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Phosphoric Acid Manufacture by Prayon Process

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Glossary

$/t	Dollars per metric ton
¢/lb	Cents per pound
AACE	Association for the Advancement of Cost Engineering
ACFM	Actual cubic feet per minute
atm	Atmospheres
Bcm	Billion cubic meters
BFD	Block flow diagram
BFW	Boiler feedwater
BLI	Battery limits investment
BPL	Bone phosphate of lime
Btu	British thermal units
°C	Degree Celsius
cP	Centipoise
CPP	Central-Prayon Process
cf/ft^3	Cubic feet
CS	Carbon steel
CW	Cooling water
DAP	Diammonium phosphate
DH	Dihydrate
dia	Diameter
DM	Demineralized
DPP	Dihydrate Prayon Process (Mark-4)
EPA	US Environmental Protection Agency
EPC	Engineering, procurement and construction
EV	Electric vehicle
°F	Degree Fahrenheit
ft	Feet
ft^2	Square feet
ft^3	Cubic feet
ft dia	Feet diameter
FDA	US Food and Drug Administration
FRP	Fiberglass reinforced plastic
g	Grams
G&A	General and administrative
gal	Gallon(s)
GCT	Groupe Chimique Tunisien
gpm	Gallons per minute
GRAS	Generally recognized as safe
h	Hours
HH	Hemihydrate
HH-DH	Hemihydrate-dihydrate
IPL	Incitec Pivot Ltd.
ISBL	Inside battery limits
kg	Kilograms
kJ	Kilojoules
kPa	Kilopascals
KTA	Kilotons per annum
kWh	Kilowatt-hour(s)
lb	Pound(s)
lb/h	Pounds per hour
LFP	Lithium iron phosphate
LLFC	Low-level flash cooler
LMFP	Lithium manganese iron phosphate
LP	Low pressure
MAP	Monoammonium phosphate

MGA	Merchant-grade phosphoric acid
mgal	Thousand gallons
mlb	Thousand pounds
ml/h	Milliliter per hour
MMt	Million metric tons
MMtpa	Million metric tons per annum
MMt/y	Million metric tons per year
MOC	Material of construction
mol%	Molar percent
mPa	Megapascals
MPC	Ma'aden Phosphate Co.
NA	Not applicable
NESHAP	National Emission Standards for Hazardous Air Pollutants
OSBL	Outside battery limits
OCP SA	Office Chérifien des Phosphates Société Anonyme
PEP	Process Economics Program
PFD	Process flow diagram
PH1	Hemihydrate Prayon Process
PH2	Hemihydrate then dihydrate Prayon Process
PH3	Hemihydrate then dihydrate then hemihydrate Prayon Process
ppb	Parts per billion
ppm	Parts per million
psi	Pounds per square inch
psia	Pounds per square inch absolute
psig	Pounds per square inch gauge
ROI	Return on investment
RPM	Rotations per minute
s	Second(s)
SAP	Solid ammonium phosphate
scf	Standard cubic feet
scm	Standard cubic meter
SDA	Soaps and Detergent Association
SPA	Super phosphoric acid
SS	Stainless steel
STPP	Sodium tripolyphosphate
t	Metric ton
t/d	Metric tons per day
t/y	Metric tons per year
TFC	Total fixed capital
TSP	Triple superphosphate
USGC	US Gulf Coast
UOM	Unit of measure
vol%	Volume percent
WPAA	Wet-process phosphoric acid
w/w	Weight for weight

Abstract

Phosphoric acid (H_3PO_4) is the most important oxyacid of phosphorus (P) and is majorly used to produce phosphate fertilizer products like ammonium phosphates and triple superphosphate. It is also used in dental cements, in the preparation of albumin derivatives, in sugar and textile industries and for potential of hydrogen or acidity (pH) control in food industries like cheese products, fats, shortening and soft drinks [1, 2]. Fertilizer production accounts for more than 80% of the global market for phosphoric acid, with animal feed accounting for about 5%. The remainder is consumed in a variety of industrial applications [CEH-Phosphoric Acid].

The fastest growing market for phosphoric consumption is for lithium iron phosphate (LFP) and lithium manganese iron phosphate (LMFP) batteries that are used in electric vehicles (EVs), particularly in mainland China, with an expected annual growth rate of 15%-20% till 2029. Traditional markets for H_3PO_4 are mature on a global level and are expected to grow at less than 1% annually. On a volume basis, the production of diammonium phosphates (DAPs) has the largest influence on global phosphoric acid growth rates, accounting for about one-third of global consumption, followed by monoammonium phosphates (MAPs) [CEH-Phosphoric Acid].

From 2023 to 2024, significant capacity reductions occurred in Central and Eastern Europe; however, these were offset by more capacity expansion in Africa, mainland China, Kazakhstan, and Russia. Over the next five years, a few million metric tons of new capacity expansion is further expected in the Middle East, India, Oceania, and Central and South America.

In the Process Economics Program (PEP), not much work has been done in recent years on phosphoric acid production technologies. The last PEP report from the phosphoric acid series PEP reports (RP08C) was published in August 1982 covering the process economics for dihydrate, hemihydrate-dihydrate, and hemihydrate processes while PEP Review 1992-03-02 covered the economics for phosphoric acid production from the thermal process, and its purification to technical and food-grade phosphoric acid products. Phosphoric acid plants also produce a large quantity of gypsum (4.5 to 6 tons per ton of P_2O_5, depending on the rock feed CaO/P_2O_5 ratio), which has limited applications. PEP Review 1986-02-02 covered gypsum utilization to produce sulfuric acid and aggregate and construction applications using the DMC-FIPR process, “a joint venture of Davy McKee Corp. and Florida Institute of Phosphate Research.”

This review extends the earlier PEP works and covers the major technology developments in the last five decades and presents the production economics for the Prayon Hemihydrate-Dihydrate (HH-DH) process, or “PH2 process,” for phosphoric acid production for a 1,200-ton per day (t/d) capacity plant (on P_2O_5 basis) at a US Gulf Coast location. It also presents the economics comparison of the designed phosphoric acid plant for gypsum byproduct utilization and disposal cases. An iPEP Navigator tool is also attached with the electronic version of this report. The interactive iPEP Navigator process optimization module provides an economic snapshot for the process, allowing the user to select and compare the processes, units, and regions of interest.

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