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REVISION J: PARA 5.1 NOTE 6 ADDED
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PARA 8.3 MMS VALUES UPDATED
REVISION K: PARA 5.1: NOTE 7 ADDED
PARA 5.5: OILHEATER EVENT H AND L ADDED, PICTURE UPDATED
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1. Basic Scope of Document

This document aims at summarizing the basic principles to define the settings of alarms, shutdowns and interlocks for BCA compressors units in respect to the relevant operating modes and processes.

This document provides links to related BCA documents and regulations.

The given rules shall be taken as general guidelines; in certain cases, deviations might be necessary. In case of deviations or special requirements which do not correspondent with those mentioned below, please contact your line manager or the responsible competence center.

2. Abbreviations

A	Alarm
DC	Design Case
EL/EH	Event High / Event low
F	Flow
FS	Flow switch
I	Interlock
L	Low
LS	Level switch
H	High
HP	High pressure
P	Pressure
PCV	Pressure control valve
PD	Differential pressure
PSV	Pressure safety valve
RMS	Root mean square
SD	Shut down
SI	Start Interlock
T	Temperature
TE	Temperature element
VX / VY	Vibration in X / Y direction
ZX / ZY	Rod drop X / Y direction

RMS1	Prognost designation for 1 Segment analysis, default when trigger signal is lost
RMSx	Prognost designation for x Segment analysis eg, RMS36 means 1 revolution is divided in 36 segments of 10° each.

3. Introduction of Product Lines

3.1. Special Features of the Different Compressor Types

3.1.1. PL1: Laby®

Especially for oxygen compressors several limits exist. Refer to the white book for oxygen compressors (TDO 2023990) for details.

3.1.2. PL2: Process

3.1.3. PL3: Laby®-GI

3.1.4. PL4: Hyper

The set point list for hyper compressors is required because typically for the process section of hyper compressors, the compressor is protected by instrument and control devices in client scope of supply.

Pressures (Design, hydro test, alarm and shutdown high) must be defined in accordance with VBCA 546007 → A tool is available for that purpose, see:

"S120017a:\30_KNOWLEDGE\50_CALCULATION_TOOLS\40_PL4_HYPER\Calculation tool for pressures acc VBCA546007_D.xls".

4. Definition of Set Points

Normally, the instrument list defines the set point for all signals within BCA scope and defines the levels of protection, also for the process parameters.

The values in the instrument list have to be reviewed and compared during commissioning and start up with the real situation at site and have to be updated after receipt of the log sheet from the service engineer.

5. Tables for Set Points

In type, SD stands for shutdown, A for alarm and I for interlock, SI for start-interlock of the compressor. An interlock in brackets means that the interlock is depending on the given case. E.g. for dry gases a low suction temperature start interlock makes no sense, but for wet gases this is very important.

Temperature design case is the temperature defined by customer in his requisition. It can also be a range if several temperatures are defined by customer.

Special consideration has to be taken if Nitrogen runs are the limiting factors. Low temperature shut downs shall always be approved by sizing department due to expected motor load and rod load as well as shift of intermediate pressures.

5.1. Process Gas Temperatures

Location	Temperature	Type	[°C]	Comment
Suction	T_{HH}	SD	= T_{DC} + 20	If required [3]
	T_{H}	A	= T_{DC} + 15	
	$T_{Design\ case}$	-		
	T_{L}	A, (I)	= T_{DC} – 15	If required [5] [6]
	T_{LL}	SD	= T_{DC} – 20	If required [1] [2] [6]
Interstage	T_{HH}	SD	= T_{DC} + 20	[3] [7]
	T_{H}	A	= T_{DC} + 15	
	$T_{Design\ case}$	-		
	T_{L}	A	= T_{DC} – 15	If required
	T_{LL}	SD	= T_{DC} – 20	If required
Discharge	T_{HH}	SD	= T_{DC} + 20	[3] [4] [7]
	T_{H}	A	= T_{DC} + 15	
	$T_{Design\ case}$	-		
	T_{L}	A	= T_{DC} – 15	If required
	T_{LL}	SD	= T_{DC} – 20	If required

Notes:

1. Necessary, when ambient temperature is below condensation temperature or if condensation is possible and no separator is available.

2. Necessary if the rod load is critical
3. Maximal temperature has to consider temperature limitations of process (e.g. polymerisation of PP), compressor material (e.g. valves and seals) and common rules and regulations (e.g. PED).
4. As per API 618 5th edition clause 6.5.2 the trip point shall not exceed 180 °C, for hydrogen 165 °C. The recommended set points for alarm are 20 °C above the predicted temperature and 30 °C for the trip.
5. The lower the suction temperature, the higher is the mass flow and the resulting required motor load.
6. Depending on significant lower ambient temperature than gas suction temperature and also depending on range of suction temperature lower values might be considered, especially for startup during winter when piping is cold.
7. CEM uses max temperature case with +10°C margin to design the seal and guide rings for PL2. To be checked with CEM by PE before setting T HH Value. No damage will occur in case of exceeding the values, but increased wear will occur

5.1.1. Process Gas Depending Max Operating Temperatures

Trip value of temperature shall be below or equal the below values in the table (comment).

Gas	Max Op. Value [°C]	Comment
Ammoniac (NH_3)	150 (160)	170 °C for “Ship-Compressors”
Ethylene (C_2H_4)	150 (120° above 100 bar)	Limit 120 °C defined by BASELL for LUPOTECH Process
Acetylene/Ethin (C_2H_2)	70 (pure)	
Butadiene (C_4H_6)	60	
Chlorine	90 (110)	2)
Carbon monoxide (CO)	130 (150)	2)
Methyl chloride (CH_3Cl)	120	
Ozone (O_3)	100	
R12 (coolant fluid)	150	
R22 (coolant fluid)	150	
Hydrochloric acid (HCl)	120	
Oxygen (O_2)	185 until 50 bar	200 °C acc. EIGA Doc no. IGC

		Doc10/09 § 4.7.3
Silane ($SIHCl_3$)	120 preliminary!	Max allowable 135 °C 2)
Hydrogen (H_2)	165	API 618 clause 6.5.1, defines 135 °C as max predicted adiabatic discharge temperature.
Nitrogen (N_2)	220	
Polypropylene Novolene process	150	Acc. Novolene
Polypropylene (PP)	135	Risk of polymerisation
Carbon dioxide (CO_2)	No process limit	Take special care on condensation.

Notes:

1. The above temperatures are mandatory for the processes mentioned in the comment line.
2. For details of first part refer to intranet-> CEM / Sizing / Gasdaten und Grenzwerte respectively Engineering manual chapter 10.1

Remark: The max. values above are max allowable operating temperatures and are used by sizing during the layout of the compressor. Some of them are only for reference and can be adjusted before or during project execution. The values depend on pressure and operating conditions and have to be verified by the project manager.

Note: Customers have in many cases more stringent limitations that have to be considered.

5.1.2. Compressor Valve Temperatures

If requested by client valve temperature measurement can be included. Evaluation and alarming of differential Valve Temperatures are mandatory for Oxygen compressors only. Such compressors are always without valve unloaders.

Due to different temperatures of actuated and not actuated valves two machine configurations have to be considered: Compressors with valve unloaders and compressors without valve unloaders.

a) Without valve unloaders:

Preferred possibility is to set an alarm on the temperature difference of two valves of the same cylinder. Refer to the memorandum of the ERFA 17.3.1997, see annex 2.

For differential temperature, the alarm shall be 6°K.

b) With valve unloaders:

There is no alarming on valve temperatures. For analysis of valve condition trending of valve temperature has to be considered.

In case of client insisting on valve temperature alarm please define the max allowable temperatures according the values defined in chapter 5.1. To cover the heat generation of the valve (pressure loss) +15 °C shall be added to create the absolute alarm value. Analysis by differential temperature of several valves is not possible

Note: Temperatures for nitrogen case with valve unloaders might be up to 50 °C higher than normal operation if e.g. compressor valve is optimised for hydrogen. In case of valve unloading the temperature can be much higher as during normal operation. This depends on the configuration of the cylinders.

5.1.3. Temperature Monitoring Oxygen Compressors on Valves and Piston Rod Packing/Piston Rod Gland

Nowadays, nearly 70% of all oxygen compressor units are equipped with temperature monitoring for compressor valves and piston rod glands. The temperature monitoring will help to detect valve failures or worn out packing/gland rings in an early stage and scheduling the compressor stop and maintenance work in accordance to the required availability of the machine.
The arrangement, numbering system and evaluation of the valve temperature monitoring shall be done in acc. to annex no. 2 ‘Valve Temp Control Oxygen’.

