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Revision E in Purple: general revision

1 Scope of document

This document defines the principles of cooling water systems for typical cooling applications for BC compressors. It provides necessary guidelines to use BC standard specifications for cooling water systems and helps to deal with Client requirements. This document is not mandatory but shall be used as guideline for selection or specifying the cooling water system. Deviation from this document may be required on case to case basis depending on Customer specifications and availabilities.

2 Basics of cooling water system

Cooling water systems are applied in BC compressor plants for cooling the compressor and various auxiliaries. Cooling water systems are primarily used in BC compressor plants as open, closed or semi-closed cooling systems.

Following paragraphs detail some of the guidelines useful in specifying and selecting cooling water systems and skids.

2.1 Purpose of cooling system

The purpose of the compressor cooling water system is to supply coolant for cooling of following items:

- Compressor cylinders / piston rod packing.
- Compressor guide bearings.
- Compressor crossheads.
- Gas interstage- / after- coolers.
- Compressor thermal barrier (low temperature applications).
- Lube oil (external cooler).
- Main motor-cooling.
-

In addition to the above, coolant systems are often used:

- To heat up components in compressor plant prior to start up.
- To maintain a minimum temperature during standby of the compressor or prior to start-up.

2.2 Selection of a cooling system

Following criteria must be consider selecting the cooling water system:
- Availability of fresh water / plant cooling
- Risk of condensate
- Risk of Freezing
- Water Quality on-site

This paragraph describes the criteria for selection of the different cooling systems.

2.2.1 Fresh / open cooling water system

Recommended for all plants where:
- When sufficient fresh water / plant cooling medium capacity is available.
- No risk of gas condensation exists in any of the coolant consumers.
- No risk of freezing of the water / plant cooling medium exists.
- Water / plant cooling medium quality is good.
- Water / plant cooling medium feed will during start-up and operation always be above the required minimum temperature of 15°C (required for crosshead and guide bearing of Laby compressors).

2.2.2 Semi-closed cooling water system

Recommended for all plants where:
- Sufficient fresh water / plant cooling medium capacity is available.
- One or several of the consumers need warm coolant to avoid condensation, e.g. PE / PP plants.
- The minimum required water / plant cooling medium feed temperature of 15°C (required for crosshead and guide bearing of Laby compressors) cannot be guaranteed otherwise.
- Water / plant cooling medium quality is good

2.2.3 Closed cooling water system

Recommended for all plants where:

- A risk of freezing exists.
- No plant cooling system or not sufficient capacity is available at the installation site (mostly the case for BOG-LNG compressors).
- Quality of water / plant cooling medium is not sufficient.

A selection table for coolant system type is available TDO2054222 (Extension to White Book Coolant Systems, Standard Coolant Skids). BC standard coolant skids are described there(D).

Two separate or more cooling water systems for cooling the gas stream, compressor and accessories are possible in a single plant depending on the specific process demand. E.g. the compressor could

be cooled with a closed cooling system and auxiliaries could be looped in an open system, or the compressor in closed system, one of the gas coolers in semi closed system and the rest of the consumers in open system.
***IMPORTANT**: In any system, if one of the components requires warm water (e.g. compressor) and other component cold water (e.g. main motor and gas coolers), then the cooling loops for the two elements can be separate.*

- In case of multiple compressor units, it is strongly recommended to provide one common cooling system for all the units instead of individual units. This is especially important when one or more of the units are standby units. This can influence the sizing of the cooling system components substantially and eventually save costs.

3 Design of cooling water skids

Cooling water systems can be skid-mounted, or foundation mounted, depending on whether the system is open type or closed. Normally, open cooling systems do not require any skid whereas semi-closed and closed cooling systems are normally skid mounted. In the following paragraph we restrict the description to skid mounted systems only.

Templates (ZVL) available in SAP:

Complete skid supply (preferred and recommended solution):

~~**One single skid:**~~	~~CW_SKID:CW skid (2016, single skid)~~	~~TSP_CW_SKID_E03~~
Multiple skids[1]:	CW_SKID:CW skid (2016, multiple skids)	TSP_CW_SKID_E02

Note 1)This template only will be kept up to date.

