ENGINEERING STANDARD

FOR

PROCESS DESIGN OF COOLING WATER CIRCUITS

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PART ONE
COOLING WATER CIRCUITS
FOR
INTERNAL COMBUSTION ENGINES AND RECIPROCATING COMPRESSORS

0. INTRODUCTION

The primary purpose of IPS standard specifications on "Process Design of General Heating & Cooling and Flushing Systems" is to establish minimum requirements and design criteria needed in process design of the following standards:

STANDARD CODE	STANDARD TITLE
IPS-E-PR-400	"Process Design of Cooling Water Circuits"
IPS-E-PR-410	"Process Design of Hot Oil & Tempered Water Circuits"
IPS-E-PR-420	"Process Design of Heat Tracing and Winterizing"
IPS-E-PR-430	"Process Design of Cleaning/Flushing Networks"

The specifications and basic practices covered under these Standards are made in the light of available existing accumulated information and knowledge experienced and known to the Company at the time of writing, but it has been impossible to consider every possible factor that might affect the process design on a particular point.

This Engineering Standard Specification covers:

"PROCESS DESIGN OF COOLING WATER CIRCUITS"

1. SCOPE

1.1 General

1.1.1 This Standard Specification is covered in Two Parts.

Part One: Cooling Water Circuits for Internal Combustion Engines and Reciprocating Compressors.

Part Two: Cooling Water Circuits for Intercooling and Aftercooling Facilities.

1.1.2 In Part One, the Company's minimum requirements for process design of cooling water circuits for reciprocating internal combustion engines and reciprocating compressors are covered. The scope covered in this part shall also be applicable for cooling water system requirements of integral gas-engine-drive compressors used in general refinery services.

1.1.3 Part Two covers the minimum requirements for process design of interstage cooling and aftercooling facilities of multistage reciprocating compressors used in general refinery services and other services. This Standard Specification shall be applicable for the similar intercooling and aftercooling system of any other type compressors, unless otherwise specified.

2. REFERENCES

Throughout this Standard the following standards and codes are referred to. The editions of these standards and codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in standards and codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor/Consultant:

TEMA (TUBULAR EXCHANGER MANUFACTURERS ASSOCIATION, INC)

TEMA Class R Heat Exchangers

IPS (IRANIAN PETROLEUM STANDARS)

E-PR-440	"Process Design of Piping Systems (Process Piping and Pipelines)"
E-PR-740	"Process Design of Pumps"
E-PR-750	"Process Design of Compressors"
E-PR-785	"Process Design of Air Cooled Heat Exchangers(Air Coolers)"
C-ME-100	"Atmospheric Above Ground Welded Steel Storage Tanks"
C-ME-110	"Large Welded Low Pressure Storage Tanks"
C-ME-120	"Aviation Turbine Fuel Storage Tanks"
C-ME-130	"Pressure Storage Spheres (for LPG)"
E-ME-100	"Atmospheric Above Ground Welded Steel Storage Tanks"
E-ME-110	"Large Welded Low Pressure Storage Tanks"
E-ME-120	"Aviation Turbine Fuel Storage Tanks"
E-ME-130	"Pressure Storage and Spheres (for LPG)
G-ME-220	"Shell & Tube Heat Exchangers"
E-PM-100	"General Design Requirements of Machineries"
C-PI-100	"Plant Piping Systems"
E-PI-120	"Offshore Piping Systems"

API (AMERICAN PETROLEUM INSTITUTE)

API Standard 610 "Centrifugal Pumps for General Refinery Services", 7th. Ed., February 1989, Clause 2, "Basic Design".

API Standard 618 "Reciprocating Compressors for General Refinery Services". 3rd. Ed., February 1986, Clauses 2.1.3, 2.6.3, 3.7 and 3.8 "Intercoolers and Aftercoolers".

API Standard 619 "Positive Displacement Compressors", 2nd. Ed., Mai 1985, "Intercoolers and Aftecool- ers".

API Standard 660 "Shell-Tube Heat Exchangers for General Refinery Services", 4th. Ed., September 1982, Reaffirmed, December 1987.

API Standard 661 "Air-Cooled Heat Exchangers for General Refinery Services", 2nd. Ed., January 1978, Reaffirmed, December 1987.

API Standard 680 "Packaged Reciprocating Plant and Instrument Air Compressors for General Refinery Services", 1st. Ed., October 1987, Clause 3.2.5.

API Specification 11 P (Spec. 11 P)

2nd. Ed., November 1.1989, Clause 5, "Cooling System".

ASME GAS AND OIL POWER CONFERENCE

Louisville, Ky, May 1957, specified on quantity of heat to be removed from gas compressor cylinder jacket, by: W.F. and A.G. Clark.

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.

FRANKD. GRAHEM "Power Plant Engine Guides", 3rd. Ed., 1993, Chapter 41, "Inter-Coolers and After-Coolers".

NIGC (NATIONAL IRANIAN GAS COMPANY)

Engineering Standard No. 313.2, Volume 2, Clause 713.2.8, "Intercoolers and Aftercoolers".

3. DEFINITIONS AND TERMINOLOGY

The terms used in this Standard are defined in the 3.1 through 3.22 for the Part One and for the Part Two.

3.1 After-Cooler

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

3.2 Air-Cooler

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

3.3 Ambient Temperature

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

3.4 Brake Kilowatt

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

3.5 Combustion

Combustion is the rapid oxidation of fuel accompanied by production of heat.

3.6 Condensation

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

3.7 Cooling System

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

3.8 Energy Conservation

Energy conservation is 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).

3.9 Heating Surface

Heating surface is the surface which transmits heat directly from the heating medium to the cooling medium.

3.10 Inlet Temperature

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

3.11 Inter-Cooler

Inter-cooler is 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.

3.12 Liquid Coolant System

Liquid coolant system is the coolant system by which the heating surfaces are cooled by liquid.

