Task for the Engineering Cup

OPTIMISING LIME CONSUMPTION IN PHOSPHOGYPSUM NEUTRALISATION

Focus area

Solutions in the field of chemical and technological processes and efficiency improvement in mineral fertiliser production

Objective

To develop an engineering solution that enables automated control and regulation of the phosphogypsum neutralisation process, reduces excess lime consumption, and improves the quality of the final product.

Company overview

LLC *Phosphorit Industrial Group* is one of the largest chemical industry enterprises in Russia and is part of the EuroChem mineral and chemical company.
The company specialises in the production of wet-process phosphoric acid and mineral fertilisers, as well as in the processing of by-products, particularly phosphogypsum used in construction and agriculture.

The enterprise actively implements engineering and technological solutions aimed at increasing efficiency, reducing costs, and enhancing the environmental sustainability of production processes.

Context and relevance

In the process of producing wet-process phosphoric acid, a by-product - phosphogypsum - is generated.
To reduce its acidity and make it suitable for further use, it undergoes neutralisation with quicklime.

Currently, the pH of raw phosphogypsum is measured manually once every four hours. Such infrequent sampling leads to delayed adjustment of reagent dosing, which results in excess lime consumption, higher production costs, and increased risk of producing low-quality material.

Automating the monitoring and control of lime consumption will help reduce operating costs, stabilise product quality, and increase the environmental safety of the production process.

Problem

The absence of an automated system for in-stream pH measurement of phosphogypsum and precise control of lime feed leads to reagent overconsumption and reduces the overall efficiency of the neutralisation process.

Challenge for participants

Develop an engineering solution for optimising the consumption of quicklime in phosphogypsum neutralisation.

Participants must:

- calculate the optimal reagent (quicklime) consumption based on active CaO content and the initial pH of phosphogypsum in order to achieve the target pH range (6.4–8.5);
- select a suitable pH measurement method and propose its hardware implementation;
- develop a scheme for automatic lime feed regulation;
- propose a cascade control algorithm based on the parameters of the incoming flows;
- assess the economic effect and cost savings achieved through precise dosing;
- estimate the project budget and implementation timeline;
- prepare a roadmap for deploying the solution.

Initial data

- Phosphogypsum line throughput: 100–438 t/h
- Initial phosphogypsum pH range: 2–4
- Target pH after neutralisation: 6.4–8.5
- Average active CaO content in lime: 65%
- Current lime consumption: 7.3 kg/t
- Cost of quicklime: 7,100 RUB/t
- Quicklime conforms to GOST 9179-2018
- Production description — extract from Permanent Process Regulation No. 22 (Appendix)

Constraints

- The neutralisation unit is located 680 m away from the main production area
- In winter, steam formation and icing occur on the conveyor
- Phosphogypsum tends to adhere and harden, complicating feed and dosing control
- The solution budget must be economically justified and technically feasible within the existing infrastructure

Expected Deliverables

1. Calculation of optimal reagent consumption and a regulation model for the neutralisation process
2. Proposal for the pH measurement method and its technical implementation
3. Scheme or algorithm for automatic lime feed regulation
4. Economic justification: calculation of cost reduction and payback period
5. Implementation plan and project roadmap

Additional materials

Appendix 1. Extract from Permanent Process Regulation No. 22 for neutralised universal phosphogypsum production

Appendix 2. Information about LLC *Phosphorit Industrial Group*

If participants have questions, they may contact:
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Appendix 1. Extract from Permanent Process Regulation No. 22 for neutralised universal phosphogypsum production

Extract from Permanent Process Regulation No. 22 for the Production of Neutralised Universal Phosphogypsum

1. General Description of Production

The name of the production process: manufacture of the target product (secondary raw material) *"Neutralised Universal Phosphogypsum"* from secondary resources (waste generated during the decomposition of natural phosphates with sulfuric acid — phosphogypsum — in the production of wet-process phosphoric acid, hereinafter referred to as "phosphogypsum before neutralisation").

"Phosphogypsum before neutralisation" is generated in the production of wet-process phosphoric acid as a result of decomposing natural phosphates with sulfuric acid, producing extraction slurry, which is then separated into liquid and solid phases using carousel and belt vacuum filters.
This waste is classified as a secondary resource in accordance with Article 17.1 of Federal Law No. 89-FZ of 24.06.1998 "On Production and Consumption Waste".

Applied technology: neutralisation of "phosphogypsum before neutralisation" using quicklime.

Design production capacity: 3,263 thousand tonnes per year.
Annual operating time: 330 days (7,920 hours).
Number of process streams: one.
Location of technology implementation:
Production site of mineral fertilisers at LLC *Phosphorit Industrial Group*. Phosphogypsum Neutralisation Unit.

Phosphogypsum line throughput: 300 t P_2O_5/h (Section 2) and 138 t P_2O_5/h (Section 1).

