures (batch freezing, etc), fast pull down capacity control is necessary to avoid that the compressor runs continuously in part-load.

2.1.2.1 General diagram of electrically operated capacity control



Legend	
A	Top view of compressor
B	Valve lifting mechanism
C	oil return to crankcase
D	oil pump
E	electrical wiring to start/delta switch of the motor
G	solenoid valve for unloaded starting (NO)
H	supply of oil pressure
J	solenoid valve(s) for capacity control (NC)
NO	Normally Open
NC	Normally Closed

2.1.2.2 DIAGRAMS Grasso 10

Table 2.1-1 Solenoid valve/cylinder numbering for capacity control

Compr. type Grasso	HP cilinders No.	Cylinder number/ solenoid valves				
		NC[a]	NO[b]	NC[a]		
		FPD[c]	UNL[d]	No. 1	No. 2	No. 3
210	-	-	1	2	-	-
310	-	-	1	3	2	-
410	-	-	1 + 2	3	4	-
610	-	-	1 + 2	5	3 + 4	6
810	-	-	1 + 2	6	3 + 4	5 + 7 +8
2110	1	-	1	2 + 3	-	-
2110FPD	1	3	1	2	-	-
3110	2	-	2	1 + 3	4	-
3110FPD	2	1	2	3	4	-
4210	2-4	-	2	1 + 3	4 + 5	6
4210FPD	2-4	4	2	1 + 3	5	6
6210	2-4	-	2	1 + 6	4 + 5 + 7 + 8	3
6210FPD	2-4	4	2	1 + 6	5 + 7 + 8	3

a. NC= Normally closed
b. NO= Normally open
c. FPD= Fast Pull Down
d. UNL= Unloaded starting

Table 2.1-2 Capacity control steps

Compr. type Grasso	Capacity %[a]	Remarks	Cylinders	Solenoids	φ[b]
210	50	-	1	-	-
	100	-	1+2	1	-
310	33	-	1	-	-
	67	-	1+3	1	-
	100	-	1+2+3	1+2	-
410	50	-	1+2	-	-
	75	-	1+2+3	1	-
	100	-	1+2+3+4	1+2	-
610	33	-	1+2	-	-
	50	-	1+2+5	1	-
	67	-	1+2+3+4	2	-
	83	-	1+2+3+4+5	1+2	-
	100	-	1+2+3+4+5+6	1+2+3	-
810	25	-	1+2	-	-
	37	-	1+2+6	1	-
	50	-	1+2+3+4	2	-
	62	-	1+2+3+4+6	1+2	-
	75	-	1+2+5+6+7+8	1+3	-
	87	-	1+2+3+4+5+7+8	2+3	-
	100	-	1+2+3+4+5+6+7+8	1+2+3	-
2110	0	starting only	1	-	0.0
	100	-	1+2+3	1	2.0
2110 + FPD[c]	0	starting only	1	-	0.0
	50	starting only	1+3	FPD	1.0
	100	-	1+2+3	1+FPD	2.0
3110	0	starting only	2	-	0.0
	67	-	1+2+3	1	2.0
	100	-	1+2+3+4	1+2	3.0
3110 + FPD	0	starting only	2	-	0.0
	33	starting only	1+2	FPD	1.0
	67	-	1+2+3	1+FPD	2.0
	100	-	1+2+3+4	1+2+FPD	3.0
4210	0	starting only	2	-	0.0
	50	-	1+2+3	1	2.0
	75	-	1+2+3+6	1+3	3.0
	100	-	1+2+3+4	1+2+3	2.0
4210 + FPD	0	starting only	2	-	0.0
	25	starting only[d]	2+4	FPD	0.0
	50	starting only	1+2+3+4	1+FPD	1.0
	50	-	1+2+3	1	2.0
	75	-	1+2+3+4+6	1+3+FPD	1.5
	75	-	1+2+3+6	1+3	3.0
	100	-	1+2+3+4+5+6	1+2+3+FPD	2.0

Compr. type Grasso	Capacity %[a]	Remarks	Cylinders	Solenoids	φ[b]
6210	0	starting only	2	-	0.0
	33	-	1+2+6	1	2.0
	50	-	1+2+3+6	1+3	3.0
	67	-	2+3+4+5+7+8	2+3	2.0
	83	-	1+2+4+5+6+7+8	1+2	2.5
	100	-	1+2+3+4+5+6+7+8	1+2+3	3.0
6210 + FPD	0	starting only	2	-	0.0
	0	starting only	2+4	FPD	0.0
	33	starting only	1+2+4+6	1+FPD	1.0
	33	-	1+2+6	1	2.0
	50	-	1+2+3+4+6	1+3+FPD	1.5
	50	-	1+2+3+6	1+3	3.0
	67	-	2+3+4+5+7+8	2+3+FPD	2.0
	83	-	1+2+4+5+6+7+8	1+2+FPD	2.5
	100	-	1+2+3+4+5+6+7+8	1+2+3+FPD	3.0

a. Refers to the swept volume expressed as a percentage of the full-load swept volume for single stage compressors, resp. LP full-load swept volume for two-stage compressors.
b. Number of LP/ Number of HP cylinders
c. FPD compressor; incl. Fast Pull Down (optional)
d. FPD=Fast Pull Down step only;

2.1.3 MANUAL CAPACITY CONTROL

General

Instead of the recommended electric capacity control in combination with the Monitron CR, a manual operated capacity control system can be delivered for single stage and booster compressors.

Electrical supply still required for solenoid valve(s).

Manual capacity control system is equal to standard electric control system with as extra an electric capacity control switch.

Capacity control steps are equal to electric capacity control.

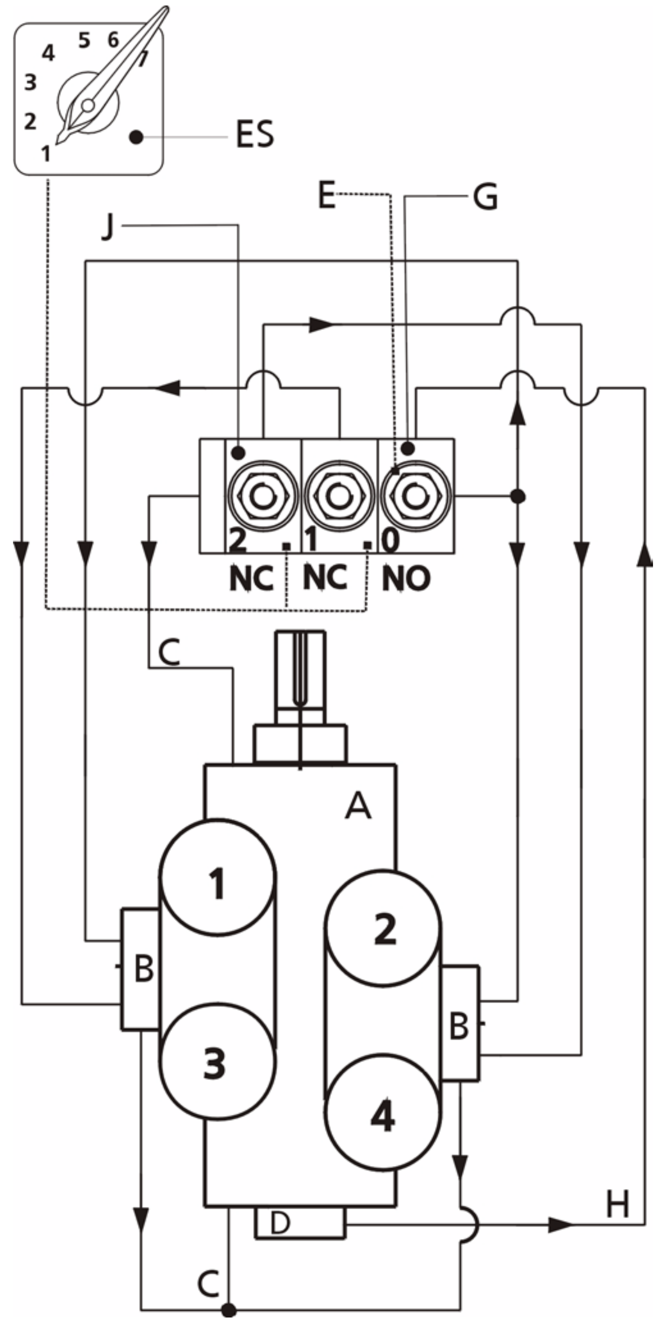


Fig. 2.1-1 Diagram of manually operated capacity control system

Legend	
A	Top view of compressor
B	Valve lifting mechanism
C	oil return to crankcase
D	oil pump
E	electrical wiring to start/delta switch of the motor

Procedure and data

- Monitron CR is not applied.

Standard scope of supply

- Standard electric capacity control.
- Electric capacity control switch.

Legend	
G	solenoid valve for unloaded starting (NO)
H	supply of oil pressure
J	solenoid valve(s) for capacity control (NC)
NO	Normally Open
NC	Normally Closed
ES	Electric capacity control switch

2.2 CONTROLS, SAFETIES, GAUGES AND SWITCHES

2.2.1 MONITRON CR CONTROL DEVICE

General

Grasso can supply a solid state microprocessor-based control device for monitoring, protecting and controlling compressors.
See Fig. 2.2-1 below and Fig. 2.2-2 overleaf.

Data

- Limitations:
  - ➩ Protection Class IP55.
  - ➩ Ambient temperature between +0 and +55 °C.
  - ➩ Relative humidity between 0 and 95%.
- Features:
  - ➩ Display of all relevant operating parameters.
  - ➩ Automatic start/stop.
  - ➩ Sequence control.
  - ➩ Capacity control, based on a pressure or temperature signal. The accessory "Electric capacity control" is necessary.
  - ➩ Controlling all individual limits of operation of the compressor.
  - ➩ Real time clock with battery back-up.
  - ➩ Data storage in EEPROM.
  - ➩ Alarm history file for the last 20 alarms.
  - ➩ Computer communication via MPC (option).
  - ➩ Sensor failure detection.
  - ➩ Emergency stop button (3).
  - ➩ Built-in time relay for unloaded starting.
  - ➩ Password protection.

Main input signals

1 Imot; motor current (optional)
2 Olev; oil level (optional)
3 Pcrk; crankcase pressure
4 Pdis; discharge pressure
5 Pext; external pressure (optional)
6 Pint; LP discharge intermediate pressure
7 Poil; oil pressure
8 Psuc; suction pressure
9 Tcil; cylinder head temperature protection (optional)
10 Text; external temperature (optional)
11 Tdis; discharge temperature
12 Tinh; HP suction intermeditate temperature
13 Tint; LP discharge intermediate temperature
14 Toil; oil temperature in crankcase
15 Tsep; oil temperature in oil separator (optional)
16 Tsuc; suction temperature

Additional input signals (optional)

External safety, External start, motor temperature protection, start/delta switch.

Main output signals

1 Cap; capacity control
2 FPD; fast pull down
3 Inj; injection solenoid valve (interstage cooling system (Ecotron) A/B
4 Oret; oil return protection (optional)
5 Unl; unloaded starting

Additional output signals

Alarm, Start, Running, Start request.

Standard scope of supply (Fig. 2.2-2)

- Steel cabinet (2) including the electronic control unit.
- Terminal unit (keyboard/display; 1), connected to the cabinet.
- Console (4).
- Pressure transducers and temperature sensors (mounted and wired).[1]
- Wiring of three-way solenoid valves of electrical capacity control and unloaded start.
- Discharge pressure safety switch(es) (Refer to table below)
- All cabling and wiring of components and accessories which are built together with the compressor or package.

1. Grasso can supply compressors with sensors only, without control unit and display.

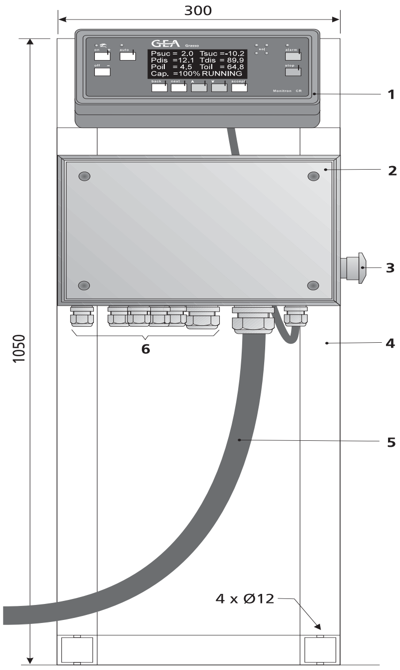


Fig. 2.2-1 Monitron CR control device

1	Terminal unit with keyboard and display
2	Steel cabinet containing the control unit
3	Emergency stop button
4	Console for terminal unit
5	Communication cable
6	Cable entries of e.g. power supply, temperature and pressure signals, etc.

Options

- Motor current transducer (supplied loose).
- External pressure sensor (supplied loose).
- External temperatur sensor incl. signal transducer PT1000/4-20mA) (supplied loose).
- Pressure safety switch system according to UVV-VBG20 (mounted on suction filter housing).
- Monitron Protocol Converter (MPC; supplied loose).

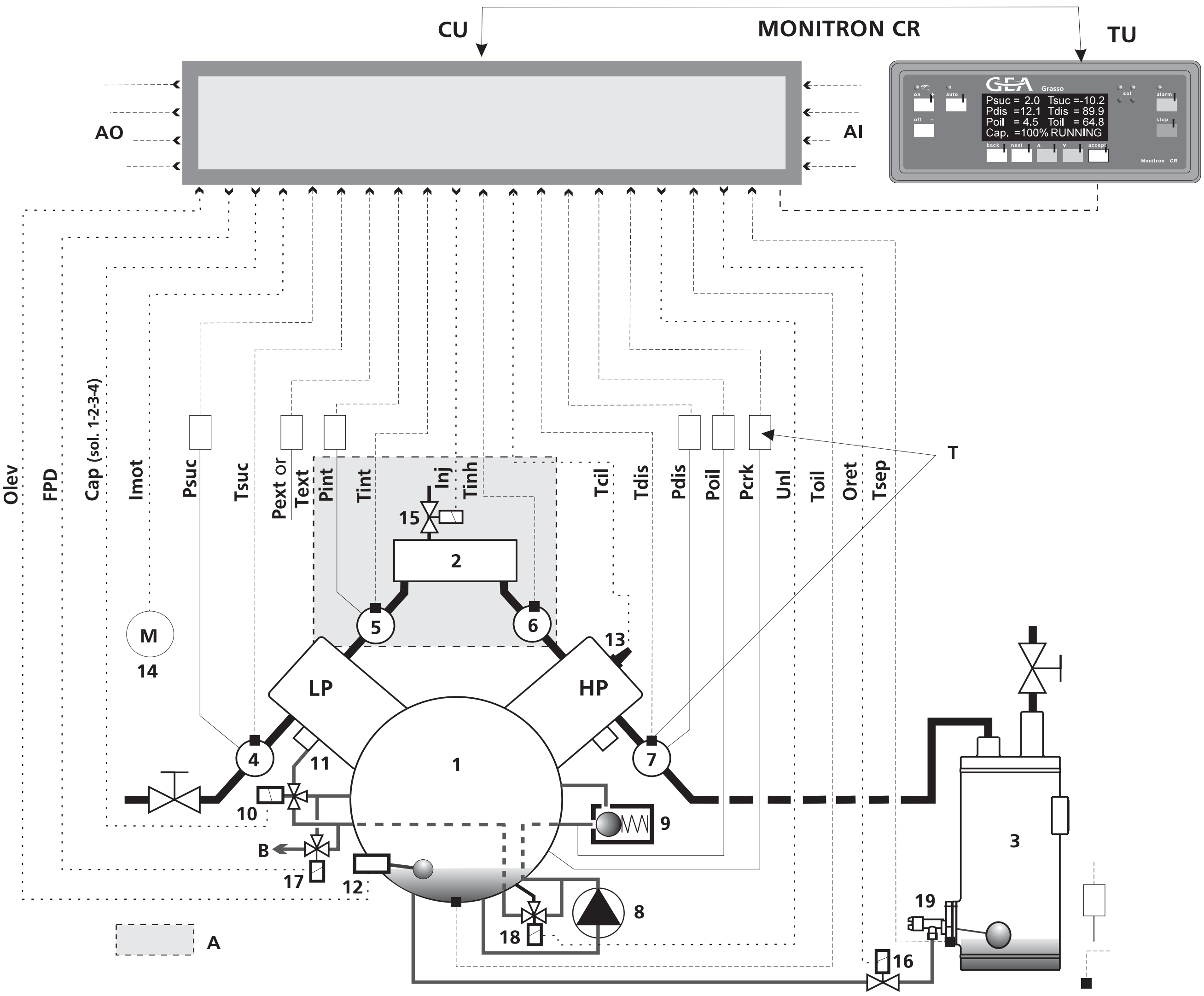


Fig. 2.2-2 Schematic flow diagram

1	two-stage compressor
2	interstage cooling system A, B, C or D
3	oil separator
4	LP suction header
5	LP discharge header
6	HP suction header
7	HP discharge header
8	oil pump
9	oil pressure regulator
10	three-way solenoid valve
11	hydraulic cylinder of valve lifting mechanism (capacity control)
12	oil level float switch
13	sensor plug of discharge temperature protection