Following values are recommended:

TAH Piston Rod Packing: 65°C

TAHH Piston Rod Packing: 75°C

Note:

These values have to be adjusted during commissioning. Setting after commissioning: Measured value plus 15°C = TAH, plus 25°C = TAHH

5.2. Process Gas Pressures

Location	Pressure	Type	[bar g]	Comment
Suction	P_{HH}	SD	= P_{DC} + x[2)] bar	If required [1)]
	P_{H}	A	= P_{DC} + y[2)] bar	[1)]
	$P_{Design\ case}$	-		
	P_{L}	A, (I)	= P_{DC} - y[2)] bar	[5)]
	P_{LL}	SD	= P_{DC} - x[2)] bar	If required [3)]
Interstage	P_{HH}	SD	= P_{DC} + x[2)] bar	[6)]
	P_{H}	A	= P_{DC} + y[2)] bar	
	$P_{Design\ case}$	-		
	P_{L}	A	= P_{DC} - y[2)] bar	If required
	P_{LL}	SD	= P_{DC} - x[2)] bar	If required [7)]
Discharge	P_{HH}	SD	= P_{DC} + x[2)] bar	[6)]
	P_{H}	A	= P_{DC} + y[2)] bar	
	$P_{Design\ case}$	-		
	P_{L}	A	= P_{DC} - y[2)] bar	If required
	P_{LL}	SD	= P_{DC} - x[2)] bar	If required [4)]

Pressure ranges (especially suction side) shall be approved by Sizing Department prior setting the limits.

Notes:

1. The higher the suction pressure, the higher is the mass flow and the resulting motor load.
2. Below 20 bar g (respectively when relief valve set pressure is less than 2 bar higher as the rated pressure) y should be approx 40% of the difference between relief valve set pressure and the rated pressure and x = 80%.
   Above 20 bar g y should be approx 33% of the difference between relief valve set pressure and the rated pressure and x = 66%.

   Example: P_{DC} = 10 bar g, P_{SV} = 11 bar g, then P_{H} = 10.4 bar g and P_{HH} =10.8 bar g
3. Necessary if the rod load is critical, in this case a differential pressure alarm and trip is recommended.
4. Sometimes also required to detect a line break in the customer piping.

5. Sometimes necessary to detect failure in the process stream
6. Recommended by BCA, as BCA philosophy requires a trip to avoid activation of PSV.
7. For start-up and stop process better use differential pressure for rodload protection, as p_{LL} has to be supressed during start-up until the pressure is built up.

5.2.1. Differential Pressure Suction Strainer

Sometimes suction strainers are equipped with a differential pressure measurement device. Recommended value is 250 mbar.

Normal pressure loss (clean) is approx. 0.1-0.3 percent of the operating pressure. Allowable pressure drop of the process and collapse pressure of the strainer has to be taken into consideration.

In case there are suction strainers at high pressures and/or high viscosity PEO@Burckhardtcompression.com can do a calculation of the pressure loss over the suction strainer. Based on that result the set point can be set."

5.3. Purge System (Seal Gas and Cooling)

Purge/seal gas (buffer gas) systems are necessary in PL2 compressors, refer to intranet global contracting for details. For single distance pieces the crankcase is purged instead of the distance piece. Other solutions with purged packing also exist.

For Laby® compressors purge system are necessary for dirty gases e.g. PP to avoid contamination and degradation of the lube oil (dilution of gas in oil). Heavy process gas tends to solute into the lube-oil, please consider table in the intranet. For prevention, purge or buffer gas is needed.

For oxygen compressor indoor installation no purge system is required, for outdoor installation in dirty atmosphere purge of distance piece is mandatory.

5.3.1. Piston Rod Packing/Piston Rod Gland Temperatures

Sometimes for oxygen compressors the piston rod gland temperature is measured to ensure low temperature of the piston rod gland and rod (refer to chapter 5.1.3 for details).

For PL2 compressors packing temperature measurement measures only indirectly the temperature and is mainly influenced by the cooling medium temperature. Recommended value is 15 °C above the cooling medium supply temperature.

Attention: For dry running Hydrogen compressor, when leak gas temperature is measured the alarm setting shall be set at 80°C

5.3.2. Buffer and Purge Gas Pressure PL2

Location	Pressure	Type	[bar g]	Comment
Buffer gas supply pressure	P_H	(A)	= optional pressure alarm to	Standard distance piece design pressure value for

			be defined 0.25 – 0.5 bar below crankcase / distance piece design pressure	PL2 is 4 bar g.
Buffer pressure packing	PCV	-	Min 1.0 bar over disposal system pressure	Note [1)] If the backpressure is variable a differential pressure PCV control is recommended to reduce Buffer and purge gas consumption
Buffer pressure packing	$P_{L\ Buffer}$	A, I	0.3 - 0.5 bar below PCV set but in any case above disposal system	
Purge packing	PCV $_{Purge}$	-	0.35 bar above disposal system	
Purge “in outboard”	PCV	-	If routed to flare, set pressure 0.35 – 1.5 above flare pressure, but 0.5 bar below buffer pressure.	Refer to TDO 2052973 and PID 122.354.360 Sheet 3 of 6 (buffer gas pressure to be 1 bar above flare backpressure, see also API 618 fig I-1 and I-2). If necessary due to high flare backpressure the pressure might be set only min 0.5 bar above. 0.5 bar below buffer pressure
Purge “in outboard”	$P_{L\ Purge}$	A, I	0.3 - 0.5 bar below PCV set but in any case above flare pressure	
Buffer intermediate	PCV	-	0.5 bar above	Normally same supply and

packing			purge in outboard	pressure as buffer pressure packing

Notes:

1 HP Leak gas pressure to be considered to set appropriate set and alarm values.

Packing Cooling System

Location	Measuring	Type	[bar g]	Comment
Common packing cooling supply	P_L	I, A	2	Note [1)]
	P_{LL}	SD	1.5	SD req. for dry running PL2, better solution is FLL
Common packing cooling return	F_L	I, A	50%	Of nominal flow
	F_{LL}	SD	30%	SD req. for dry running PL2 (usually SD by temperatures preferred by BCA)

Notes:

1 Approx. 1 bar higher in case cooling oil is used (depending on viscosity).

5.4. Capacity Control

Pressure of N_2 or instrument air (N_2 is mandatory for ATEX) supply for capacity control shall be at least 1.0 bar higher than pressure requested for actuating suction valve unloaders (consider the flare backpressure!). The requested value for opening valve is provided by Sizing department. Consider pressure drop in line between PCV and valve unloaders.

Pay attention for valve unloader for LNG application as bellows are used (back pressure), set pressure is limited at 6 barg maximum.

Installation of a PCV on inlet/instrument board is only required in case of:

- too high gas pressure supply from the client (higher than design pressure of the valve unloaders and the solenoid valves)
- request from the client to provide a PCV

Note: Normal design pressure of solenoid valves is 10 bar g.

Installation of a PSV depends on design pressures and supply pressure.

In case many unloaders are used, foresee an accumulator to have enough pressure available for actuating the unloaders (avoid pressure loss by large flow velocities).

Make sure that the supply line has enough capacity to actuate all unloaders in parallel.

5.5. Oil System

For PL1, PL2 and PL3 one lubricating oil skid for the compressor is required. For PL4 lubricating oil skids for crank gear, cylinder cooling & flushing and cylinder lubrication are needed.

