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Thermochemical decomposition of phosphogypsum to lime and sulphur dioxide described with intuitionistic fuzzy generalized nets

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Abstract

The aim of the present paper is to model thermochemical decomposition of phosphogypsum to lime and sulphur dioxide with generalized nets.

Introduction

Phosphogypsum is a waste product from the production of extraction phosphoric acid obtained through sulphuric acid decomposition of natural phosphates. The amount of phosphogypsum produced per annum worldwide is expected to reach 220-280 millions of tonnes [1,2]. Various methods are developed for its utilization. With thermochemical decomposition of phosphogypsum to lime (calcium oxide) and sulphur dioxide, complex utilization is possible of phosphogypsum's valuable components - calcium oxide and sulphur; moreover, in this way ecological problems are solved successfully [3]. However, a major drawback of this method is the large consumption of primary energy carrier - natural gas. A basic task in technological design of an industrial plant is, therefore, to seek possible ways for its reduction.
In this paper, an intuitionistic fuzzy generalized net is proposed for the process of thermochemical decomposition of phosphogypsum. All relevant notations are as in [4].

Process description

The furnace unit for thermochemical decomposition of phosphogypsum to lime and sulphur dioxide with the products of incomplete combustion of natural gas with air consists of:

- an oven for reduction of phosphogypsum at 1000–1100^{0}C;
- heat exchangers for heating the air, phosphogypsum and natural gas;
- separator.

Natural gas is used both as a raw material and as a heat carrier. The oven gas leaves the system with a temperature of 360^{0}C, and phospholime with 100^{0}C.
The consumption of natural gas is 154,8 Nm^3/t phosphogypsum.

The present work considers an optimal structure of a furnace unit for thermochemical decomposition of phosphogypsum to lime and sulphur dioxide which, by improving the degree of heat recuperation, makes it possible to reduce natural gas consumption to 154,8 Nm^3/t phosphogypsum and at the same time, to reduce capital investments for heat-exchanging equipment (Fig. 1) [4].

