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Specification for Process Design

Discipline: Process

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Chemical Complex for Phosphates Processing Project

CONTENT

1 General & Project Description

As part of the implementation of a strategic investment project, "EuroChem" decided to build a Chemical Complex for the processing of phosphates in the Republic of Kazakhstan. The Project Site is located approx. 25 km west of Zhanatas. This chemical complex will comprise process units and utilities as defined in the following paragraphs, and includes a set of interconnected productions:

Number	Production unit
7G16	Sulfuric Acid Plant (SAP)
7G21	Potassium Sulfate Plant (SOP)
7G25	Di Calcium Phosphate Production Plant (DCP)
7G17	Calcium Chloride ($CaCl_2$)
7G02	Offsite & Utilities (O&U)

2 Abbreviations

The list of abbreviations used in this document is provided in the below table:

Abbreviation	Description
OWNER	EuroChem Karatau, Limited Liability Company
CNCEC	China National Chemical Engineering Group Corporation Ltd.
PRAYON	Process Design Package Licensor of DCP Plant
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
BFW	Boiler Feed Water
CSC	Car Seal Close
CSO	Car Seal Open
EOR	End of Run
SOR	Start of Run
GA	General Arrangement
HMB	Heat and Mass Balance
IPDS	Instrument Process Datasheet
OSBL	Outside Battery Limit
ISBL	Inside Battery Limit
MSDS	Material Safety Datasheet

Abbreviation	Description
NPSHa	Net Positive Suction Head Available
TEMA	Tubular Exchanger Manufacturers Association
TL	Technology Licensor
TSV	Thermal Safety Valve
P&ID	Piping & Instrumentation Diagram
PDS	Process Datasheet
PFD	Process Flow Diagrams
PSV	Pressure Safety Valve
PVRV	Pressure Vacuum Relief Valve
SIL	Safety Integrity Level

3 Codes & Regulations of Kazakhstan

Following codes and regulations shall be applied to the project.

Description	Document No.	Rev.
Dry Mineral Fertilizers and Plants Protection Chemicals Storage Facilities	SN RK 3.02-30	2019
Regulations for Ensuring Industrial Safety for Chemical Hazardous Industrial Facilities	Order No. 345	Dated on December 30th, 2014, amended as of 2022-09-19
Pressure Vessels. Main Requirements for Design	ST RK 1357	2005
Industrial Safety Rules for Operation of Pressure Equipment	Order No. 358	dated on December 30th, 2014, amended as of 2022-05-06
Process Equipment and Process Pipelines	SP RK 3.05-103	2014 amended as of 2017-09-07
Boiler Units	SN RK 4.02-05	2013 amended as of 2017-09-07
On Approval of the Technical Regulation “Requirements for Safety of Fertilizers”	Order of the Minister of Agriculture of the Republic of Kazakhstan No. 143	dated on April 29th, 2020
Steel Welded Vessels and Apparatus. General Specifications	GOST 34347	2017

Industrial Safety Rules for Operation of Compressor Stations	Order of the Minister of Investments and Development of the Republic of Kazakhstan No. 360	dated on December 30th, 2014
Occupational Safety Standards System. Noise. General Safety Requirements	GOST 12.1.003	2014

4 Application

The specification outlines and establishes the principle for process design shall be applied to all process and utility units in Chemical Complex for Phosphates Processing Project.

Additions or revisions to the specification may be proposed by licensor or sub-contractors by raising a technical query.

The objective of this document is to ensure consistency of approach to design of equipment and bulk items across the project.

5 General Principle

The philosophy established in this document shall be applied to the sizing of equipment, line and control valve, design pressure/temperature of equipment and line, and other aspects of process design.

6 Reference Documents

Document No.	Title
7G02-00-16-001	Design Basis for the Facility (ITB Stage)
	DCP Plant: Basis of Design

7 Equipment Sizing Criteria

7.1 Vessel

7.1.1 Drum Surge Capacity and Hold-up Volume

For drums the surge capacity (hold-up) is defined as the volume between high and low liquid levels.

