DEVELOPMENT AND INTRODUCTION OF AN INNOVATIVE TECNNOLOGY OF EXHAUST GAS PURIFICATION FOR MANUFACTURE OF MANGANESE AGGLOMERATE

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ABSTRACT

In this paper it is reported about the development and introduction of a non-waste exhaust gas purification technology for manufacture of manganese agglomerate under the conditions of Bogdanovska Beneficiation and Sintering Plant at Ordzhonikidze Ore Mining and Processing Plant Public Joint-Stock Company.

Arrangements related to dust and gas purifying system retrofit allowed to improve efficiency of gas purification up to 99.6% and to arrange recycling of collected dust.

The level of dust and gas emissions is one of the main parameters of industrial process perfection as far as it directly affects raw material and fuel utilization efficiency and determines expenditures for environmental protection measures.

Distinguishing feature of any production operations related to processing of charge material of various chemical composition and size as well as to their complex physical and chemical transformations during high-temperature processes is that these operations are accompanied by emission of a considerable amount of dust and gas, and agglomerate manufacture, including manufacture of manganese agglomerate pertaining to such production operations. Agglomeration process is one of the main sources of emissions in metallurgical production cycle.

Purification of gases leaving sintering zone in agglomerate manufacture constitutes a rather complex process (as opposed to other ones in ferrous industry).

Exhaust gases leaving sinter machine feature unique qualitative and quantitative properties; they contain sulfur dioxide and nitrogen oxide what at dew point phase transition determines a constant risk of sulfuric and nitric acids generation and thus a risk of gas purification units corrosion.

Necessity to maintain stable negative pressure in sinter machine in order to conduct agglomeration process, high temperatures of exhaust gases and presence of dust having various grading fraction and composition are also among the main difficulties of gas purification in the sintering zone.

Dust collectors must therefore have the following main performance indicators: they must operate with as law pressure differential as possible, be efficient in wide temperature range and not be affected by accidental but inevitable operation periods below the dew point.

Dust coarse fraction of agglomerate gases is highly abrasive and requires special solutions to protect against abrasive wear of gas purification units.

In the majority of cases, during gas purification in agglomerate manufacture an outdated dust cleaning scheme is used where battery cyclone or other devices operating on the same principle are applied. These purification systems may be additionally equipped with a wet gas purification unit not having gas purification efficiency required for today and being quite energy-consuming.

Having said that, residual dust content in gases discharged into the chimney makes approximately 100 mg/m^3 of suspended matters (dust containing up to 50% of manganese dioxide) while purification efficiency is up to 70-80%.

These figures cannot meet environmental and nature protection requirements and standards. According to nature protection standards, manganese dioxide emissions must be 5 mg/m^3 max.

K4-50 sinter machine with active sintering area of 65 m^2, machine useful surface length of 26 m and width of 2.5m is installed at Bogdanovska Beneficiation and Sintering Plant.

The major task of Bogdanovska Beneficiation and Sintering Plant dust and gas treatment system retrofit was searching for enhancement of agglomerate manufacture environmental safety through environmental discharge reduction and arrangement of collected matters recycling what shall not cause decline of production and degeneration of the manufactured agglomerate quality.

For the first time a network of two gas purification units using bag filters has been installed at the plant. One of these units was installed on cooling section, and it is not a novelty, but the other one was designed and mounted in sintering zone. It is a technically new approach, because nobody has been experienced operation of gas purification units using bag filters in sintering zone until now either in Ukraine or in CIS countries.

Previously at Bogdanovska Beneficiation and Sintering Plant at Ordzhonikidze Ore Mining and Processing Plant Public Joint-Stock Company, process gases **in sintering zone** were drawn from vacuum chambers collector using H-

6700 blower and were delivered to the first purification stage, to БЦ Р540/6х90 battery cyclone, and next to КМП-8 wet coagulation dust collector (4 items) (the second purification stage).

In order to fulfill the assigned tasks it was suggested to implement a unit of two-stage purification system using ЦГ-450 horizontal cyclone spark arrester and ФРИР-7700 bag filter for obtaining final dust content of max. 10 mg/m^3 (where initial dust content of aspirated gas was 3.2 g/m^3).