Single equipment supplies (not recommended to be used for small systems):

Skid specification with scope split:		TSP_CW_SKID_E01
Expansion vessel:	CW_EXP:CW Expansion Vessel	TSP_CW_EXPANSION_E01
Coolant pump:	CW_PU:CW Coolant Pump	TSP_CW_PUMP_E01
Heater:	CW_HEA:CW Heater	TSP_CW_HEATER_E01
Cooler:	Shell & tubes: CW_EXCH: CW_Cooler	TSP_CW_COOLER_1_E01
	Air Cooler: BEH_AIREXCH	TSP_CW_AIRCOOLER_E01
Piping material:	GZUB_ROHR_SATZ:Pipinglist CW	TSP_PIPINGLIST_CW_000

Following are the main parameters to be specified for designing / specifying cooling water skids:

3.1 Engineering

- Normally BC will supply a general layout drawing of the skid assembly. Based on this drawing, the packager should be entirely responsible for design of the final skid, viz. skid frame design and calculation of beam sizes, and issue the final, detailed skid assembly drawing.
- Normally, BC will not provide any detailed piping isometrics, as the arrangement of piping may vary depending on the final design of the skid.
- In any case, the packager has to follow given main overall skid sizes, terminal points and foundation bolting locations as per BC general arrangement (GA).
- The packager shall be solely responsible for the layout within the skid and checking the functionality of the equipment on the skid.
- Normally, the cabling and instrument tubing is done at site due to scope split between BC and the Client. However, if specifically required by the contract, instrument tubing and cabling could also be done at packager's workshop. In this case, the packager will be responsible for design and implementation of impulse lines of pressure instruments, cabling of instruments (PT, TE, FS, LS), cabling of electrical devices such as pumps, heaters etc., design of cable trays and / or conduits etc., to the local instrument board, local operator panel and junction boxes. Cabling check shall be made for the instruments as per BC connection diagrams.

3.2 Engineering Hints

Engineering hints here listed should help project engineers to carry out their work.

3.2.1 General

- General arrangement as well as PIDs are available in BC Elements.
- In case of semi-closed or closed cooling systems, the cylinder cooling water inlet temperature should be approx. 6°C higher than the gas inlet temperature (also refer to API 618, pt. 2.6.3.3) or gas dew point temperature. Reference shall also be made to the specific dew point curve of the process gas (refer to the RecipCalc computation sheets) to define the cooling water inlet temperature at all times to avoid condensation on the cylinder wall.
- This requirement above is not applicable for LNG plants where closed cooling circuit is employed due to non-availability of water and use of anti-freezing agents with water to prevent freezing in cooling jackets for cylinders. The warm coolant in LNG plants is required for providing a thermal barrier between the cylinders and the crank gear.
- In closed systems, a heater as well as a coolant cooler is commonly installed. These elements shall be installed in parallel streams with a 3-way thermostatic control or pneumatic control to regulate the flow of coolant through these elements.
- In plants where, ambient temperatures could fall below the freezing point and if no glycol is used, it is recommended to provide a small bypass to the non-return valve on the discharge. This line should include an orifice to circulate a small amount to the standby pump to prevent the coolant in the idle piping / pump from freezing. Such an arrangement could also prevent use of special materials for the pumps in case of very low ambient temperatures, viz. below -20°C.
- In plants where, ambient temperatures could sink below freezing point of the coolant, it is recommended to drain the cooling system during extended shutdown periods. Otherwise, the use of appropriate anti-freezing agents shall be considered.
- If glycol-water mixture is required due to ambient or process requirement (LNG), use of ethylene glycol is recommended since the freezing point of ethylene glycol mixtures is lower than other normally available anti freezing agents.
- Factsheet about Thermosyphon system is available on TDO_2012870_E05 (E)

3.2.2 PlantCalc

Release of Templates and prepared systems in PlantCalc are available for following systems:
- Standard Coolant Skid (CWB and CWT)

Use Case:
- Pressure loss calculation
- LO/CW Heater rating calculation
- Basis for project specific adaptions

