Master's Thesis

Development of technical measures for the normalization of working conditions for the staff of "Shakhtinskaya Ceramiks"

Student: Anastasiia Stepantsova

05/07/2021

Chair of Mining Engineering and Mineral Economics
Department Mineral Resources Engineering
Montanuniversitaet Leoben

A-8700 LEOBEN, Franz Josef Straße 18
Phone: +43 3842-402-2001
Fax: +43 3842-402-2002
bergbau@unileoben.ac.at

Declaration of authorship

I declare in lieu of oath that this thesis is entirely my own work except where otherwise indicated. The presence of quoted or paraphrased material has been clearly signaled and all sources have been referred. The thesis has not been submitted for a degree at any other institution and has not been published yet."

Preface, Dedication, Acknowledgement

In everyday life we often face this simple thing as dust, but do not think about exposure to our health, because the amount of dust is not significant.

However, a high spread of the dust and gas contaminations of the working area at mineral resource enterprises is one of the most important topic for health and safety engineers. This problem can lead to a high degree of risk of acquiring occupational diseases by employees performing work in unfavorable conditions.

So, what measures must be taken to avoid all this problems?

Abstract

Purpose and objectives of the study:

The purpose of the work is to normalize the working conditions of the staff of "Shakhtinskaya Ceramiks".

Tasks:

1. Analysis of technological and organizational factors that lead to the formation of dust.

2. Assessment of the state of the air environment by the dust factor.

3. Selection of measures aimed at minimizing the impact of the dust factor.

Subject and object of research:

The object of the study is the workplaces of electric and gas welders at "Shakhtinskaya Ceramiks".

The subject of the study is the dust situation at "Shakhtinskaya Ceramiks" and ventilation equipment designed to reduce dust and gas pollution in the air of the working area of the electric and gas welder.

Theoretical and methodological basis:

A systematic, comprehensive, cyclical approach to the study of the aspiration process, as well as the choice of effective measures to improve the equipment and the process of capturing dust particles from the air of the working area.

Scientific novelty of the work:

The dependence of the durability of the filter material of the bag filter on the physical and chemical properties of the fibers of this material is proposed.

Practical significance of the results of the work:

The use of the most wear-resistant materials for the production of filter hoses.

Content

1. Introduction

Today, the continuous development of various types of technological processes is one of the priorities in the world.

With the introduction of new technologies it is necessary to introduce and improved methods of combating production factors.

Industrial factors are a special case of the factors of human environment and human activity, associated and (or) generated by industrial and labor activity.

According to the origin of all production factors are divided into 2 classes:

1. Factors of the production environment.
2. Factors of work process.[11]

Of the totality of production factors for the purposes of labor safety by the criterion of the possibility of causing harm to the working man's body are distinguished:

- adverse production factors;
- production factors, which are not adverse, i.e. neutral or favorable effect.

Factors that are not adverse, for the purposes of labor safety do not allocate, do not record and do not name.

Unfavorable production factors on the resulting impact on the human body are divided into:

1. harmful production factors - factors that lead to illness, including those that aggravate existing diseases.

2. hazardous production factors - factors that lead to injury, including fatal. [12]

One of these hazards is a chemical factor, which reflects the dustiness and gassiness of the air of the working area.

This situation occurs to a greater extent in the field of mineral complex during mining, transportation and processing of rock mass and minerals.

Developing in such conditions occupational respiratory diseases can manifest themselves not only in the form of short-term deterioration of employee health, but also in a partial or complete loss of ability to work.

To date, there are many ways to reduce dustiness and air gassiness in the working area, but it is necessary to select the most effective and economically feasible action or set of measures to resolve the current unfavorable situation for finding a person.

To solve this type of problem, aspiration systems are designed based on a preliminary examination of the object, the study of technological processes of a particular production.

Therefore, the purpose of this work is to analyze the technological and organizational factors that lead to the formation of dust at workplaces of mining and processing plants, as well as the justification of methods to reduce dustiness and gassiness of the working area air at "Shakhtinskaya Ceramics".

2. Main part

2.1. Impact of dust on human body

The air in all production rooms is to some extent contaminated with dust; even in those rooms which are usually considered clean and dust-free, there is dust in small amounts.

However, in many industries, due to the nature of the technological process, production methods applied, nature of raw materials, intermediate and finished products and many other reasons, intensive dust generation occurs, which pollutes the air of these rooms to a large extent.

This may pose a certain danger to people working in such conditions. In such cases, the dust in the air becomes one of the factors of the production environment, determining the working conditions of workers; it is called an industrial dust. [11]

Dusts are formed due to crushing or abrasion (disintegration aerosol), evaporation with subsequent condensation into solid particles, (condensation aerosol), combustion with formation of solid particles in the air - products of combustion (fumes), a number of chemical reactions and many other ways.

In production conditions, dust formation is most often associated with the processes of crushing, grinding, screening, grinding, sawing, transferring and other movements of bulk materials, combustion, melting and so on.

This situation occurs to a greater extent in the mineral complex during mining, transportation and processing of rock mass and minerals.

Developing in such conditions professional diseases of the respiratory organs, in particular pneumoconiosis, can manifest itself not only in the form of short-term deterioration of employee health, but also in partial or complete loss of ability to work in such unsuitable conditions.

The nature and severity of adverse effects depend primarily on the chemical composition of the dust, which is mainly determined by its origin.