In cooling section several aspiration units were installed:

- a plant downstream from pan cooler (cooling section): two Venturi scrubbers and Н-6500-11-4 blower;
- in storage bins assembly: СИОТ-8 Venturi scrubber and a smoke exhauster;
- in primary mixing assembly: a smoke exhauster and СИОТ-8 Venturi scrubber;
- in transfer unit: a smoke exhauster and ЦВП No.6 centrifugal cyclone.

Purified aspiration air was discharged into the atmosphere through the vent pipes of the primary mixing assembly, charge preparation plant and agglomerate machine body as well as through the exhaust pipe of H=100 m.

Retrofit measures provide assembling of all suction devices from all dusting areas for purification in ФРИР-5000Ш bag filter. Gases coming from the following local suction devices are purified in the bag filter:

- sinter machine cooling section;
- aspiration device in storage bin assembly;
- aspiration device in primary mixing assembly;
- aspiration device of transfer unit;
- aspiration device of sinter machine body;
- points for transfer from pan cooler to conveyor No.9;
- agglomerate storage space;
- points of charging from conveyor No.9 to conveyor No.10;
- points of charging from gas purification conveyor to conveyor No.5;
- sinter machine main radius

Table 1. Gas purification main indicators

Item No.	Name	Unit of measure	Quantity
	Sintering zone		
1	Overall gas consumption for purification in normal conditions (at t= 60° to 170ºC)	thous. nm3/h	290.3÷345.1
2	Overall gas consumption for purification in operating conditions (at t= 60° to 170ºC)	thous. m3/h	353.4÷558.9
3	Gases temperature after sinter machine	ºC	60÷170
4	Gases humidity after sinter machine	%	22
5	Gases dust content after sinter machine	g/mn3	3.2
6	Gases dust content after bag filter	g/mn3	0.01
7	Chemical composition of agglomeration gases (before battery cyclone): SO_2 H_2S CO CO_2 $NO+NO_2$ O_2	volume %	 0.0025÷0.004 - 0.2÷2.0 3.4÷5.5 0.0018 16.7÷17.0
8	Chemical composition of dust (sampling in battery cyclone): -iron and its compounds -iron oxide (Fe_2O_3) -iron protoxide (FeO); - manganese and its compounds; -manganese dioxide; -manganese oxide (II); -chrome^{6+}; -silicon dioxide; -silicon; -aluminum; -aluminum oxide; -calcium oxide	%	 3.5 4.73 4.21 11.72 18.51 16.26 0.001 24.75 11.56 0.98 1.82 5.6
9	Required negative pressure in vacuum chambers	kPa	6÷10