If a uniform discharge rate is important, provide the general hold-up time based on design flow rate below:

Service		Hold-up time (Minutes)
Feed to column or furnace (feed surge) Drum diameter, meter	<1.2	20
	1.2 - 1.8	15
	>1.8	10
Reflux to column		5
Product to storage		2
Flow to heat exchanger		2
Flow to sewer or drain		1

In case hold-up must be provided for both product and reflux, the larger volume is used instead of the sum of both volumes.

When the discharge rate is unimportant, a nominal hold-up time of approximately two (2) minutes shall be provided.

The normal liquid level (NLL) should be taken as the midpoint between the high and low level. Level control should span between the high and low level. Where high and low level trip are required, these should be located at a reasonable elevation above and below the high and low levels respectively, to allow operator intervention before a trip occurs.

Low liquid level (LLL) shall be at least 200 mm above the bottom (for horizontal vessel) or bottom tangent line (for vertical vessel).

For horizontal vessel, the high liquid level (HLL) is either 300 mm or 20% of the drum diameter from the top, whichever is the greater. Note: if a crinkled wire mesh pad is present then HLL is 300mm from the bottom of the pad.

For vertical vessel, if vapor flow is present, the highest liquid level shall be at least 300mm below the bottom of the inlet nozzle. If little or no vapor is present, the highest liquid level shall be at least 300 mm or 15% of the drum diameter from the top tangent line, whichever is the greater.

The minimum time between a HHLL (LLLL) alarm and HHHLL (LLLLL) trip shall be no less than 2 minutes.

7.1.2 Column Bottom Surge Capacity and Hold-up Volume

The liquid residence time (from the low to high level) for the design of the bottom section of a column is as follows:

(a) Bottom as feed to a subsequent column on level control is five (5) minutes.

(b) Bottom as feed to a subsequent column on flow control is ten (10) to twenty (20) minutes, when the column is acting as a feed surge drum to another unit. This surge capacity may be obtained by swaging to a larger diameter for the hold-up section of the column, in some cases.

(c) Bottom to a heat exchanger or tank is two (2) minutes. This may be reduced in order to prevent fouling in the column.

7.2 Heat Exchanger

7.2.1 Fouling Factor

Specific fouling factors shall be set as shown below. However, where licensor has requirements that are more stringent than these, then licensor values shall be applied.

(a) Cooling water in open recirculation loop: 0.00034 ($m^2 \cdot K$)/W

(b) Steam service: 0.000086 ($m^2 \cdot K$)/W

(c) Other service: as per TEMA and licensor standard

7.2.2 Fluid Allocation

To allocate fluids to shell or tube side of an exchanger, the following general principles of fluid allocation shall apply:

(a) Cooling water on tube-side

(b) Corrosive fluid on tube-side

(c) Higher fouling fluid on tube-side

(d) Viscous fluid on tube-side

(e) Large volume of condensing vapor on shell-side

(f) Smaller flow on shell-side when both sides are single phase

The above principles may conflict in some instances and alternative designs shall be investigated. In these cases the most economical design shall be selected.

7.2.3 Pressure Drop

The pressure drop available shall be specified as below and all hydraulic calculation shall allow for the specified pressure drop.

(a) Liquid Flow

Total Pressure Drop			
Viscosity @ avg. temp. cP	One Shell kPa	Two Shells in Series kPa	Three Shells in Series kPa
<1	35 - 70	35 - 70	70 - 100
1 - 5	70	100	100 - 135
5 - 10	100	100 - 135	135
> 10	135	135 - 200	200

Note: The same total pressure drop applies for liquid flow through plate exchanger.

(b) Gas Flow

Operating Pressure bara	Total Pressure Drop kPa
0 - 1.7	Approx. 3 - 7
>1.7	14 - 35

(c) Condenser

1) Total Condenser

The pressure drop is usually low or negligible.

2) Surface Condenser (vacuum service)

Allow 0.4 - 0.67 kPa for operating pressures about 0.04 bara.

7.3 Pump

The available NPSH (NPSHa) shall exceed the required NPSH (NPSHr) by 0.6m at rated flow rate. For boiler feed water pump, NPSHa shall exceed NPSHr by a minimum 2.1m margin up to design capacity at the initial calculation stage. When accurate pump suction layouts are known this margin may be reduced to 1.5m following review of the calculation.