14	compressor drive motor
15	solenoid valve of interstage cooling system A or B
16	solenoid valve of oil return protection
17	three-way solenoid valve for fast pull-down feature for two-stage compressors
18	three-way solenoid valve for unloaded starting
19	mechanical float valve
TU	Terminal unit
TC	Control unit
AI	Additional input signals
AO	Additional output signals
T	Transducer (temperature or pressure)
A	For two-stage compressors only
B	To valve lifting mechanism(s)

Table 2.2-1 Safety switches used with Monitron CR

<table>
<tr><th rowspan="3">Description of pressure safety switches</th><th colspan="8">Application[a]</th><th rowspan="3">Type</th><th rowspan="3">Range of pressure setting (bar (e))[b]</th><th rowspan="3">Range of contact differential pressure (bar)[b]</th><th rowspan="3">Remarks[c]</th></tr>
<tr><th colspan="4">Standard</th><th colspan="4">TÜV</th></tr>
<tr><th>S</th><th>B</th><th>TAB</th><th>TCD</th><th>S</th><th>B</th><th>TAB</th><th>TCD</th></tr>
<tr><td rowspan="8">Discharge pressure switch</td><td>NH_3</td><td rowspan="2">-</td><td>NH_3</td><td>NH_3</td><td>-</td><td rowspan="2">-</td><td>NH_3</td><td>NH_3</td><td>RT 6AB</td><td rowspan="2">10 to 28</td><td rowspan="2">3 fixed</td><td rowspan="4">pressure limitor switch, locking device, external reset, protection class IP54</td></tr>
<tr><td>R</td><td>R</td><td>R</td><td>R</td><td>R</td><td>R</td><td>RT 6B</td></tr>
<tr><td rowspan="2">-</td><td>NH_3</td><td colspan="2" rowspan="2">-</td><td rowspan="2">-</td><td>NH_3</td><td colspan="2" rowspan="2">-</td><td rowspan="2">RT 30AB</td><td rowspan="2">1 to 10</td><td rowspan="2">0.3 fixed</td></tr>
<tr><td>R</td><td>R</td></tr>
<tr><td colspan="4" rowspan="4">-</td><td>NH_3</td><td rowspan="2">-</td><td>NH_3</td><td>NH_3</td><td>RT 6AS</td><td rowspan="2">10 to 28</td><td rowspan="2">3 fixed</td><td rowspan="4">pressure safety switch, locking device, external reset, protection class IP54</td></tr>
<tr><td>R</td><td>R</td><td>R</td><td>RT 6S</td></tr>
<tr><td rowspan="2">-</td><td>NH_3</td><td colspan="2" rowspan="2">-</td><td rowspan="2">RT 30AS</td><td rowspan="2">1 to 10</td><td rowspan="2">0.3 fixed</td></tr>
<tr><td>R</td></tr>
<tr><td rowspan="4">Intermediate pressure switch</td><td colspan="3" rowspan="4">-</td><td>NH_3</td><td colspan="3" rowspan="4">-</td><td>NH_3</td><td rowspan="2">RT 30AB</td><td rowspan="4">1 to 10</td><td rowspan="4">0.3 fixed</td><td rowspan="2">pressure limitor switch, locking device, external reset, protection class IP54</td></tr>
<tr><td>R</td><td>R</td></tr>
<tr><td rowspan="2">-</td><td>NH_3</td><td rowspan="2">RT 30AS</td><td rowspan="2">pressure safety switch, locking device, external reset, protection class IP54</td></tr>
<tr><td>R</td></tr>
</table>

a. **S** = single-stage; **B** = booster; **T** = two-stage; **T**AB = two-stage system A or B; **T**CD = two-stage system C or D;
b. 1 bar = 10^5 N/m^2 = 100 kPa = 1.02 kgf/cm^2 = 14.5 psi.
c. Protection class of enclosure according to IEC 144 and DIN 40050.

Example: TÜV, two-stage, NH_3 System C: Pressure safety switches applied are; RT6AB, RT6AS, RT30AB and RT30AS.

2.2.2 PRESSURE GAUGE AND SAFETY SWITCH CABINET

General

Grasso can deliver a pressure gauge and safety switch cabinet.
This cabinet included stainless steel industrial gauges are glycerine filled to reduce the vibration of pointer and protected against overloading and/or pressure safety switsches.

Selection and Data

- Pressure range suction and intermediate gauge (=also discharge booster): -1 to 12 bar(e).
- Pressure range discharge gauge: -1 to 31bar(e).
- Pressure range lubricating oil pressure gauge: -1 to 12 bar(e).
- Types of gauges and switches dependant on refrigerant.
- Number (3, 4, 5 or 7) of switches dependant on type of compressor, interstage cooling system and TÜV approval
- Type of switches acc. to table below.
- Number of gauges dependant on single-stage (3) or two-stage (4)

Standard scope of supply single-stage and booster

- 3 gauges (suction, discharge, lubricating oil)
- 3 switches (suction, discharge, lubricating oil)

Standard scope of supply two-stage interstage cooling system A, B, C and D

- 4 gauges (suction, discharge, lubricating oil, intermediate)
- 4 switches (suction, discharge, lubricating oil, intermediate)

Scope of supply single-stage and booster with TÜV approval

- 3 gauges (suction, discharge, lubricating oil)
- 4 switches (suction, discharge safety, discharge limitor, lubricating oil)

Scope of supply two-stage interstage cooling system A and B with TÜV approval

- 4 gauges (suction, discharge, lubricating oil, intermediate)
- 5 switches (suction, HP-discharge limitor, HP-discharge safety, lubricating oil, intermediate)

Standard scope of supply two-stage interstage cooling system C and D with TÜV approval

- 4 gauges (suction, HP-discharge safety, HP-discharge limitor, lubricating oil, LP-discharge)
- 7 switches (suction, discharge limitor, discharge safety, lubricating oil, LP-discharge safety, LP-discharge limitor)

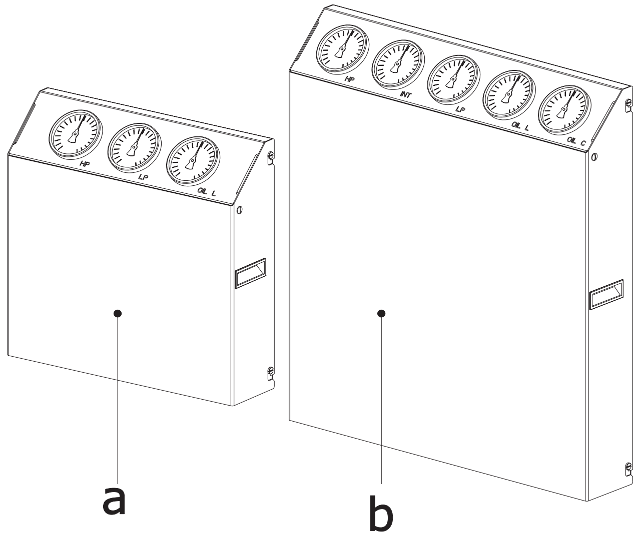


Fig. 2.2-3 Pressure gauge and safety switch cabinet

Legend	**REMARK:** Diameter gauges 100 mm.
a	small cabinet
b	large cabinet

Table 2.2-2 Pressure safety switches

Pressure safety switches[a]	Application[b] Standard S	Standard B	Standard Tab	Standard Tcd	Alternatives S	Alternatives B	Alternatives Tab	Alternatives TCD	TÜV S	TÜV B	TÜV TAB	TÜV TCD	Type	Range of pressure setting (bar (e))[c]	Range of contact differential pressure (bar)[c]	Remarks[d]
Discharge pressure switch	NH_3	-	NH_3	NH_3	-				-				RT 5A	4 to 17	1 to 4	locking device, external reset, protection class IP66
	R		R	R									RT 5			
	-	NH_3	-										RT 1A[e]	-0.8 to 5	0.4 to 1.6	
		R											RT 1[e]			
	-				NH_3	-	NH_3	NH_3	NH_3	-	NH_3	NH_3	RT 6AB[f]	10 to 28	3 fixed	pressure limitor switch, locking device, external reset, protection class IP54
					R		R	R	R		R	R	RT 6B[f]			
					-	NH_3 / R	-		-	NH_3 / R	-		RT 30B[f]	1 to 10	0.3 fixed	
	-				-				NH_3	-	NH_3	NH_3	RT 6AS[f]	10 to 28	3 fixed	pressure safety switch, locking device, internal reset, protection class IP66 (RT 6AS and RT 65) or IP54 (RT 30AS)
									R		R	R	RT 65[f]			
									-	NH_3 / R	-		RT 30AS[f]	1 to 10	0.3 fixed	
Suction pressure switch	NH_3	NH_3	NH_3	NH_3	-				NH_3	NH_3	NH_3	NH_3	RT 1A	-0.8 to 5	0.5 to 2	locking device, external reset, protection class IP66
	R	R	R	R					R	R	R	R	RT 1		0.3 to 2	
Intermediate pressure switch	-		NH_3	NH_3	-				-		NH_3	NH_3	RT 1A	-0.8 to 5	0.3 to 1.3	without locking device, protection class IP66
			R	R							R	R	RT 1		0.5 to 1.6	
			-								-	NH_3 / R	RT 30B[f]	1 to 10	0.3 fixed	pressure limitor switch, locking device, external reset, protection class IP54
												NH_3 / R	RT 30AS[f]	1 to 10	0.3 fixed	pressure safety switch, locking defice, external reset, protection class IP54
Oil differential pressure switch	NH_3	NH_3	NH_3	NH_3	-				-				MP 55A	0.3 to 4.5	0.2 fixed	locking device, external reset, internal time relay, protection class IP54
	R	R	R	R									MP 55			
	-				NH_3 / R	NH_3 / R	NH_3 / R	NH_3 / R	NH_3 / R	NH_3 / R	NH_3 / R	NH_3 / R	RT 260A	0.5 to 4	0.3 fixed	without locking device, without time relay, protection class IP66

a. When mounted on a panel all pressure connections of the safety switches are provided with a clamp coupling for ø6 x 1 mm steel precision tube.
b. **S** = single-stage; **B** = booster; **T** = two-stage; **T**AB = two-stage system A or B; **T**CD = two-stage system C or D;
c. 1 bar = 10^5 N/m^2 = 100 kPa = 1.02 kgf/cm^2 = 14.5 psi.
d. Protection class of enclosure according to IEC 144 and DIN 40050. Some of the safety switches are provided with a locking device so that, when cut out, the compressor does not become operative automatically on return of the original pressure. To unlock, an external or internal reset button is used but only after the reason for cut-out has been investigated.
e. These switches, which break contact at rising pressure, are provided with a sticker "discharge pressure" to distinguish them from the similar suction pressure switches.
f. Obligatory pressure safety switches in case a Monitron CR is applied. Refer also to Table 2.2-1.

2.2.2.1 Electrical wiring schematic oil differential pressostat (RT260A)

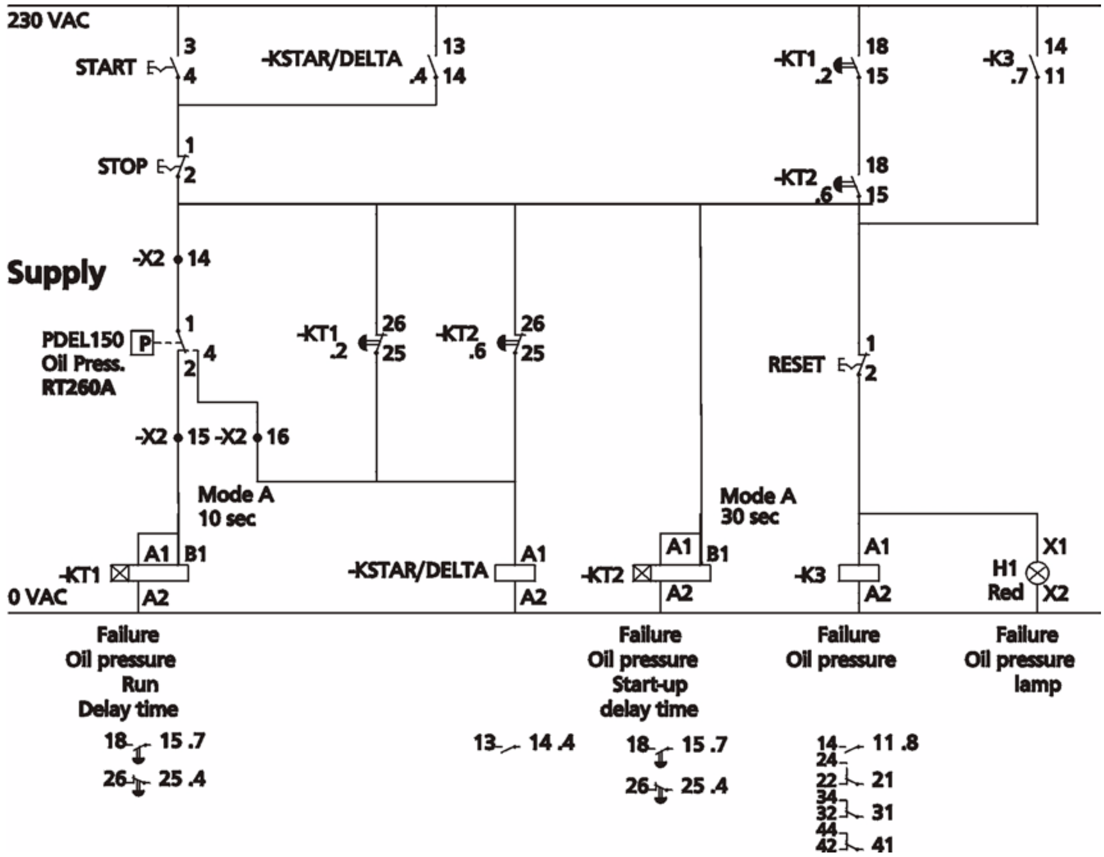


Fig. 2.2-4

2.2.3 CYLINDER HEAD DISCHARGE TEMPERATURE PROTECTION

Recommended for all applications with discharge temperatures > 120 °C.

General

Grasso can supply an electronic temperature safety device to protect each individual cylinder.
The discharge temperature may not exceed 170 °C. If the temperature in one or more cylinder heads rises beyond this value there is the risk of damage due to amongst others high pressure ratio, high suction superheat, broken valves, faulty interstage cooling system, etc.

Selection and Data

- Recommended for automatically operated plants.
- Max. 6 sensors (PTC thermistors) wired in series.
- Preset value of sensors 170 °C (R = 4500 Ω, can not be adjusted).
- Wiring: If one or more sensors > 170 °C then interrupt of the control current circuit of electric motor.
- Reset-Differential 5K.
- Sensor cicuit 2.5 V/DC.
- Ambient temperature between -20 and +50 °C.