The classification of dust by particle size (dispersity) is important. It determines the stability of particles in the air and the depth of penetration into the respiratory organs of the worker.

Industrial dust occurs in various sizes. In most cases, up to 60...80% of dust particles have a diameter of up to 2 microns, and 10...20% have a diameter of 2 to 5 microns, and up to 10% have a diameter over 10 microns. (Morgulis and Mazus 1977, 158)

Not all dust entering with inhaled air remains in the respiratory system. Part of the dust, being retained by nasal mucosa, nasopharynx, ciliary epithelium of trachea and bronchi, is excreted with sputum and nasal mucus.

However, small dust particles penetrating the airways cause a reaction of the connective tissue, resulting in the development and progression of pulmonary fibrosis.

2.2. Classification of dust collection methods

Various types of dust collectors are used to control harmful dust and gases emitted into the air during work.

Dust collectors are mechanisms capable of capturing solid mechanical particles of different sizes and structures. These units are used in manufacturing facilities where the concentration of harmful substances is constantly increasing during the operation of machines and other similar structures.

There are 3 main types of dust collection:

- Mechanical dust collection - dry and wet.

- Electrostatic dust collection.

- Air cleaning with sound and ultrasonic coagulation.

The most popular type of dust collection is mechanical cleaning, which is subdivided into dry and wet cleaning. Dry cleaning methods generally include:

- Gravity settling, which is mainly used for coarse primary cleaning. The settling mechanism is based on gravity, which causes the settling of suspended particles without changing the direction of the air flow.

- Inertial and centrifugal dust collection. In inertial settling, suspended particles tend to maintain their original direction of motion when the direction of the main gas flow is changed. This method is also only suitable for coarse cleaning. The centrifugal method of gas cleaning is based on the action of centrifugal force.

- Filtration. Based on the purification of gases using a variety of filtering materials (cotton, wool, chemical fibers, ceramic metal).

In wet gas cleaning, the gas is flushed with a liquid. This method is suitable for cleaning of dust, smoke, fog and other pollutants. It is often used as an additional cleaning step after mechanical cleaning.

Electrostatic gas cleaning is suitable for a variety of aerosols, acid mists, for all sizes of dust particles. The method is based on ionization and charging of aerosol particles during the passage of the air-gas stream through a high voltage electric field. The particles are deposited on grounded electrodes. This method is often used in metallurgy, thermal power plants, cement shops, etc. [13]

Industrial dust can cause not only respiratory diseases, but also diseases of the eyes (conjunctivitis) and skin (peeling, coarsening, eczema, dermatitis). Occupational diseases caused by dust are among the most severe and widespread worldwide.

The content in the air of mechanical contaminants of varying hardness and size is not only harmful to personnel, but can lead to a decrease in product quality on several indicators at once.

Aspiration systems are used to minimize this production factor.

Industrial air aspiration is a system of measures using specialized equipment aimed at extracting dust from the air of a particular room, removing it from circulation and, if possible, disposal. Air cleaning equipment can trap contaminants of different origin and size, separate streams, remove mist particles and purify gases.

Designing an aspiration system is based on a preliminary examination of the facility, studying the technological processes that take place in production.

Among the important parameters include the volume of pollutants emitted into the air and the composition of pollutants, the required air exchange, the characteristics of the existing or projected ventilation system, temperature and other conditions in the production facility.

A typical ventilation and aspiration system consists of the following components:

- fan - creates vacuum (negative pressure);

- cleaning device - filters (cyclones, scrubbers, bag and cartridge filters);

- air ducts - ventilation ducts for controlling air flows;

- dust collectors or accumulators - stationary or built-in containers (reservoirs) for collection of solid impurities. [14]

We will use bag filters as a cleaning device, the principle of operation of which is to trap dust contaminants on the surface of microporous textile filtering elements, similar to sleeves or narrow bags.

The cleaning efficiency of bag filters can reach 99.9%, even for the most complex contaminant composition, including fine particles, sticky and wet contaminants. On the other hand, they are the most expensive and difficult to maintain.

2.3. General information about Company

Negative impact of dust and aerosols of mainly fibrogenic action is one of the most acute problems at the enterprise "Shakhtinskaya Ceramics".

Therefore, to solve the problem of dustiness and gassiness of the working area air, it is proposed to increase the efficiency of the dust collection unit - bag filter, namely, to choose the most suitable filtering material for filtering dust and aerosols that are emitted during the working hours of the electric and gas welder.

The main activity of "Shakhtinskaya Ceramics" is the production of ceramic glazed tiles and dry construction mixtures, as well as the production of ceramic tiles, the trade of products of own production, and other necessary activities not prohibited by the current legislation. (Unitil, 2021)

The company is located on four industrial sites, where the main production technological flows, auxiliary services and departments, warehouses: In addition to industrial sites, the company is divided into 8 workshops:

1. Shop № 1 flow "facing tiles;
2. Workshop № 2 flow "facing tiles";
3. Workshop № 3 of the flow "Porcelain tiles";
4. Shop flow "Decorative elements";
5. Shop flow "Dry Building Mixtures";
6. Shop of press and stamping equipment;
7. Repair-mechanical workshop;
8. Electric-repair shop.

Today the production volume of "Shakhtinskaya Ceramics" makes more than 20 percent of the all-Russian volume. The raw materials and auxiliary materials are transported by auto and electric forklifts, and the finished goods are shipped by auto and railway transport.