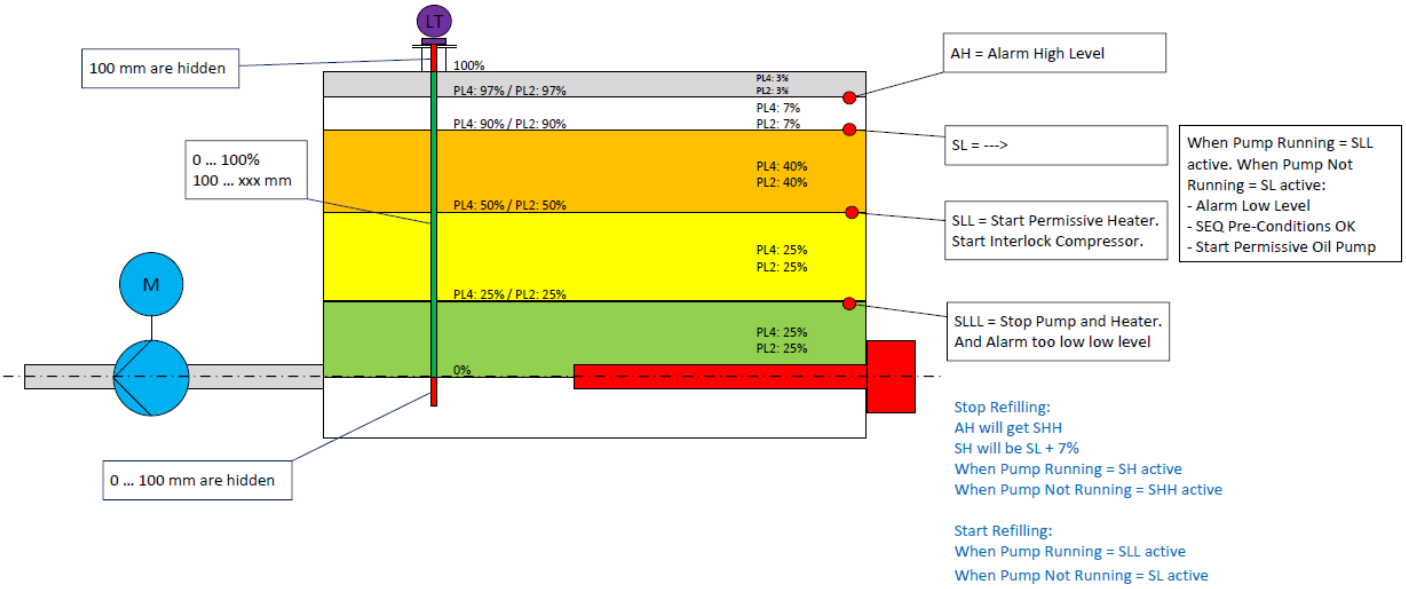
Location	Measuring	Type	[Unit]	Comment
Oil level in the crankcase	SG	-		Sight glass, only visual
Oil level in the crank-case/oil tank	LSL	I		Oil level designed according oil consumption of the system
Oil level in the oil tank (Level Switch)	LSLL	I		Optional Signal for oil heater only
Oil level in the oil tank (level Transmitter) Refer to sketch at end of the chapter for illustration, values to be finetuned on site based on tank and site conditions	EH EL LAH LAL(SL) LAL(SLL) LALL(SLLL)	 I I (SD)	~ 70 % ~ 60 % 97% 90 50% 25%	EH/EL for auto refilling pump, if applicable, only when pump is running recom.filling for startup 95% Start Interlock for LO Pump SI for STBY Pump and Compressor
Oil temperature crank-case/oil tank	TAL EH EL	I	15 °C 25°C 17°C	
Oil temperature compressor inlet	TAH TAHH	A (SD)	55 °C 70 °C	Optional
Oil filter return line to compressor (duplex oil filter)	PDAH	I, A	> = 1.2 bar	Differential pressure over filter. Differential Pressure for clean filter at operation temperature = 0.2 bar Manufacturer recommendation to be

				observed
Oil Pressure PL1 & PL2	PAL PALL	A SD	1.0 (delta bar) 2.0 barg	below min operating pressure for PL 2 refer to TDO2019888 for details
Oil Pressure PL4	PAL PALL	A SD	1.0 (delta bar) 2.0 barg	below min operating pressure
Differential pressure over oilsystem PL1	PDAL PDALL	I SD	2.5 bar 2.0 bar	
Differential pressure over oilsystem PL3	PDAL PDALL	I SD	3.5 bar 2.5 bar	Measured at oil collector outlet (after last bearing supply)
Oil heater on the compressor/oil tank	TSH TSHH	A A	70 °C 100°C	Incl. temperature controller (TC) on the heater Temperature class to be considered (exzone) TSHH heater switch off Heater controller to be set 70°C as second safeguard in case TE controller fails. Setpoint is that high to allow oilflushing on site in case needed

For more details please check the folders with the standard oil skids (Laby® and PL2).

API 618: If required API 618 values has to be considered. Especially the oil pressure has to be higher than the water pressure.

API 614: Only if specially required by client. API 614 is normally excluded by sales.



Note: A level drop of 20-30% can occur after LO Pump start. In case of significant higher or lower level drop LAL and EH/EL might need adjustments during Startup.

5.5.1. Cylinder Lubrication

For lubricated compressors the following timers has to be set:

1. Pre-lubrication timer: To be set to ensure proper lubrication prior to start. (Standard setting: 2 Minutes, to be adjusted on site)
2. Over lubrication timer: A cumulative timer to avoid over lubrication and consequential damage due to liquid knock. (Standard setting: 5 minutes, to be adjusted on site). Reset of over lubrication timer shall be done either by signal 'Motor running' or by manual barring of compressor and operator action of local 'ready for start' button.

For lubricated PL2 and PL3 compressors the following set points have to be considered, based on oil as per (VSB) 1001133:

Location	Measuring	Type	[Unit]	Comment
Either Oil pressure to cylinder (measured at last pump of lubricator)	PALL PAL	(SD), I SI	50% P_{DC} 55% P_{DC}	Timer will start in case of low pressure (PAL): - After 5 min alarm will be indicated - Optional: After additional 30minutes the compressor shall be tripped to avoid mechanical wear. No damages expected because of rod drop sensors. Timer will be reset immediately in case pressure is increasing over set point. Value may be rounded up/down (+/- 3%). P_{DC} = Operating pressure relief valve
or Flow of lubrication oil (measured at last pump of lubricator)	FALL	SD, I	see annex 1	Alternatively, instead of pressure Flow can be used to ensure proper function of lubricator, for details of principle and settings refer to Email J. Ehmer 31.3.2011, see annex 1
Oil temperature oil tank for PL2	TAH	-	55 °C	

	TAL TSH TSL	I, A - -	15 °C 40 °C 25 °C	 Heater Stop Heater Start
Oil temperature oil tank for PL3	TAH TAL TSH TSL	- I, A - -	55 °C 10 °C 40 °C 30 °C	 5°C possible but not recommended Heater Stop Heater Start
Temperature of electrical oil heater		I	70 °C	Interlock only regarding „in operation or not“
Level in tank	LAL	A	Above oil heater	For heater protection only. Trip heater in case of low alarm
Level control in tank for refilling	LSH		80%	OPTIONAL: For control of refilling device if applicable
	LSL		30%	
Flow in N2 blanketing supply to tank	FAL	A	1 m^3/h	OPTIONAL: On client request only, value to be confirmed after tank design

For PL4 the **cylinder lubrication** is running with another combination of components and values, based on oil as per (VSB) 1001134:

Location	**Measuring**	**Type**	**[Unit]**	**Comment**
Temperature of cylinder lubricating tubing	TAH TAL	 I	75 °C 50 °C	
Temperature of electrical air heater	-		50 °C	Interlock only regarding „in operation or not“
Oil pressure	PAL PALL	I SD	x bar x bar	Monitoring pre lubrication, value depending on calculation
Speed Sensor			rpm	
Motor controller	RUN	A	-	Depending on logic of MCC

Oil temperature oil tank	TAH TAL TSH TSL	- I, A - -	80 °C 60 °C 68 °C 62 °C	 Heater Stop Heater Start
Temperature of electrical oil heater		I	75 °C	Interlock only regarding „in operation or not“ Elmess heater set to 70°C (cost reason only)
Oil level in the oil tank	LSLL	I		Signal for oil heater only
Oil level in the oil tank	LSH LSL LAH LAL LALL	 (SD)	90 % 70 % ~ 95% ~ 25% ~ 20%	LSH / LSL for refilling pump, if applicable Depending on length of level transmitter and nozzle locations LL covered by pressure transmitter LO-pump

5.5.2. Hydrostatic Jack-Up Unit

Hydrostatic jack-up unit is used to lift of the crankshaft during maintenance and start up to avoid damage to the first bearing due to additional load from main motor.

Hydrostatic jack-up unit is required for hyper compressors type K with a radial static load >400kN (typically ≥ K10). In case of a F or H-Type to be discussed with CEM.

Design conditions for PL4 hydrostatic jack-up: PSV set: 130 bar g, flow: 4 l/min

For big PL2 the requirement of hydrostatic jack-up unit has to be checked with CEM case by case.

Hydrostatic jack-up compressor	PAL	I	70 bar g	Interlock for start-up and/or maintenance if required Peak detection

5.6. Main Motor

The set points for the main motor have to be given by the main motor supplier. Below values are **typical** values.

Location	Measuring	Type	[Unit]	Comment
Winding temperature phase U, V and W	TE	SD A	HH: 145 °C H: 135 °C	
Bearing temperature NDE and DE side	TE	SD A	HH: 120 °C H: 110 °C	If required
Bearing vibration NDE and DE side	VG	SD A	HH: 11 mm/s H: 7 mm/s	If required
Motor space heater	TAL	A		If required to avoid condensation
Motor bearing oil heater	TAL	A, I	L: 0°C	Only if required
Level switch	LSH	A		If required for water cooled motors
Purge	P_L	I		For Ex p motors only
Cooling water flow	F_L	I, A		If applicable

Hydrostatic jack-up motor pressure	PS	I	Defined by sub-supplier	Interlock for start up and/or maintenance (if required)

5.7. Coolant System

Various coolant systems are requested, depending on the application:

a) - Open coolant system

b) - Semi-closed coolant system

c) - Closed coolant system

Location	Measuring	Type	[Unit]	Comment
Cooling water return from Cylinder/guide bearing PL1	FAL	I, A	50% of nominal flow	Flow transmitters are more flexible.
Cooling water return from Cylinder/Packing PL2	FAL	I, A, (SD)	50% of nominal flow	Dry running compressor even a SD is recommended
Cooling water main return	FAL	I, A	50% of nominal flow	If required

Cooling water flow over heater	FAL	I, A	50% of nominal flow	[1], [2]
Cooling water inlet to crosshead bearing PL1	TAL	I, A	Min15°C	Because of crosshead bearing gap
Cooling water inlet to cylinder	TAL	A	5 °C over gas inlet temperature	[1], [3], [6]
Cooling water outlet from cylinder	TAL	I, A	5 °C over gas inlet temperature	If applicable instead of inlet temperature measurement see note [6]
Cooling water inlet to compressor	PAL	A	1.0 bar g	[1] If required [4]
Open CW tank	LAL	I, A,		Level above heater and tank outlet [5]

Notes:

1. In semi closed and closed coolant system with heater
2. If no flow is over the heater, heater can't be started. In some cases, heater is provided with a level switch for the same purpose
3. In case of risk of gas condensation in the cylinder, API 5th edition para 6.8.3.4.3 requires coolant inlet temperature min. 5 °C higher than gas inlet temperature.
4. In case of low pressure start of second pump. Pressure depends on project condition (eg. bladder accumulator, open tank, location of cw skid …)
5. Required only for open cw tank to ensure heater function and avoid gas in the coolant system
6. Instead of the inlet temperature it is BCA philosophy to monitor the outlet temperature to be sure that the cylinder is heated up and that the heat radiation is not bigger than the heat of the coolant supplied.