Link for elements and nodes denominations used in PlantCalc (marked PID's)
For system templates, below are the Plantcalc ID's:

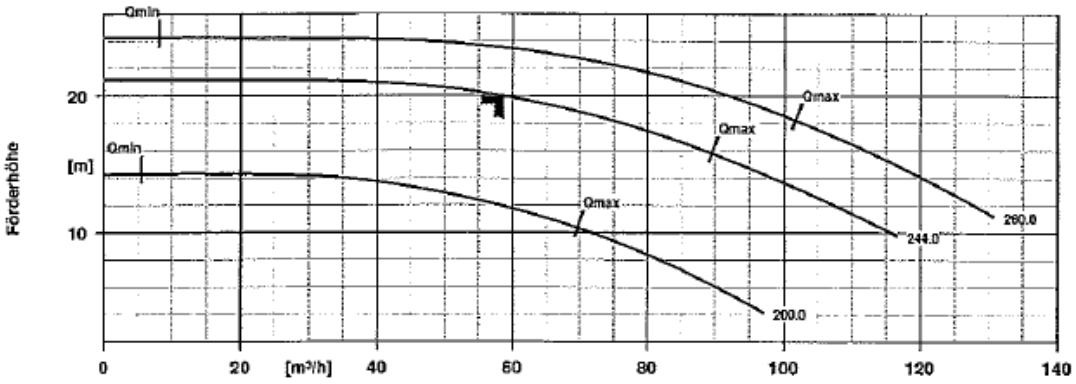
- Coolant Skid Template_R01: PlantCalc ID 1004067
  Replacing Coolant Skid Template Old Version : PlantCalc ID 1001335 (E)

3.2.3 CW pump

- Suction line to coolant pumps shall not be smaller than the inlet port of the pump.
- The differential head for coolant pumps when used only for pump coolant through cylinders shall be in the range of ~1.5 – 2.0 bar g. For pumps pumping coolant through the complete system with long piping, the differential head could be around ~2.5 – 3.0 bar g maximum. A higher differential head for pumps would not be possible and could lead to shift of operation point for the pumps during operation.
- The size of the pump wheel should allow a change to a bigger or smaller wheel to adapt, if necessary, the flow or head on-site without changing the complete pump.
- The flow should always be in the flow range given by the pump supplier, see curves below of example CPKN pump of KSB. Otherwise, cavitation will occur and damage the pump.
- Isolation valves shall be provided before and after the pumps to enable isolation for maintenance. These isolation valves shall be gate type valves to avoid excess pressure drop.
- Non-return valve shall be provided at the outlet of each pump (when using two pumps, one operating and other standby) to avoid back flow.
- Be aware that API610 pumps are producing huge cost impact and space requirements (The skid will be considerably bigger then BC std skids GA(E)).
- White Book TDO 2012065 Cooling water pumps

CPKN-S1 080-250
Chemie-Normpumpe nach EN 22858/ISO 2858/ISO 5199

Versions-Nr.: 3



3.2.4 Expansion tank, Bladder, Open Tank

- For closed cooling systems with open tank (reservoir), the expansion tank should be placed in a way that the low level in the tank is always at a higher level than the highest point of the cylinders. This is mandatory for the following reasons:
  - Avoid air pockets in the cylinders during shutdowns which could cause corrosion inside the cylinders cooling chambers.
  - Avoid that the coolant from the complete system will flow back in the tank (not sized for this purpose).
  - Guarantee enough suction pressure at the pump inlet (E).
- Due to required height for expansion tanks for reservoir systems (API618), it might be necessary to design a separate support for the tank with access ladders and maintenance platform. This structure could need dismantling during transportation.

- White Book TDO 2012205 Expansion vessel

3.2.5 Cooler

- In case of systems with air cooled heat exchangers, the heat exchanger shall be placed in open area and not under shelter to have better heat exchange.
- It is important to specify the correct anti-freezing agent for calculating the coolers as the heat capacity for these agents is different and could have effect on the overall sizing of the coolers. E.g. ethylene glycol has a lower specific heat capacity as compared to propylene glycol. Hence, a cooler designed with propylene glycol mixture would be insufficient while using ethylene glycol mixture as cooling medium.