Standard scope of supply

- Number of temperature sensors.
- If Monitron is not applied: Number of TSU units.
- If monitron is applied: mounting and wiring.
- Not included: Refer to Fig. 2.2-5

Options

- Two stage:
  All cylinders OR HP cylinders only.

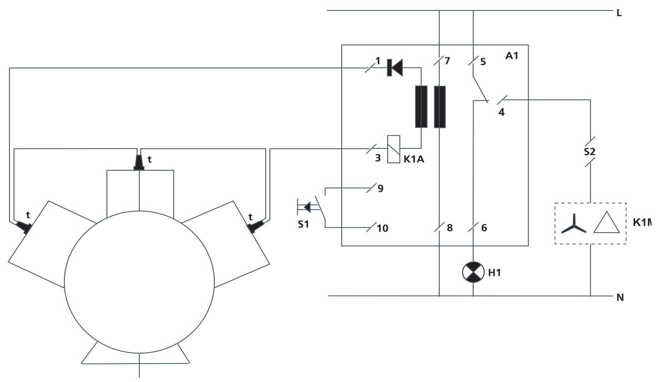


Fig. 2.2-5 *Wiring diagram of temperature safety device*

Number of compressor cylinders	Temperature sensor plug		Relay unit (if monitron is not applied)	
	Number	**Type**	**Number**	**Type**
2	2	170G13	1	TSU685
3	3			
4	4			
6	6			
8	8		2	

Legend	
t	Temperature sensor
K1M	Start delta switch (not included)
S1	Remote reset button (not included)
H1	Signal lamp (not included)
A1	TSU685 unit

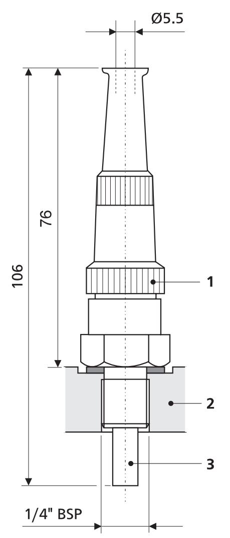


Fig. 2.2-6 PTC thermistor (temperature sensor)

2.2.3.1 SCOPE OF SUPPLY GRASSO 10

2.3 DIRECT AND V-BELT DRIVE

2.3.1 SELECTION OF DIRECT DRIVE

General

Grasso can supply a complete standard direct drive, consisting of a torsional stiff coupling and accessories.

Procedure and data

- Selection: Consult COMSEL.

Standard scope of supply

- Torsional stiff coupling including all parts necessary for mounting and securing.

Options

- Drive guard acc. to CE.
- Tool for removing coupling from shaft.
- Tool for alignment

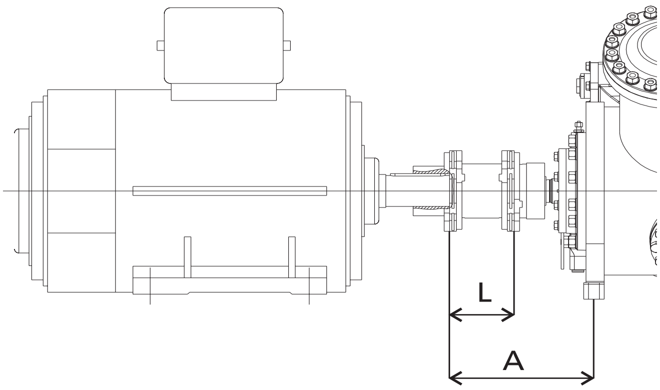


Fig. 2.3-1 Standard direct drive

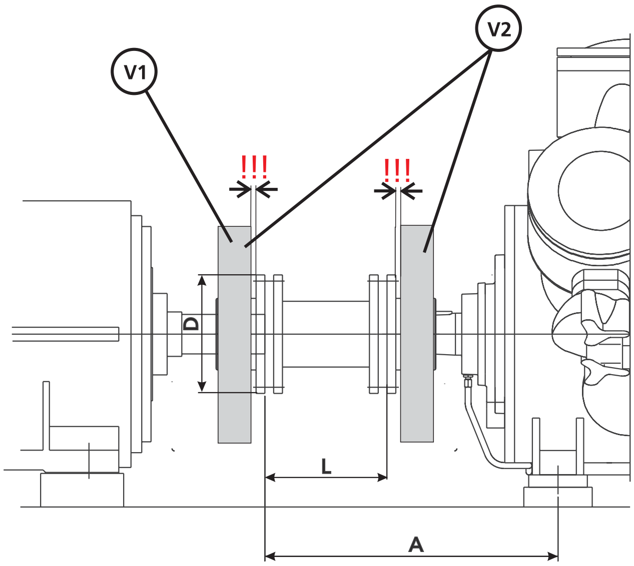


Fig. 2.3-2 Torsional stiff coupling

Type of coupling	Dimensions in mm		
	A (compressor foot-motor shaft end)	D	L
195	317	195	142
195V1			
195V2			

V1=Flywheel on motor side only, V2= fly wheel on motor side and compressor side.

2.3.2 SELECTION OF V-BELT DRIVE, applicable to 1475 min^{-1} (50 Hz) and 1775 min^{-1} (60 Hz) motors

General

Grasso can supply a complete V-belt drive system.

Procedure and data

- Selection: Consult COMSEL or graphs below.

Standard scope of supply

- Refer "Options" on Page 60

Options

- Flywheel (supplied loose).
- Motor pulley (mounted for packages, else supplied loose).
- Set of V-belts (supplied loose).
- Drive guard:
  - ⇨ one side protection
  - ⇨ two sides protection acc. to CE (mounted for packages, else supplied loose).

Table 2.3-1 Flywheel data

Number of grooves[a]		8
Type of Groove		SPB
Mass. approx.	kg	41
Mass moment of inertia	$kg.m^2$	2.224
Dimensions (mm)	D (nom.)	500
	a	158
	b (pitch)	19.0
	c	12.5
	d	76
	e	221.5

a. To determine the required number of V-belts, refer to the graphs.

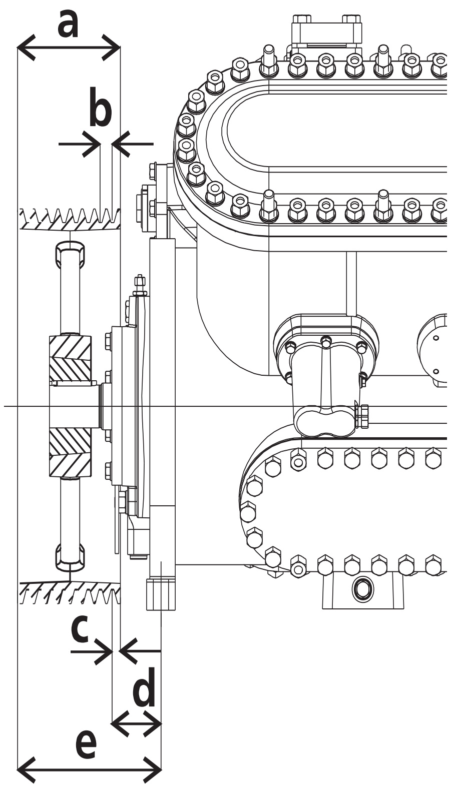


Fig. 2.3-3 Flywheel

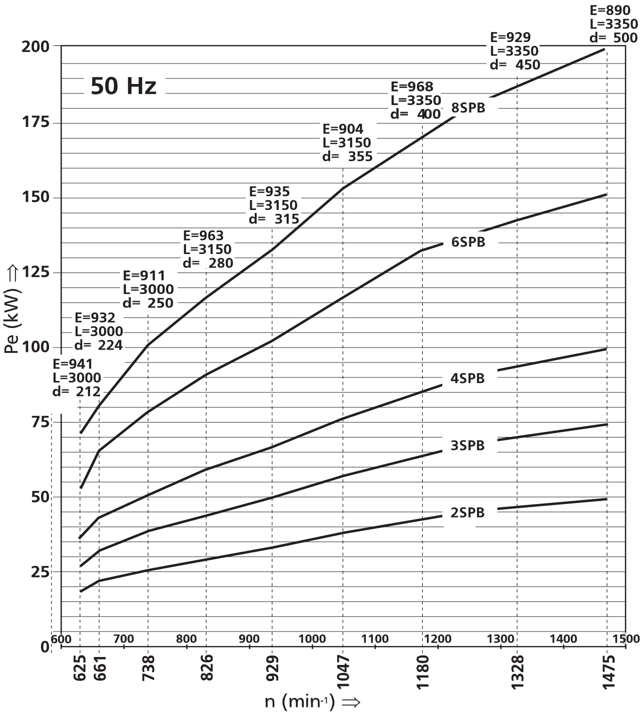


Fig. 2.3-4 Selection V-bellt 50 Hz

Legend	
N	Standard compressor speed (min^{-1})
Pe	Maximum installed motor power (kW) to transmit
#V	Number of V-belts
E	Centre distance flywheel - Motor pulley (mm)
L	Pitch length of V-belts (mm)

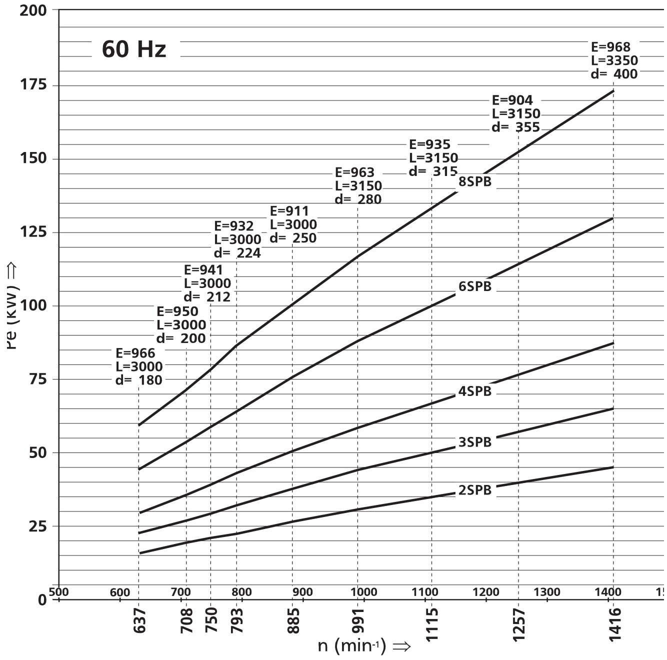


Fig. 2.3-5 Selection V-belts 60 Hz

Legend	
N	Standard compressor speed (min^{-1})
Pe	Maximum installed motor power (kW) to transmit
#V	Number of V-belts
E	Centre distance flywheel - Motor pulley (mm)
L	Pitch length of V-belts (mm)

2.4 PACKAGED BASE FRAME AND FOUNDATION BLOCK

2.4.1 PACKAGED BASE FRAME

General

For mounting on a concrete foundation block, Grasso can supply a standard welded steel base frame to support compressor, motor and accessoiries.
Especially for vibration free operation on floors and on roof tops, a base frame with vibration dampers can be delivered (concrete foundation block can be omitted).

A. Base frame for mounting on concrete block

Design Data

- Base frame to be placed on concrete foundation block. For foundation block dimensions consult Grasso.
- There should never be a direct rigid connection whatsoever between the foundation block and the floor or any other main part of the building.
- The concrete block should be extend down to any subsoil.

Scope of supply

- Steel base frame, incl mounting of compressor, electric motor and accessories.

B. Base frame for mounting on vibration dampers

Design Data

- Frame to be placed direct on floors and on roof tops (every structural floor should be designed to take the weight of the packaged unit).
- Concrete foundation block can be omitted.
- The first two pipe supports must be secured to a solid foundation.
- Horizontal piping must be arranged parallel to the crankshaft of the compressor.
- Consult always Grasso.

Scope of supply

- Steel closed box profile base frame, including mounting of compressor, electric motor and accessories.
- Set of vibration dampers.

2.4.1.1 PACKAGED BASE FRAME

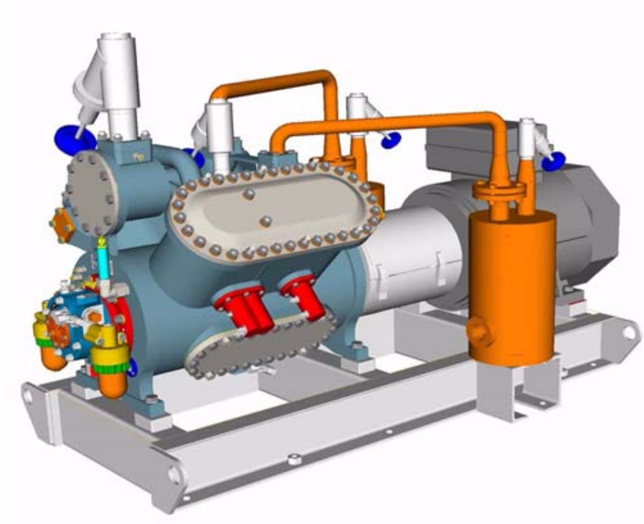


Fig. 2.4-1 Grasso 10 package, direct drive with oil separator

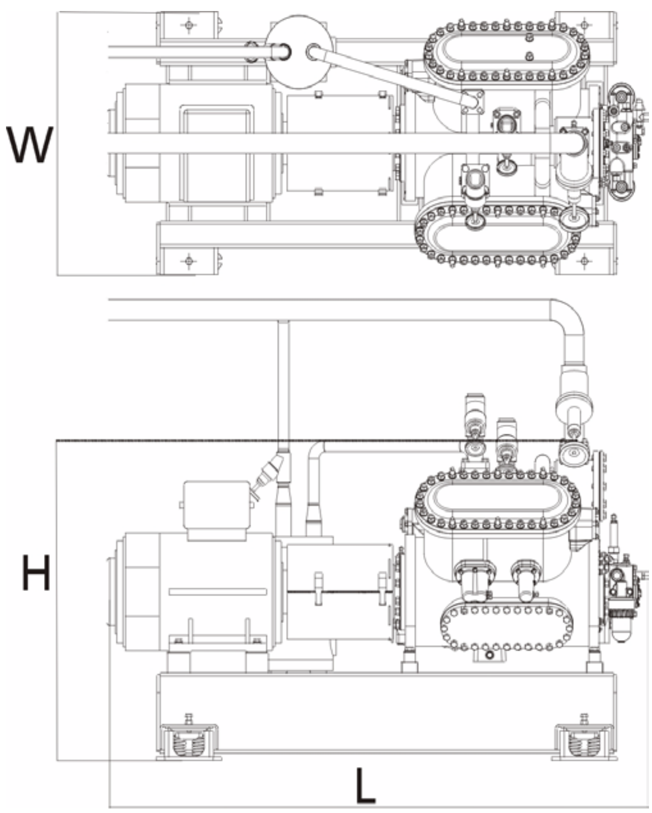


Fig. 2.4-2 Packaged base frame for mounting on vibration dampers for direct drive

Approx. dimensions and weights
Direct driven Grasso 10 compressor at NH_3
-10/+35, 1475 min^{-1}, incl. oil separator (excl. stop valves)

Number of cylinders	(kg)	L(mm)	W(mm)	H(mm)
2	1010	1695		1180
3	1200	1910		1240
4	1230	1730	940	1300
6	1630	2095		1300
8	1940	2445		1470

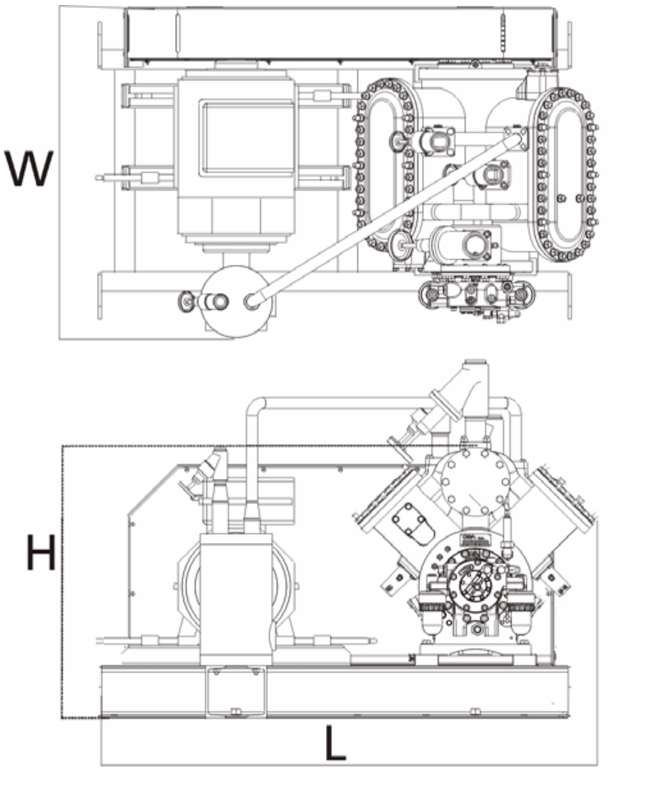


Fig. 2.4-3 Packaged base frame for mounting on concrete block for V-belt drive

Approx. dimensions and weights
V-belt driven Grasso 10 compressor at NH_3
-10/+35, 1475 min^{-1}, incl. oil separator (excl. stop valves)

Number of cylinders	(kg)	L(mm)	W(mm)	H(mm)
2	1060	1715	1060	1180
3	1250	1715	1180	1240
4	1280	1785	1100	1300
6	1700	1855	1255	1300
8	2020	1855	1530	1470

2.4.2 BARE COMPRESSOR ON CONCRETE FOUNDATION BLOCK

For direct driven compressors, a packaged base frame is strongly recommended

General

In case a base frame is not applied, a V-belt driven compressor can be mounted direct on a concrete foundation block.