3.13 Maximum Allowable Working Pressure (MAWP)

Maximum allowable working pressure is 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.

3.14 Maximum Suction Pressure

Maximum suction pressure is the highest allowable suction pressure to which the pump is subjected during operation.

3.15 Multi-Stage Reciprocating Compressor

Multi-stage reciprocating compressor is 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.

3.16 Net Positive Suction Head Required (NPSHR)

Net positive suction head required (NPSHR) is 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.

3.17 Outlet Temperature

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

3.18 Rated Capacity

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

Note:

The acceptable standard for reciprocating compressor industry, tolerance of ±3 percent is applicable to capacity. Because of this tolerance on capacity, the manufacturer will increase the required capacity by 3 percent prior to sizing the compressor.

3.19 Rated Discharge Temperature

The rated discharge temperature is the highest predicted (not theoretical adiabatic) operating temperature resulting from the rated service conditions.

3.20 Rated Speed in Rotations (Revolutions) Per Minute

Rated speed in rotations (revolutions) per minute is the highest speed required to meet any of the specified operating condition.

3.21 Seal Chamber Pressure

Seal chamber pressure is 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.

3.22 Working Pressure

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

4. SYMBOLS & ABBREVIATIONS

A_i	=	Area corresponding to the inside-diameter of the cylinder, in	(m^2)
A_o	=	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)
h_1	=	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	
NIGC	=	National Iranian Gas Company	
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)
$\gamma_{(tau)}$	=	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

5. UNITS

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

6. DESIGN

6.1 Internal Combustion Engines, Cooling Systems

6.1.1 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.

6.1.2 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.

6.1.3 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.

6.1.4 Calculation of heat lost to cylinder's inside surface

Unless otherwise specified, 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 obtained by using general heat transfer equation, as;

$$Q = h_1 . A_i (t_1 - t_2) \gamma \qquad \textbf{(Eq. 1)}$$

or,

$$t_2 = t_1 - Q/h_1 . A_i . \gamma \qquad \textbf{(Eq. 2)}$$

Temperature t_2 shall drop to outside surface temperature of cylinder t_3, when the quantity of heat (Q), is traveled through the cylinder wall i.e.,

$$Q = (k/L)\, A\, (t_2 - t_3) \gamma \qquad \textbf{(Eq. 3)}$$

or,

$$t_3 = t_2 - Q . L/k . A . \gamma \qquad \textbf{(Eq. 4)}$$

The heat traveled so, to outside surface of the cylinder wall as per equation 4, will continuously be absorbed by circulating soft water and carried away through a closed cooling system.

Where:

Q	is quantity of heat transferred, in (J);
k	is the thermal conductivity of the metal, in (W/m.K);
L	is the thickness of cylinder wall , in (m);
A	is mean area between the inside and outside diameter of the cylinder, in (m^2);
t_2	is the average temperature of inside surface of the cylinder, in kelvin (K);
t_3	is outside surface temperature of the cylinder, in kelvin (K);
γ (tau)	is the time, in (s).

6.1.5 Requirements of cooling system

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

6.1.5.1 Design features

a) 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.

b) The heat exchanger used shall be of shell and tube exchanger. Using of air-cooled heat exchanger shall be based on Company's distinct request.

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

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

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

1) An uninterrupted flow of cooling water will always be maintained through the cylinder jackets.

2) The water used for cooling of cylinder jacket shall be free from scale and impurities and shall not be of corrosive nature.

3) The inlet water temperature to cylinder jackets shall be maintained at 63°C to 68°C.

4) The maximum water temperature rise within the cylinder jackets including the heat absorbed from cylinder heads and exhaust valves shall not exceed 10°C.

5) The system shall be designed to meet the working pressure of not less than 520 kPa and testing pressure of 800 kPa.

6) An automatic control system shall be considered for controlling of inlet water temperature.

7) Thermometers, complete with thermowells shall be fixed at cooling system outlets.

8) 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.

9) 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.

10) 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.

11) The system shall be provided with an appropriate draining connection. The connection shall provide facilities for perfect washing, cleaning and draining of the system.

12) 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 in e.3 above.

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

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

6.1.5.2 Equipment/devices and process design

6.1.5.2.1 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.

a) Soft water circulating pumps.
b) Soft water circulating piping.
c) Reservoir (or surge tank) for soft water.
d) Soft water circulating, heat exchanger (or cooler).
e) Thermometers for measuring inlet and outlet temperatures.
f) Temperature regulator to control the outlet temperature.
g) A soft water high temperature protective device to control the excessive cylinder jacket temperature.

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

6.2 Reciprocating Compressors' Cooling System

6.2.1 General

6.2.1.1 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.

6.2.1.2 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 is also results in a slight reduction in the compression brake kilowatt.

6.2.1.3 Unless otherwise specified, the following standard, codes, and specifications to the extent specified herein, form the Company's minimum requirement for the process design of a complete closed cooling water system for reciprocating compressor cylinder jackets, it's engine cylinder jackets, it's lubricating oil cooling circuit and the compressor packing box cooling in part or in integral.

6.2.1.4 Throughout this Standard, references are mainly made to the API Standard 618, API Specification 11 P and API Standard 680 along with other internationally acceptable codes, standards and engineering practices and many important applied design book and resources.

6.2.2 Methods

6.2.2.1 The heat traveled to the cylinder wall can be carried off either by direct air-cooling or by indirect liquid cooling process. Most cylinders have water jackets to remove the heat and maintain required cylinder and /or liner temperature. Usually small kilowatt power units may use air-cooling system.