- White Book TDO 2011219 for Tubular Heat Exchangers,
- White Book TDO 2100626 for Plate Heat Exchangers
- White Book TDO 2012204 for Air Cooled Heat Exchangers

3.2.6 TCV

- While selecting the TCV valve (AMOT), the pressure drop recommendation from valve manufacturer across the valve has to be considered. This is important as there is no possibility to make adjustments at site and changes are possible only by replacement of the complete valve.
- Sizing tool for semi-closed TCV is newly available. The tool is only available for dedicated groups, please contact PEO (peo@burckhardtcompresion.com) for sizing of the TCV(E)

3.2.7 Valves

- Valves in the coolant return lines from individual consumers shall be globe type to allow adjustments in the flow at site to obtain required temperature rise across each consumer.

- As per BC philosophy, isolation valves are provided only on the return lines for each consumer. With this design philosophy, only one thermal relief valve on the inlet header is sufficient. However, if client requirements ask for isolation valves in all supply and return lines, then each line should be equipped with a separate thermal relief valve between the isolation valves.
- White Book TDO 2011525_E01 for valves

3.2.8 Pipes

- In case that flow measurement is required on the header (flow transmitter or flow indicator), it is necessary to maintain the straight lengths of pipe before and after the instrument to display the correct value

- White Book TDO 2011930_E01 for piping
- Link to pipe classes: BC Piping class

3.2.9 Instruments / Control

- In order to ensure that the cylinder is at appropriate temperature during start-up and / or running, the temperature control shall always be on return line
- Flow switch shall be provided in return header to protect the compressor from running without coolant. This switch signal is used as starting interlock for the compressor
- Normally, there is no compressor trip provided due to low coolant flow. In case of low or no coolant flow to the compressor or auxiliaries, the compressor will shut down due to rise in gas temperature.
- For closed or semi-closed cooling systems with flow heaters, it is necessary to provide an additional flow switch and / or a level switch in the heater circuit to ensure positive coolant flow through the heater. This flow switch is used as starting interlock for the heater operation as well as for the compressor.

- In the event of failure of the main pump or low flow / low pressure, the control system shall be programmed to switch-over to the stand-by pump automatically.

- During cold weather periods it is advisable to keep the system running to maintain the cooling water temperature for a quick start.

3.3 Scope of supply

The split of scope between BC and packager has to be decided by the project engineer depending on the requirements of the project and its complexity. In normal circumstances, the equipment on the skid, viz. the coolant pumps, heater, vessel and coolant cooler could be procured by the supplier. However, in cases where BC needs to get approval from Client for all the individual items mounted on skid or where deliveries are critical, it is advisable to get such items procured directly by BC and then supply them to the packager for mounting on the skid. The instrumentation is procured by BC and supplied to the packager for skid assembly.

The decision about procurement of individual equipment by BC or the packager is dependent on the delivery periods required, costs, location and competence of the supplier.

4 Water Quality

4.1 Impact of water quality on design

The water quality has an impact on materials and / or on the type of cooling water system to be chosen. In an open or semi-closed CWS, it might be necessary to choose high alloy steels in order to avoid corrosion, whereas in a closed CWS, corrosion can be reduced with an appropriate chemical water treatment.

A procedure for water quality check (ABL 2077546_E13) is available.
Carbon and low alloy materials can only be used if water quality parameters are within a certain range. Refer to document VBCA200050 "Cooling Water Quality Requirements" for the design range for different water quality parameters.

4.2 Impact of water quality on material

In case of deviation from range indicated in VBCA200050, special materials and / or a closed CWS has to be chosen.

As a guideline following information about water quality impact on materials can be useful:

- **Carbon steel and low alloy steel:** within range of table VBCA200050
- **Copper material:**
  - For high chloride content, e.g. seawater.
  - Ammonia content shall be < 50 mg/l and H_2S content shall be < 0.1 mg/l.
  - Recommended water velocity shall be within range of 1…3.5 m/s.
- **High alloy steel** (with low “Mo”)**:**
  - For demineralised water with low pH-value.
  - Only suitable if chloride content is < 50 mg/l and water temperature is < 50°C.
  - For higher chloride content, high Mo content is required.
  - Ammonia has no impact on this material.