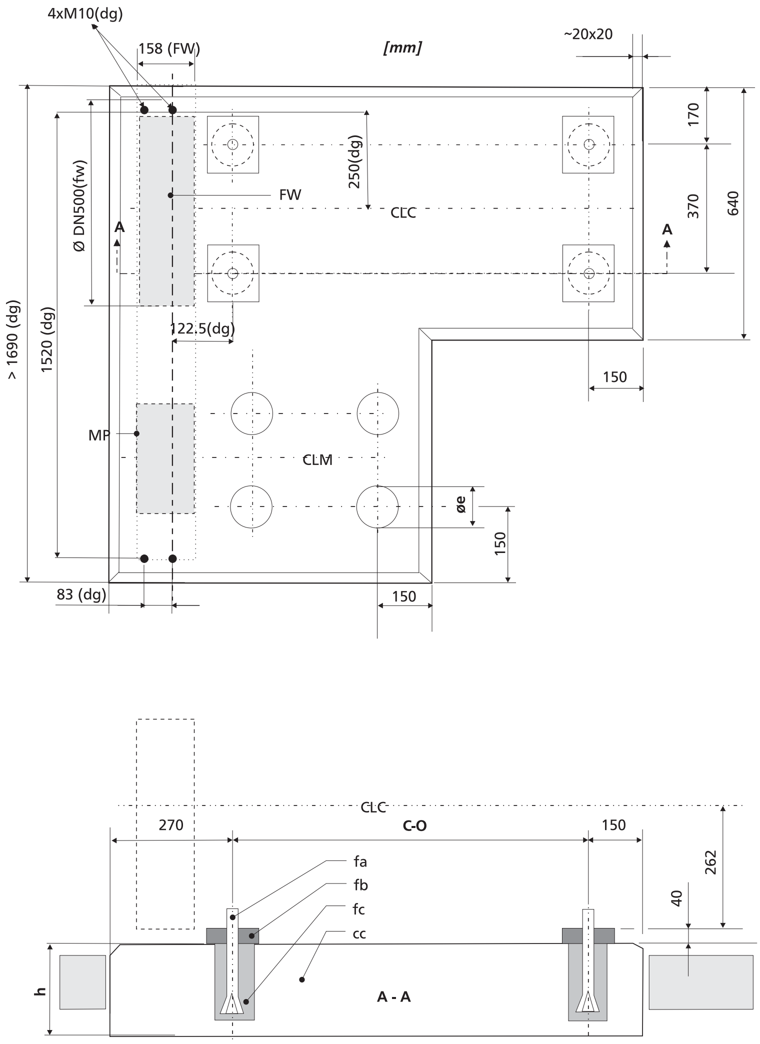
This Data Sheet should not be considered to be a guide to the design and lay-out of the foundation block as such.

This matter requires practical experience and a detailed knowledge of the situation on the spot. Therefore it is strongly recommended to leave the disign and carrying out of foundations entirely to qualified firms, which, at the same time, are prepared to take full responsiblility for the job.

Selection and Data

- Consult grasso to determine dimensions of concrete foundation block
- There should never be a direct rigid connection whatsoever between the foundation block and the floor or any other main part of the building.
- The concrete block should extend down to any subsoil.
- Dimensions in the table below are directly related to the compressor and the drive. Other dimensions are determined by amongst other the electric motor.

2.4.2.1 FOUNDATION BLOCK GRASSO 10



Legend	Dimensions in mm	
dg	Drive guard	
FW	Fly wheel	
MP	Motor pulley	
CLC	Centre line compressor	
CLM	Centre line motor	
fa	Foundation anchor (number of foudation anchors for compressor = 4)	
fb	Foundation block	
fc	Filling compound	
cc	Concrete	
C-O	Compressor dimension O	
	Grasso 210/410/3110	555
	Grasso 310/610/2110/4210	735
	Grasso 810/6210	1085

Legend	Dimensions in mm
e	2.5 x diameter of foundation anchor (= 50 mm for Grasso10-compressor; only valid when using filling compound)
h	Total height of concrete block (consult Grasso)

2.5 OIL SEPARATOR; OIL RETURN PROTECTION; OIL LEVEL FLOAT SWITCH; OIL QUALIZING AND OIL RETURN

2.5.1 OIL SEPARATORS

General

Grasso can supply standard oil separators, designed for application in discharge lines (also LP discharge lines for interstage cooling system C and D).

Procedure and Data

- Selection:
  - Consult Grasso software program COMSEL and/or selection table.

Standard scope of supply

- Standard oil separator.
- Float valve assembly, for automatic return of oil to crankcase of the compressor and stop valve (not mounted).
- Oil drain stop valve (not mounted).

Options

- TÜV approval (other approvals on request).
- Set of flanges (DIN2635) for in- and outlet connections.
- Welding mating flanges.
- Base support for mounting on concrete floor.
- Oil return protection.

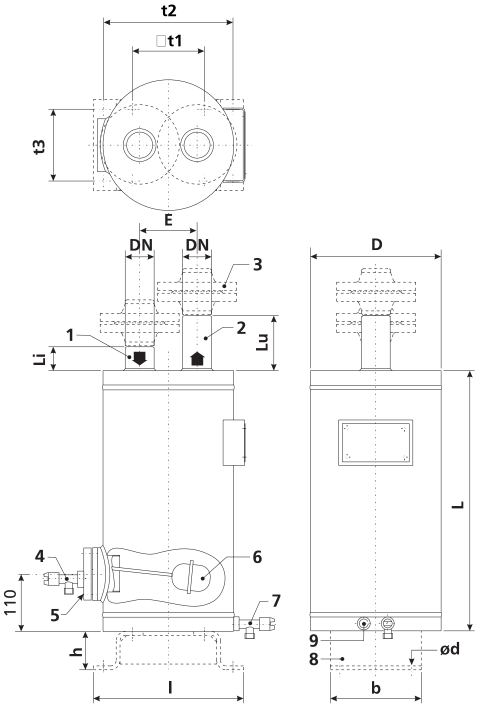


Fig. 2.5-1 Oil separator (types OC50 up to OC125)

1	inlet connection
2	outlet connection
3	set of flanges (optional)
4	stop valve (type TAH8) for oil return to crankcase
5	connection for temperature transmitter
6	float valve
7	stop valve (type TAH8) for oil drain
8	base support (optional)
9	dirt drain

Table 2.5-1 Oil separator design data

OIL SEPARATOR TYPE		OC50	OC80	OC100	OC125	OC160
Dimensions (mm)	L	500	630	790	1155	ref. drawing
	D	273	323.9	460	610	
	DN	50	80	100	125	
	Li	50	50	50	50	
	Lu	115	150	160	160	
	E	120	155	205	270	
	l	330	330	455	455	
	h	80	80	80	80	
	b	190	190	315	315	
	ød	14	14	18	18	
	t1	150	150	275	275	
	t2	270	270	395	395	
	t3	150	150	275	275	
Shipping mass	(kg)	59	121	201	335	545
Shipping volume	(m^3)	0.2	0.3	0.5	0.9	1.5
Oil charge	(dm^3)	4.6	6.0	12.2	21.9	12.2
Design pressure	(bar)	25.0	25.0	23.0	23.0	23.0
Test pressure	(bar)	32.5	32.5	29.9	29.9	29.9

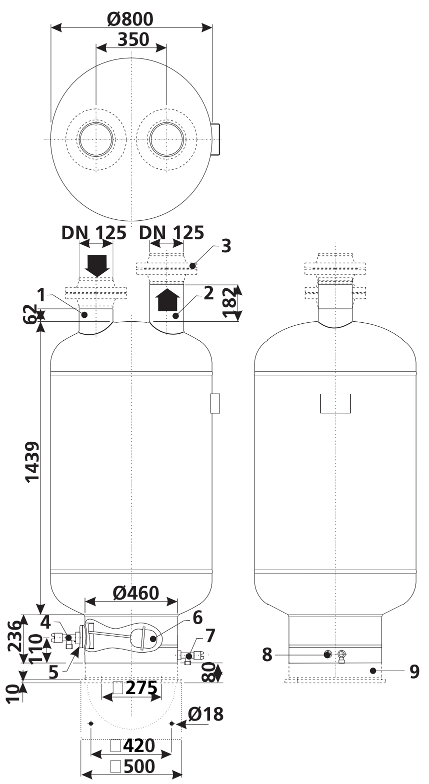


Fig. 2.5-2 Oil separator (type OC160)

1	inlet connection
2	outlet connection
3	set of flanges (optional)
4	stop valve (type TAH8) for oil return to crankcase
5	connection for temperature transmitter
6	float valve
7	stop valve (type TAH8) for oil drain
8	dirt drain
9	base support (optional)

2.5.1.1 OIL SEPARATOR SELECTION

Table 2.5-2 Oil separator selection Grasso 10

Type of oil separator	Maximum compressor discharge volume rate (m^3/h)			
	Ammonia	Halocarbons	Ammonia	Halocarbons
	Booster compressor and two-stage compressor on LP stage		Single-stage compressor and two-stage compressor on HP stage	
OC50	214	123	134	80
OC80	369	212	231	138
OC100	776	447	485	291
OC125	1379	793	862	517
OC160	2369	1362	1481	888

2.5.2 OIL RETURN PROTECTION

General

Grasso can supply an oil return protection system, to prevent excessive foaming of oil in crankcase, which can occur when starting the compressor after a long period of standstill with relatively low oil temperature. (refer also to accessory 'crankcase heater')

Selection and Data

- The minimum oil return temperature of the thermostat has to be set at approx. 40 °C.
- Solenoid valve is always closed during compressor standstill.
- Sensor to be connected to float valve connecton of oil separator.

Standard scope of supply

- Solenoid valve, different types for NH_3 and halocarbons (not mounted).

A) When Monitron is applied:
- Temperature sensor (not mounted).

B) When Monitron is not applied:
- Thermostat with sensor (not mounted).
- Solenoid valve can also be used in combination with accessory oil level float switch.

Options

For packages with built-on oil separator(s):
- Mounting and wiring solenoid and temperature sensor OR thermostat.

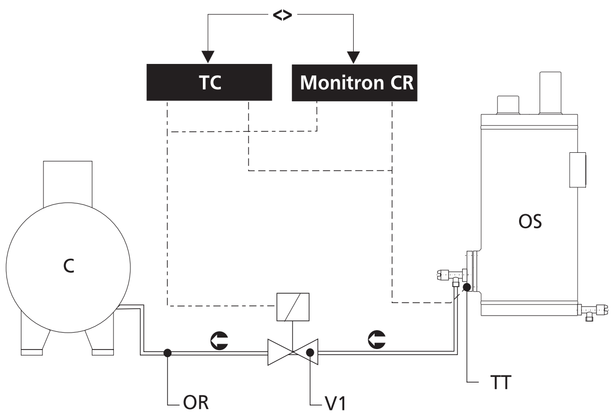


Fig. 2.5-3 Oil return protection

Legend	
C	Compressor
OR	Oil return line[a]
V1	Solenoid valve
TC	Thermostat
TT	Temperature transmittor
OS	Oil separator

a. Oil return via the suction line is not allowed!

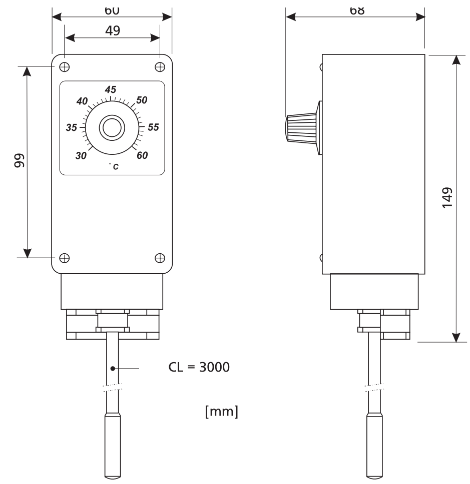


Fig. 2.5-4 Thermostat with sensor

	Legend (dimensions in mm)
CL	Cable length

2.5.3 CRANKCASE OIL LEVEL FLOAT SWITCH

General

In case two or more compressor operate in parallel on one common oil reservoir, Grasso can supply an electric oil level float switch.

Selection and Data

- Mounted in special housing provided with a sight glass
- Housing to be fitted on crankcase sight glas connection
- Max peak current = 1 A (auxiliary relay required)
- Wiring: If 'Low oil level' and 'Compressor is running' then 'solenoid valve open'

Standard scope of supply

- Oil level float switch
  Not included: refer to Fig. 2.5-5.