One of the necessary elements to increase the capacity of produced volumes is quality material. Shakhtinskaya Ceramics receives raw materials for production from Vladimirovsky quarry of refractory clay that since 1993. Deposit located on the land of Krasnosulinsky District of Rostov Region near the village of Vladimirovskaya. (Vladimirovsky quarry of refractory clay, 2021)

It is extracted and transported using specialized equipment:

Loading of raw materials into special bunkers is the first stage of porcelain stoneware production. After this the components are dosed and fall into a huge metal cylinder (mill), where they are mixed in the presence of water at high temperature and high pressure - the vitrification process takes place. The result is an aqueous solution (suspension) of the smallest and equally sized and shaped particles, which is called a slurry.

The finished slurry is stored in special tanks under constant stirring, and then coloring pigments are added to it in specified concentrations.

The slurry then enters the atomizer (spray tower dryer), where it is dehydrated. The slicker, sprayed inside the atomizer, falls to the bottom already in the form of a dry powder, which is fed to a conveyor belt. (HITACHI, 2021)

The next stage is pressing, during which the future porcelain stoneware takes its shape. Pressing is carried out in two stages. Primary pressing - at a load of about 80 kg/cm^2 contributes to the removal of air from the powder. In the second stage, at a pressure of more than 500 kg/cm^2, porcelain tiles are formed.

The "raw" tiles are then placed in a drying chamber to remove all moisture. After drying, the humidity of the mixture in the tile is already a hundredth of a percent and the porcelain stoneware is almost ready for firing. But before that, as a rule, there is one more step. (Mogilev auto, 2021)

First, if necessary, a glaze is put on the surface, after which it is painted or patterned.

After coloring, the future porcelain tiles are put in special vaults (in the form of huge cabinets) and automatically transported by forklifts to the baking, which radically changes their properties, so that the pressed tiles, which can be easily crushed by hand, become very strong porcelain tiles. (Unitil, 2021)

Firing of porcelain tiles is made in special furnaces in several stages. First, the tile is fired at 400 degrees Celsius (pre-firing), then heated to 900 (preheating), then the main firing occurs at a temperature of 1200-1300 degrees, and finally, the temperature decreases gradually.

During quality control, it is necessary to sift out tiles with defects. Quality control takes place in two modes: automatic (checking the weight, size and flatness of the tiles by a special machine) and manual (visual inspection of color and other defects by the operator). Ready porcelain tiles are sent for packing, which is fully automated. After packing, porcelain tiles in branded boxes with "Shakhtinskaya Tile" and "GraciaCeramica" markings are sent to the finished product warehouse and then to the consumer. (Unitil, 2021)

2.4. Extraction of mineral resources

The supplier of raw materials for Shakhtinskaya Keramika is Vladimirovsky quarry of refractory clays.

Since 1993 Vladymirovskiy quarry of refractory clays has been developing Vladimirovskoye deposit of refractory and refractory clays, which is located in Rostov region near the village of Vladimirovskaya.

The field was explored in 1983 to create a reliable raw material base for ceramic industry in the south of Russia. The approved reserves are 12,997 thous. tons (by category B+C) and 2,819 thousand tons by category C2.

The clay is intended for production of sanitary ceramic products, ceramic facade tiles, floor tiles, tiles for inner wall lining, acid-proof bricks, face bricks and stones, as well as for other industries.

Production capacity of the quarry is 215 thousand tons. Industrial reserves of the deposit allow to maintain this capacity for 65 years.

Clays of Vladimirovsky quarry have high plasticity, high mechanical strength after firing, good sinterability. All products of the Vladimirovsky quarry undergo radiological and hygienic certification.

Since 2005, the technology of clay extraction and pre-production preparation has been completely changed. Quarry clays extracted from the mine face are stored in separate stacks, according to the varieties with the maximum account of indicators: chemical, mineralogical, ceramic. Extended laboratory research on the properties of extracted raw materials, in particular with the study of physical and mechanical tests, allowed to clearly present the final result - shrinkage, water absorption, mechanical strength. (Vladimirovsky quarry of refractory clay, 2021)

Nowadays Vladimirovsky open-cast mine besides the area of 32.6 hectares developed since 1994 possesses 68.2 hectares of Fedorovsky deposit joined since 2006 and put into operation in October 2013, as well as 85.7 hectares of plot 2 of Vladimirovsky deposit.

Stripping operations at VCTG are mainly carried out in winter, while the mining season starts in spring depending on weather conditions.

Selective mining, its crushing, charge-forming allow:

- To average and charge clay with different indicators to form the brand most suitable for the production of a particular type of ceramic products by the consumer;
- To control clay quality operatively in the process of charge preparation.

Clay classification is as follows:

1) by composition;

2) by origin;

3) by coloring;

4) on the use in practice.

Names kaolinite, halloysite, clay receives if its composition is dominated by one of the minerals. Most clay contains a mixture of three or more minerals (polymineral).

Clay almost always contains impurities, various fragments of rocks or minerals, organic matter and newly formed minerals. If the content of these impurities is high, there is a transition of clay to marl, clayey sand, clayey coal, etc.

Physico-chemical and technological properties of clay depend on the chemical, mineralogical and granulometric composition of clays, namely

1) plasticity,

2) swelling,

3) shrinkage,

4) sinterability,

5) refractoriness,

6) effervescence,

7) adsorption.

These are the properties that determine the industrial application of clay.

Characteristic feature of refractory and refractory clays is a high content of alumina, about 20 to 42%, as well as high cohesiveness and plasticity.