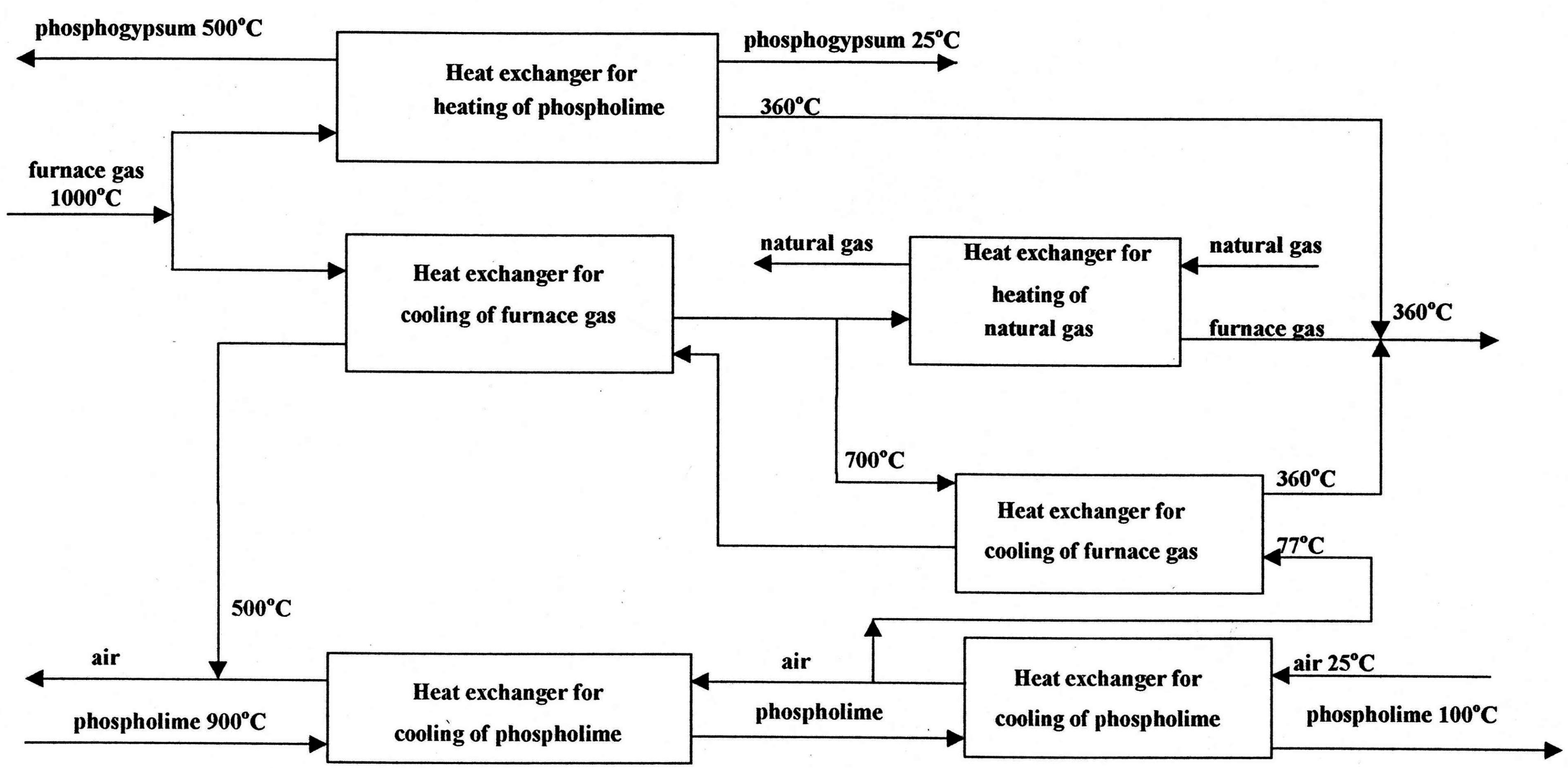

phosphogypsum 500°C
Heat exchanger for heating of phospholime
phosphogypsum 25°C
360°C
furnace gas 1000°C
Heat exchanger for cooling of furnace gas
natural gas
Heat exchanger for heating of natural gas
natural gas
furnace gas
360°C
700°C
360°C
Heat exchanger for cooling of furnace gas
77°C
500°C
air
Heat exchanger for cooling of phospholime
air
phospholime
Heat exchanger for cooling of phospholime
air 25°C
phospholime 900°C
phospholime 100°C

Figure 1

Let us denote:
T_{ng} - natural gas temperature
T_{og} - oven gas temperature
T_{phg} - phosphogypsum temperature
T_l - lime temperature
T_{phl} - phospholime temperature

The tokens enter the GN through place l_1 with initial characteristic "$T_{ng} = 25^0 C$".

$$Z_1 = \langle \{l_1, l_{15}\}, \{l_4, l_5\}, r_1, \vee(l_1, l_{15}) \rangle,$$

where

r_1	l_4	l_5
l_1	*false*	*true*
l_{15}	*true*	*false*

The tokens obtain the characteristics "$T_{og} = 360^0 C$" in place l_4 and "$T_{ng} = 400^0 C$" in place l_5.

Tokens enter the GN through place l_2 with initial characteristic "$T_{phg} = 25^0 C$".

$$Z_2 = \langle \{l_2, l_{21}\}, \{l_6, l_7\}, r_2, \vee(l_2, l_{21}) \rangle,$$

where

r_2	l_6	l_7
l_2	*true*	*false*
l_{21}	*false*	*true*

The tokens obtain the characteristics "true" in place l_6 and "$T_{og} = 360^0 C$" in place l_7.