5.8. Instruments on Compressor (Vibration, Rod Monitoring and Stuffing Box Temperatures)

Note: For vibration instruments please also refer to annex 8.3

5.8.1. Laby, Process, Laby-GI (PL1, PL2, PL3)

Location	Measuring	Type	[Unit]	Comment
Compressor main bearing temperature	TAH	A	65 °C	1) 8)
	TAHH	SD	70 ° C	SD: MAX. 80 °C to avoid damage to the white metal layers
Pin Bearing temperature	TAH	A	65°C	Option: Kongsberg / AMOT 1)
	TAHH	SD	70° C	SD: MAX. 80 °C to avoid damage to the white metal layers
Crosshead temperatures	TAH	A	65 °C	1)
	TAHH	SD	70 ° C	SD: MAX. 80 °C to avoid damage to the white metal layers
Frame vibration (PL2)	VAH	A	6 mm/s RMS 4)	To be finally adjusted during commissioning on site, but shall never exceed these values 2)
	VAHH	SD	8 mm/s RMS 4)	
Frame vibration (PL1 and PL3)	VAH	A	3g Peak 3)	For use with 4 – 20mA transmitter (e.g. Holthausen) only. For protection systems equipped with accelerometers on the crossheads refer to PL2 above. To be finally adjusted during commissioning on site, but shall never exceed these values
	VAHH	SD	4g Peak 3)	
Crosshead vibration	VAH	A	40 m/s² (4g) 2)	To be finally adjusted during commissioning on site, but shall never exceed these values
	VAHH	SD	60 m/s² (6g) 2)	

Cylinder vibration	(VAH)	(A)	Max. allowed 13 mm/s RMS [2) 4) 5)]	SD must be avoided because of practical reasons. Only on special client request! [5)]
Rod position [7)] (PL2)	ZXAH	A	[2) 6)]	For set-points refer to document "Piston Rod Monitoring" [6)]
	ZXAHH	SD	[2) 6)]	
Rider Ring Wear Monitoring [7)] (PL2)	ZXAH	A	[2) 6)]	Absolute distance signal to be trended in DCS. Alarm generation in DCS. For details on implementation refer to document “Compressor Control Description” and for set-points refer to document "Piston Rod Monitoring" [6)]

5.8.2. Hyper (PL4)

Location	Measuring	Type	[Unit]	Comment
Compressor main bearing temperature	TAH	A	75 °C	9)
	TAHH	SD	80 ° C	Max 85°C [10)]
Pin Bearing temperature	TAH	A	85°C	Option: Kongsberg / AMOT [1)]
	TAHH	SD	90° C	
Intermediate crosshead temperatures	TAH	A	75 °C	
	TAHH	SD	80 ° C	
Plunger temperatures	TAH	A	70°C	Common standard values
	TAHH	SD	75°C	
	TAL	A	10°C	
Crosshead frame	TAH	A	75 °C	

plate temperature	TAHH	SD	80 ° C	
Frame vibration	VAH	A	10 mm/s RMS [4]	To be finally adjusted during commissioning on site, but shall never exceed these values [2]
	VAHH	SD	12 mm/s RMS [4]	
Crosshead vibration	VAH	A	40 m/s² (4g) [2]	To be finally adjusted during commissioning on site, but shall never exceed these values
	VAHH	SD	60 m/s² (6g) [2])	
Cylinder vibration	(VAH)	(A)	Max. allowed 13 mm/s RMS [2] [4] [5]	SD must be avoided because of practical reasons. Only on special client request! [5]
Plunger vibration (K-Type)	ZXAH	A	200 µm	peak to peak [2]
	ZXAHH	SD	400 µm	
	ZYAH	A	200 µm	
	ZYAHH	SD	400 µm	
Plunger vibration (F-Type)	ZXAH	A	150 µm	peak to peak [2]
	ZXAHH	SD	250 µm	
	ZYAH	A	150 µm	
	ZYAHH	SD	250 µm	
Plunger: GAP measurement	ZAH	A	500 µm	Absolute distance, 2oo2 voted [2] To ensure to detect as loss of plunger immediately, to avoid consequential damage.
	ZAHH	SD	700 µm	

Notes:

1. Alarm 20 °C above normal lubricating oil operating temperature
2. For detailed information about frequency ranges, type of measurements, time settings etc. for different protection systems refer to annex 8.3 . Type of measurement peak or RMS depends on MMS Supplier and Instrumentation.
3. According API618 5th edition mechanical vibrations switches like Robertshaw® are unacceptable. In case no protection system (Prognost / Bently) is installed, only a BC customized 4-20mA transmitter type “Holthausen” must be used. Other vibration

protection solutions (other transmitter brands, impact counters etc.) are generally not recommended by BC. In case customers insist on an own solution, it must be tested and approved by the R&D department!

4. For additional information refer to KV 4031
5. If applicable, vibration on cylinders is normally measured as acceleration and used for valve and other diagnostics inside the monitoring system, but not for alarm and never for shutdown inside the protection system.
6. Refer to project specific document created by the I&C and CEM department
7. The classical Rod-Drop measurement according API 618 / API 670 has shown not to be reliable in every application. Use the Rod-Position and Rider Ring Wear measurement instead. Use the classical Rod Drop measurement only upon special client request!
8. In the case where the temperature measurement probe is installed on the lower half of the bearing (currently BC & BE type), significantly higher temperatures (about 10K) may be observed during startup due to friction and oil film buildup. Also, oil sensors in the lower part have a copper piece between bearing half and Sensor for faster temperature sensing. Temperature sensors in upper half are spring-loaded pressed against the bearing. After some minutes the bearing shell temperature is aligned independent of the measuring point. Setpoints may need to be reviewed and adjusted accordingly, however not exceeding the design limit of the bearing itself.
9. Please note that first bearing on DE side has to bear motor load in case of one bearing motors (normally only for large motors), thus it is normal that first bearing can show 5-10°C higher temperature than the other bearings.
10. In case of single bearing motors and when bearing temperature of first DE bearing show stable temperatures and crank deflection has been checked, then temperature for Shutdown and alarm can be increased. Max value for Trip allowed is then 85°C.

6. Summary

This document gives an overview of common used set points. In any case the project manager has to review the specialities of each project (e.g. pressure, temperature, gas composition) to define the set points of his project.

7. Reference Documents

- TDO 2023990 White Book Oxygen (O2) - Contracting
- KV 4031 Vibration allowable at compressors on rigid foundation acc DIN ISO 10816-6 (VDI 3838)

- VBCA546007 Protection against over-pressurisation of BCA secondary compressors
- EIGA Doc IGC DOC10-09
- API 618 fifth edition
- PROGNOST® SILver alarm Standardeinstellungen (confidential)
- Piston rod monitoring parameter sheet: SAP ZVL template “TDO_BER_ZYL_UEB”

8. Annex

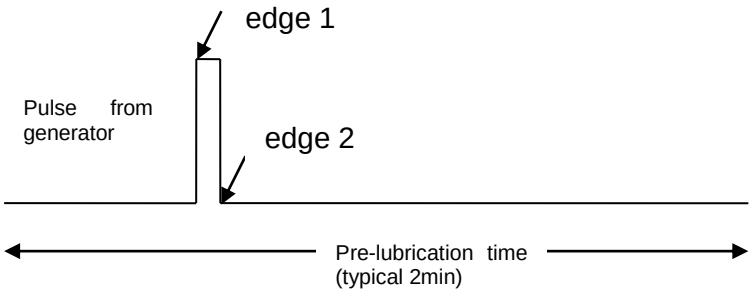
8.1. Annex 1: Email BCA-Borouge Cylinder Lubrication Problem 2000842

Project No. 2000842, Comp. s/n 200086/7

Start up:

The function of the LALL 2507 has to be overridden during the pre and over lubrication time.
The function of the LAL 2507 has to be overridden during the pre and over lubrication time.
The function of the LAH 2507 has to be overridden during the pre and over lubrication time.