2. Characteristics of the Manufactured Product

Technical name of the product according to normative and technical documentation: Neutralised Universal Phosphogypsum

Technical specification:
TU 20.13.41-022-56937109-2023 "Neutralised Universal Phosphogypsum. Technical Requirements and Product Standards"

Product indicators

Indicator	Standard
1. Mass fraction of calcium sulfate ($CaSO_4$), %, not less than	90
2. Mass fraction of total phosphates (as P_2O_5), %, not more than	1.9
3. Mass fraction of water-soluble phosphates (as P_2O_5), %, not more than	0.4

Neutralised Universal Phosphogypsum is a solid, fine-crystalline material ranging from white to grey in colour, containing particles (lumps).

Applications

Neutralised Universal Phosphogypsum is used in the production of:

- Neutralised phosphogypsum (TR 20.13.41-018-56937109-2019)
  Safety Data Sheet No. RPB 56937109.20.64457 of 23.10.2020
  Used in the cement industry, gypsum binders, construction materials, calcium thermosulfate production, land reclamation (including backfilling pits and excavations), and as a material for constructing containment dams.
- Agrochemical “Phosphogypsum for Agriculture” (TU 20.15.49-019-56937109-2019)
  Registered by the Ministry of Agriculture of the Russian Federation
  Safety Data Sheet No. RPB 56937109.20.77599 of 26.10.2022
  Used as a chemical ameliorant for slightly acidic, slightly solonetzic, and saline soils; as a calcium–sulfur fertiliser; and as raw material for composting.
- Reclamation agent based on neutralised phosphogypsum (TR 23.99.19-021-56937109-2021)
  Intended for technical land reclamation at mining sites and for grading landforms according to construction project requirements.

Hazardous substance registration

Main components of Neutralised Universal Phosphogypsum:

- **Calcium sulfate dihydrate** — registered in the Hazardous Chemical and Biological Substances Information Database
  Series No. AT-000430 of 03.04.1995 (ARIPS “Hazardous Substances”, online at http://www.rpohv.ru/online/)
- **Calcium sulfate hemihydrate** — registered in the Hazardous Chemical and Biological Substances Information Database
  Series No. AT-003001 of 18.12.2007 (ARIPS online database)

3. Characteristics of Raw Materials and Intermediates

Raw materials / intermediates	Standard / regulatory document	Mandatory indicators	Regulated limits
1. “Phosphogypsum before neutralisation” (after feeder pos. 164)	Process Regulation No. 5 for WPP production (Section 1 of WPP workshop)	Mass fraction of total phosphates (as P_2O_5)	Not regulated
		Mass fraction of water-soluble phosphates (as P_2O_5)	Not regulated
		Mass fraction of H_2O	Not more than 45.0%
		Total P_2O_5 content	Not regulated

2. “Phosphogypsum before neutralisation” (after feeders pos. 1164, 3164, 4164)	Process Regulation No. 4 for WPP production (Section 2 of WPP workshop)	Water-soluble P_2O_5	Not regulated
		Total moisture content	Not more than 36%
3. Quicklime (ground with additives): calcium (grades 1,2,3), magnesian and dolomitic (grades 1,2,3)	GOST 9179-2018	CaO + MgO content, %; active MgO content, %; CO_2 content, %	50–90; 5–40; 3–9

Origin information

This type of waste is generated in the production of wet-process phosphoric acid during decomposition of natural phosphates by sulfuric acid in dihydrate and hemihydrate modes, producing extraction slurry consisting of wet-process phosphoric acid (liquid phase) and calcium sulfate dihydrate/hemihydrate (solid phase), which is then separated using carousel and belt vacuum filters.

4. Description of the Chemical and Technological Process and Process Scheme

The method of producing *Neutralised Universal Phosphogypsum* is neutralisation of “phosphogypsum before neutralisation” with quicklime.

“Phosphogypsum before neutralisation” is produced on:

- carousel vacuum filter (CVF) pos. 142 in Section 1 of the WPP workshop,
- CVFs pos. 1142, 3142 and
- belt vacuum filter (BVF) pos. 4142 in Section 2 of the WPP workshop,
  all within the wet-process phosphoric acid production.

It is transported via a system of belt conveyors to the neutralisation unit.

Neutralisation Unit

The unit consists of:

- Silo pos. C1 containing quicklime.
- Lime is fed via automatic belt weighfeeder pos. D1 onto conveyor belt pos. 166/2g with “phosphogypsum before neutralisation”.
- Reaction produces Neutralised Universal Phosphogypsum.
- Lime flow is controlled by slide gate pos. Z1; silo equipped with vibrator pos. V1 to prevent bridging.
- Lime is delivered in bulk truck tankers and pneumatically transferred into silo C1.