Tokens enter the GN through place l_3 with initial characteristic "$T_l = 360^0 C$".

$$Z_3 = \langle \{l_3, l_{22}\}, \{l_8, l_9\}, r_3, \vee(l_3, l_{22}) \rangle,$$

where

r_3	l_8	l_9
l_3	*false*	*true*
l_{22}	*true*	*false*

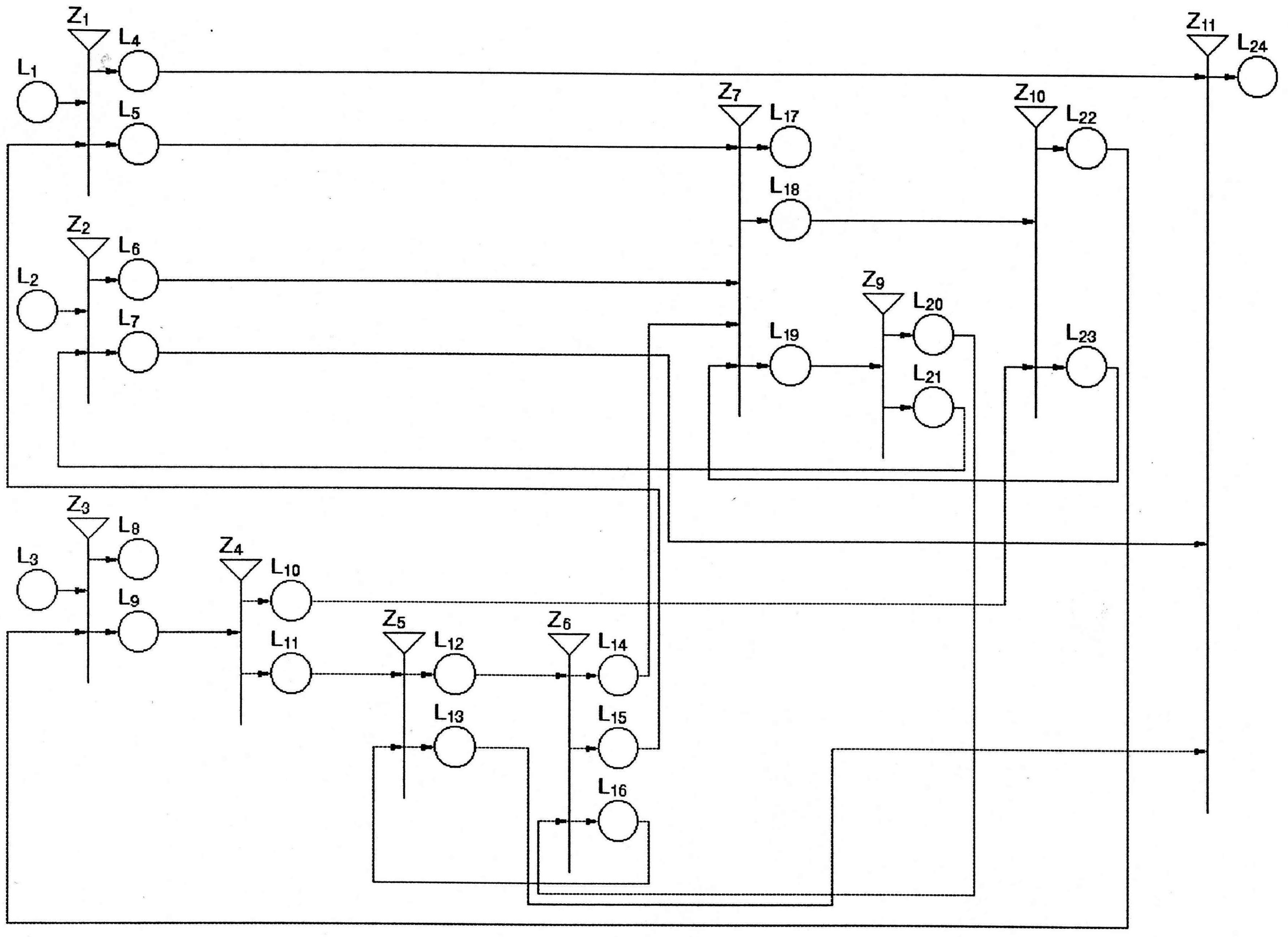
The tokens obtain the characteristics "$T_{phl} = 100^0 C$" in place l_8 and "$T_l = 77^0 C$" in place l_9.