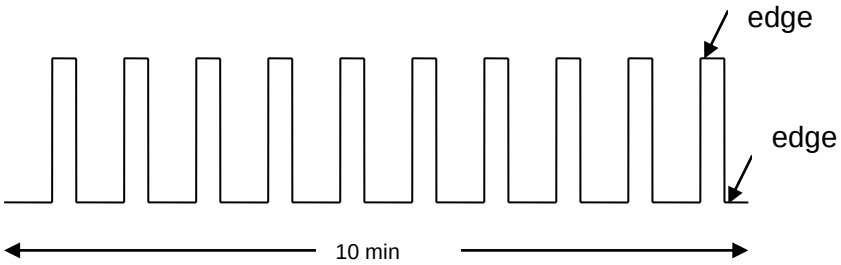
Start Interlock: min. 2 edges (Pulses) during the pre-lubrication time (KI2503) from the FS 2507



During main motor is running:

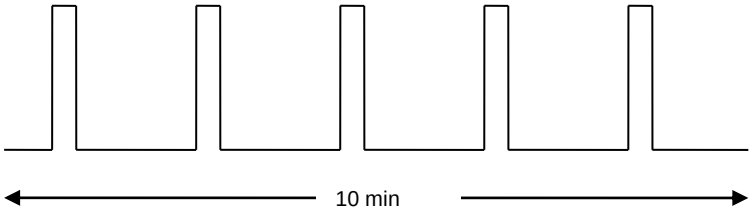
Operating value:

Counting of 20 edges (pulses) in 10 min
Counting start is with the motor start

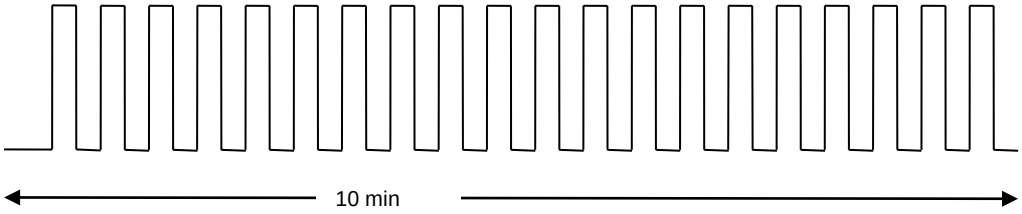


Alarm:

LAL: Counting of ≤ 15 edges (pulses) in 10 min
Counting start is with the motor start



LAH: Counting of ≥ 40 edges (pulses) in 10 min
Counting start is with the motor start



Shut down:

LALL 2507: Counting of 10 edges (pulses) in 10 min
Counting start is with the motor start. If it will count ≤ 10 edges (pulses) after 10 minutes counting, the compression will shout down.

8.2. Annex no. 2 Valve Temperature Control Oxygen

Valve Temperature Control for Oxygen Compressors

4D225B-2D_1 SUMITOMO FENG HSIN

Burckhardt Compression

File name, 01/27/2005
Page 1 of total pages

GENERAL

- Valve temperature control is recommended for Oxygen service compressors
- Allows early indication of valve failure – avoiding serious compressor damage and burning
- BCA established special valve temperature control standard philosophy in 1997 after heavy compressor damage on machine in spite of existing valve control!

BCA valve temperature control philosphy

- History:

  Even if a valve control sytem was installed to the machine by the client, in 1997 heavy compressor damage occured to 4D300 Oxygen compressor installed in Germany.

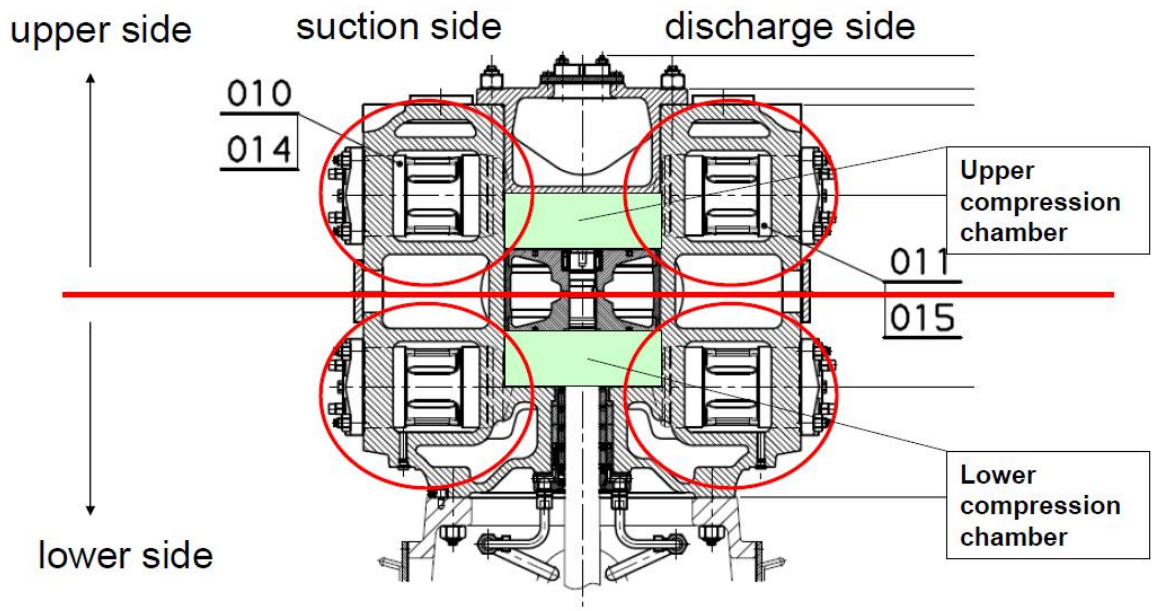
- What happened:

  Temperature difference was measured of all valves installed to individual suction and discharge side of cylinder. So, the damage of only one valve was not detected since the differential temperature of all 4 valves installed did not increase above alarm set point.

- Conclusion:

  Installed system programming was not reliable! Only the temperature difference between one upper and one lower valve must be compared!

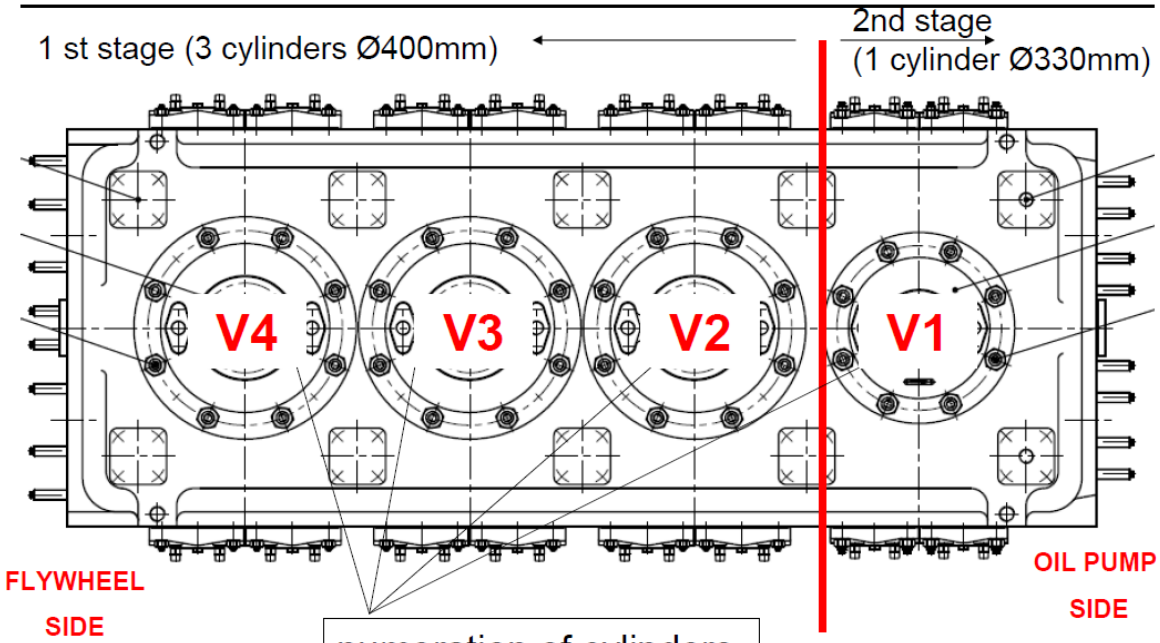
CYLINDER BLOCK 4D225B-2D_1 – SECTIONAL VIEW (FRONT)