6.2.2.2 According to API Standard 618, three following methods of cooling may be used, depending on the extended period of time where, cylinders will or will not be required to operate fully unloaded.

a) Thermosyphon coolant systems may be used where cylinders will not be required to operate fully unloaded for extended period of time and either (a) expected maximum discharge temperature is between 88°C and 99°C or (b) the rise in adiabatic gas temperature is less than 66°C (see Fig. B.1 (a) in Appendix "B").

b) Static field coolant system may be used when the cylinders will not be required to operate fully unloaded for extended period of time. The expected maximum discharge temperature is less than 88°C and the rise in adiabatic gas temperature (difference between suction and discharge temperatures based on the isentropic compression) is less than 66°C (see Fig. B.1 (b) in Appendix "B").

c) Forced liquid coolant system shall be provided, where cylinders will operate fully unloaded for extended period of time and either (a) the expected maximum discharge temperature is above 99°C or (b) the rise in adiabatic gas temperature is 66°C or greater (see Fig. B.1, (c) of Appendix "B").

6.2.2.3 Unless otherwise specified, forced closed cooling water system shall be used for taking away the heat traveled to cylinder wall. The water shall be pumped through the secondary cooler and then back to cylinder jacket for reuse.

6.2.2.4 The Vendor is required to evaluate the Company's proposed standard coolant system as specified under Clause 6.2.2.3 above against his own standard coolant system or any other standard coolant system and shall recommend the use of the most efficient, effective and techno-commercially feasible other coolant system together with strong convincing proves. However the employment of any other coolant system will solely be upon the Company's written approval.

6.2.3 Calculation of heat rejected to circulating cooling water

The Vendor/Manufacturer will furnish complete design data on quantity of compression heat to be removed from cylinder jacket and the head in J/BkW. h.

6.2.3.1 The Vendor/Manufacturer if deemed necessary may furnish an integral closed cooling water system for compressor cylinder jackets, engine cylinder jackets, lubricating oil circuit and compressor packing boxes, he should provide separate design data on the quantity of heat rejected to cooling system from each section separately and as a whole along with quantity of water circulating and pressure drops.

6.2.4 Requirements

6.2.4.1 General

A closed cooling water system for packaged reciprocating compressor shall be furnished either in separate for cylinder jacket cooling or integral with engine cylinder, lubricating oil and cooling of compressor packing boxes, within the temperature limit recommended by the manufacturer for the specified compression services.

6.2.4.2 Cylinder jackets cooling

6.2.4.2.1 Unless otherwise specified, the following requirements shall be considered when the closed cooling water system is used only for cylinder jacket cooling:

a) The cylinder jackets when designed, all protective measures must be taken to prevent the process gas flow into the cooling water circuit.

b) A liberal supply of cooling water for cylinder jacket and cylinder head must be maintained.

c) The cylinder cooling system provided shall be designed to prevent gas condensation in the cylinder, that may dilute or remove lubricant or may cause knocking.

d) The use of untreated or scale depositing water that will cause fouling and plugging of the water passage, reducing cooling efficiency should strongly be avoided.

6.2.4.3 Integral cooling system

6.2.4.3.1 Not withstanding the requirements set-forth under clause or 6.2.4.2 unless otherwise specified, the following requirement, shall be considered when the closed cooling water system is used for an integral compressor and engine cylinder jackets, lubricating oil and packing box cooling:

a) The cooling circuit shall include engine lubricating oil, engine cylinder jacket, compressor cylinder jacket and packing boxes.

b) Elevated deaerating type reservoir with gage glass, vent line, cooling water level switches, overflow, filling connections and drains.

c) Cooling water temperature control shall be provided.

d) Plugged manual drain connection(s) for complete draining of the system.

6.2.4.4 Packing box cooling system

6.2.4.4.1 If a separate closed cooling circuit is specified for the piston rod pressure packing (see Fig. D.1), the criteria given in 6.2.4.4.2 and 6.2.4.4.3 shall be followed.

6.2.4.4.2 When packing is cooled by forced circulation, the Vendor shall supply a suitable filter of appropriate mesh rating.

6.2.4.4.3 Where cooling of packing is required, the Vendor shall be responsible for determining and informing the Company on the minimum requirements such as flow, pressure, pressure drop and temperature as well as filteration and corrosion protection criteria.

6.2.4.5 Lubricating oil cooling system

6.2.4.5.1 Since cooling of the lubricating oil shall be considered as an integral part of the closed cooling water system, the following recommendations apply:

a) Since liquid coolant is used, the design should minimize the chance of the lube oil being contaminated.
b) The coolant pressure should be less than the lube oil pressure at all time.
c) Adequate cooling water circulating rate for removal of total heat rejection to lube oil, should be maintained.

6.2.5 Design features

6.2.5.1 Unless otherwise specified, the provisions set-forth under 6.1.5.1 of this Standard when applicable, shall be considered as the design feature for a closed cooling water system for reciprocating compressors.

6.2.5.2 The cooling water supply to each cylinder jacket shall be at temperature of at least 6°C above gas inlet temperature as per API Standard 618.

6.2.5.3 The quantity of cooling water circulation by each pump shall be regulated to maintain a rise in cooling water temperature across only of the individual cylinder and cylinder head between 6°C to 11°C (as per API Standard 618).

6.2.5.4 An oil detection device shall be provided in the water supplied to pumps suction head.

6.2.5.5 In case of compressor cylinder cooling, the following should be observed:

a) Coolant inlet temperature less than 6°C greater than gas inlet temperature may cause gas constituent condensation.

b) Cooling water rate and velocity shall be provided by the Vendor to prevent fouling of cylinder jacket system.

c) Cooling water exit temperature more than 17°C above gas inlet temperature may cause compressor capacity reduction.(As per API Specification 11 P).

6.2.5.6 Installations for reciprocating compressor integral with engine cylinder, lubricating and packing box cooling system shall be as indicated in Fig. E.1 of Appendix "E". The system shall be capable of providing the following:

a) Cooling water for reciprocating compressor cylinder jackets.
b) Cooling water for engine cylinder jackets.
c) Cooling water for lubricating oil coolers.
d) Cooling water for cooling of compressor packing boxes (or in case of refrigeration services, water for warming of packing).