Refractory clays are characterized by monomineral composition and refractoriness, usually not lower than 1580°C. While refractory clays have refractoriness in the range from 1350 to 1580 ° C.

Charge is shipped to customers from our own loading wall, located 15 km from the quarry, at Sadki village. The charge is delivered by motor transport with the following shipment by excavator EO-6123A to the railway cars.

For more productive work VKTG gradually renews the technical park. We started with the mining equipment: two new Hitachi excavators equipped with a cutting edge for selective clay excavation were bought on credit. Then we leased four SCANIA vehicles, four MoAZ vehicles, and continue to buy new quarry equipment. (Vladimirovsky quarry of refractory clay, 2021)

2.5. Analysis of existing research on the topic

The inventor of the bag filter is considered to be Hippocrates, as it was he who in about 500 BC invented a device ("Hippocratic sleeve") representing a cage with cotton woven bags fixed on it to filter various impurities and to separate from water.

Over time, there was a modernization of filtering materials - cotton gauze, baize and felt were replaced by needle-punched, thermal and chemical-type nonwoven materials, branded textiles and others.

Dust collectors of sleeve type based on nonwoven (needle-punched) materials of polyester, meta-aramid, glass fiber, polypropylene are the most widely spread. Aspiration of dust in this case reaches the degree of purification up to 99%, and bag filters have high reliability and simple design.

On the other hand, units with bag filters are the most expensive and difficult to maintain. However, they can be used in abrasive blasting and cutting of metals and alloys, graphite, ceramics, rubber, polymers, stone; sandblasting and shot blasting; engraving; jewelry making; crushing and grinding of minerals; grinding, screening, transferring and packaging of powder materials.

The problem of reducing dust and gas content in the air in the working area with the help of bag filters has been solved by many Russian and foreign scientists, whose contribution is invaluable. For example, L.M. Morgulis, M.G. Mazus in the book "Bag filters" considered the basics of aerosol filtration in bag filters, the influence of various factors on the dust collection efficiency. On the basis of this book, employees of Belarusian National Technical University I.S. Brakovich and V.D. Sizov disclosed the method of calculation and selection of the bag filter depending on production conditions. (Brakovich and Sizov 2011, p. 21)

On November 15, 1961, M.M.Zaitsev, N.S.Timofeev and V.I.Teplitsky published in "Bulletin of Inventions" a patent for an improved bag filter, capable of operating at temperatures up to 300 ^{o}C.

G.M. Gordon and I.L. Leysakhov in their book "Dust Collection and Gas Cleaning" published in 1977 considered the theoretical principles of operation, design features and operational performance of apparatuses and installations for capturing dust and chemical purification of gases. Specified the advantages and disadvantages of each type of equipment and gave an analysis of the field of their application.

Later in 1994 Y.A. Bannov patented a new simplified model of the bag filter with element-by-element pulse regeneration which allowed the owners to save the operating costs.

One of the latest patents in this area can be considered the invention of V. I. Ivanovsky, S. I. Baradushko and V. Kokorin. V. They were able to increase the efficiency of the capture unit by reducing the cost of equipment and simplification of the capture scheme.

It is known that the bag filter refers to the equipment, which operates on the principle of passing the gaseous substance through the fabric, on which all fine impurities and dust will be deposited, so exactly the evaluation of the filtering properties of the material plays the main role in the filtration process.

However, to date, there is no "perfect" filter material, which by its performance properties could be used everywhere, so different materials are used in the most favorable conditions for them.

In accordance with the above, one of the tasks is to analyze the existing filtering materials and choose the most effective and durable one for the parameters of the air environment at "Shakhtinskaya Keramika".

Hypothesis of the research - quality of filtration depends on filter bag material, namely on physical and chemical properties of the fibers of this material.

2.6. Identification of hazards in the workplace of the electric and gas welder

Due to its distinctive features, the welding process is accompanied by saturated dust emissions, leading to a large dustiness of the production room with toxic fine dust, gas emissions, acting negatively on the whole organism of the worker.

The increased temperature of the welding arc contributes to saturated oxidation and evaporation of metal, flux, shielding gas, alloying parts. Oxidized by air oxygen, these vapors form fine dust, and convective flows formed during welding and thermal cutting carry gases and dust into the upper layers of the room, leading to high dustiness and gassiness of the workplace of the electric and gas welder. (Malahov 2016, p. 25)

The main constituents of dust during welding and cutting of steel are iron, manganese and silicon oxides (in the range of 41, 18 and 6%, respectively).

The most harmful dust emissions are:

- Iron oxides, mechanical irritation of lung tissue, chronic poisoning, dermatosis, CNS damage;

- Manganese oxides, causing diseases of the nervous system, lungs, liver and blood;

- Silicon compounds, have a damaging effect on the lungs, resulting in persistent shortness of breath, chest pain, and dry cough;

- Chromium compounds, can accumulate in the human body, causing headaches, gastrointestinal inflammation, and general weakness;

- Aluminum compounds, mechanical irritation of lung tissue, decreased hemoglobin;

Compounds of tungsten, vanadium, zinc, copper, nickel and other elements also have adverse effects on the worker's body. When entering the worker's body through the respiratory tract and digestive tract harmful gaseous substances cause lesions throughout the body.