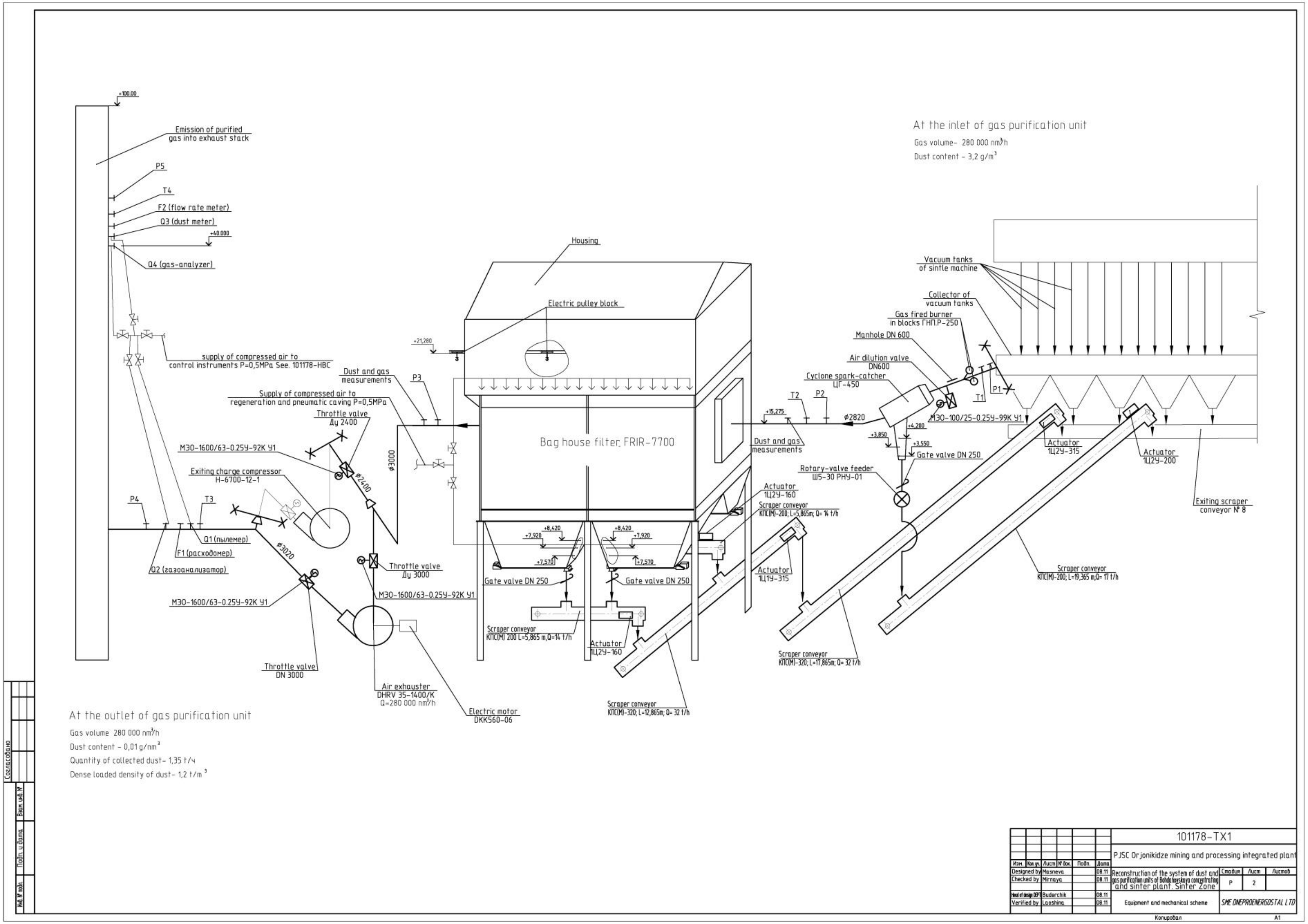
10	Gases dew point temperature	ºC	+56
11	Sinter machine running regime	Continuous running with shutting down for repair	
12	Total operating hours per year	h/year	6500
13	Dust bulk density	t/m3	1.2
14	Dust physical and chemical properties	Adhesion and abrasive ability	
	Cooling section		
15	Volume of aspiration air for purification in operating conditions: - from sinter machine cooling section; - from aspiration device in storage bin assembly; - from aspiration device in primary mixing assembly; - from aspiration device of transfer unit; - from aspiration device of sinter machine body; - agglomerate storage space; - points of charging from conveyor No.9 to conveyor No.10; - points of charging from gas purification conveyor to conveyor No.5; - dust exhaust at main radius of sinter machine;	thous. m^3/h	307.3÷521.8 54.0 21.0 7.0 15.0 5.0 12.7 3.0 3.0
16	Total volume of aspiration air for purification in operating conditions	thous. m^3/h	307.3÷521.8
17	Volume of aspiration air for purification in normal conditions: - from sinter machine cooling section; - from aspiration device in storage bin assembly; - from aspiration device in primary mixing assembly; - from aspiration device of transfer unit; - from aspiration device of sinter machine body; - agglomerate storage space; - points of charging from conveyor No.9 to conveyor No.10; - points of charging from gas purification conveyor to conveyor No.5; - dust exhaust at main radius of sinter machine;	thous. nm3/h	201.4 50.66 17.86 5.95 13.88 4.66 11.83 2.8 2.8
18	Total volume of aspiration air for purification in normal conditions	thous. nm3/h	285.3÷320.4
19	Aspiration air temperature: - in sinter machine cooling section; - in storage bin assembly; - in primary mixing assembly; - in transfer unit; - in sinter machine body.	ºC	60÷220 18 48 48 22
20	Aspiration air inlet temperature at gathering manifold	ºC	170
21	Volume of dusty gases fed for purification in operating conditions (at t=170ºC)	thous. m^3/h	521.8
22	Chemical composition of agglomeration gases (before battery cyclone): SO_2 H_2S CO CO_2 $NO+NO_2$ O_2	volume %	0.021÷0.023 0.16÷0.17 2.0÷3.2 0.00093÷0.0018 15.0÷16.0
23	Humidity of exhaust gases: - in sinter machine cooling section; - in storage bin assembly; - in primary mixing assembly; - in transfer unit; - in sinter machine body.	%	12 20 23 22 12
24	Inlet dust content of aspiration air in operating conditions: - in sinter machine cooling section;	g/m^3	2.47