6.2.5.7 Typical installation for cylinder jackets and cylinder head cooling system of the reciprocating compressor shall be as indicated in Fig. C.1 of Appendix "C".

6.2.5.8 Typical installation for packing box cooling system of the reciprocating compressor shall be as per Fig. D.1 of Appendix "D".

6.2.5.9 Working pressure

The system shall be designed for not less than 520 kPa working pressure and a hydraulic test pressure of 800 kPa.

6.2.6 Piping and appurtenances

6.2.6.1 Unless otherwise specified by the Company, the Vendor shall supply a closed cooling water piping system for all equipment mounted on the compressor package. The piping shall be arranged to provide single flanged inlet and outlet connections at the edge of the skid. Necessary valves and bypasses shall be provided for temperature control.(See Figs. A.1, C.1, & E.1 of Appendices "A", "C", & "E" as the case may be).

6.2.6.2 Unless otherwise specified, piping design, inspection and testing shall be in accordance with relevant IPS-E-PR-440 and IPS-E-PI-120 and IPS-C-PI-100.

6.2.6.3 The piping of the cooling system shall be pre-piped, factory skid mounted and complete with various pressure and temperature indicators, alarm and other specific instrumentation required.

6.2.6.4 The inlet water connections shall be located at the lowest point of cylinder, so that water can easily be drained from cylinder when compressor is shut down.

6.2.6.5 The discharge connection should be at the highest point to ensure of complete filling of water jackets with no air pockets.

6.2.6.6 The water piping should be provided with a valve controlling the flow of water.

6.2.6.7 If the Company does not specify the extent of closed cooling water piping, the Vendor shall supply piping with single inlet and a single outlet connection on each cylinder requiring cooling (see Appendix "B", Fig. B.1, Plan c).

6.2.6.8 Coolant piping shall be arranged so that air can not be trapped. Where air trap can not be avoided, vent equipment shall be provided. Low points shall have drains.

6.2.6.9 Both, cooling water inlet line and cooling water outlet to each compressor cylinder shall be provided with a gate valve. A globe valve with union shall be provided on the main outlet line from each cylinder. A sight flow and temperature indicator shall be installed in the outlet line from each cylinder.

Note:

Where more than one cooling water inlet and outlet point exist on a cylinder, one sight flow indicator and regulating globe valve shall be provided for each outlet point on each cylinder.

6.2.6.10 For the packaged reciprocating compressor, Vendor shall supply all necessary piping, valves and fittings for all instrument and instrument panel.

6.2.6.11 The cylinder cooling system piping shall be equipped with vents and low point drains. Manual block valves to permit working on the compressor unit or auxiliary equipment without draining the engine cooler shall be furnished.

6.2.6.12 Internals of piping and appurtenances shall be accessible through openings or by dismantling for complete visual inspection and cleaning.

6.2.6.13 External drain and vent piping shall be of Schedule 80 carbon steel and of not less than DN 25 (Diameter Nominal 25 mm) size. However vent connection in the packing case and inter connecting tubing, shall be of 300 series stainless steel and at least 6.35 mm outside diameter (OD). With a minimum wall thickness of 1.24 mm.

6.2.7 Coolers

6.2.7.1 Unless otherwise specified by the Company, shell and tube heat exchanger shall be used for forced closed cooling water system on reciprocating compressors and internal combustion engine cylinder cooling.

6.2.7.2 The Vendor shall advise, when a cooler other than shell and tube exchanger is preferred. However the use of any cooler other than shell and tube, shall only be made upon the Company’s written approval.

6.2.7.3 Heat exchanger's tube-bundle shall be designed removable with clean and non corrosive fluid flowing through the tube side.

6.2.7.4 The mechanical design, testing and inspection of the shell and tube exchanger in closed cooling water system shall be in accordance with IPS-G-ME-220, unless otherwise specified.

6.2.7.5 Unless otherwise specified, process design of shell and tube exchanger shall be in accordance with the following conditions:

- Velocity in exchanger tubes	1.5-2.5 m/s
- Maximum allowable working pressure	≥ 690 kPa (ga) or 6.9 bar (ga)
- Test pressure	1.5 × MAWP
- Maximum pressure drop	100 kPa or (1 bar)
- Maximum inlet temperature	32°C
- Maximum outlet temperature	49°C
- Maximum temperature rise	17°C
- Minimum temperature rise	11°C
- Shell corrosion allowance	3.2 mm
- Fouling factor on water side	0.35 m^2. K/kW

Note:

The Vendor shall notify the Company if the criteria for minimum temperature rise and velocity in exchanger tube result in a conflict. The criterion for velocity in exchanger tubes is intended to minimize water-side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. The Company will approve the final selection. (Mod. to API Std. 618, Clause 2.1.3).

6.2.7.6 The following recommendations shall be applied for the coolers used in closed cooling water system in general and for the lubricating oil cooler in particular:

a) The heat exchange surface should be located and arranged so that it can be removed for maintenance or replacement.

b) Provide means for draining both sides of the cooler during shutdown.

Cautions:

These drains need to be protected from draining the reservoir during operation.

c) Vent connections should be provided on the cooler to permit air removal.

d) When dual coolers are used, the three-way change over valve should be designed so that oil flow will not be interrupted when transferring from one cooler to the other.

e) Since liquid coolant is considered to be mainly used, the design should minimize the chance of lube oil being contaminated.

1) Separate seals or gaskets should be provided for the coolant and the lube oil sealing. The space between the seals should be open to the ambient.

6.2.7.7 When air-cooled heat exchanger is recommended to be used by the Company, its process design shall conform to IPS-E-PR-785.

6.2.8 Cooling water reservoir

6.2.8.1 Unless otherwise specified, Vendor mechanical design, inspection and testing shall be in accordance with IPS-C-ME-100, 110, 120 and 130 & IPS-E-ME-100, 110, 120 and 130 Standards.