$$Z_4 = \langle \{l_9\}, \{l_{10}, l_{11}\}, r_4 \rangle,$$

where

r_4	l_{10}	l_{11}
l_3	*true*	*true*

The tokens obtain the characteristics "$T_l = 77^0 C$" in place l_{10} and "$T_l = 77^0 C$" in place l_{11}.


Z1
L1
L4
L5
Z2
L2
L6
L7
Z3
L3
L8
L9
Z4
L10
L11
Z5
L12
L13
Z6
L14
L15
L16
Z7
L17
L18
L19
Z9
L20
L21
Z10
L22
L23
Z11
L24

$Z_5 = \langle \{l_{11}, l_{16}\}, \{l_{12}, l_{13}\}, r_5, \vee(l_{11}, l_{16}) \rangle$,
where

r_5	l_{12}	l_{13}
l_{11}	*true*	*false*
l_{16}	*false*	*true*

The tokens obtain the characteristics "$T_l = 500^0 C$" in place l_{12} and "$T_{og} = 500^0 C$" in place l_{13}.

$Z_6 = \langle \{l_{12}, l_{20}\}, \{l_{14}, l_{15}, l_{16}\}, r_6, \vee(l_{12}, l_{20}) \rangle$,
where

r_6	l_{14}	l_{15}	l_{16}
l_{12}	*true*	*false*	*false*
l_{20}	*false*	*true*	*true*

The tokens obtain the characteristics "$T_l = 500^0 C$" in place l_{14} and "$T_{og} = 700^0 C$" in place l_{15}. and "$T_{og} = 700^0 C$" in place l_{16}.

$Z_7 = \langle \{l_5, l_6, l_{14}, l_{23}\}, \{l_{17}, l_{18}, l_{19}\}, r_7, \vee(l_5, l_6, l_{14}, l_{23}) \rangle$,
where

r_7	l_{17}	l_{18}	l_{19}
l_5	*true*	*false*	*false*
l_6	*false*	*true*	*true*
l_{14}	*false*	*false*	*true*
l_{23}	*false*	*false*	*true*

The tokens obtain the characteristics "$T_{phw} = 900^0 C$" in place l_{18} and "$T_{og} = 1000^0 C$" in place l_{19}.

$Z_8 = \langle \{l_{19}\}, \{l_{20}, l_{21}\}, r_8 \rangle$,
where

r_8	l_{20}	l_{21}
l_{19}	*true*	*true*

The tokens obtain the characteristics "$T_{og} = 1000^0 C$" in place l_{20} and "$T_{og} = 1000^0 C$" in place l_{21}.

$Z_9 = \langle \{l_{10}, l_{18}\}, \{l_{22}, l_{23}\}, r_9, \vee(l_{10}, l_{18}) \rangle$,
where

r_9	l_{22}	l_{23}
l_{10}	*false*	*true*
l_{18}	*true*	*false*

The tokens obtain the characteristics "$T_{og} = 1000^0 C$" in place l_{22} and "$T_l = 500^0 C$" in place l_{23}.

$Z_{10} = \langle \{l_4, l_7, l_{13}\}, \{l_{24}\}, r_{10}, \vee(l_4, l_7, l_{13}) \rangle$,
where

r_{10}	l_{24}
l_4	*true*
l_7	*true*
l_{13}	*true*

The tokens obtain the characteristics " $T_{og} = 360^0 C$" in place l_{24}.

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