	- in storage bin assembly; - in primary mixing assembly; - in transfer unit; - in sinter machine body.		3.00 1.00 0.04 ---
25	Total inlet dust content of aspiration air before filter in operating conditions	g/m^3	2.23
26	Dew point temperature	ºC	50-60
27	Unit running regime	Continuous running with shutting down for repair	
28	Total operating hours of the unit per year	h/year	6500
29	Dust bulk density	t/m^3	1.2
30	Dust physical and chemical properties	Adhesion and abrasive ability	

Circuit of agglomeration gases purification unit in sintering zone comprises the following main components: ЦГ-450 horizontal cyclone spark arrester (the first purification stage); ФРИР-7700 bag filter with pulse regeneration, DHRV-35-1400/K high-duty two-flow exhaust fan; conveyor system for evacuation of collected dust and automatic process control system.

Circuit of agglomeration gases purification unit in cooling section comprises the following main components: ФРИР-5000 bag filter with pulse regeneration; ДН-26х2Ф centrifugal two-side smoke exhauster; conveyor system for evacuation of collected dust; air-ducting system with shutoff and control valves and automatic process control system.

Process flow diagram of the system of dust and gas purification units in sintering zone



Technical characteristics of the main gas purification equipment

Technical characteristics of ЦГ-450 horizontal cyclone spark arrester:

- gas production rate — up to 353.4÷558.9 thous. m^3/h
- purification efficiency — up to 70%
- hydraulic resistance — 1200 Pa

Technical characteristics of ФРИР-7700 bag filter:

- Production rate of gas to be purified — up to 353413.8 ÷558902.5 m^3/h
- Gas to cloth ratio — 0.92 m^3/m^2x min.
- Surface of filter area — 7700 m^2
- Dust concentration at filter inlet — max. 10 g/m^3
- Dust concentration at filter outlet — max. 0.01 g/m^3
- Filter hydraulic resistance — max. 3000 Pa
- Compressed air consumption — max. 6.3 nm^3/min.
- Pressure of compressed supply air — 0.4÷0.6 MPa
- Number of filter sleeves — 2880 pcs.
- Length of filter sleeves with outer diameter of 139 mm
  length — 6300 mm
- Sleeves material — needlona[R] NO/NO 501
- Operational temperature — plus 200ºC
- Thermal stability limit — plus 220ºC

Technical characteristics of DHRV-35-1400/K high-duty two-flow exhaust fan:

- Operation capacity in normal conditions — 290305÷ 345102 nm^3/h;
- Operation capacity in operating conditions (t=150^{o}C) — m^3/h;
- Suction head — 12 000 Pa;

Technical characteristics of ФРИР-5000 bag filter:

- Production rate of gas subject to purification — up to 521867.9 m3/h
- Gas to cloth ratio — up to 1.67 m3/m2x min.
- Surface of filter area — 5045 m2
- Dust concentration at filter inlet — max. 10 g/m3
- Dust concentration at filter outlet — max. 10 mg/m3
- Filter hydraulic resistance — max. 3000 Pa
- Compressed air consumption — max. 6.3 nm3/min.
- Pressure of compressed supply air — 0.4-0.6 MPa
- Number of filter sleeves — 2304 pcs.
- Length of filter sleeves with outer diameter of 139 mm
  length — 5160 mm
- Sleeves material — needlona[R] NO/NO 501
  long-term thermal stability — plus 200ºC
  thermal stability limit — plus 220ºC

Technical characteristics of ДН-26х2Ф smoke exhauster manufactured by ZAO 'RUVEN'(Closed Joint-Stock Company):

- impeller diameter — 2600 mm
- electric motor type — AOD;
- motor capacity — 1600 kW;
- voltage — 6000 V;
- production rate — 500 thous.m^3/h;
- total pressure — 6500 Па;
- impeller revolution rate — 750 rpm.
- maximum gas temperature at smoke exhauster inlet not exceeding — +250ºC

Dusty agglomeration gases **in sintering zone** are drawn off from the existing collector of vacuum chambers.