6.2.8.2 The cooling water reservoir should be located above the highest point of the closed cooling water system.

6.2.8.3 Working capacity of the reservoir shall be at least equal to the normal capacity of the pump per 5- minutes.

6.2.8.4 The reservoir shall be furnished with gage glass level indicator, with sufficient length covering working range of the reservoir and normal expansion and contraction of the system.

6.2.8.5 Level control system shall be provided for automatic control and maintaining of desired level and pumping suction head.

6.2.8.6 The reservoir shall be furnished with level switches and alarm, vent/overflow and filling connection and drain.

6.2.8.7 The reservoir vent/overflow line size shall have a diameter not less than ½ the diameter of the pump suction line.

6.2.8.8 The design of the suction line from the reservoir to the pump shall not provide any air pocket.

6.2.8.9 Reservoir shall be furnished with necessary chemical injection facilities to maintain more corrosive nature of circulating water.

6.2.8.10 Continuous steam injection line shall be provided for required rate of steam flow to the reservoir's top position for blanketing and spilling out the air.

6.2.8.11 The Company shall specify wether the installation is to be indoor or outdoor and the climatic conditions, including maximum and minimum temperature. The Vendor shall take all necessary protective measures in design by proper winterizing of the reservoir and other auxiliaries in cooling water system.

6.2.9 Circulating pumps

6.2.9.1 Unless otherwise specified, two horizontally mounted centrifugal pumps(main and spare) shall be furnished by the Vendor (see Figs. A.1, C.1, D.1 & E.1. in Appendices "A", "C", "D" & "E").

6.2.9.2 All process design requirements and criteria specified in IPS-E-PR-740 and API 610 and not covered hereinunder shall be used as integral part of this Standard.

6.2.9.3 The equipment and auxiliaries, shall be designed for a minimum service life of 20 years and at least 3 years of uninterrupted operation. This shall be considered as a design criterion.

6.2.9.4 The equipment rated operating point shall be specified on the data sheets along with any other anticipated operating conditions.

6.2.9.5 The Vendor shall specify on the data sheets the NPSHR when pump is operated on water at the rated capacity and rated speed, when water temperature is less than 66°C.

6.2.9.6 Pumps shall be designed for mechanical sealing in accordance with requirements of IPS-E-PM-100, unless otherwise noted on data sheets. Pumps shall have mechanical seals with flushing line to maintain a seal chamber pressure greater than the maximum suction pressure and, to ensure that the temperature and pressure in the seal chamber prevent vaporization while providing continuous flow through the seal chamber.

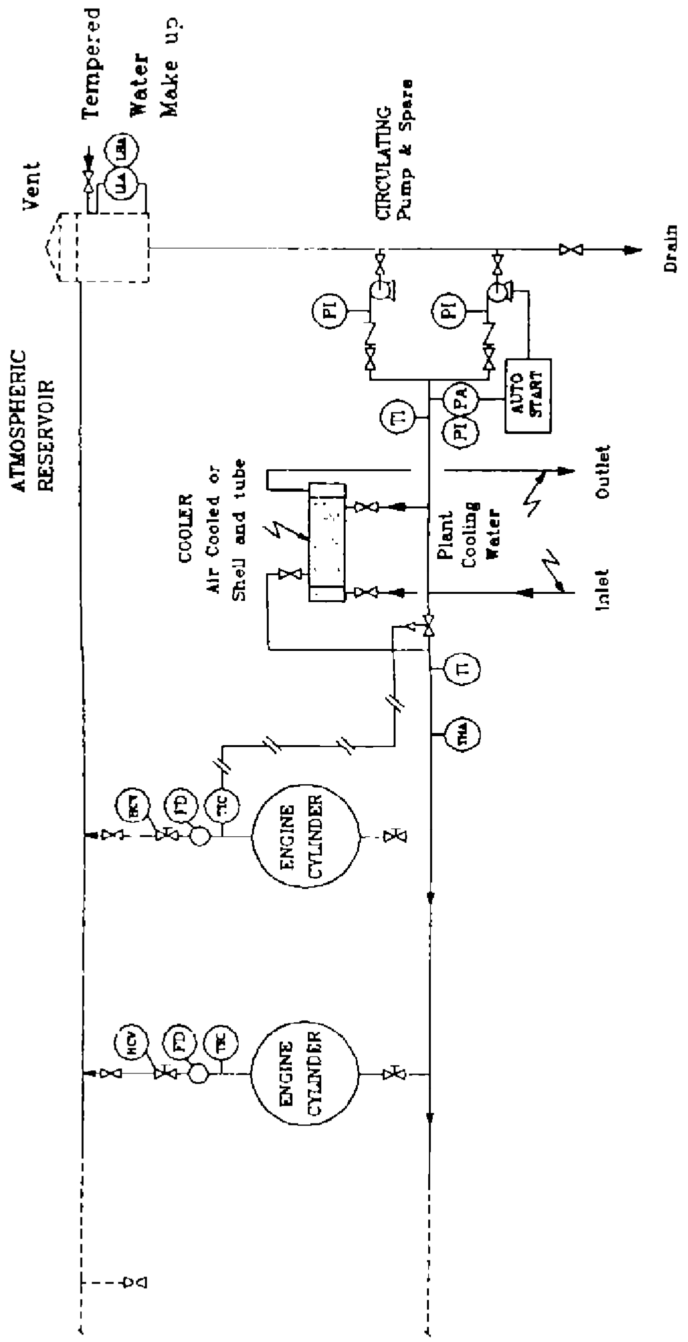
6.2.9.7 Pumps shall be provided with constant-speed motor drivers or steam turbine drive, (if required by the Company). Motor driver of the pumps(main and spare) shall be on the secondary selective electric system. (Emergency Power).