The most dangerous gases emitted during welding:

- Nitrogen oxides (especially nitrogen dioxide), entering the body leads to damage to the lungs and circulatory organs;

- Carbon monoxide (asphyxiant gas) - a colorless gas, which can accumulate in the room and displaces oxygen, with a concentration above 1% irritates the respiratory tract, causing fainting, shortness of breath, seizures and damage to the nervous system;

- Ozone, in high concentrations its odor resembles the odor of chlorine, is formed during welding in inert gases, causes eye irritation, dry mouth and chest pain;

- Hydrogen fluoride is a colorless gas with a pungent odor, acts on the respiratory tract and even in small concentrations causes irritation of mucous membranes. [9]

In accordance with the Decree of the Chief State Sanitary Doctor of the Russian Federation of February 13, 2018 № 25 "On approval of hygienic standards GN 2.2.5.3532-18 "Maximum allowable concentrations (MAC) of harmful substances in the air of the working area" allocate the following MPC of harmful substances in the workplace electric welder. (Russian State Standard)

Substance name	Formula	MAC mg/m^3	Class of hazard	Physical form	Peculiarities of action on the organism
Nitrogen dioxide	NO_2	2	3	v	O
Aluminium oxide	Al_2O_3	6	4	a	F
Diiron trioxide	Fe_2O_3	6	4	a	F
Mangan	Mn	0,6	2	a	-
Silicon dioxide	SiO_2	3	3	a	F
Chromic oxide	CrO_3	0,03	1	a	C
Carbon Monoxide	CO	20	4	v	O
Ozon	O_3	0,1	1	v	O
Fluorine hydride	HF	0,5	1	v	O

Table 1. MAC of harmful substances in the air of the working area

Note:

Column 5 - four hazard classes in accordance with the classification of GOST 12.1.007-76. "SSBT. Hazardous substances. Classification and general safety requirements": (Russian State Standard)

Class 1 - extremely hazardous;

2nd class - highly hazardous;

3rd class - hazardous;

4th class - moderately hazardous.

Column 6 - aggregate state of the substance in the air of the working area (vapor, aerosol).

In column 7 "Peculiarities of action on the organism" special symbols indicate substances with an acute mechanism of action, requiring strict control over their content in the air, carcinogens, allergens and aerosols, mainly of fibrogenic action. The following designations were used:

O - substances with an acute mechanism of action, requiring automatic control of their content in the air,

C - carcinogens,

F - aerosols of predominantly fibrogenic action. (Russian State Standard)

Besides aerosols and gases, a number of other factors, which worsen working conditions, also have a negative impact on the body of workers in welding shops. These include: the radiant energy of the welding arc, ultraviolet and infrared radiation, their action leads to burns of exposed parts of the body and overheating of the organism (especially in summer), the noise in combination with ultrasonic vibrations causes a persistent hearing loss of workers. Apart from the noise created by welding, blanking operations (straightening, dressing, assembling) and especially plasma arc cutting will produce a lot of noise. Poorly installed ventilation units (or assembled without vibration bases) also create noise (Malahov 2016, 26).

The analysis of production technology shows that one of the most dangerous production factors at Shakhtinskaya Ceramics is the chemical factor. The expert assessment based on the special assessment of working conditions for the research and testing laboratory, flow repair and mechanical section, the gas and sanitary section, the press and die tool shop and the repair and mechanical workshop indicates the presence of hazards associated with dustiness and gas content in the working area air.

The repair-mechanical workshop (Figure 1) emits inorganic dust containing silicon dioxide over 70% with an average concentration of 4.6 mg/m^3, methylcellulose with an average concentration of 3.8 mg/m^3. 5 years of work experience at this place.

Calculation of dust load (DL):

$$DL = C_{fact} \cdot T \cdot N \cdot V_l = (4{,}6 + 3{,}8)\ mg/m^3 \cdot 5\ a \cdot 240\ \text{work shift} \cdot 7\ m^3 = \\ = 70\ 560\ mg \tag{1}$$

Calculation of the control dust load (CDL):

$$CDL = C_{MAC} \cdot T \cdot N \cdot V_l = (1 + 6)\ mg/m^3 \cdot 5\ a \cdot 240\ \text{work shift} \cdot 7\ m^3 = \\ = 58\ 800\ mg \tag{2}$$

The value of the CDL for average length of service:

$$T = C_{MAC} \cdot T \cdot N \cdot V_l = (1 + 6)\ mg/m^3 \cdot 25\ a \cdot 240\ \text{work shift} \cdot 7\ m^3 = \\ = 294\ 000\ mg \tag{3}$$

Allowable length of service:

$$T' = T / C_{fact} \cdot N \cdot V_l = 294000\ mg / (3{,}4 + 4{,}3)\ mg/m^3 \cdot 240\ \text{work shift} \cdot 7\ m^3 \\ = 22\ g \tag{4}$$

Calculation of excess control dust load

$$DL/CDL = 70\ 560\ mg / 58\ 800\ mg = 1{,}2 \tag{5}$$

The actual dust load exceeds the reference dust load value by 20%, so the class of working conditions is harmful.

Figure 1. Repair-mechanical section

When the CDL values are exceeded, protective measures are reduced to reducing the average daily concentration in the air of the working area. For example, the use of machines and mechanisms, during the operation of which dust formation is minimal; periodic cleaning of the working space from dust; irrigation of settled dust and others.

2.7. Selection and justification of ventilation system for the workshop

To reduce the negative impact on the health of workers in the repair-mechanical section of "Shakhtinskaya ceramics" should be properly equipped with a ventilation system, taking into account the rate of air exchange (the number of full changes of air volume of the premises for one hour) so that the speed of air flow in the repair-mechanical section was greater than the rate of deposition of dust.