The possibility of pump cavitation shall be excluded in all possible operating range of the pump.

Process engineers shall identify the turndown flows below 50% of the design capacity on the process specification, when such flows are possible during long-term operating conditions covered by guarantees of plant performance.

The reference level for setting NPSHa shall be the bottom tangent line for vertical vessel, the bottom of the vessel for horizontal vessel, the low low level for tank and the pump impeller center line for pump.

The following elevation for pump centerline shall be assumed before pump vendor details are available:

Flow m^3/h	Centerline Elevation m
Up to 45	0.76
45 - 225	0.91
225 - 2270	1.07
2270 - 4540	1.37

Final hydraulic check will be performed with vendor data and final isometrics. A minimum flow bypass will be foreseen for centrifugal pump for the following cases:

(a) Differential pressure of pump higher than or equal to 35 bar

(b) Large pump with driver power higher than 160 kW

(c) For process reason (turndown), flow rate lower than or equal to 30% of max flowrate

Note: A final comparison between the turndown flow and the minimum flow by pump protection shall be made with data given by pump vendor regarding the required minimum flow.

To protect the pump, the following systems could be used:

(a) Pressure (flow) regulator in the minimum flow bypass

(b) Restriction orifice (RO) in the minimum flow bypass

The choice of the configuration will be done on a case by case study. Nevertheless, except for particular cases, the protection with a permanent recirculation flow is usually adopted for pumps capacity less than 15 m^3/h.

7.4 Equipment Design Life

The design life of equipment shall be no less than 20 years.

7.5 Equipment Design Temperature

7.5.1 Upper Design Temperature

Upper design temperature (UDT) shall be set at 30°C above the maximum operating temperature (not applicable for FRP/plastic equipment). The minimum UDT shall be 80°C.

The maximum operating temperature is defined as the highest material balance temperature. Consideration shall also be given to other conditions such as startup, shut-down and failure of upstream coolant. Such temperature should be considered on a case by case basis to establish if they should be taken as the maximum operating temperature.

In the case of coolant failure for process units, the maximum operating temperature upstream of the cooler shall be taken as the downstream design temperature. This should apply to downstream pipeline, only up to the next major item of equipment.

7.5.2 Lower Design Temperature

The lower design temperature (LDT) for which process equipment must be designed will normally be specified as the lower value of:

a) Minimum operating temperature minus 5°C

b) Minimum mechanical temperature resulting from ambient temperature

   1) The minimum mechanical temperature of pressurized equipment operated above ambient temperature shall be -20°C.

   2) The minimum mechanical temperature of pressurized equipment operated at ambient temperature shall be -42°C of minimum temperature DESIGN.

7.6 Equipment Design Pressure

7.6.1 Tank

a) Tank with open vent

The design pressure shall be considered full of liquid at the operating specific gravity (SG). If the open vent is a pipe, pressure drop through the vent pipe should be considered.

b) Tank with breather valve

The design pressure shall be considered full of liquid at the operating specific gravity plus the maximum gas pressure in the tank.

Note:

Both types of tank shall be designed for the specific gravity of the fluid at ambient temperature or 1.0, whichever is higher.

7.6.2 Pressure Vessel

The design pressure shall be the higher value of the following:

a) 3.5 barg

b) Values specified in 4.6.3

7.6.3 Equipment in Non-pump System

The design pressure for equipment in non-pump system shall be as follows.

Maximum Operating Pressure (MOP), barg	Design Pressure, barg
≤0.3	Set on a case by case basis
0.3 - 17	MOP + 1.7
17 - 40	110% of MOP
40 - 80	4.0 + MOP

The design pressure for equipment in pump system shall be determined as per pump shut-off pressure. 130% of pump differential pressure (head) could be used as shut-off pressure for current stage and shall be verified with selected pump performance curve during detailed engineering.

7.6.4 Vessel under Vacuum Condition

Vessels which may operate under vacuum conditions during normal operation shall be designed for full vacuum. In addition, the steam side of heat exchanger shall be designed for full vacuum also.