Options

- Mounting
- In case of Monitron CR:
  Wiring

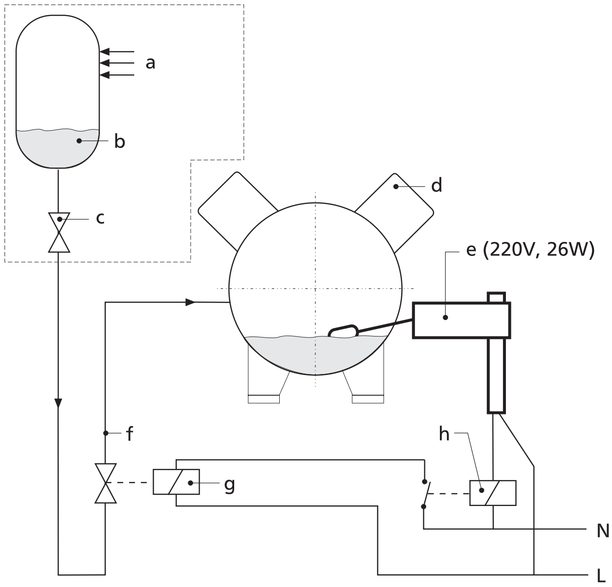


Fig. 2.5-5 Float switch wiring diagram

Legend	
a	oil from oil separators
b	common oil reservoir (not included)
c	hand operated stop valve (not included)
d	compressor (not included)
e	oil level float switch
f	oil return from oil separator or liquid rectifier
g	solenoid valve (not included)
h	auxilary relay (not included)
N	Neutral
L	Live

2.5.3.1 CRANKCASE OIL LEVEL FLOAT SWITCH

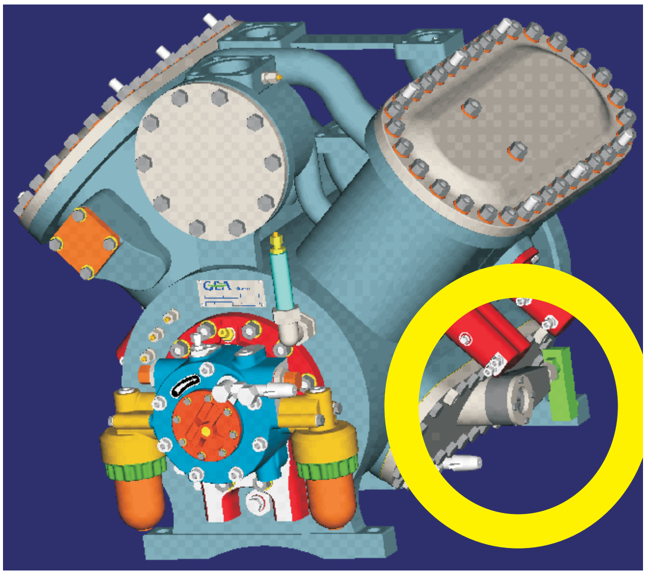


Fig. 2.5-6 Crankcase oil level switch

2.5.4 COMMON OIL RETURN AND OIL EQUALIZING CONNECTION

General

In case two or more compressor operate in parallel on one common oil separator / oil reservoir, the oil return to the crankcase must be arranged as follows;

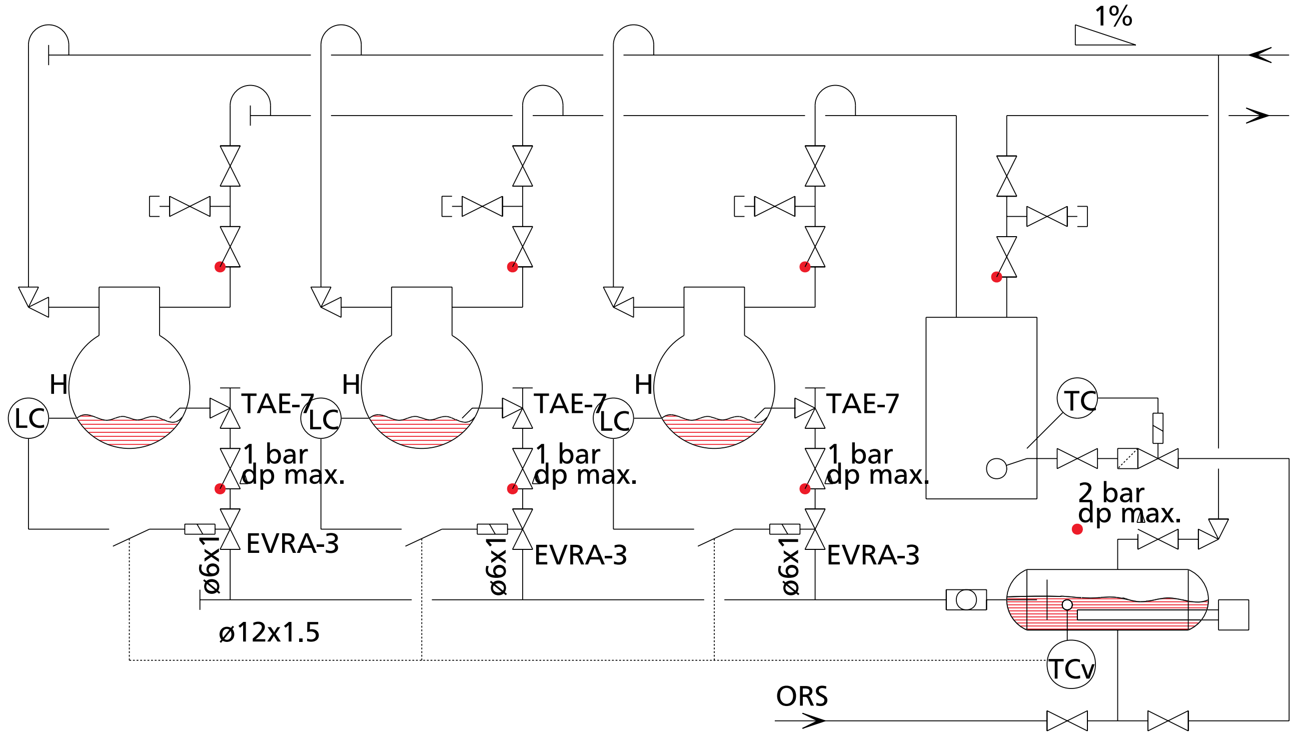


Table 2.5-3 Oil level control crankcase

Legend	
ORS	from oil return system
LC	Grasso oil level float switch (optional)

If compressor crankcase level = LC_{High}, stop compressor.

Crankcase heater (optional) is recommended

Oil return via suction line of the compressor is not allowed.

2.5.5 OIL RESERVOIR FOR MARINE USE

This option is obligatory for compressors installed aboard ships.

General

Whenever a compressor is installed aboard ships, an adequate supply of crankcase oil to to oil pump will be enabled by an oil reservoir.
The crankcase of the compressor has an extra flange connection underneath the crankcase, to mount this reservoir.

REMARK: The type designation of compressor with a marine oil reservoir is **M**Grasso10.

Standard scope of supply

- Oil reservoir
- Internal suction line oil pump

Options

- Mounting (for packages only)

2.5.5.1 OIL RESERVOIR FOR MARINE USE

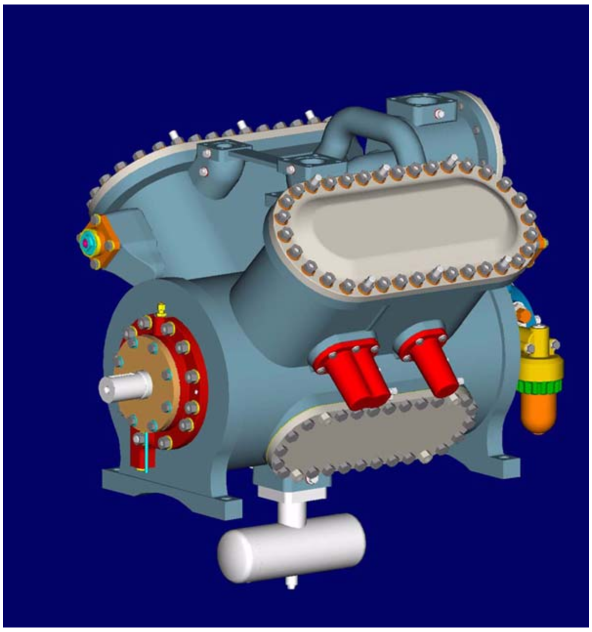


Fig. 2.5-7 Oil revervoir for marine use

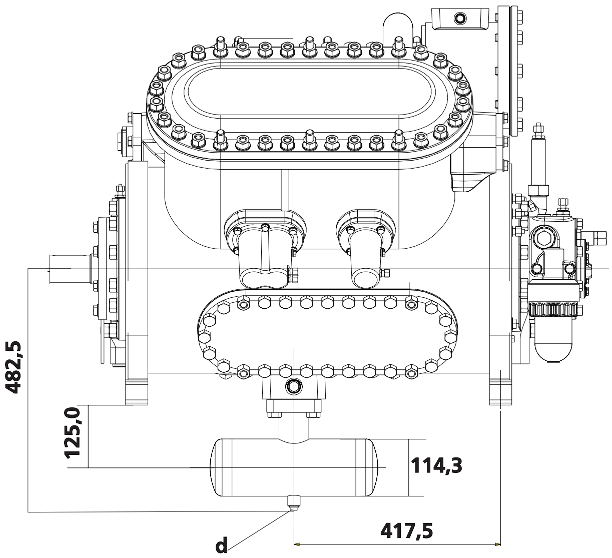


Fig. 2.5-8 Location of marine oil reservoir

2.6 CRANKCASE HEATER

Recommended for all types of refrigerant and all types of compressors.

General

During standstill of the compressor, refrigerant may dissolve in the oil charge of the crankcase or it may even condense, both due to an increase of crankcase pressure, a decrease of crankcase temperature and/or possible temperature differences between crankcase and evaporator.

Excessive foaming of oil in crankcase, can occur when starting the compressor after a long period of standstill with relatively low oil temperature which may result in damaging the compressor by a lack of lubrication.

Low oil temperatures may also cause a high oil viscosity, which may result in troublesome starting.

Selection and Data

- Refer to table.
- Engine room temperatures between 15 and 20 °C.
- Heater fitted into a sleeve so can be exchanged while compressor is in operation.
- Wiring: If 'compressor NOT running' then 'element is energized'.

Standard scope of supply

- Heater element (mounted).

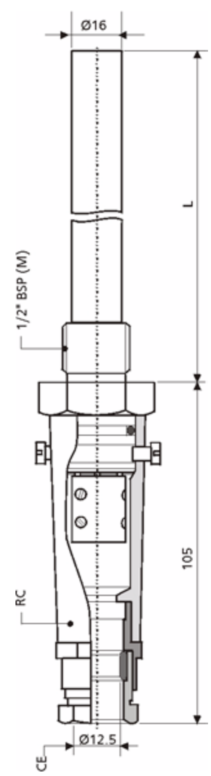


Fig. 2.6-1 Crankcase heater

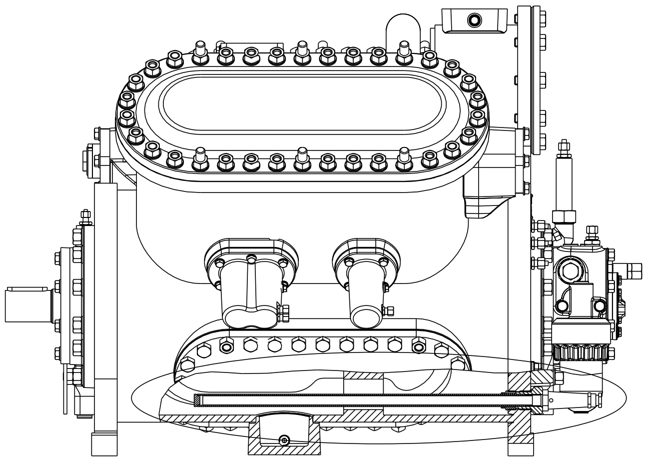


Fig. 2.6-2 Location of crankcase heater sleeve

Legend	
CE	Cable entry
RC	Removable cap to protect connections

2.6.1 DETAILS GRASSO 10

Number of compressor cylinders	Installed power of heater element	Dimension L (mm)
2-4	325	380
3-6-8	525	600

2.7 STOP VALVES, FLANGES AND FILTERS

2.7.1 SUCTION AND DISCHARGE STOP VALVES AND FLANGES

Refer to “Main Dimensions and Space Requirements” to determine DN connections

General

Grasso can deliver (straight through) stop valves to suit suction, intermediate and discharge connections.
It is strongly recommend to apply always suction, intermediate and discharge stop valves.

Selection and Data

- For more detailed information refer to Engineering Data of Revalco B.V.

Standard scope of supply

- Suction and discharge stop valve (not mounted).

Options

- Set of flanges for suction and discharge line (not mounted).
- Two stage:
  Stop valves for intermediate lines (not mounted).
  Options:
  ⇨ Set of flanges to suit for intermediate line (not mounted).
- Welding stop valves and mating flanges.

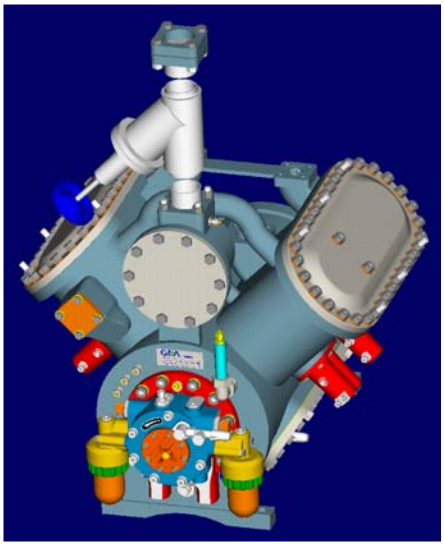


Fig. 2.7-1 Compressor with stop valve

2.7.1.1 DETAILS Grasso 10

2.7.2 INTERMEDIATE SUCTION GAS FILTER

Compulsory for interstage cooling system C and D

Table 2.7-1 Intermediate filters

Suction gas filter type	Suitable for compressor type: Grasso	Danfoss type
DN32	2110, 3110	FIL32-D-2-2-1
DN50	4210, 6210	STA50-D-2-2-1

General

Grasso can supply a suction gas filter which is compulsory for HP suction lines of two stage compressors interstage cooling system C/D to protect the compressors.

Selection and Data

- Refer to table.

Standard scope of supply

- filter and mounting materials to fit onto compressor (not mounted).

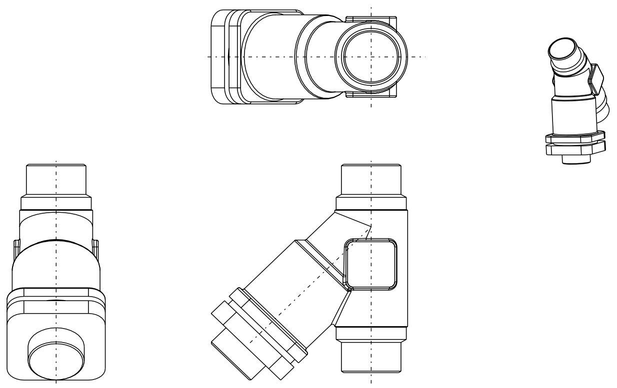


Fig. 2.7-2 HP-Suction gas filter Danfoss DN 32

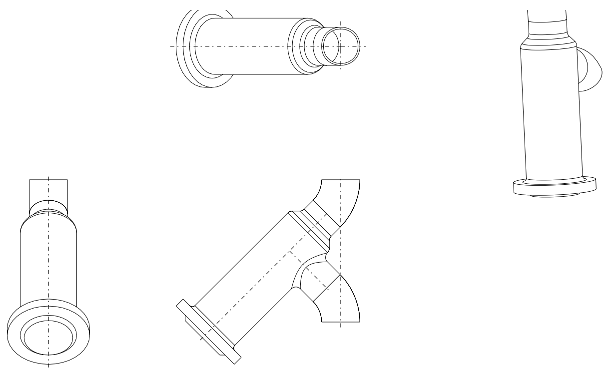


Fig. 2.7-3 HP-Suction gas filter Danfoss DN 50

2.8 INTERSTAGE COOLING SYSTEMS

2.8.1 SURVEY OF INTERSTAGE COOLING SYSTEMS FOR TWO-STAGE COMPRESSION

General

The criteria for two-stage compression, at certain combination of condensing temperature t_c and evaporating temperature t_o, are as follows:

1. Actual discharge temperature too high,
2. Capacity per unit of swept volume too low (poor volumetric efficiency),
3. Unfavourable specific power consumption.

As a rule of thumb:
Two-stage compression becomes necessary when t_c-t_o exceeds 50 K with ammonia or 70 K with halocarbons, at full load conditions; under partload conditions 5 K less.

Survey

One has a choice out of two possibilities: namely booster operation with LP and HP compressor or compound operation with LP and HP stage integrated in one compressor by means of separate cylinder groups.
In principle there is no difference between booster or compound operation. In both cases gas cooling as close as possible to saturation point is necessary between the LP- and HP-stage. Use is made of the possibilities in the installation itself, whereby liquid cooling usually takes place between condenser and evaporator.
Different systems of interstage cooling are available whereby the advantages and disadvantages of each system determine the field of application. The current systems are shown schematically in the figures overleaf.