Lime feed calculation depending on slurry flow to vacuum filters

SP = (((2F330 + 2F376 + 2F320) * 0.512 + 2F304 * 0.572) / 100) * SP_Oper
Where:

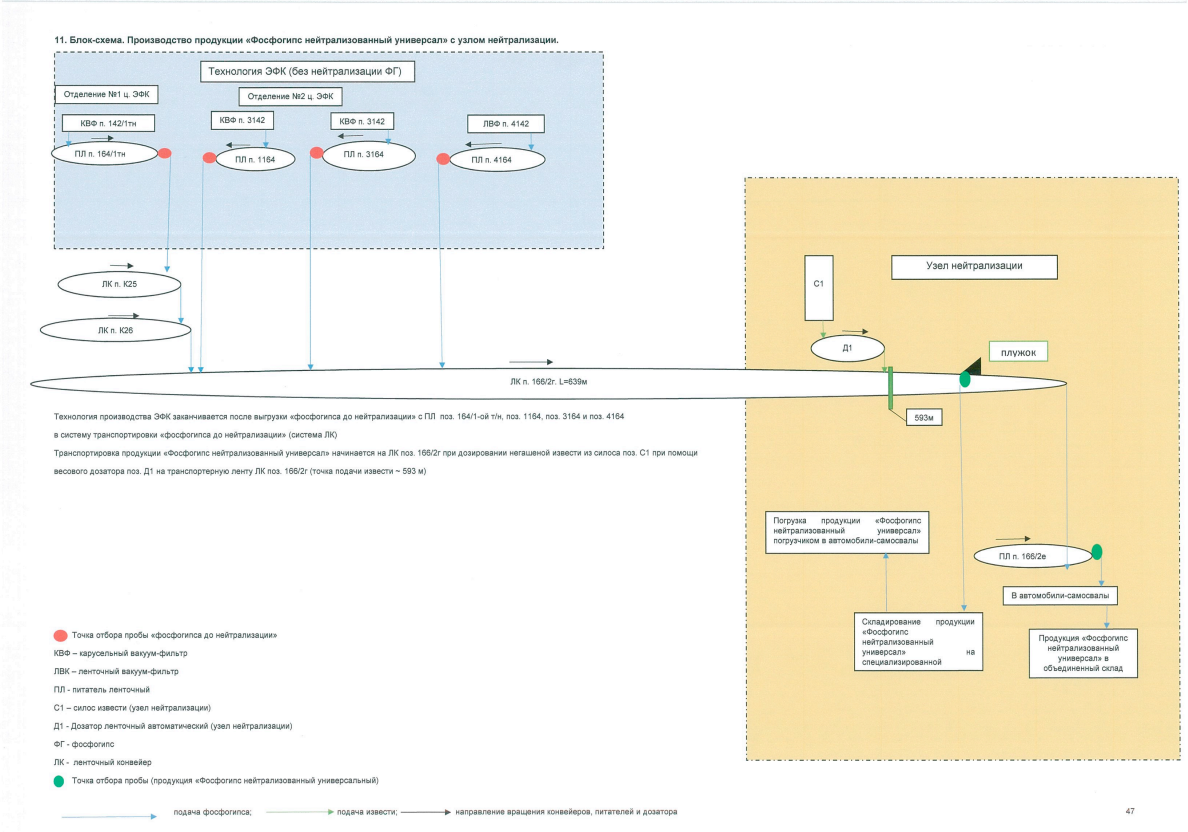
- **SP** — setpoint for the feeder (t/h)
- **SP_Oper** — operator-set coefficient (0.1–3.5), currently 0.75
- **2F330** — slurry flow to BVF4 (m³/h)
- **2F376** — slurry flow to CVF3 (m³/h)
- **2F320** — slurry flow to CVF4 (m³/h)
- **2F304** — slurry flow to CVF, Section 1 (m³/h)

Product handling

The resulting material is transported by conveyor pos. 116/2g to hopper BT-2, fed via belt feeder pos. 166/2e into dump trucks (Volvo A40G/A40F, payload 39 t), and delivered to the combined storage yard or specialised site.

Stored product is used for manufacturing various types of final products.

Process flow diagram



Information About the Company

LLC “Phosphorit Industrial Group”

1. Company Name

LLC *Phosphorit Industrial Group*.

2. Industry

Chemical industry, production of mineral fertilisers and chemical products.

3. Mission and Core Values

The company’s mission is to supply the agro-industrial sector of Russia and international markets with efficient and safe mineral fertilisers while advancing environmentally sustainable production.

Core values:
- technological development and innovation;
- environmental responsibility;
- reliability and high product quality;
- professionalism and occupational safety.

4. Number of Employees

Approximately 2,000 employees at the Kingisepp production site.
EuroChem Group, of which Phosphorit is a part, employs over 28,000 people worldwide.

5. Overview of Operations

LLC *Phosphorit Industrial Group* is one of the largest chemical enterprises in Russia, located in Kingisepp, Leningrad Region.
The company is part of *EuroChem*, a global leader in the production of mineral fertilisers.

Key areas of activity include:
- production of wet-process phosphoric acid;
- manufacturing of phosphate-based mineral fertilisers;
- processing and neutralisation of phosphogypsum, a by-product of production;
- development of technologies for secondary use of industrial waste and reduction of environmental impact.

The enterprise actively implements innovative technologies in chemical-process engineering, production automation, and engineering solutions aimed at improving operational efficiency and ensuring sustainable production.