8 Line Sizing Criteria

8.1 Liquid Flow

The guidelines shown in the following table should be used to size process piping for liquid (for slurry see 5.3). The guidelines cover most normal situations for systems within unit battery limit, but they may not be applicable for all cases. For critical services and long headers, the total pressure drop in the system must be checked to ensure the system meets the design pressure balance, whether or not individual process lines meet the pressure-drop and velocity criteria given here.

Sizing Liquid Line	**Recommended High Limit**	
	△P per 100 m bar	**Velocity m/s**
Pump suction line (1) (2)	0.10	1.5 - 2
Pump discharge line		
≤3”	0.7	1.5 - 3
>3”	0.5	
Liquid transfer line (3)	0.35	1 - 2
Cooling water line		
- Main header	0.15	3.5
- Branch	0.30	2.0
Steam condensate line	-	1.0

Notes:

1) Pump suction line size should normally not be more than two (2) standard line sizes larger than the pump suction nozzle.

2) For reciprocating pump, acceleration head loss has to be taken into account in the pump suction circuit design. The installation of a damper may be required to avoid acceleration loss which is to be studied with pump vendor.

3) Or as required by system pressure balance.

8.2 Vapor Flow

The guidelines shown in the following table should be used to size vapor line. The guidelines cover most normal situations for systems within unit battery limits, but they may not be applicable for all cases. For critical services and long headers, the total pressure drop in the system must be checked to ensure the system meets the design pressure balance, whether or not individual process lines meet the pressure drop and velocity criteria given here.

Sizing Vapor Line	**Recommended High Limit**	
	△P per 100 m bar	**Velocity m/s**
Air compressor inlet line	0.02	10 - 15
Air compressor discharge line	1% of discharge pressure	15 - 20
Low pressure steam (<10 bara)	3% of inlet pressure	15 - 20
Medium pressure steam (10~40 bara)		20 - 40
High pressure steam (>40 bara)		40 - 60
Vacuum service		
≤0.5 bara	0.011	5 - 10
>0.5 bara	0.02	
Atmospheric gas	0.02	10 - 20
Compressed gas		
<2 bara	5% of inlet pressure	8 - 12
2~6 bara		10 - 20
6~10 bara		10 - 15

8.3 Slurry Flow

Slurry lines are to be designed on a case by case basis. Solid suspension and erosion shall be considered in the design.

8.4 Drain and Vent

Drain and vent line for process/utility lines shall be normalized to 3/4" unless otherwise specified. Drain and vent line for vessels shall be sized as below.

Vessel Volume, m^3	Vent	Drain
1.5	25 (1")	25 (1")
1.5 - 5.6	25 (1")	40 (1 1/2")
5.6 - 17	50 (2")	50 (2")
17 - 70	50 (2")	80 (3")
70 and over	50 (2")	80 (3")

8.5 Line Design Life

The design life of pipeline shall be no less than 15 years.

8.6 Line Design Temperature

Refer to 7.5.

8.7 Line Design Pressure

The line design pressure shall be no less than that of connected equipment. The design pressure of equipment refers to 7.6.

9 Utility Station

Utility station used in supplying materials for temporary cleaning, replacement, start-up preparation, incident handling and maintenance, shall not be used for normal operation.

The following shall be considered for utility station:

a) Utility station design shall be based on different process conditions and requirements and material properties.

b) Plant air shall be used for utility station, and instrument air is not allowed.

c) Fire water, steam with pressure higher than 10 barg, cooling water and steam condensate shall not be used for utility station.

d) Location of utility station should be considered to ensure pipeline can still be used even if a section or unit is shutdown.

10 Overdesign Margin

As a general rule, the following overdesign margin shall be taken for the sizing of individual equipment item. For pump and compressor in licensed process unit, overdesign margins proposed by the licensor will be retained where larger than specified hereafter. For other equipment, the design specified by licensor will be applied and supersedes the overdesign margin hereafter.

Equipment	Design Margin for 100% Capacity
Heat exchanger	10% of duty and flow
Pump	
For process service	10% of flow
For utility service	20% of flow
Compressor	10% of Flow