Gas is fed through a gas duct with rated diameter of 2800 mm to ЦГ-450 cyclone spark arrester where separation of coarse and maybe smoldering particles of charcoal takes place. After cyclone gas goes to ФРИР-7700 bag filter manufactured by "Dneproenergostal" Scientific and Manufacturing Enterprise.

Further on, purified gas is fed to the exhaust pipe. DHRV-35-1400/K exhaust fan manufactured by Venti Oelde (Germany) is used as draft mechanism.

Chemical composition of agglomeration gases includes among others sulfur dioxide.

Reacting with water, this chemical compound forms solution of sulfur dioxide deteriorating equipment surfaces.

To avoid gases condensation during sinter machine startup, two ГНП.Р-250 gas burners shall be installed on the gas duct.

They allow heating of gas to be purified up to the temperature + 80ºC. The burners are switched on simultaneously, or in 10-15 minutes after exhaust fan actuation or at thermocouples signal. They are switched off upon thermocouples signal or remotely by operator.

To maintain the temperature of gases to be purified both gas ducts from the collector of vacuum chambers to the blower and bag filter are heat-insulated.

At filtration negative pressure at filter inlet and outlet is measured. Mechanical loads on filter sleeves decrease owing to pulse regeneration.

Regeneration starts when differential between negative pressures exceeds 2000 Pa. Filter regeneration is performed by means of compressed air with pressure of P=0.6 MPa.

Structurally, the filter is divided into 16 sections. Regeneration takes place in the filter section by section, thus maintaining constant resistance at the level of 2000 Pa. This is necessary to stabilize negative pressure in sinter machine.

Installation of a variable speed driver for the exhaust fan is performed with the same purpose. It maintains negative pressure in sinter machine automatically by changing the speed of electric motor rotor.

Nipples for gas and dust measurements are mounted at bag filter inlet and outlet.

The dust collected by bag filter is discharged into filter bins. Its discharge starts at the signal of dust 'working' level sensor in the bins. Scraper conveyor that is the last downstream from dust is actuated, and then КПС(М)-200 scraper conveyors are started followed by screw conveyors located directly under filter bins. In order to prevent accidents chain failure sensors are mounted on scraper conveyors.

Discharge of dust is stopped at signal of lower dust level sensor. Conveyors are switched off in reverse order.

Discharge of dust from under cyclone spark arrester is carried out independently of dust discharge in filter bins, at sensor signal about working dust level, or with respect to time, or else at operator's signal. To that end, scraper conveyor is actuated automatically. Discharge of dust is stopped at signal of the lower dust level sensor. Dust discharge equipment is switched off in the reverse order.

Dust discharge disabling signal is designed for the cases when scraper conveyor is out of operation. Other interlocking devices are provided to prevent operator's errors at conveyors switching on during remote dust discharge.

Three Vegavib 63 dust level sensors (indicating the lowest, working and emergency dust levels) are mounted on each bin of bag filter and spark arrester.

Aspiration air **in cooling section** is tapped from the five main agglomerate sintering stages: sinter machine cooling section, storage bin assembly, primary mixing assembly, transfer unit, sinter machine body and agglomerate storage space.

By means of ДН-26х2Ф smoke exhauster aspiration air is fed to ФРИР-5000 bag filter for purification. Then purified aspiration air is discharged to the atmosphere through available exhaust pipe with diameter of 4200 m and 100 m high.

To maintain the temperature of aspiration air, gas ducts up to bag filter are heat-insulated.

To prevent sleeves thermal deformation at emergency peak temperature of aspiration air two motor-operated air suction valves are mounted on gas duct at bag filter inlet.

At aspiration gases temperature $t_{г.}$=+200ºC the valve opens at a thermocouples signal and closes when aspiration gases temperature is less than +180ºC.

Process performance of gas purifying unit is shown in Table 2.

