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PROCESS DESIGN OF COOLING WATER CIRCUITS

(PROJECT STANDARDS AND SPECIFICATIONS)

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SCOPE

This Project Standards and Specifications covers:

- Cooling Water Circuits for Internal Combustion Engines.
- Cooling Water Circuits for Reciprocating Compressors.
- Cooling Water Circuits for Inter cooling and After cooling Facilities.

REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

1. **TEMA (Tubular Exchanger Manufacturers Association, Inc)**

   TEMA Class R Heat Exchangers

2. **API (American Petroleum Institute)**

   - API Standard 610 - "Centrifugal Pumps for Petroleum, Petrochemical and Natural Gas Industries"
   - API Standard 618 - "Reciprocating Compressors for Petroleum, Chemical and Gas Industry Services"
   - API Standard 619 - "Positive Displacement Compressors for Petroleum, Chemical and Gas Industry Services"
   - API Standard 660 - "Shell-and-Tube Heat Exchangers for General Refinery Services"
   - API Standard 661 - "Air-Cooled Heat Exchangers for General Refinery Services"

3. **API Specification 11 P (Spec. 11 P)**

   "Specification for Packaged Reciprocation Compressors for Oil and Gas Production Services"

4. **ASME (American Society for Mechanical Engineers)**
   - ASME Standard, No. 120, Prepared by Pannel IV of Joint ASME-ASTM-NEMA Committee on "Gas Turbine Lubrication System", Clause 6.0, "Coolers", Louisville, Ky, May 1957.
   - ASME Code, Section VIII, Division 1 Part 2, Appendix A.

DEFINITIONS AND TERMINOLOGY

After-Cooler - A species of surface condenser in which compressed air/gas is cooled after compression.

Air-Cooler - An exchanger in which the heating surface is indirectly cooled by air.

Ambient Temperature - The temperature level of atmosphere in the environment of the equipment installation.

Brake Kilowatt - The actual power input at the crankshaft of the compressor drive.

Combustion - The rapid oxidation of fuel accompanied by production of heat.

Condensation -Tthe constituent of air or gas when liquified due to certain reduction in coolant temperature against the air/gas inlet temperature.

Cooling System - A self-contained, closed cooling water system, capable for taking the heat transmitted to the heating surface, to the extend specified by the manufacturer.

Energy Conservation - Saving in power consumption, as by rough estimate, each 5.5°C decrease in gas temperature between the stages shall result in one percent in power consumption (see ASME Standard No. 120 & Power Plant Engine Guides).

Heating Surface - Yhe surface which transmits heat directly from the heating medium to the cooling medium.

Inlet Temperature - The temperature of liquid coolant entering the heating surface at specified point in the inlet piping.

Inter-Cooler - A species of surface condenser placed between the two consecutive cylinders of a multistage compressor so that, the heat of compression generated in the first stage cylinder may be removed (in part or whole) from the compressed air/gas, as it passes through the next stage cylinder's inter-cooler.

Liquid Coolant System - The coolant system by which the heating surfaces are cooled by liquid.

Maximum Allowable Working Pressure (MAWP) - The maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified temperature.

Maximum Suction Pressure - The highest allowable suction pressure to which the pump is subjected during operation.

Multi-Stage Reciprocating Compressor - The compressor in which the compression, when a perfect gas or air is isentropically compressed, the gas inlet temperature as well as the amount of work spent is the same of each stage.

Net Positive Suction Head Required (NPSHR) - The NPSH in meters, determined by the vendor testing, usually by water. NPSHR is measured at the suction flange and corrected to the datum elevation. NPSHR is the minimum NPSH at rated capacity required to prevent a head drop of more than 3 percent due to cavitation within the pump.

Outlet Temperature - The temperature of liquid coolant discharged from the heating surface at specified point in the outlet piping.

Rated Capacity - Rated process capacity specified by the Company to meet process conditions with No Negative Tolerance (NNT) permitted.

Rated Discharge Temperature - The highest predicted (not theoretical adiabatic) operating temperature resulting from the rated service conditions.

Rated Speed in Rotations (Revolutions) Per Minute - The highest speed required to meet any of the specified operating condition.

Seal Chamber Pressure - The highest pressure expected at the seals during any specified operating condition and during start up and shut down. In determining of this pressure, consideration should be given to the maximum suction pressure, the flushing pressure and the effect of internal clearance changes.

Working Pressure - The maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred).

SYMBOLS AND ABBREVIATIONS

SYMBOL/ABBREVIATION	DESCRIPTION
Ai	Area corresponding to the inside-diameter of the cylinder, in (m^2)
Ao	Area corresponding to the outside diameter of the cylinder, in (m^2)
A	Mean area between the inside and outside surface of cylinder, in (m^2)
API	American Petroleum Institute
ASME	American Society for Mechanical Engineers
ASTM	American Society for Testing and Materials
DN	Diameter Nominal, in (mm)
h1	Inside surface heat-transfer coefficient, in (W/m^2. K)
ID	Inside Diameter, in (mm)
K	The thermal conductivity of the metal , in (W/m. K)
L	The thickness of the cylinder wall, in (m)
NEMA	National Electrical Manufacturer's Association
OD	Outside Diameter, in (mm)
Q	Quantity of heat transferred, in (J)
TEMA	Tubular Exchanger Manufacturers Association, Inc
t_1	The combustion gas temperature in Kelvin (K)
t_2	The average temperature of inside surface of the cylinder, in Kelvin (K)
t_3	Outside surface temperature of the cylinder, in Kelvin (K)
γ (tau)	The time, in (s)