Burckhardt Compression

File name, 01/27/2005
Page 4 of total pages

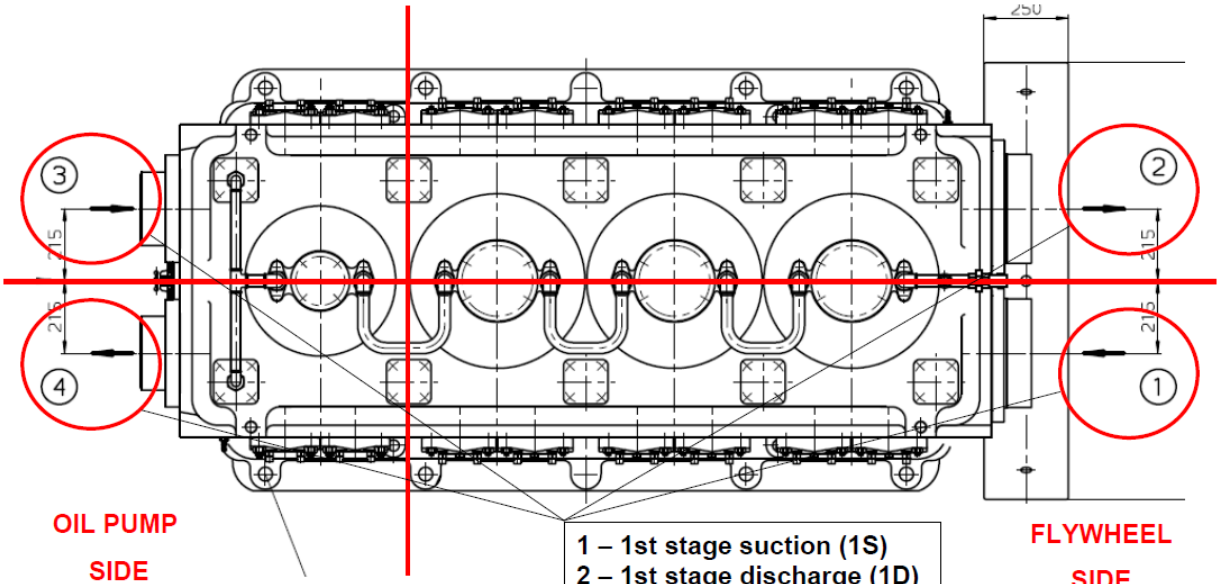
CYLINDER BLOCK 4D225B-2D_1 – TOP VIEW



Burckhardt Compression

File name, 01/27/2005
Page 5 of total pages

COMPRESSOR 4D225B-2D_1 – TOP VIEW



Burckhardt Compression

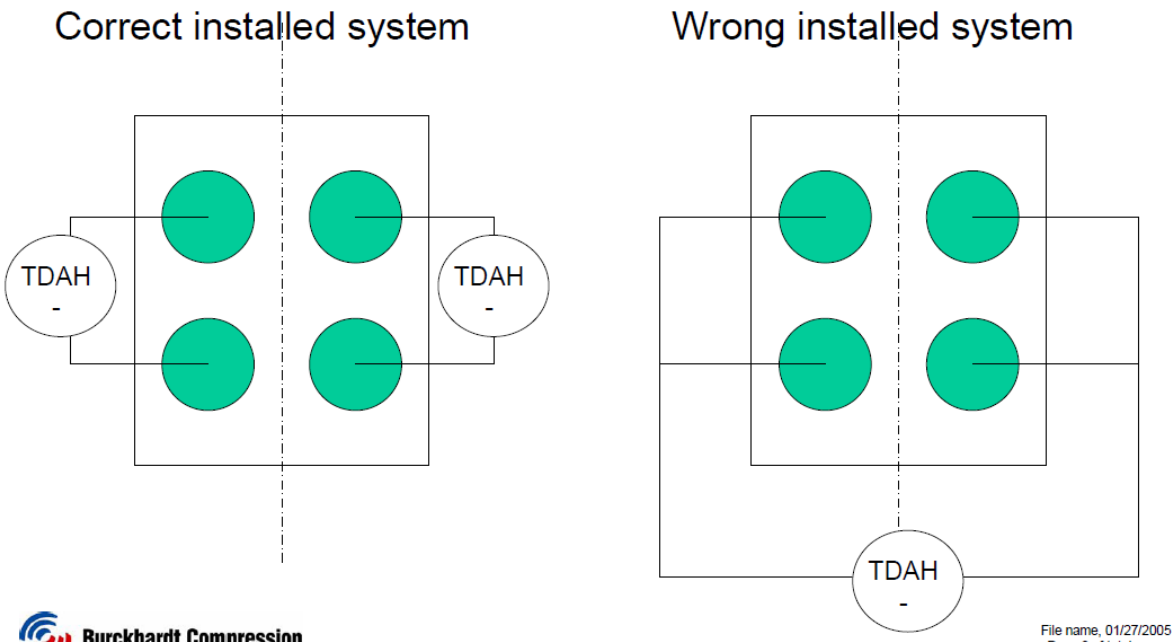
File name, 01/27/2005
Page 6 of total pages

COMPRESSOR 4D225B-2D_1 – DESIGN FEATURES

- **Totally 32 valves installed**
  - **12 suction + 12 discharge valves 1st stage (4 each cylinder, 2 each compression chamber)**
  - **4 suction + 4 discharge valves 2nd stage (4 each cylinder, 2 each compression chamber)**

Burckhardt Compression

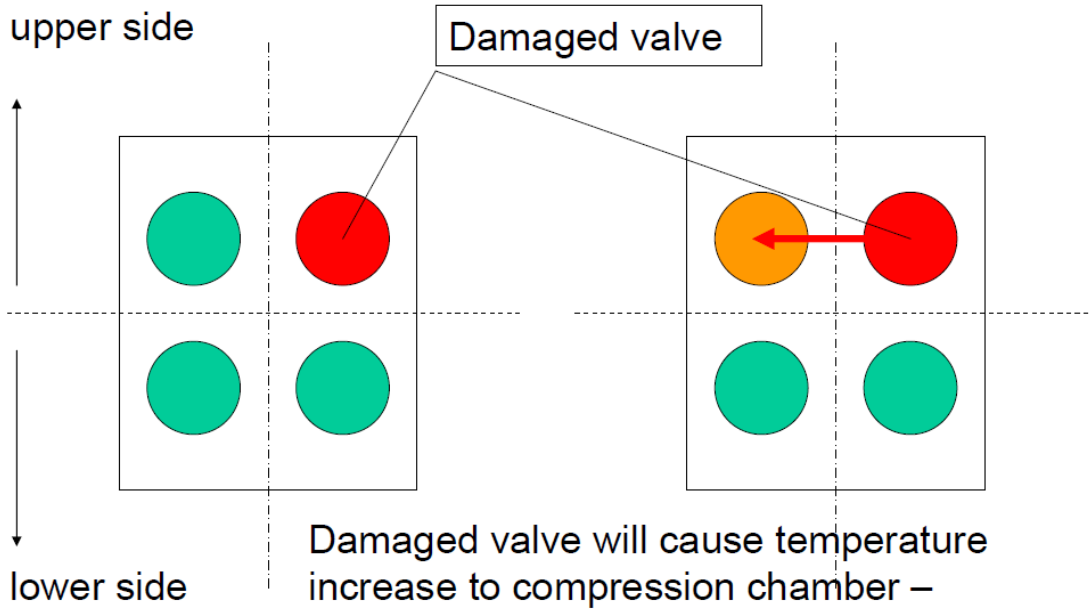
BCA valve temperature control philosphy



Burckhardt Compression

File name, 01/27/2005
Page 8 of total pages

BCA valve temperature control philosphy



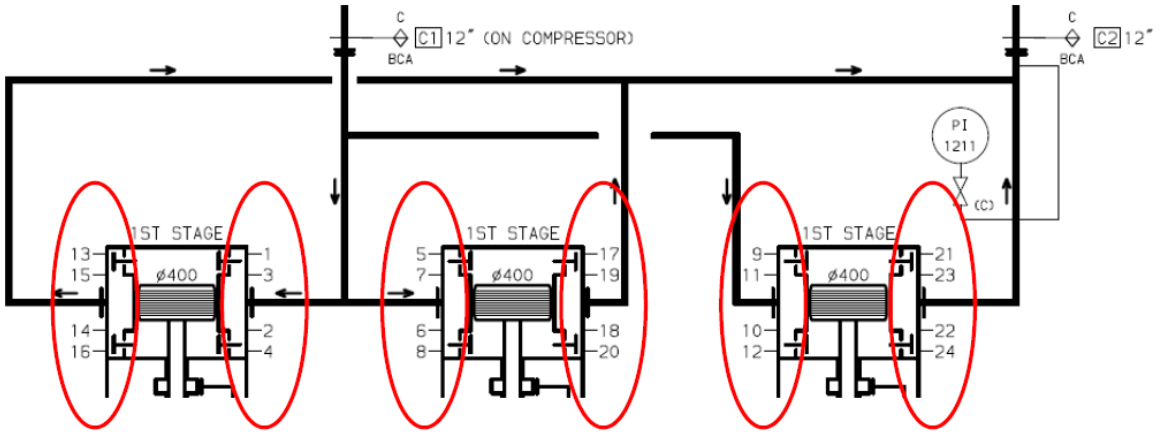
Damaged valve will cause temperature increase to compression chamber – respectively also to valve next beside