For hazardous substances emitted during welding, the recommended air intake velocity is 0.8 - 0.9 m/s.

Area of the repair-mechanical site of "Shakhtinskaya Ceramics":

$$S = a \cdot b = 12{,}19\ m \cdot 6{,}058\ m = 73{,}85\ m^2 \quad (6)$$

where: a - length of repair-mechanical site of "Shakhtinskaya ceramics", m;

b - width of repair-mechanical site of "Shakhtinskaya ceramics", m.

Volume of repair-mechanical section of "Shakhtinskaya ceramics":

$$V = S \cdot c = 73{,}85\ m^2 \cdot 5\ m = 369{,}25\ m^3 \quad (7)$$

where: c is the height of the workshop, m.

Cross-sectional area of the repair-mechanical section of "Shakhtinskaya ceramics":

$$S_{sec} = b \cdot c = 6{,}058\ m \cdot 5\ m = 30{,}3\ m^2 \quad (8)$$

The required amount of supply air Q:

$$Q = K \cdot V = 30 \cdot 369{,}25\ m^3 = 11077{,}5\ m^3/h = 3{,}08\ m^3/s \quad (9)$$

where K is the air exchange rate. For this production area multiplicity will be 30. That is, for 1 hour the air flow will be changed 30 times.

The air speed at the repair-mechanical section of "Shakhtinskaya Ceramics":

$$Q = v \cdot S_{сеч} \Rightarrow v = Q/S_{сеч} = 3{,}08\ m^3/s\ /30{,}3\ m^2 = 0{,}1\ m/s \quad (10)$$

At this speed there will be deposition of dust both in the space of the workshop and in the workplaces. The accumulated dust must be effectively removed from the air of the working area. For this purpose it is necessary to choose the right equipment.

Substance name	Formula	Intensity of selection, m^3/s	Density kg/m^3	Class of hazard	MAC mg/m^3
Carbon Monoxide	CO	0,019	1,25	4	20
Fluorine hydride	HF	0,024	0,99	1	0,5
Nitrogen dioxide	NO_2	0,09	2,11	2	2
Ozon	O_3	0,28	2,145	1	0,1

Table 2. Harmful substances released into the air of the work area

The final concentration of harmful chemicals in the air:

$$C_{к(co)}=C_0 + k_n \cdot p_r \cdot I_r \cdot 10^6/Q=0 + 1 \cdot 1,25\ kg/m^3 \cdot 10^3 \cdot 0,019\ m^3/s\ /\ 30,03\ m^3/s \quad (11)$$

$= 0,79\ mg/m^3$ (MAC is not exceeded; working conditions class 2)

$$C_{к(HF)}=C_0 + k_n \cdot p_r \cdot I_r \cdot 10^6/Q=0 + 1 \cdot 0,99\ kg/m^3 \cdot 10^3 \cdot 0,024\ m^3/s/\ 30,03\ m^3/s \quad (12)$$

$= 0,79\ mg/m^3$ (MAC is exceeded)

$$C_{к(No2)}=C_0 + k_n \cdot p_r \cdot I_r \cdot 10^6/Q=0 + 1 \cdot 2,11\ kg/m^3 \cdot 10^3 \cdot 0,009\ m^3/s/\ 30,03\ m^3/s \quad (13)$$

$= 0,63\ m^3/s$ (MAC is not exceeded; working conditions class 2)

$$C_{к(O3)}=C_0 + k_n \cdot p_r \cdot I_r \cdot 10^6/Q=0+ 1 \cdot 2,145\ kg/m^3 \cdot 0,0028\ m^3/s \cdot 10^6\ /\ 30,03\ m^3/s \quad (14)$$

$= 0,2\ mg/m^3$ (MAC is exceeded))

Calculation of the total concentration of harmful substances in the air of the working area

$$C_{общ} = \Sigma(C\ /\ MAC) = 0,79/20 + 0,79/0,5 + 0,63/2 + 0,2/0,1 = 3,9 \quad (15)$$

Since the total concentration is greater than 1 - class of working conditions is harmful.

According to calculations, with the given system of general combined extract and input ventilation (Figure 2), it is impossible to ensure a minimum air velocity of 0.8 m/s, so in order to improve working conditions of workers in the mechanical repair shop, it is proposed to equip the production facility with a ventilation system that includes local suction for the removal of harmful air impurities and a bag filter for cleaning this composition, as it is focused on eliminating problems associated with aerosols.