6.2.9.8 Each pump shall be designed for capacity required, to maintain complete cooling requirement of the system.

6.2.9.9 Each pump shall be operative as the spare of the other and shall automatically be started upon loss of pressure in the discharge of the main pump.

APPENDICES

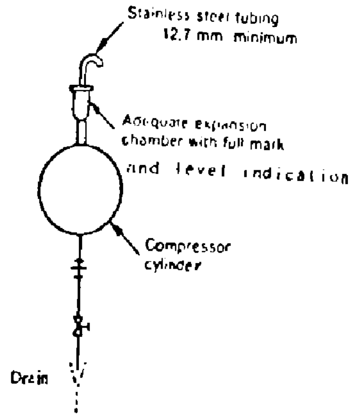
APPENDIX A



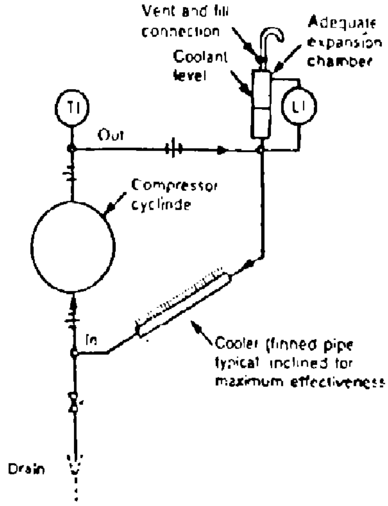
CLOSED COOLING WATER SYSTEM FOR MULTIPLE ENGINE INSTALLATIONS

Fig. A.1

APPENDIX B



b - STATIC (STANDPIPE) SYSTEM



a - THERMOSYPHON SYSTEM

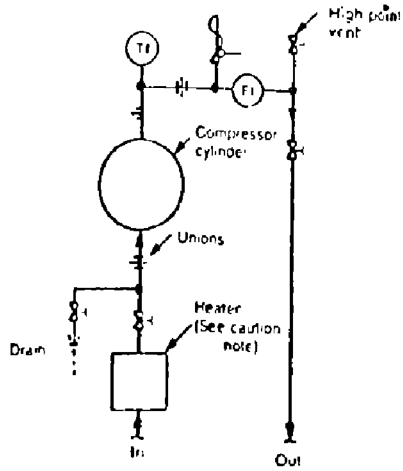
CAUTION:

When jacket water temperature is to be controlled by steam spraying the following precautions should be observed:

a. A silent (water-hammer-cushion type) steam sprayer should be placed in the water inlet line to the jacket system.

b. The water flow rate must remain constant in accordance with the manufacturer's requirements.

c. The steam flow into the water should be regulated automatically to maintain the water jacket temperatures in accordance with 6.2.4.2.1.c



c - FORCED LIQUID COOLANT SYSTEM

COOLING PROVISIONS FOR RECIPROCATING COMPRESSOR CYLINDER

Fig. B.1 (a-c)

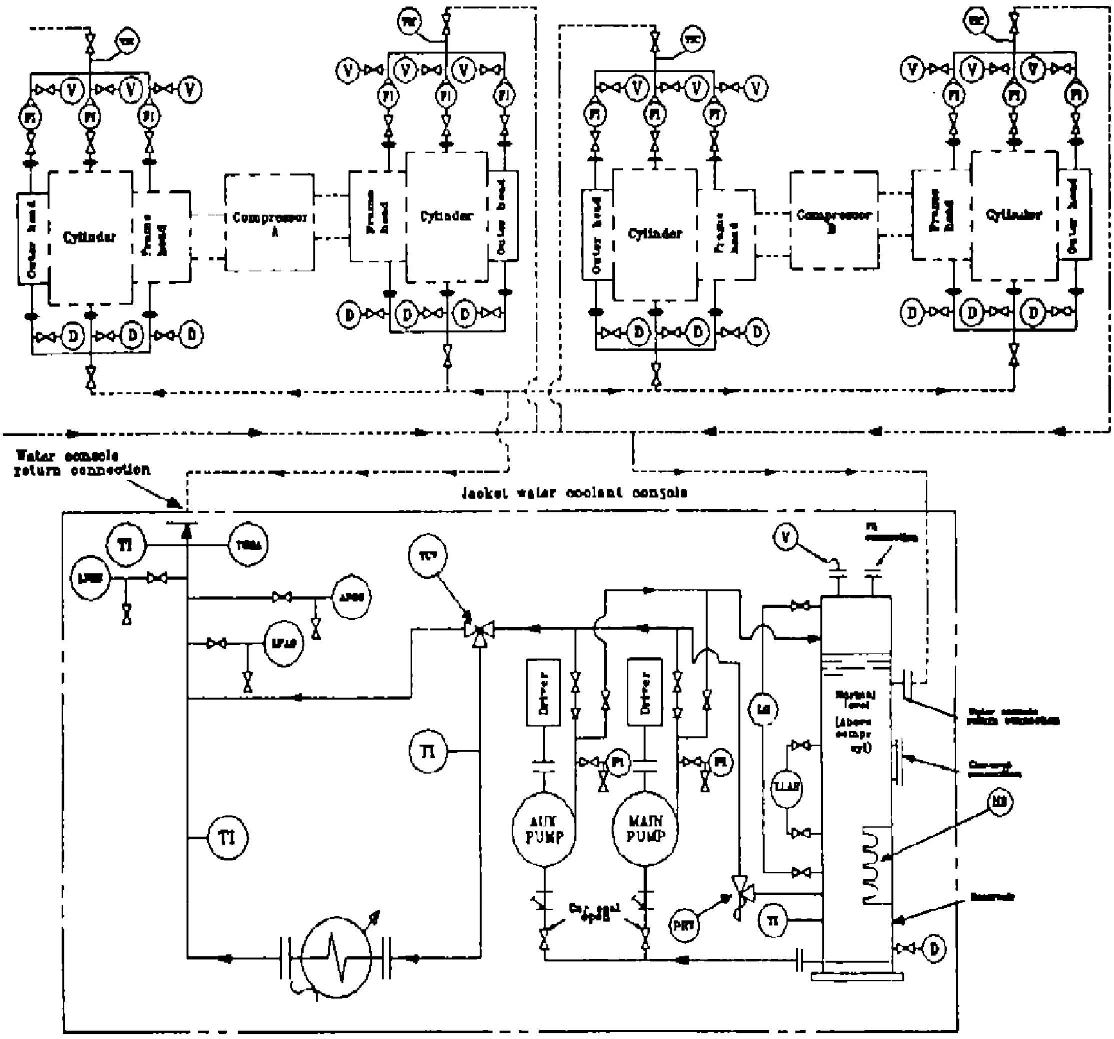
Notes:

1) The console shown in Plan is typical; more or less equipment may be furnished.

2) Heaters used to preheat the cylinder cooling water (if needed to meet the requirements) may be electric, hot water or steam.

They must be sized to take into account heat losses of surface areas of the cylinder, pipe, and fittings. Good judgment must be exercised so that heaters will not be undersized.

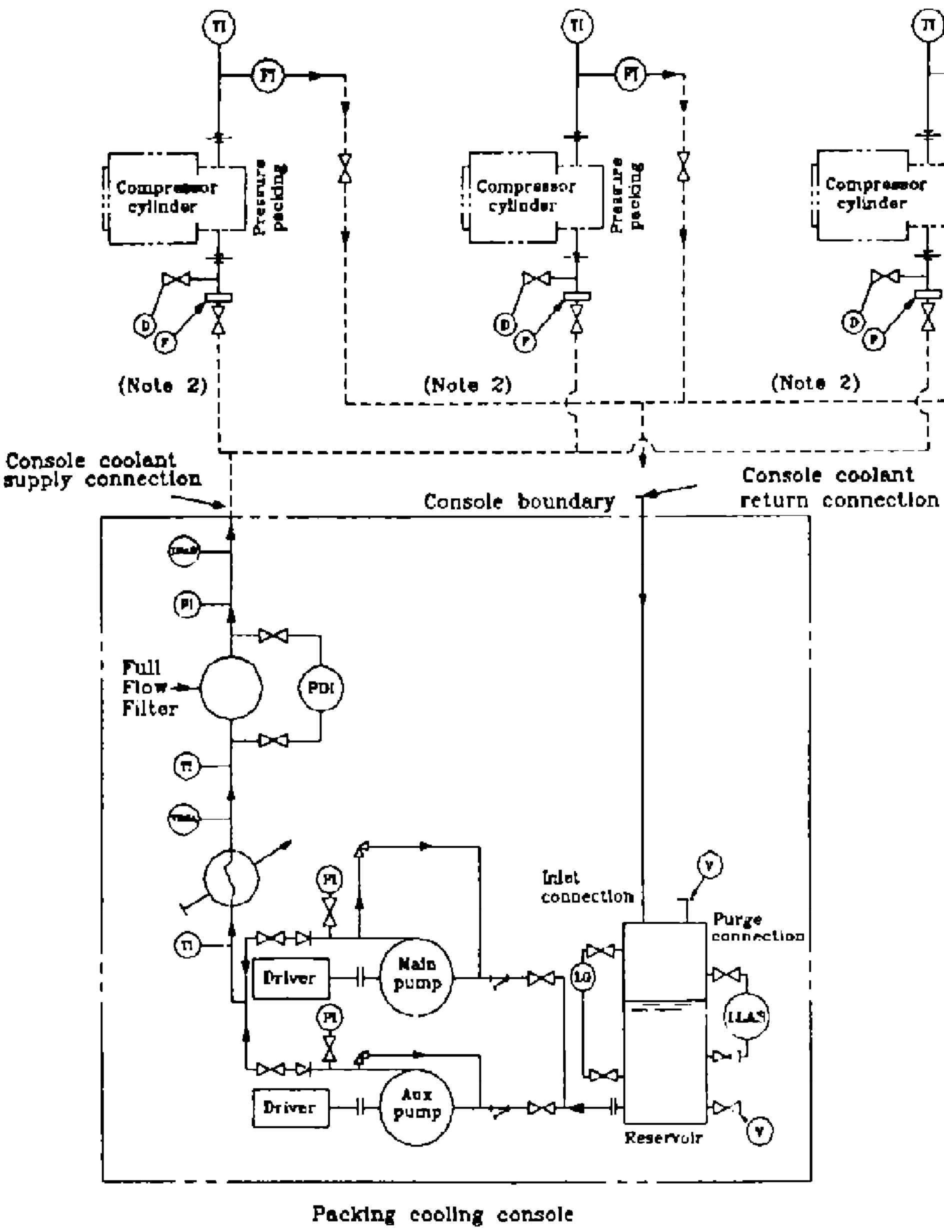
APPENDIX C



CLOSED COOLING WATER SYSTEM FOR RECIPROCATING COMPRESSOR CYLINDER AND HEAD COOLING INSTALLATIONS

Fig. C.1

APPENDIX D



TYPICAL SELF-CONTAINED COOLING SYSTEM FOR PISTON ROD PRESSURE PACKING

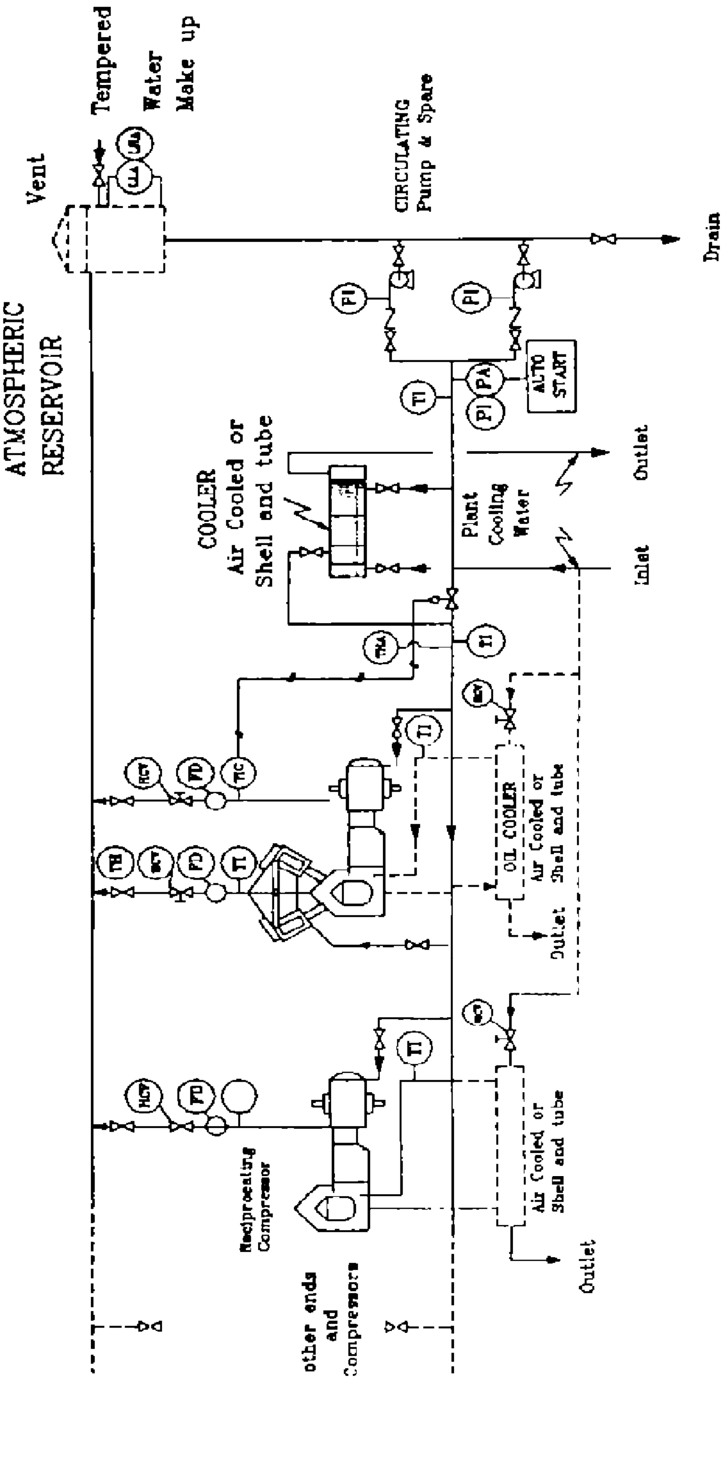
Fig. D.1

Notes:

1) The system shown is typical; more or less equipment may be furnished.

2) If a packing cooling console is not supplied, individual filters are required.

APPENDIX E



CLOSED COOLING WATER SYSTEM FOR RECIPROCATING COMPRESSORS INTEGRAL WITH ENGINE, LUBRICATING OIL AND COMPRESSOR PACKING BOX COOLING INSTALLATIONS

Fig. E.1

PART TWO
COOLING WATER CIRCUITS
FOR
INTER-COOLING AND AFTER-COOLING FACILITIES

6.3 Desing Requirements and Features

6.3.1 Unless otherwise specified by the Company, Vendor shall supply water cooled intercoolers and aftercoolers for skid mounted reciprocating compressors.

6.3.2 Unless otherwise specified. The process design of the intercoolers and aftercoolers shall be based on IPS-E-PR-750 "Process Design of Compressors" and the Appendix "C" thereof.

6.3.3 Not withstanding Clause 6.3.2 above, shell and tube heat exchangers shall be used for intercooling and aftercooling and shall be in conformity with API 619, and API 680, on the following:

a) Water-cooled intercoolers and aftercoolers for nonflammable, nontoxic services (air, inert gas, and so forth) shall be designed and constructed in accordance with the ASME Boiler and Pressure Vessel Code. For flammable or toxic gas services, TEMA* Class R heat exchangers shall be furnished and shall be in accordance with API Standard 660 and Section VIII, Division 1 of the ASME Code.