4.3 Impact of water quality on type of CWS

- If the water is very corrosive, it may be more economical to choose a closed CWS and to add corrosion inhibitors.
- If the water analysis exceed the values indicated in VBCA200050 and there is a risk of corrosion or fouling, the water shall be chemically treated.
- In case of using demineralised water it is recommended to ensure that the pH value is > 9.
- Further ensure that no oxygen can enter the system
  (especially at elevated temperatures > 60°C). Otherwise, high alloy steel has to be used or appropriate inhibitors have to be considered.

- It is recommended to design the coolant system in such a way, that the minimum water velocity is 1.2 m/s. For “clean” water the maximum velocity shall not exceed 3 m/s (carbon steel) to avoid abrasion.

4.4 Impact of water quality - General

- If the coolant system contains suspended solids, it is recommended to install a strainer or filter with a mesh size of approx. 250-500 µm.
- For coolers it is recommended to select tubes with the same or higher alloy content than for the tube sheets because of high risk for corrosion at tube connections.
- For detailed selection of the appropriate material, it is recommended to contact QUALITEC / department water analysis refer to procedure for water quality check (ABL 2077546_E13).

4.5 Impact of water quality - General

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For detailed selection of the appropriate material, it is recommended to contact QUALITEC / department water analysis

4.6 Water make-up frequency

The quality of the cooling water must be checked at regular intervals, including expiry date of the Glycol. It is recommended to check it minimum once per year.
Do not use aggressive cooling water which easily builds up deposits.
For details about maintenance please refer to compressor manual.

5 Materials of construction

5.1 Piping and cooling system equipment

- BC Piping class or(D) piping classes from Client, if available.
- Surrounding conditions, e.g. outdoor near sea, petrochemical plants, etc.
- Carbon steel is normally the recommended material of construction for piping and equipment in cooling system.
- Stainless steel is used only in case of aggressive coolant or surrounding conditions.
- For details of water quality impact on the material refer to chapter 4.2.

5.2 Skid / frame, supports etc.

The skid is normally manufactured in C-steel and painted for surface protection. Proper maintenance access to all components on the skid shall be ensured during engineering. If required, the access walkways shall be provided with grating to obtain anti-slip surfaces. A drainable tub arrangement for skid can be used in case of glycol-water mixtures to avoid spilling of these mixtures on to foundation.

5.3 Coolers, pumps and heaters

See recommendations of material selection in the dedicated White Books

- White Book TDO 2011219 for Tubular Heat Exchangers,
- White Book TDO 2100626 for Plate Heat Exchangers
- White Book TDO 2012204 for Air Cooled Heat Exchangers
- White Book TDO 2012065 Cooling water pumps
- White Book TDO 2012417 Cooling water heaters.
- White Book TDO 2012205 Expansion vessel

6 Applicable standards and codes

Design standards	BC standards / API 618 Client specifications
Design codes	EN 13480 / PED/2014/68/EU ASME Section VIII, Division 1(U-stamp, if required)
Electrical and instrumentation codes	Relevant IEC / CENELEC / ATEX according to project specifications
Flanges according to	EN1092 B1/2 ASME B16.5, RF
Piping according to	ASME B 31.3 EN13480

7 Other requirements for specifying the cooling systems

7.1 Surface treatment

- Project specific painting system shall be specified for the complete skid. Either, BC specification or Customer painting specification shall be provided.
- Individual components, viz. standard equipment like valves could be procured with manufacturer's painting system. These components shall be finish painted as per project specification by the packager.
- Skid packager could be responsible for the final painting including all components mounted onto the skid, viz. pumps, coolers, expansion vessels etc.
- Normally stainless-steel equipment does not receive any painting if not insulated or not installed near the seashore. These items are only cleaned, pickled and passivated. For insulated piping and skids installed near the seashore (typically for LNG plants), it is recommended to paint the stainless-steel piping as per applicable project or BC specification.