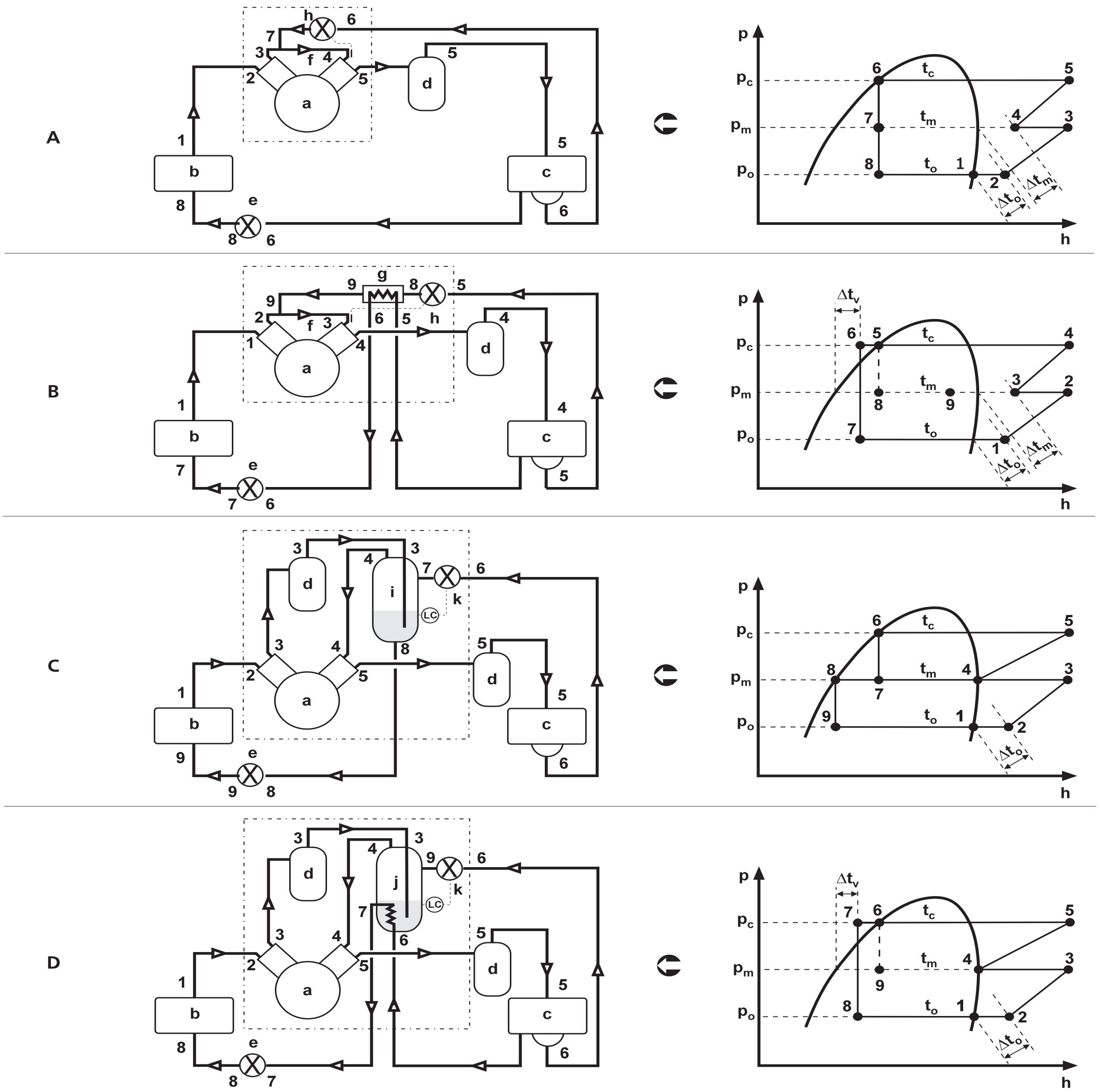


Fig. 2.8-1 Survey of Grasso's interstage cooling systems

a	two-stage compressor
b	evaporator
c	condenser
d	oil separator
e	throttle control valve for evaporator feeding
f	injection interstage gas cooler
g	injection interstage liquid cooler
h	thermostatic expansion valve
i	open flash interstage cooler
j	closed flash interstage cooler
k	throttle control valve for feeding interstage cooler

LC	level control
t_c	condensing temperature {T cond.}
t_m	saturation intermediate temperature {T interm.}
t_o	evaporating temperature {T evap.}
Δt_m	HP suction superheat {DT interm.}
Δt_o	LP suction superheat {Superheat}
Δt_v	temperature difference between outlet liquid coil and saturation intermediate temperature tm {DT cooler}
p_c	absolute condensing pressure
p_m	absolute intermediate pressure
p_o	absolute evaporating pressure
h	enthalpy

Explanation of the operation and comparison of interstage cooling systems

System A (Injection interstage gas cooling)

Interstage cooling takes place by injecting liquid refrigerant from the condenser into an interstage gas cooler via an expansion valve. This cooler is mounted between the LP discharge and HP suction connection of the compressor.

ADVANTAGES:

- Interstage cooling section very simple and inexpensive; no need for additional isolation stop valves, oil separator in the LP discharge line or suction filter in the HP suction line.
- Complete interstage cooling system can be built onto the compound compressor, thus saving on floor space in the engine room.
- The installation is conveniently arranged and easy to control.
- Suitable for all refrigerants
- Reduced oil carry over due to the priority of the liquid supply to the intercooler expansion valve, especially when using ammonia and with the feed taken from the lowest position of the receiver, priority vessel (see installation instructions) or HP-float, (take care of dirt), settled oil will be drained.

In case of large plants; exessive oil return is possible, safe guard compressor against overfilling

DISADVANTAGES:

- Less efficient as the interstage economiser cooling system B, C and D.
- Expansion valve operation requires condensing pressure control, to ensure a minimum pressure-difference over the expansion valve(> 4 bar). Too low pressure-differences result in hunting.
- Expansion valve operation requires a minimum load of 25% to obtain stable control. Injection only possible in 2-stage mode.

CONCLUSION:

- Application in small to medium-large refrigeration plants, resulting in low costs and simple operation.

System B (Combined interstage gas and economiser cooling)

The liquid subcooler is integrated in the gas cooler. The full liquid refrigerant flow is subcooled in a parallel circuit inside the interstage cooler.

ADVANTAGES:

- Thermodynamically identical alternative for system D (see text further on).
- Is characterized by a neglectible refrigerant charge of the interstage cooler.
- Trouble-free oil return to the HP stage.
- Interstage cooling section smaller, simpler and more convenient than for system D.
- In principle complete interstage cooling built onto compound compressor is possible, resulting in saving on floor space in engine room.
- As with system A: no need for additional isolation stop valves, LP oil separator or HP suction filter (direct piping between LP discharge and HP suction).
- Suitable for all refrigerants.
- Less expensive than system D while retaining favourable capacity and power consumption.
- Reduced oil carry over due to the priority of the liquid supply to the intercooler expansion valve, especially when using ammonia and with the feed taken from the lowest position of the receiver, priority vessel (see installation instructions) or HP-float, (take care of dirt), settled oil will be drained.

In case of large plants; exessive oil return is possible, safe guard compressor against overfilling

- Injection on single stage operation allowed as liquid load of sub cooler ensures stable expansion valve operation, resulting in controlled discharge temperatures during pull down.

DISADVANTAGES:

- Expansion valve operation requires condensing pressure control, to ensure a minimum pressure-difference over the expansion valve. (>4bar) Too low pressure-differences result in hunting.

REMARK: On/off control of main user liquid flow should be prevented. Use base load valve open at running compressor, selected on about 70% of minimum cooling capacity at maximum condensing pressure and a level controlled valve (HP/LP) selected on 120% of maximum capacity on lowest condensing pressure

REMARK: Do not connect a HP-float after the subcooler, as this will result in condensation of high stage vapour in the subcooler, resulting in large capacity losses, high intermediate pressures and high end temperatures.

CONCLUSION:

– Synthesis of the systems A and B, applied in small and medium-large installations, with the advantages of system A (simplicity and space-saving) as well as system D (favourable power consumption and running costs).

System C (Open flash interstage cooling)

Interstage cooling takes place by passing the full hot discharge gas flow from the LP stage through a bath of liquid refrigerant inside a interstage cooler vessel, which is aspirated at intermediate pressure by the compressor HP stage.
At the same time, the full liquid refrigerant flow is passed through this vessel, thereby undergoing a double- expansion: first from condensing to intermediate pressure via a level-controlled throttle valve and then the saturated liquid at intermediate pressure is fed from this vessel to the evaporator via a second throttle control valve.

ADVANTAGES:

– Enthalpy difference over evaporator has maximum possible value for given operating conditions. Therefore, maximum two-stage refrigerating capacity with minimum specific power consumption and minimum compressor price per unit of capacity.
– Minimum operating costs assuming a sufficiently large number of running-hours per year.

DISADVANTAGES:

– Interstage cooling section rather complicated and expensive due to the necessity of isolation stop valves, an oil separator in the LP discharge line and a suction strainer in the HP suction line.
– Requires extra floor space in the engine room.
– (Flash) interstage cooler contains a considerable volume of liquid refrigerant and traps oil coming from the LP-stage. Therefore less suitable for R22 (expensive supply of refrigerant and hindrance of undissolved oil).
– Low pressure difference accross the throttle control valve for evaporator feeding.Risk of forming flash gas in liquid line from interstage cooler to evaporator.
– Risk of forming flash gas in liquid line from interstage cooler to evaporator.
– Sensative for intermediate pressure fluctuations

CONCLUSION:

– Optimum system of interstage cooling, with application in medium-large to very large ammonia installations where the interstage cooler has been fitted approx. level or above the evaporator and the distance between these components has been kept to a minimum (both installed in engine room).

System D (Closed flash interstage cooling)

This is a variant of system C. The interstage cooling takes place in a similar manner, but the liquid refrigerant flows under condensing pressure via a closed cooling coil in the interstage cooler vessel to the throttle control valve of the evaporator. So, the liquid expansion is singular and the level-controlled throttle valve for feeding the interstage cooler vessel, has only to inject just that amount of liquid required for the interstage gas cooling.
At the same time, the full liquid refrigerant flow through the coil is subcooled.

ADVANTAGES:

– Alternative for system C, excluding the operational disadvantages. In other words, full pressure difference condenser-evaporator available to properly operate the throttle control valve for evaporator feeding and hardly any risk of flash gas bubbles in liquid line from interstage cooler vessel to evaporator.

DISADVANTAGES:

- Refrigerating capacity at given conditions somewhat lower than that of system C (approx. 3.5%, due to higher enthalpy of liquid-vapour mixture at evaporator inlet). Therefore, specific power consumption and compressor price per unit of capacity somewhat higher.
- Interstage cooler slightly more expensive than the one of system C due to the built-in coil.
- Total operating costs are somewhat higher than those of system C, though still considerably better than those of system A.
- As system C: more complicated, more expensive, takes up more room, less suitable for R22, necessity of LP oil separator, HP suction filter and isolation stop valves between stages.

REMARK: Do not connect a HP-float after the subcooler, as this will result in condensation of high stage vapour in the subcooler, resulting in large capacity losses, high intermediate pressures and high end temperatures.

CONCLUSION:

- Application as with system C in medium-large to very large ammonia installations. Not the optimum solution, yet more universal, i.e. without restrictions regarding erection of the different components in respect of one another.

General remarks A, B, C, D:

- Ensure a continuous condensed liquidsupply to the intercooler expansion valve. Connect the intercooler expansion valve supply-line to a lower position than the main-user line(s) otherwise hunting of the expansion valve could occur.
- If no receiver is available (high pressure float control), use a priority vessel. (For system A only: In case of Witt HP-floats, the drain-valve EA-10-GB under the float-vessel can be used to connect the intercooler expansion valve supply.)
- Create enough liquid head or subcooling to prevent flash gas formation by pressure loss and/or radiation otherwise hunting of the expansion valve could occur. If the conditions are such that this can occur, or in worst case if the intercooler is positioned above the condenser/receiver, Grasso can supply a priority vessel with integrated liquid lifting device.
- If subcooling is expected please inform us to prevent oversizing of the expansion-valve otherwise hunting of the expansion valve could occur.
  A built in sight glass before the expansion valve makes it possible to check if a continuous liquid supply is secured.

For more detailed layout see general installation instructions.

2.8.1.1 Graphics interstage cooling system A and B

Installation schematic system (Ecotron)A;

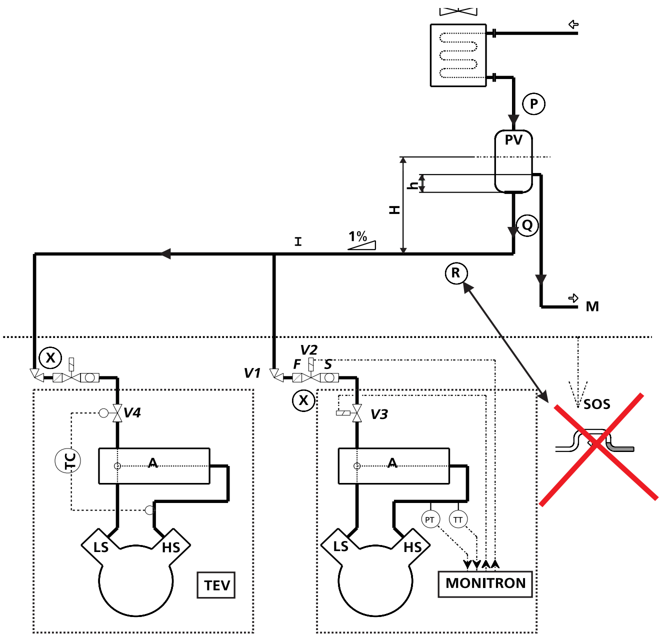


Fig. 2.8-2 Installation schematic system (Ecotron)A;

Legend/installation instructions	
A	Gas cooler
TC	Temperature Controller
TT	Temperature Transmitter
PT	Pressure Transmitter
V1	Stop valve
V2	Solenoid valve
V3	Electronic Expanson Valve(s) In case of Monitron; Danfoss AKVA for all refrigerants!
V4	Thermostatic expansion valve(s) Danfoss TEA for all refrigerants
F	Filter
S	Sight glass
SOS	Scope of supply

Legend/installation instructions	
I	Injection Flow
PV	Priority Vessel Gives injection priority to main flow by height (h)
M	Liquid to main users
P	Liquid velocity < 0.3 m/s (preferred velocity to allow gas to flow back to condenser) Diameter Priority Vessel (PV) approx. 3 x diameter of condenser connection
Q	Line velocity (m/s)/H(cm/m equivalent line length) =< 0.7 / 20 0.5 / 10 =<0.3 / 5
R	STOP WRONG! No gas traps STOP No liquid-rise, otherwise use Grasso Priority Vessel (PV)
X	To be opened: System A; 2-stage mode only System B; 1- and 2-stage mode Single stage injection is required for system B to offset the effects of LP superheat and the heatload created by consenser liquid in sub cooler
h	Buffer height
H	Required static height (refer Q)

Priority Vessel (PV);

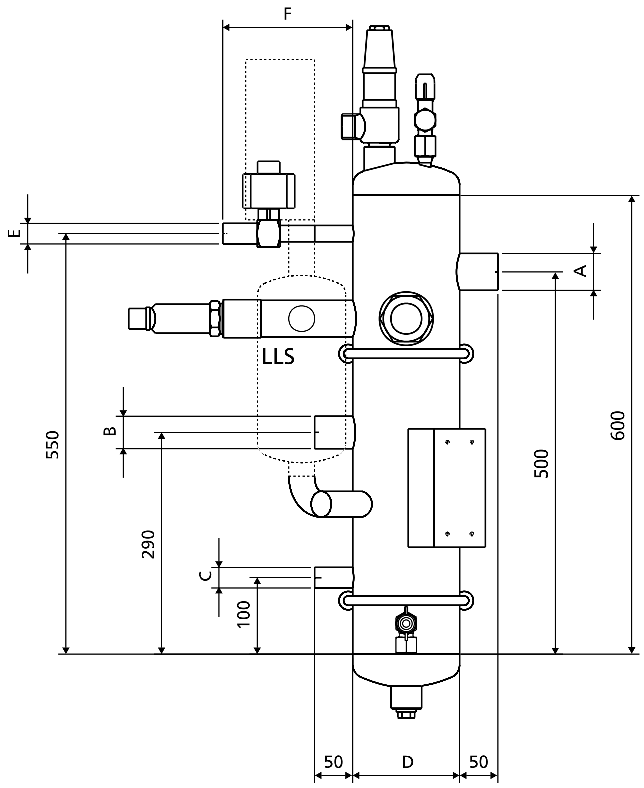


Fig. 2.8-3 Priority Vessel (PV);