b) Water shall be on the tube side of the heat exchanger.

c) Unless otherwise specified the water side of shell and tube exchanger shall be designed in accordance with Part One, Clause 6.2.7.5 of this Standard.

d) Intercoolers shall be mounted separately or on the machine, as specified by the Company.

e) Relief valves shall be provided on the process side of both intercoolers and aftercoolers.

f) Rupture discs on the shell side shall be furnished only when specified by the Company.

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6.3.4 Intercoolers and aftercoolers shall be provided by the Vendor, with facilities to separate, collect and discharge condensate through a continuous drainer. Condensate collection pots shall be per the ASME Code, Section VIII or other pressure vessel code specified by the Company.

6.3.5 Air-cooled heat exchanger shall only be used for skid mounted compressor's intercoolers and aftercoolers upon the Company's requirements and approval.

6.3.6 When air-coolers are specified by the Company, they shall conform either to API Standard 661, or shall be of Vendor's standard. Vendor shall inform the Company on the advantages of Vendors's standard and shall acquire Company's written approval.

6.3.7 Unless otherwise specified, air-cooled heat exchangers used for intercoolers and aftercoolers shall have automatic temperature control. This control may be accomplished by louvers, variable pitch fans, bypass valve or by any combination thereof. The proposed control systems shall be approved by the Company.

6.3.8 Caution should be exercised because of the susceptibility of heat-exchangers and their supporting structures to pulsation-induced vibration.

6.3.9 Thermometer wells should be located at the inlet and outlet of the intercoolers and aftercooler and temperature reading should be taken at these points.