Burckhardt Compression

File name, 01/27/2005
Page 9 of total pages

NUMBERING SYSTEM FOR VALVES

The numberbing system is indicated on the P&ID GAS SYSTEM



NUMBERING SYSTEM FOR VALVES

Philosophy for numbering system:

- **Odd numbers for upper valves (1, 3, 5, 7, 9, 11 …)**
- **Even numbers for lower valves (2, 4, 6, 8, 10 …)**
- **Numeration of valves follows the gas flow – from 1st stage suction to 1st stage discharge and 2nd stage suction to 2nd stage discharge etc.**
- **For each single stage, direction of numbering is from driven side (flywheel) to oil pump side of compressor**

8.3. Annex no. 3 Instrumentation on compressor

For mounting positions refer to

PL1 TDO 2018470

PL2 TDO 2018473

PL4 TDO 2018474

Note: These documents are partly outdated and will eventually be superseded by TDO 2044699

Minimum vibration sensors on compressor WITHOUT protection system			
Laby	*Type of Measurement*	*Standard Delivery Set-Points[1)]*	*Remark*
Frame vibration	Acceleration (Peak) Signal: 4…20mA Range: 0..10g Band width (-3 dB) 2…2000Hz Signal conditioning Peak, decay time 0,08s Average over low-pass filter 0,36Hz	Alarm : 3g Shut-Down : 4g	Only BC customized transmitter type “Holthausen/Hauber” must be used
Crosshead vibration[2)]	See frame vibration[2)]		
Process compressor	N/A: Protection system for process compressor mandatory, open if mandatory as well for vertical process gas compressors		
Hyper	N/A: Protection system for hyper compressor mandatory		

Notes:

1. These values represent the maximum allowable values. Values shall be lowered during commissioning if possible.
2. Although the acceleration transmitter is mounted on a crosshead slide we still use the term "frame vibration" to avoid lengthy discussions with customers. Only in case there are additional velocity transmitters mounted on the upper frame (below the cylinders) we distinguish between frame- and crosshead vibration.

Minimum vibration sensors on compressor <u>WITH protection system</u> ➔ Prognost SILver System			
Laby	*Type of Measurement*	*Standard Delivery Set-Points [1)]*	*Remark*
Frame vibration valid speed	<u>Velocity:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> 6 mm/s during 3 turns <u>Shut-Down :</u> 8 mm/s during 5 turns	
Frame vibration invalid speed [3)]	<u>Velocity:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> 6 mm/s during…see [3)] <u>Shut-Down :</u> 8 mm/s during…see [3)]	Only in case no trigger signal available [3)]
Crosshead vibration valid speed	<u>Acceleration:</u> RMS 36 Segment[2)] <u>Signal:</u> mV	<u>Alarm :</u> **2** seg. over 6 g during 3 turns <u>Shut-Down</u>: **4** seg. over 6 g during 5 turns	
Crosshead vibration invalid speed [3)]	<u>Acceleration:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> 4g during…see [3)] <u>Shut-Down :</u> 6g during…see [3)]	Only in case no trigger signal available [3)]
Cylinder vibration valid speed (option)	<u>Acceleration:</u> RMS 36 Segment[2)] <u>Signal:</u> mV	<u>Alarm :</u> '- [4)] <u>Shut-Down</u>: '- [4)]	
Cylinder vibration invalid speed [3)] (option)	<u>Acceleration:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> '- [4)] <u>Shut-Down</u>: '- [4)]	Only in case no trigger signal available [3)]

Trigger *(Key Phasor)*	Pulse Signal: Digital (NAMUR)	N/A	

1. These values represent the maximum allowable values. Values shall be lowered during commissioning if possible.
2. At the time of delivery all segments are set to the same set-point. After commissioning the segments have to be adjusted by a specialized Prognost engineer (not in scope of BCAG!)
3. If for some reason no trigger signal is present the set-points for “invalid speed” take effect. Instead of the actual speed a predefined speed-value is applied (parameter “minimum analysis speed”). The time base for the analysis is then equal to 60[s] divided by “minimum analysis speed” [rpm]
4. Only on client request a value will be set during commissioning with PSG based on measured values with a factor for margin

Minimum vibration sensors on compressor <u>WITH protection system</u> ➔ Prognost SILver System			
Process compressor	*Type of Measurement*	*Standard Delivery Set-Points [1)]*	*Remark*
Frame vibration valid speed	<u>Velocity:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> 6 mm/s during 3 turns <u>Shut-Down :</u> 8 mm/s during 5 turns	
Frame vibration invalid speed [3)]	<u>Velocity:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> 6 mm/s during …see [3)] <u>Shut-Down :</u> 8 mm/s during …see [3)]	Only in case no trigger signal available [3)]
Crosshead vibration valid speed	<u>Acceleration:</u> RMS 36 Segment [2)] <u>Signal:</u> mV	<u>Alarm :</u> **2** seg. over 6 g during 3 turns <u>Shut-Down</u>: **4** seg. over 6 g during 5 turns	
Crosshead vibration invalid speed [3)]	<u>Acceleration:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> 4g during …see [3)] <u>Shut-Down :</u> 6g during …see [3)]	Only in case no trigger signal available [3)]
Cylinder vibration valid speed (option)	<u>Acceleration:</u> RMS 36 Segment[2)] <u>Signal:</u> mV	<u>Alarm :</u> '- [4)] <u>Shut-Down</u>: '- [4)]	
Cylinder vibration invalid speed [3)] (option)	<u>Acceleration:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> '- [4)] <u>Shut-Down</u>: '- [4)]	Only in case no trigger signal available [3)]

Rod-Position valid speed	Distance relative: PeakToPeak 8 Segment [2]	Alarm: 1 segment [2] over set-point [5] during 10 turns Shut-Down: 1 segment [2] over set-point [5] during 20 turns	
Rod-Position invalid speed [3]	Distance relative: PeakToPeak 1	Alarm / Shut-Down: Over set-point [5] during …see [3]	Only in case no trigger signal available [3] Not recommended for vertical compressors.
Rider Ring Wear Monitoring in DCS	Absolute distance trend calculated in DCS from the gap-voltage signal	For set-points refer to the project specific document “Piston Rod Monitoring”	Gap voltage signal transmitted to DCS by serial link from the Prognost SILver system Not recommended for vertical compressors.
Trigger (Key Phasor)	Pulse (rpm) Signal: Digital (NAMUR)	N/A	

Notes:

1. These values represent the maximum allowable values. Values shall be lowered during commissioning if possible.
2. At the time of delivery all segments are set to the same set-point. After commissioning the segments have to be adjusted by a specialized Prognost engineer (not in scope of BCAG!)
3. If for some reason no trigger signal is present the set-points for “invalid speed” take effect. Instead of the actual speed a predefined speed-value is applied (parameter “minimum analysis speed”). The time base for the analysis is then equal to 60[s] divided by “minimum analysis speed” [rpm]
4. Only on client request a value will be set during commissioning with PSG based on measured values with a factor for margin
5. For set-points refer to the project specific document “Piston Rod Monitoring” created by the I&C and CEM department.
6. For set points refer to Prognost Setpoint list stored in SAP. Prognost will define initial values for startup. Values might be adapted during commissioning.

Minimum vibration sensors on compressor <u>WITH protection system</u> ➔ Prognost SILver System			
Hyper	*Type of Measurement*	*Standard Delivery Set-Points [1)]*	*Remark*
Frame vibration valid speed	<u>Velocity:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> 10 mm/s during 3 turns <u>Shut-Down :</u> 12 mm/s during 5 turns	
Frame vibration invalid speed [5)]	<u>Velocity:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> 10 mm/s during …see [5)] <u>Shut-Down :</u> 12 mm/s during …see [5)]	Only in case no trigger signal available [5)]
Crosshead vibration valid speed	<u>Acceleration:</u> RMS 36 Segment [2)] <u>Signal:</u> mV	<u>Alarm :</u> **2** seg. over 6 g during 3 turns <u>Shut-Down</u>: **4** seg. over 6 g during 5 turns	
Crosshead vibration invalid speed [5)]	<u>Acceleration:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> 4g during …see [5)] <u>Shut-Down :</u> 6g during …see [5)]	Only in case no trigger signal available [5)]
Cylinder vibration valid speed (option)	<u>Acceleration:</u> RMS 36 Segment[2)] <u>Signal:</u> mV	<u>Alarm :</u> '- [6)] <u>Shut-Down</u>: '- [6)]	
Cylinder vibration invalid speed [3)] (option)	<u>Acceleration:</u> RMS1 <u>Signal:</u> mV	<u>Alarm :</u> '- [6)] <u>Shut-Down</u>: '- [6)]	Only in case no trigger signal available [5)]