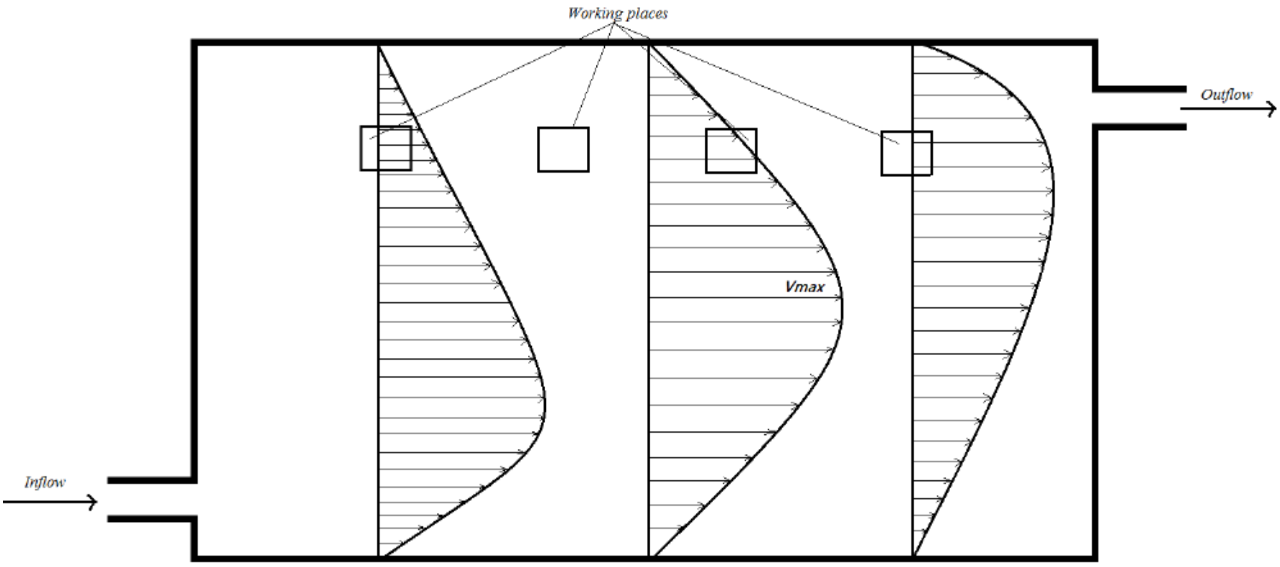

Figure 2. Schematic diagram of air movement in the supply and exhaust ventilation

When welding small items, various aerosols are emitted that contaminate the air in the work area. Therefore, it is especially important to ensure good air exchange in industrial premises, where people work in the most harmful conditions. An example of this is the installation of an exhaust hood.

Local exhaust ventilation is used when places of harmful emissions in the room are localized and it is necessary to prevent their spread throughout the room.

Local exhaust ventilation in production facilities provides catching and removal of harmful emissions: gases, smoke, dust and partially emitted from the equipment heat. (Muratov 2007, 200)

The design of local suction must be appropriate to the nature of harmful emissions. Suction should be placed in the direction of their natural movement. It must deflect the polluted air away from the breathing zone of the worker. (Torgovnikov 1983, 189)

For these conditions we will use a system with conical exhaust umbrellas at each workplace of an electric welder.

Let's take an example, when the worker is 170 cm tall doing work sitting. Then, the breathing zone - the space within a radius of up to 50 cm from the face of the worker on all sides - has a lower boundary in the area of the abdomen as in Figure 3.

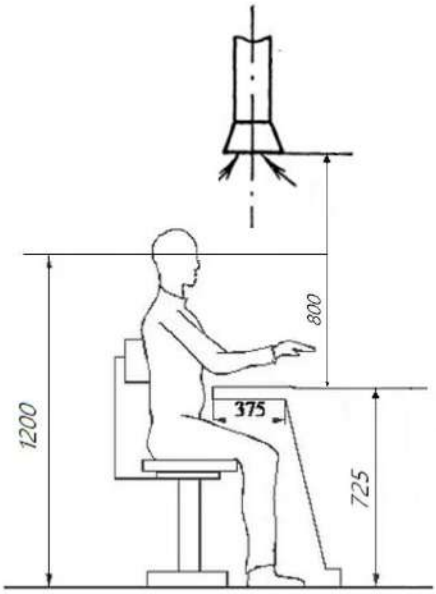

Figure 3. The workplace of the electric and gas welder.

Consequently, the height of the breathing zone $h_{z.d.}$ will be equal to 80 cm, as the hood is located at this height from the desk.

When assessing the intensity of work an important role is played by working posture. During the working time the human body deviates in different directions (Fig. 4).

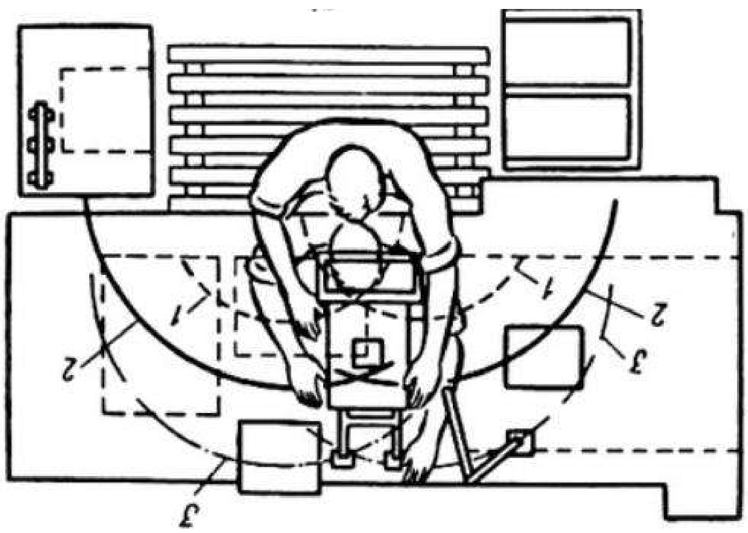

Figure 4. Working postures

Normal work posture is a posture in which the worker does not have to bend more than 10-15 degrees, and it is supported by minimal muscle tension.