7.2 Insulation and heat tracing of skid piping and components

- Requirement for insulation and heat tracing are decided based on the ambient conditions and the required process parameters.
- For locations where, ambient temperatures could go below the freezing point and the system uses a normal cooling water (without anti-freezing agents), it is advisable to use insulation as well as heat tracing to maintain the coolant temperature and avoid freezing.
- For a closed or a semi-closed cooling system with heater, it is recommended to insulate the warm coolant carrying piping in order to prevent heat loss to ambient in these lines.
- For similar reasons, it is recommended to insulate the coolant tanks in closed cooling systems.

7.3 Packing and preservation

- The skid packager or BC could be responsible for the final packing for transport to site.
- Special attention has to be given to the lifting devices of the final skid, viz. position and size of lifting lugs.
- If single point lifting of cooling skid is required, it is recommended to locate the lifting lugs in such a way that fouling of equipment is avoided when using slings or chains.
- Only if such arrangement of lifting lugs is impossible, lifting devices such as spreader bars and lifting tackles shall be used (due to cost impact). If required, these shall be designed by the skid packager as a function of the final design of the cooling water skid.
- Nitrogen purging and filling is recommended for preservation during transport and storage before installation and commissioning.

7.4 Inspection and documentation

7.4.1 Technical documentation

Packager should prepare and supply following main technical documents according to BC final documentation requirements:

- Final general assembly drawing of coolant skid with connection list, main dimensions and part list (if required).
- Base frame manufacturing drawing.
- Manufacturers data sheets, outline and sectional drawings with part list of components such as: coolers, pumps, motors, filters, heaters, control valves, manual valves, expansion vessels etc. as supplied by packager.
- Bill of material (overall parts list).
- Code calculations for expansion vessel, cooler, heater as supplied by packager.
- Base frame and support calculations.

7.4.2 Inspection, testing and certification

Following is recommended as minimum requirement:

- Certifications shall be requested as agreed with the Client, viz. 2.1 or 3.1 for materials and other tests as per inspection and test plans.
- In case of supply within EU, declaration of conformity as per ATEX (for hazardous area classification), PED and Machinery directives must be requested.
- Functional and flushing test as per KV 5025 “Flushing and testing of cooling water systems of compressors” shall be requested. Proper draining and drying of the system with dry nitrogen after flushing and filling with Nitrogen is important to avoid any corrosion of components prior to installation.

8 Economic and other considerations

- Scope of supply split should consider costs for procurement, quality, engineering, penalties for late delivery and / or performance, overall delivery etc.
- For components supplied by BC a time schedule should be provided to the packager to ensure proper scheduling of packager’s activities.
- Only truck worthy packaging of components supplied by BC is needed for transportation to the skid packager.

9 Reference documents(E)

TSP template: CW_SKID:CW skid (2016, multiple skids)	TSP_CW_SKID_E02
~~TSP template: CW_SKID:CW skid (2016, single skid)~~	~~TSP_CW_SKID_E03~~
Extension to White Book Coolant Systems, Standard Coolant Skids	TDO 2054222_E01
Flushing and testing of cooling water systems of compressors	KV5025_D_E
Procedure for water quality check	ABL 2077546_E13
Cooling Water Quality Requirements	VBCA200050_E01
Questionnaire - Evaluation Criteria for Cooling Water Quality and Water Treatment Methods	VBCA200050_E02
White Book Tubular Heat Exchangers	TDO 2011219
White Book Plate Heat Exchangers	TDO 2100626
White Book Air Cooled Heat Exchangers	TDO 2012204
White Book Cooling water pumps	TDO 2012065
White Book Cooling water heaters	TDO 2012417
White Book Expansion vessel	TDO 2012205
FINAL TECHNICAL DOCUMENTATION AUXILIARIES	VSB1029800_E01
PDF Requirements Mechanical Equipment (Quality Documentation	VBCA543000
COOLING WATER VOLUME CYLINDER PL2	TDO 2042280_D02
CYLINDER DIM. FOR COOLING WATER AREA PL2	TDO 2042280_D18
Factsheet Thermosyphon (E)	TDO_2012870_E05