A	B	C	D	E	F	PV ***
DN (mm)					mm	
40	32	20	125	15	170	DN40
50	40	25	150	15	170	DN50
65	50	32	200	15	170	DN65
80	65	40	250	20	198	DN80
100	80	50	399	20	198	DN100
LLS = Level Float switch optional on request						

Installation schematic system (Ecotron)A;

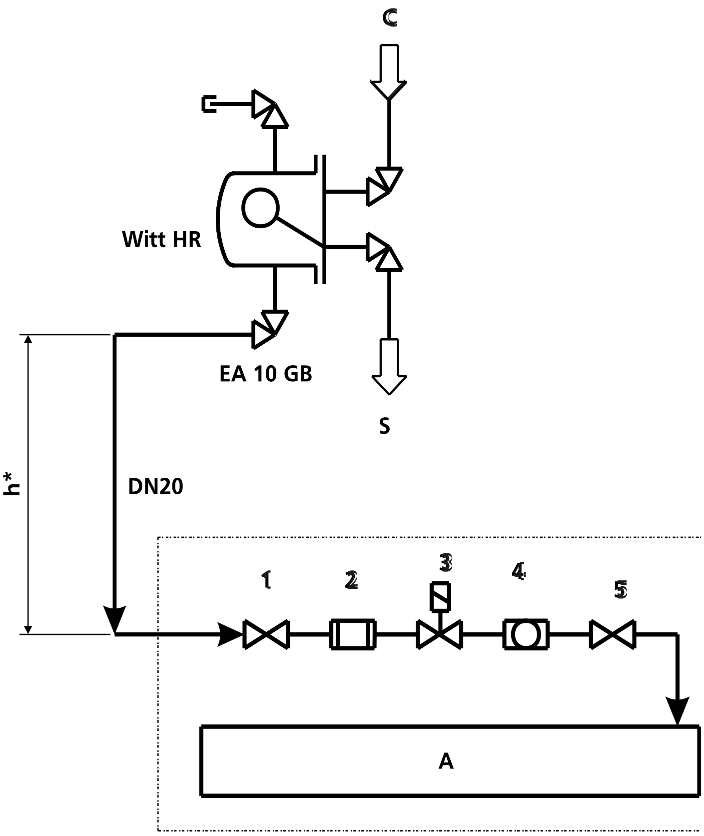


Fig. 2.8-4 Installation schematic system (ecotron)A

C	Liquid from condenser
S	Liquid to evaporator
A	Subcooler A
1	Stop valve
2	Filter
3	Solenoid valve
4	Sight glass
5	Stop valve
h^*	minimum height of float switch in relation to subcooler A * Line length max = 30 m NH_3; $h^* > (Q_{cooler}/100)^2$ (m) Halocarbons; $h^* > (Q_{cooler}/20)^2$ (m)

Installation schematic system (Ecotron) B;

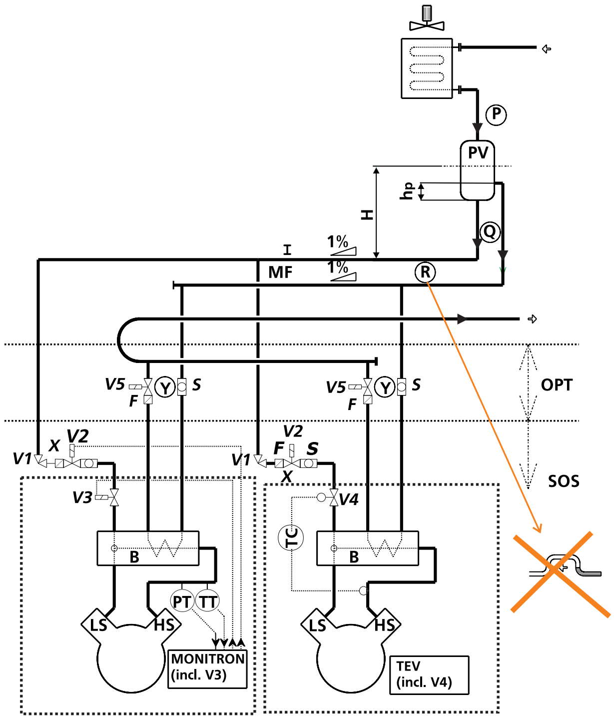


Fig. 2.8-5 Installation schematic system (Ecotron) B;

Legend/installation instructions	
B	Gas cooler with integrated subcooler
TC	Temperature Controller
TT	Temperature Transmitter
PT	Pressure Transmitter
V1	Stop valve
V2	Solenoid valve
V3	Electronic Expanson Valve (Monitron) Danfoss AKVA for all refrigerants!
V4	Thermostatic expansion valve Danfoss TEA for all refrigerants
V5	Liquid shut off valve (Danfoss EVRAT)
F	Filter
S	Sight glass

Legend/installation instructions	
SOS	Scope of supply
OPT	Optional, on request
I	Injection Flow
PV	Priority Vessel Gives injection priority to main flow by height (h_p)
M	Liquid to main users
MF	Main flow
P	Liquid velocity < 0.3 m/s (preferred velocity to allow gas to flow back to condenser) Diameter Priority Vessel (PV) approx. 3 x diameter of condenser connection
Q	Line velocity (m/s)/H(cm/m equivalent line length) =< 0.7 / 20 0.5 / 10 =<0.3 / 5
R	STOP No gas traps STOP No liquid-rise, otherwise use Grasso Priority Vessel (PV)
X	To be opened: System A; 2-stage mode only System B; 1- and 2-stage mode
Y	STOP Only necessary in case of multiple subcoolers. Opening pressure loss 0 bar (e.g.Danfoss EVRAT). Must be positioned on subcooler outlet and switched off during stand still!
Hp	Buffer height priority vessel
H	Required static height (refer Q)

Installation schematic system (Ecotron) B (Preferred)

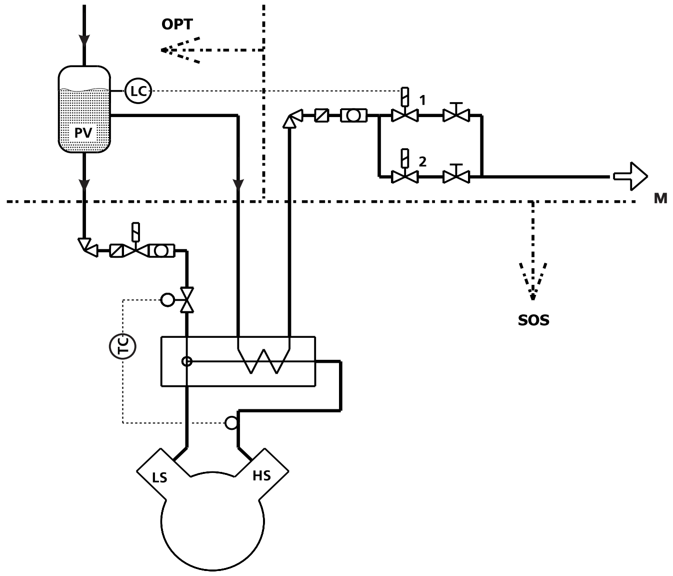


Fig. 2.8-6 Installation schematic system (Ecotron) B (Preferred)

Legend	
	Installation instruction system (Ecotron) B, insterstage cooler in combination with High Pressure Float System (Equal to system D). PREFFERED BY GRASSO
OPT	Optional, on request
M	Main users
LS	Low stage cylinders
HS	High stage cylnders
TC	Temperature controller
LC	Level controller (Optional, on request)
1	Solenoid valve; Base-load valve, to be opened with running compressor. Selected on 70% of minimum cooling capacity at highest Pc
2	Solenoid valve; Level-controlled valve. Selected on 120% of maximum cooling capacity at lowest Pc
PV	Priority vessel (Optional, on request)

Installation schematic system (Ecotron) B (Not recommended)

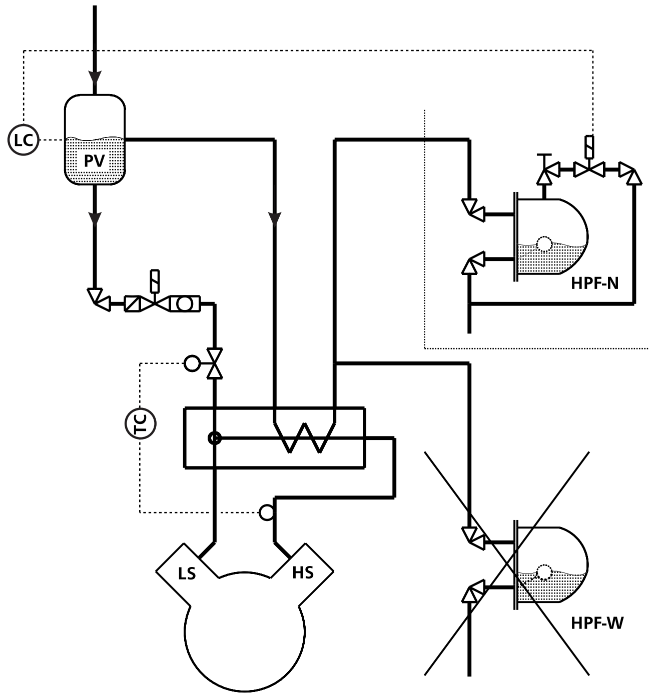


Fig. 2.8-7 System (Ecotron) B, Installation instruction with HP-floats, NOT PREFERRED BY GRASSO!

Legend	
	Installation instruction (ecotron) sytem B interstage cooler in combination with High Pressure Float Systems (equal to system D) STOP Not preferred by Grasso!
HPF-N	High pressure float, not preferred by Grasso (Consult your HP-float supplier)
HPF-W	WRONG! High pressure float drains ALL liquid ahead, when fitted lower than subcooler. Integrated subcooler will be overloaded with condensing vapour out of receiver/condenser!
PV	Priority vessel (Optional, on request)
LS	Low stage cylinders
HS	High stage cylinders
TC	Temperature controller
LC	Level controller (optional, on request)

Installation schematic Priority Vessel (PV);

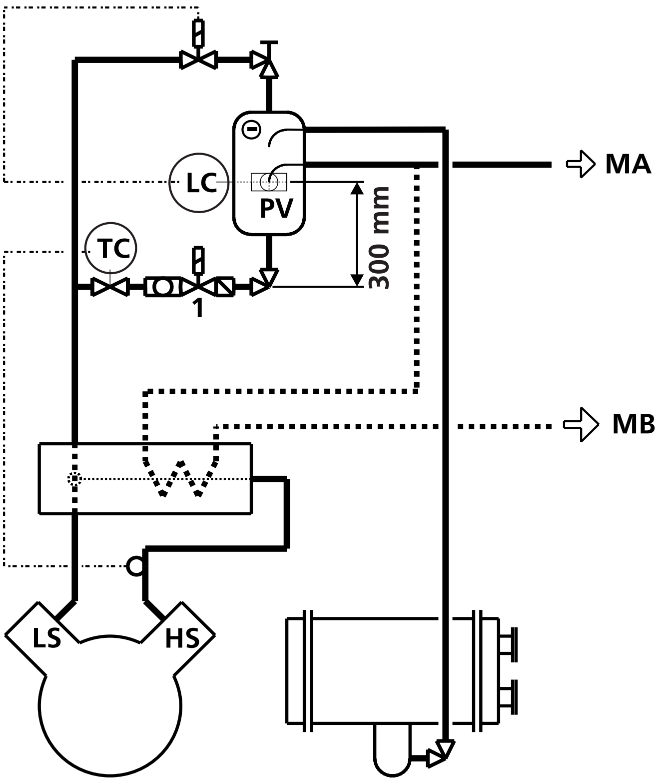


Fig. 2.8-8 Grasso Priority Vessel, installation schematic

Legend	
MA	Main Users, system A
MB	Main Users, system B
TC	Temperature controller
LC	Level controller (optional, on request)
PV	Priority vessel (optional, on request) Grasso's priority vessel compensates for approx. 3 m liquid rise and 30 m length.
LS	Low stage cylinders
HS	High stage cylinders
1	Injection unit, built on interstage cooler

Installation schematic system (Ecotron) B, double version;

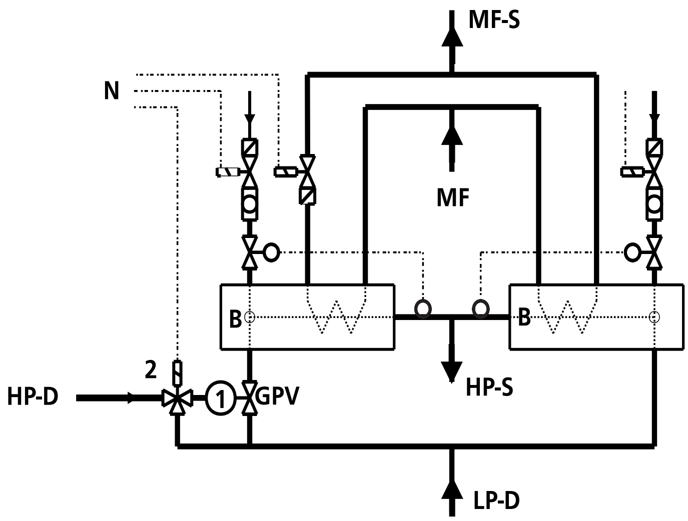


Fig. 2.8-9 Installation schematic system (Ecotron) B, double version;

Legend	
N	To be switched off at approx. 50% HP cylinders
HP-S	HP-Suction
LP-D	LP-Discharge
B	Interstage cooler B
MF	Main flow
MF-S	Subcooled main flow
HP-D	HP-Discharge pilot pressure
GPV	Gas powered valve
1	Actuator GPV
2	Three-way solenoid valve

2.8.2 INJECTION SYSTEMS (A and B)

General

Grasso can supply two types of interstage injection systems:

1. System A, gas cooling.
2. System B, gas and liquid cooling.

Both systems can be supplied with:

1. Grasso's Ecotron, an electronic expansion valve system, only possible in combination with Monitron CR.
   Advantages:
   - The software changes the injected refrigerant flow before compressor capacity step is activated, thus less sensitive.
   - Capacity step time > 60 sec.
   - Significant lower stable superheat, 5 to 10 K.
2. TEV, the conventional system with thermostatic expansion valve(s).
   Advantages:
   - cheap and simple
   - Disadvantages
   - More sensitive to rapid compressor capacity steps,
   - capacity step time > 180 sec.
   - Stable superheat 10 to 15 K.

Procedure and Data

Consult the software program COMSEL.

Standard scope of supply:

- One (1) gas cooler and one (1) injection unit.
- Depending on compressor type, operation conditions and refrigerant or when the maximum pressure loss is exceeded, an additonal gas/liquidcooler/injection unit can be necessary. Consult Comsel.

At partload conditions with =<50% of HP cylinders, one cooler and injection unit will be switched of.