Table 2. Process performance of gas purifying unit

Parameters, units of measurement	Conventional symbol	Quantity
1. Sintering zone		
Volume of dusty gas fed for purification in operating conditions (at t=170ºC)	m^3/h	558902.5
Dust content of aspiration air at the inlet of cyclone spark arrester,	g/m^3	3.2
Dust content of aspiration air at the outlet of bag filter		
Unit service hours	g/m^3	0.01
Dust volume weight	h/year	6500
Dust collected	t/m^3	1.2
Amount of dust discharged to the atmosphere	t/h	1.355
Gas purification efficiency	kg/h	4.23
	%	99.7
2. Cooling section		
Volume of dusty gas fed for purification in operating conditions (at t=170ºC)	m3/h	521867.9
Dust content of aspiration air at the inlet of bag filter	g/m3	2.23
Dust content of aspiration air at the outlet of bag filter	g/m3	0.01
Unit service hours	h/year	6500
Dust volume weight	t/m3	1.2
Dust collected	t/h	1.12
Amount of dust discharged to the atmosphere	kg/h	5.1
Gas purification efficiency	%	99.6

Additional economic effect may be achieved owing to arrangement of recycling of collected dust by conveyor system. Transportation of dust from ФРИР-7700 filter bins for recycling is performed on open platforms by conveyor; then dust is transferred and discharged on the existing scraper conveyor of agglomeration assembly.

Automated control of two filters operation (in sintering zone and in cooling section), display of filters current state on the screen, control of filter mechanisms operation in automatic, remote (by operator’s command) and manual (testing and setting-up mode) modes are implemented.

List of the main measured parameters:

– Gas negative pressure in sinter machine
– Negative pressure and gas temperature in vacuum chambers No.2, No.6, No.8, No.12, No.13, No.14
– Gas negative pressure upstream and downstream from the filter
– Gas temperature upstream and downstream from the filter
– Temperature of exhaust fan bearings
– Vibration level of exhaust fan bearings
– Temperature of exhaust fan motor bearings
– Temperature of exhaust fan motor body
– Compressed air pressure at the inlet of regeneration system
– Dust level in cyclone spark arrester bins
– Dust level in filter bins
– Scraper conveyor chain failure

Atmospheric emission monitoring system provides measurement of the following parameters:

1. Determination of gas-and-air mixture volume emission to the environment.
2. Dust content measurement of gas-and-air mixture emitted to the environment.
3. Dust content measurement of gas-and-air mixture in purification areas.
4. Temperature measurement of gases emitted to the atmosphere.
5. Pressure measurement of gases emitted to the atmosphere.

Results of dust and gas purifying system retrofit works at Bogdanovska Beneficiation and Sintering Plant meet all relevant labour protection requirements by preventing diffusion of hot and dusty air containing CO, SO_2 and NOx in the operating area.

In broader terms construction and putting into service of gas purification units in cooling section and in sintering zone allows:

- improving efficiency of agglomeration gases purification;
- improving reliability of operation and reducing operating costs for agglomeration gases purification;
- reducing the number of equipment downtime;

- replacing worn out and outdated equipment for the new one that meets modern technical requirements;
- excluding financial expenses for upkeep of wet gas purification systems (keeping slime tanks, water conduits and cutting ditches, expenses for pumping water and slimes);
- improving working conditions at the sintering plant;
- improving ecological situation at site of 'OGOK' Public Joint-Stock Company and in the city of Ordzhonikidze owing to reducing pollution emissions.

These results are the evidence of reliability and efficiency of the used ФРИР bag filters manufactured by "Dneproenergostal" Scientific and Manufacturing Enterprise and confirm possibility to resolve the problems at hand concerning elimination of emissions in agglomeration industry.

CONCLUSION:

System of non-waste exhaust gas purification technology for the manufacture of manganese agglomerate has been introduced under the conditions of Bogdanovska Beneficiation and Sintering Plant at Ordzhonikidze Ore Mining and Processing Plant Public Joint-Stock Company. This solution allowed obtaining dust content in gas and dust flow up to 0.01 g/m^3 at bag filters outlet. Efficiency of gas purification makes 99.6%. Additional economic effect was achieved owing to recycling of collected dust.

Fulfillment of such purification systems retrofitting and upgrading measures allows not only to drastically decrease degree of environmental pollution and to increase environmental safety level but also to ensure highly efficient enterprise operation with simultaneous reduction of electric power, water resources and fuel consumption.

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