Symbols used for instrumentation

APSS	Auxiliary Pump Start Switch
D	Drain
FG	Flow Gage Glass
FI	Flow Indicator
F	Filter
HCV	Hand Control Valve
HE	Heating Element
LLA	Level Low Alarm
LHA	Level High Alarm
LG	Level Gage
LLAS	Level Low Alarm Switch
LPAS	Low Pressure Alarm Switch
LPSS	Low Pressure Shutdown Switch
LFAS	Low Flow Alarm Switch
PI	Pressure Indicator
PA	Pressure Alarm
PRC	Pressure Recorder Controller
PDI	Pressure Differential Indicator
PRV	Pressure Relieve Valve
TIC	Temperature Indicator Controller
THA	Temperature High Alarm
TI	Temperature Indicator
TCV	Temperature Control Valve
TSHA	Temperature Switch High Alarm
TT	Temperature Transmitter
V	Vent

UNITS

This Standard is based on International System of Units (SI) except where otherwise specified.

DESIGN

Internal Combustion Engines, Cooling Systems

1. General

   When the fuel is burnt in the cylinder, a part of the heat developed during combustion, flows to cylinder walls. If the temperature of cylinder walls is allowed to rise above a certain limit (about 150°C) then the oil lubricating the piston starts evaporating. This action damages both piston and cylinder. The high temperature developed may sometimes cause excess thermal stresses and hence cracking of the cylinder head and piston. The hot spots may also cause preignition in the combustion space. In order to avoid any damages, the heat flowing to the cylinder walls must be carried away.

2. Methods

   All heat carried away from an engine shall finally be conveyed to atmosphere. However, the methods of cooling may be divided into two main groups of direct or air-cooling and indirect or liquid-cooling.

3. Heat transfer

   In cooling of engine cylinders, all three means of heat transfer, i.e., conduction, convection and radiation will be utilized. But, conduction will play the most important part in carrying the heat through the thin layers of hot gases and water in contact with cylinder walls and will be sole object of process design in this Standard.

4. Heat lost to cylinder's inside surface

   The quantity of heat lost per second to the heating surface i.e, inside surface of cylinder wall, head and exhaust valve cages by combustion gases shall be considered.

5. Requirements of cooling system

   Unless otherwise specified, the required cooling water system shall include the following features:

   a. Design features

      i) The closed cooling water system shall either use distilled or treated soft water which is passed through a heat-exchanger where, it is cooled and then passed through the cylinder jacket.

      ii) The heat exchanger used may usually be of shell and tube type. Using of air-cooled heat exchanger shall be based or Company's agreement.

iii) Within the cylinder jackets, only liquid phase cooling shall be permitted.

iv) The system shall be capable of providing required quantity of water for cooling of cylinder jackets, cylinder heads, exhaust valve cages and circulating oil.

v) The following operating condition shall be considered in design of cooling system:

- An uninterrupted flow of cooling water will always be maintained through the cylinder jackets.
- The water used for cooling of cylinder jacket shall be free from scale and impurities and shall not be of corrosive nature.
- The inlet water temperature to cylinder jackets shall be maintained at 63°C to 68°C.
- The maximum water temperature rise within the cylinder jackets including the heat absorbed from cylinder heads and exhaust valves shall not exceed 10°C.
- The system shall be designed to meet the working pressure of not less than 520 kPa and testing pressure of 800 kPa.
- An automatic control system shall be considered for controlling of inlet water temperature.
- Thermometers, complete with thermowells shall be fixed at cooling system outlets.
- A protection device shall be established at cooling system outlet to monitor and act, if the temperature rise exceed a critical value specified by the manufacturer.
- A cooling water high temperature alarm shall be provided on cylinder outlet. The alarm shall actuate and the compressor shall shut down when the discharge temperature of any cylinder exceeds the rated discharge temperature by 22°C.
- The quantity of circulating water by each pump shall meet the temperature rise across each and all of the cylinder, cylinder head and the exhaust valve cage and circulating oil.
- The system shall be provided with an appropriate draining connection. The connection shall provide facilities for perfect washing, cleaning and draining of the system.
- Low inlet water temperature to cylinder jackets will increase the viscosity of the lubricating oil and consequently the piston frictions.

Vendor shall make necessary provisions to control the inlet water temperature at a specified range, as specified above.

vi) Unless specified otherwise, Vendor shall furnish a detailed drawing for his proposed closed water cooling system. Company's recommended drawing shall typically be as per Fig. A.1, in Appendix "A".

vii) Unless otherwise specified, the Vendor shall supply closed water cooling piping with a single inlet and a single outlet connection on each cylinder.

b. Equipment/devices and process design

Unless otherwise specified, the process design of the following equipment/devices shall constitute a combined, self-contained closed water cooling system for internal combustion engines.

i) Soft water circulating pumps.

ii) Soft water circulating piping.

iii) Reservoir (or surge tank) for soft water.

iv) Soft water circulating, heat exchanger (or cooler).

v) Thermometers for measuring inlet and outlet temperatures.

vi) Temperature regulator to control the outlet temperature.

vii) A soft water high temperature protective device to control the excessive cylinder jacket temperature.

Fig. A.1, in Appendix "A", illustrates the required equipment/devices of an internal combustion engine's closed water cooling system.

Reciprocating Compressors' Cooling System

1. General

a. When air/gas is compressed, its temperature and pressure will rise and a considerable heat will be generated due to rise in temperature. Part of the heat so, generated, will be transferred to cylinder wall rising the wall temperature which will reduce the lubricating efficiency in cylinder and might result in, an overheated and warped rod. The heat of compression will also results in a loss by boosting of pressure.

b. It has been found desirable to remove part of this heat traveled to cylinder wall in order to get rid of any damage to cylinder barrel and heads. Any heat removed also results in a slight reduction in the compression brake kilowatt.