- For part-load conditions < 30% of HP cylinders, two parallel gas coolers and injection units must be applied. For those part-load conditions one gas cooler will be switched of by means of a gas powered valve.Consult Comsel. In case of speed control consult Grasso

2.8.2.1 MAIN DIMENSIONS AND SPACE REQUIREMENTS INTERSTAGE SYSTEMS A AND B

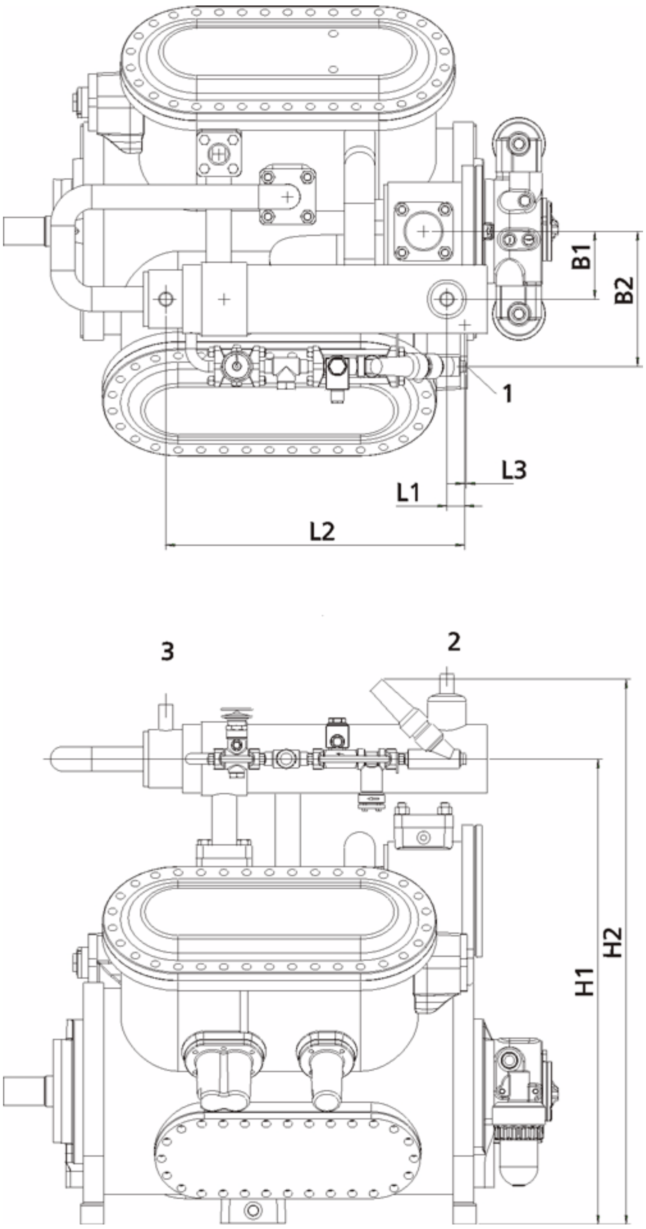


Fig. 2.8-10

Table 2.8-1

		2110	3110	4210	6210
B1	NH_3	-31	152	134	
	H[a]				
B2	NH_3	348	272	266	
	H				

		2110	3110	4210	6210
H1	NH_3	900	894	920	
	H				
H2	NH_3	1057	1051	1075	
	H				
L1	NH_3	295	63	36	425
	H				
L2	NH_3	175	421	590	980
	H				
L3	NH_3	#	-149	0	390
	H				
1		26.9 x 2.3			
2					
3					

a. H=Halocarbons

2.8.3 OPEN AND CLOSED FLASH INTERSTAGE COOLING (System C and D)

General

Grasso can supply a open (system C) or closed (system D) flash interstage cooling system. See Fig. 2.8-12.
System C consists of a vessel only and system D consists of a vessel with a built-in subcooling coil.

Symbols

- $D_{i,min}$ = minimum internal diameter in mm (based on max gas velocity of 0.25 m/s)
- n = speed in rpm
- ZH = total number of HP cylinders (RC2110 and RC4210 operation on one vessel give Z_h=3),
- Δh_s, Δt_v, Δh_v, refer to Fig. 2.8-11,
- t_c = condensing temperature
- $\Delta t_v = t_c$ - Temp. coil liquid out (normally 10K),
- t_m = intermediate temperature,
- v_m = mean log. temp. difference =
- Q_o = Refrigerating capacity,
- M_s = liquid mass flow coil,
- Q_s = coil capacity,
- F_n = cooling surface coil,
- w = liquid velocity in subcooling coil, w_{max} = 2.0 m/s.
- $k_{NH3} = -417w^2 + 2439w + 359\ W/m^2K$
  $k_{R22} = -135w^2 + 923w + 105\ W/m^2K$
- v = specific volume: NH_3liquid cooler ≅ 1.53 dm^3/kg
  R22 liquid cooler ≅ 0.75 dm^3/kg

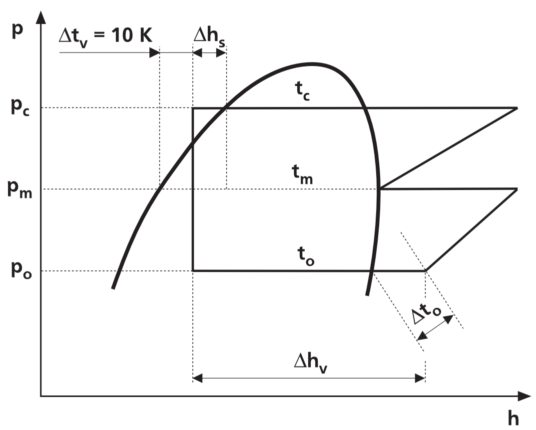


Fig. 2.8-11 Log p-h diagram

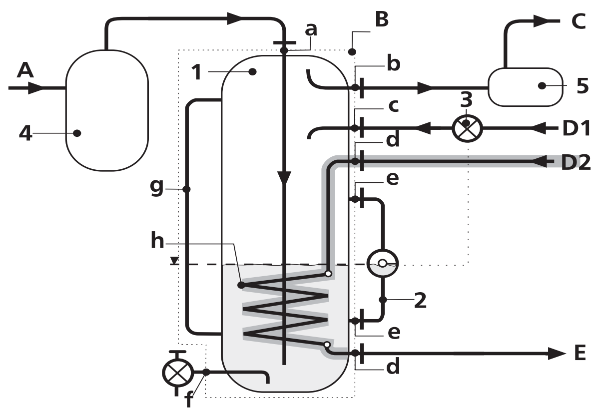


Fig. 2.8-12 Closed "flash" interstage cooling assembly (Open flash would be without subcooling coil, shown shaded)

a	vapour in
b	vapour out
c	mixture in
d	liquid (in/)out
e	standpipe
f	oil drain
g	standpipe
h	subcooling coil (system D only)
1	Open or closed "flash" interstage cooler
2	Main standpipe
3	Throttle control valve
4	Oil separator
5	Gas suction filter
A	LP-discharge
B	Vessel (System C = FTO; System D = FTG)
C	HP-suction
D1	Liquid from condenser
D2	Liquid from condenser (System D only)
E	(Subcooled) liquid to main users

Procedure and Data

A) Vessel (system C and D)

- Consult Grasso software program Comsel, OR:
- Select type of cooler from Table 2.8-2 below by means of $D_{i,min} > D_{i\text{-}table}$

B) Subcooling coil (system D)

- Determine required coil surface $F_{n\ required}$ based on required capacity $Q_{s\ required}$ and max. k value at maximum liquid velocity (w_{max} = 2.0 m/s).

$K_{NH3,w=2.0}$ = 3568 W/m^2K,
$K_{R22,w=2.0}$ = 1411 W/m^2K

- Select coil from Table 2.8-2
- Check selected coil with actual liquid velocity

Table 2.8-2 FTO/FTG data

Cooler type FTO/FTG				300	400	500	600	800	1000	1200	1400
Dimensions in mm	Shell diameter	inner	Di	308	406	488	575	786	984	1181	1375
		outer	Du	318	416	500	587	800	1000	1200	1400
	Total height		A	2290	2340	2375	2415	2515	2630	2720	2850
	Distance		B	1940	1965	1980	1990	2020	2070	2080	2150
	Distance		C	340	365	380	390	445	495	530	600
	Width of base plate		E	300	400	400	500	700	800	1000	1000
	Foot diameter		F	216	267	318	416	500	600	800	800
	Centreline distance[a]		G H	Refer to Table 2.8-3							
	Connections	vapour in[b]	a	60.3x2.9	76.1x2.9	88.9x3.2	114.3x3.6	139.7x4.0	168.3x4.5	193.7x5.6	219.1x6.3
		vapour out[b]	b	48.3x2.6	60.3x2.9	76.1x2.9	88.9x3.2	114.3x3.6	139.7x4.0	168.3x4.5	193.7x5.6
		mixture in[b]	c	26.9x2.6	26.9x2.6	26.9x2.6	26.9x2.6	33.7x2.6	42.4x2.6	48.3x2.6	60.3x2.9
		liquid (in/)out[a]	di/du	Equal to dimension B of liquid coil. Refer to Table 2.8-3							
		liquid out[b]	d	21.3x2.6	26.9x2.6	33.7x2.6	33.7x2.6	42.4x2.6	60.3x2.9	60.3x2.9	76.1x2.9
		standpipe[b]	e	21.3x2.6	21.3x2.6	21.3x2.6	21.3x2.6	21.3x2.6	21.3x2.6	21.3x2.6	21.3x2.6
Shipping mass approx.			(kg)	190	260	340	400	610	850	1220	1770
Shipping volume approx.			(m^3)	0.7	1.0	1.3	1.6	2.5	3.5	4.8	6.5
Internal volume approx.			(dm^3)	140	250	370	520	1010	1655	2475	3560
Liquid volume approx.: for type FTO[c]			(dm^3)	60	105	155	215	415	685	1035	1500
for type FTG and G = 780 mm[cd]			(dm^3)	70	125	185	260	500	815	1215	1710
for type FTG and G = 870 mm[cd]			(dm^3)	-	135	200	285	545	885	1315	1845
for type FTG and G = 960 mm[cd]			(dm^3)	-	-	-	-	-	950	1410	1975

a. Measure applicable for cooler type FTG only.
b. Measures indicate outer pipe diameter x wall thickness.
c. Liquid volume based on max. liquid level, being 250 mm below the centerline of connection c.
d. Liquid volume without built-in liquid coil.

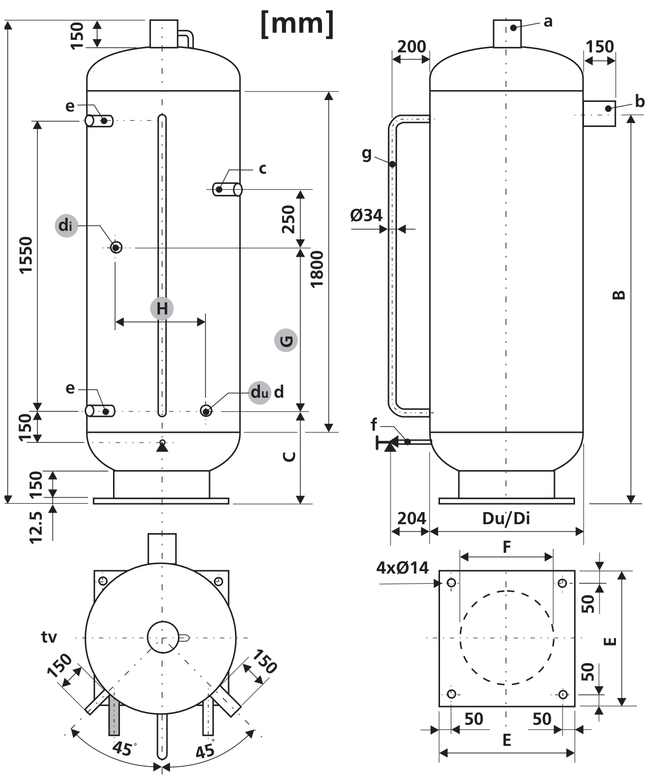


Fig. 2.8-13 Dimensioned sketch of open/closed "flash" interstage cooler

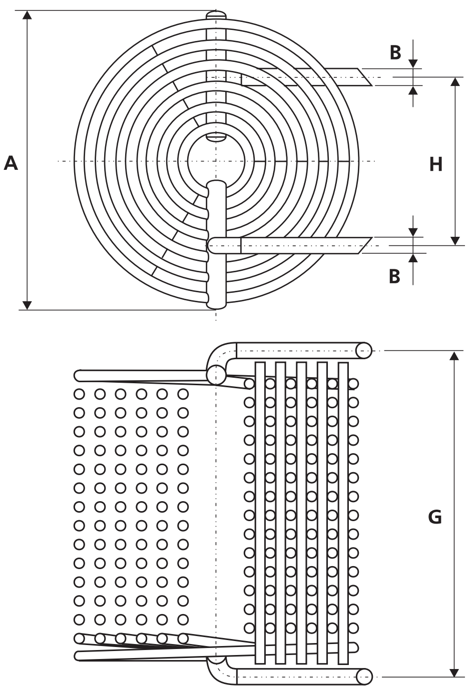


Fig. 2.8-14 Dimensioned sketch of interstage liquid subcooling coil

Table 2.8-3 Subcooling coil data

Coil type				VS 1	VS 2	VS 3	VS 4
Effective heat transfer surface area			Fs (m^2)	0.75	1.20	1.95	2.85
Number of tubes in parallel			z (-)	1		2	
Dimensions (mm)		Max. overall diameter	A (mm)	197	302	365	470
	Connections	Outer pipe diameter x wall thickness	B (mm)	26.9x2.6			
		Vertical centre distance	G (mm)	780		870	
		Horizontal centre distance	H (mm)	170	275	223	328
Total mass without liquid content approx.			(kg)	18	27	42	59
Internal volume approx.			(dm^3)	3.5	5.7	9.5	13.5
External volume approx.[a]			(dm^3)	5.4	8.8	14.7	21

a. Volume to be substracted from the liquid volume as stated in the Table 2.8-2, in order to find the actual liquid content of the vessel.

Standard scope of supply

A) FTO/FTG Vessel (system C and D)

- Vessel with welding connections, as shown in Fig. 2.8-14.
- Painting sysdrostene
  Not included are:
  - ➩ welding flanges
  - ➩ appendages and controls
  - ➩ insulation

B) Subcooling coil (system D)

- Subcooling coil, welded into vessel (see Fig. 2.8-14 and Table 2.8-3).

Options

- TÜV or Lloyds approval (Other approvals on request)

2.9 SPARE PARTS AND (SPECIAL) TOOLS

2.9.1 SPARE PARTS

General

Grasso can supply a set of the spare parts kits which may be required when then compressor has been in operation up to the recommended overhaul[1] running hours.

Scope of supply

- Shaft seal assembly,
- Oil discharge filter,
- Discharge valves (rings and springs),
- Suction valves (rings and springs),
- Required gaskets, O-rings, seals.

REMARK: All parts are supplied loose.

2.9.2 SPECIAL TOOLS

General

Grasso can supply a set of special tools, for e.g. removal and fittings of pistons, cylinder liners and shaft seal.

Standard scope of supply

- Oil filter servicing tool,
- Tool for piston removal and insertion,
- Tool for cylinder liner removal and insertion,
- Eye bolts for measurement of axial end play of crankshaft,
- Allen key for (dis)mantling shaft seal,
- Oil charge line,
- Service Instruction Manual.
- Control oil discharge pressure measurement set

This set, which can be ordered separately, is a must for every engineer who has to overhaul a compressor.

Option

- Alignment toolset for (dis)mounting direct drive coupling,

2.9.3 HAND-OPERATED OIL PUMP

Standard scope of supply

- hand-operated oil pump
- charging hose

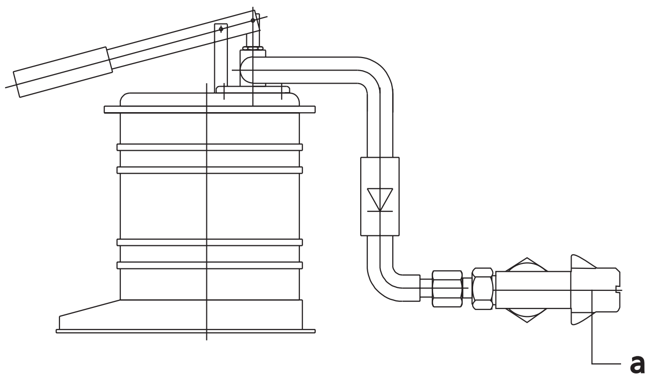


Fig. 2.9-1 Hand-operated oil pump

Legend	
a	Oil charge valve, located on the oil pump of the compressor

Don’t use the oil drain valve of the compressor.

1. Overhaul at 12000 hours, based on 4000 running hours/year, 600 starts/year, with an average part-load capacity of at least 75% and t_o/t_c = -10/+35 C (single stage), -30/-10 C (booster), -30/+35 C (two-stage). Extra starts equals 9 running hours. Consult Grasso for advice.

3. Notes

3.1

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Please contact the technical department of your supplier for extra information.