Plunger-Vibration valid speed	Distance relative: PeakToPeak1 Signal: mV	Alarm: F-type: 150um during 2 turns [3)] K-type: 200um during 2 turns [3)] Shut-Down: F-type: 250um during 2 turns [3)] K-type: 400um during 2 turns [3)]	
Plunger-Vibration invalid speed	Distance relative: PeakToPeak1 Signal: mV	Alarm: F-type: 150um during …see [5)] K-type: 200um during …see [5)] Shut-Down: F-type: 250um during …see [5)] K-type: 400um during …see [5)]	Only in case no trigger signal available [5)]
Plunger-Gap valid speed	Distance absolute: Average 1, 2oo2 voting with X and Y sensor. Signal: mV	Alarm: [4)] 400um during 2 turns Shut-Down: 500um during 2 turns	
Plunger-Gap invalid speed	Distance absolute: Average 1, 2oo2 voting with X and Y sensor. Signal: mV	Alarm: [4)] 400um during …see [5)] Shut-Down: 500um during …see [5)]	Only in case no trigger signal available [5)]
Trigger (Key Phasor)	Pulse (rpm) Signal: Digital (NAMUR)	N/A	

Notes:

1. These values represent the maximum allowable values. Values shall be lowered during commissioning if possible.

2. At the time of delivery all segments are set to the same set-point. After commissioning the segments have to be adjusted by a specialized Prognost engineer (not in scope of BCAG!)
3. Because two turns is a requirement from the plunger GAP measurement and it is not possible to set different values for plunger vibration and plunger GAP measurement.
4. An alarm setpoint for the plunger GAP measurement makes not much sense. However, to avoid discussions with the customer we set an alarm value anyway.
5. If for some reason no trigger signal is present the set-points for “invalid speed” take effect. Instead of the actual speed a predefined speed-value is applied (parameter “minimum analysis speed”). The time base for the analysis is then equal to 60[s] divided by “minimum analysis speed” [rpm]
6. Only on client request a value will be set during commissioning based on measured values with a factor for margin

Minimum vibration sensors on compressor <u>WITH protection system</u> ➔ **Bently 3500 System**			
Laby	*Type of Measurement*	*Standard Delivery Set-Points* [1)]	*Remark*
Frame vibration	<u>Velocity:</u> RMS <u>Signal:</u> mV, Low-Pass filter 1kHz	<u>Alarm:</u> 6 mm/s during 3s <u>Shut-Down:</u> 8 mm/s during 100ms	
Crosshead vibration	<u>Acceleration:</u> Peak Impulse Acceleration <u>Signal:</u> mV, Low-Pass filter 2kHz	<u>Alarm:</u> 4 g during 3s <u>Shut-Down:</u> 6 g during 100ms	
Cylinder vibration valid speed	<u>Acceleration:</u> Peak Impulse Acceleration <u>Signal:</u> mV, Low-Pass filter 2kHz	<u>Alarm :</u> '- [2)] <u>Shut-Down</u>: '- [2)]	Initial value shall be determined and adjusted during commissioning with compressor running [3)]
Trigger (Key Phasor)	<u>Pulse (rpm)</u> <u>Signal:</u> Proxy (mV)	N/A	

Notes

1. These values represent the maximum allowable values. Values shall be lowered during commissioning if possible by a specialized Bently Nevada Engineer (not in scope of BCAG!).

2. Only on client request a value will be set during commissioning based on measured values with a factor for margin
3. Alarm value: 1.5-2.0 x determined cylinder vibration initial value.
   Shutdown value: Not recommended to be used by Bently and BC.

Minimum vibration sensors on compressor <u>WITH protection system</u> ➔ Bently 3500 System			
Process compressor	*Type of Measurement*	*Standard Delivery Set-Points [1)]*	*Remark*
Frame vibration	<u>Velocity:</u> RMS <u>Signal:</u> mV, Low-Pass filter 1kHz	<u>Alarm:</u> 6 mm/s during 3s <u>Shut-Down:</u> 8 mm/s during 100ms	
Crosshead vibration	<u>Acceleration:</u> Peak Impulse Acceleration <u>Signal:</u> mV, Low-Pass filter 2kHz	<u>Alarm:</u> 4 g during 3s <u>Shut-Down:</u> 6 g during 100ms	
Cylinder vibration valid speed	<u>Acceleration:</u> Peak Impulse Acceleration <u>Signal:</u> mV, Low-Pass filter 2kHz	<u>Alarm :</u> '- [4)] <u>Shut-Down</u>: '- [4)]	Initial value shall be determined and adjusted during commissioning with compressor running [5)]
Rod-Position	<u>Distance relative:</u> PeakToPeak <u>Signal:</u> mV	<u>Alarm:</u> Over set-point [2)] during 3s <u>Shut-Down:</u> Over set-point [2)] during 1s [3)]	Recommended values from Bently Nevada [6) 7)] Not recommended for vertical compressors.
Rider Ring Wear	<u>Distance relative:</u>	<u>Alarm:</u>	Not recommended for vertical

Monitoring	Position magnitude Signal: mV	Over set-point [2] during 3s Shut-Down: N.A.	compressors.
Trigger *(Key Phasor)*	Pulse (rpm) Signal: Proxy (mV	N/A	

Notes:

1. These values represent the maximum allowable values. Values shall be lowered during commissioning if possible by a specialized Bently Nevada Engineer (not in scope of BCAG!).
2. For set-points refer to the project specific document “Piston Rod Monitoring” created by the I&C and CEM department.
3. It’s 1s because 100ms is for this measurement not selectable in the Bently system
4. Only on client request a value will be set during commissioning based on measured values with a factor for margin
5. Alarmvalue: 1.5-2.0 x determined cylinder vibration initial value.
   Shutdown value: Not recommended to be used by Bently and BC.
6. Alarmvalue: 1.8-2.0 x determined Piston rod vibration initial value.
   Shutdown value: 2.2-2.5 x determined Piston rod vibration initial value.
7. Alarmvalue:
   - BA: Piston diameter <=500mm: 500µm
   - BA: Piston diameter >500mm, <=850: 950µm
   - BA: Piston diameter >850mm: 1600µm
   - BX: Piston diameter <=500mm: 500µm
   - BX: Piston diameter >500mm: 1800µm
   - All others: 500 µm

   Shutdownvalue:
   - BA: Piston diameter <=500mm: 650µm
   - BA: Piston diameter >500mm, <=850: 1300µm
   - BA: Piston diameter >850mm: 2200µm
   - BX: Piston diameter <=500mm: 650µm
   - BX: Piston diameter >500mm: 2000µm
   - All others: 650 µm

Minimum vibration sensors on compressor <u>WITH protection system</u> ➔ Bently 3500 System			
Hyper	*Type of Measurement*	*Standard Delivery Set-Points* [1)]	*Remark*
Frame vibration	<u>Velocity:</u> RMS <u>Signal:</u> mV, Low-Pass filter 1kHz	<u>Alarm:</u> 10 mm/s during 3s <u>Shut-Down:</u> 12 mm/s during 100ms	
Crosshead vibration	<u>Acceleration:</u> Peak Impulse Acceleration <u>Signal:</u> mV, Low-Pass filter 2kHz	<u>Alarm:</u> 4 g during 3s <u>Shut-Down:</u> 6 g during 100ms	
Cylinder vibration valid speed	<u>Acceleration:</u> Peak Impulse Acceleration <u>Signal:</u> mV, Low-Pass filter 2kHz	<u>Alarm :</u> '- [3)] <u>Shut-Down</u>: '- [3)]	Initial value shall be determined and adjusted during commissioning with compressor running [4)]
Plunger-Vibration	<u>Distance relative:</u> PeakToPeak <u>Signal:</u> mV	<u>Alarm:</u> F-type: 150um during 3s K-type: 200um during 3s <u>Shut-Down:</u> F-type: 250um during 100ms K-type: 400um during 100ms	
Plunger-Gap	<u>Distance absolute:</u>	<u>Alarm:</u>[2)]	

	Average, 2oo2 voting with X and Y sensor. Signal: mV	400um during 3s Shut-Down: X/Y channels both with “out of range” signal during 100ms	
Trigger (Key Phasor)	Pulse (rpm) Signal: Proxy (mV	N/A	

Notes:

1. These values represent the maximum allowable values. Values shall be lowered during commissioning if possible by a specialized Bently Nevada Engineer (not in scope of BCAG!).
2. An alarm set-point for the plunger GAP measurement makes not much sense. However, to avoid discussions with the customer we set an alarm value anyway.
3. Only on client request a value will be set during commissioning based on measured values with a factor for margin
4. Alarmvalue: 1.5-2.0 x determined cylinder vibration initial value.
   Shutdown value: Not recommended to be used by Bently Nevada and BC.