Then, to calculate the length of the breathing zone, consider the version where the position of the worker's body is perpendicular to the floor (Figure 5). In this case the maximum length of breathing zone of employee Lz.d. will be equal to 100 cm, that is 50 cm on each side.

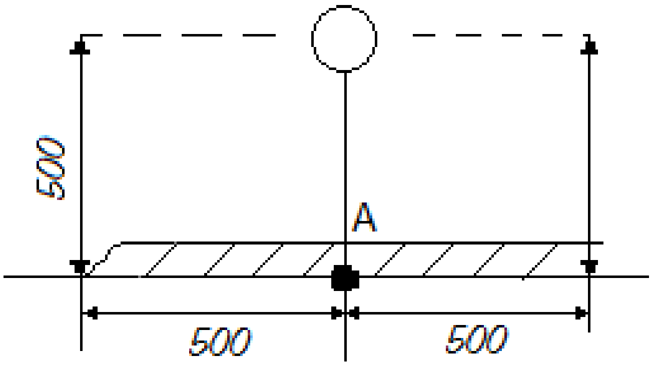

Figure 5. Schematic representation of the breathing zone of the worker

However, during work, the position of the body can change, deviating sideways by a maximum angle of 150 to the right and to the left (figure 6a). Based on this, let's find the length of the breathing zone through the tangent of the angle.

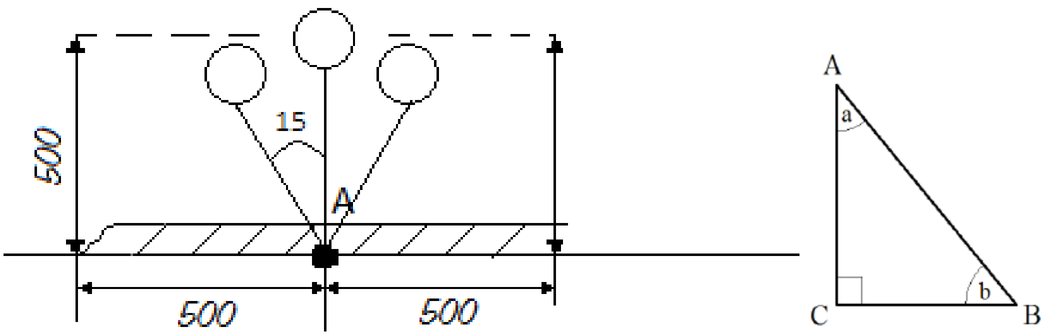

Figure 6. a) Schematic representation of deviation of a body of the person during work process in both parties. b) Scheme for counting.

The triangle formed as a result of a deviation of a body of the person during work.

We will find the change in the length of the breathing zone when the body is tilted from the right triangle ABC (figure 6 b) with side AC = 49 cm:

$$CO = x = tga \cdot AC = tg\,(15) \cdot 49 = 13{,}13 \text{ sm} \quad (16)$$

That is, when a person deviates during work at an angle of 15° the length of the breathing zone will increase by 13,13 cm relative to the initial position (perpendicular to the floor).

$$L_{з.д.}^{макс} = 2(50 + 13{,}13) = 126{,}3 \text{ sm} \quad (17)$$

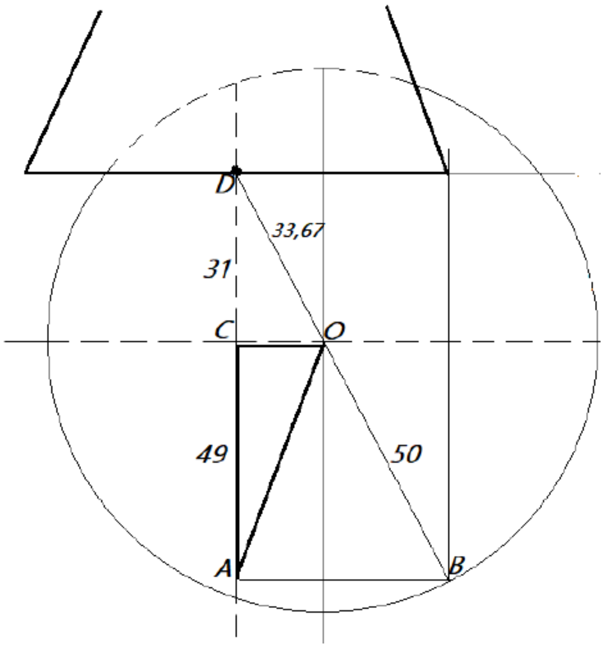

Figure 7. Schematic representation of the human breathing zone relative to point O.

Knowing the distance from the head (point C of Figure 7) to the exhaust port (point D) and the horizontal distance after deviating the position of the human body by 15^0 (segment CO) we can find DO:

$$DO^2 = CD^2 + CO^2 = 31^2 + 13{,}13^2 \Rightarrow DO = 33{,}67 \text{ sm} \quad (18)$$

Through the line DO draw a segment OS to the intersection with the circle (the conventional designation of the breathing zone of the employee). Since the radius of the circle is 50 cm and knowing the distance from the center of the intake section to the employee's head (segment OD) we will find the maximum distance at which the dust will still be sucked into the canopy:

$$DB = DO + OB = 33{,}67 + 50 = 83{,}67 \text{ sm} \quad (19)$$

From right triangle DBA find the segment AB:

$$AB^2 = DB^2 - DA^2 = 83{,}67^2 - 80^2 \Rightarrow AB = 24{,}5 \text{ sm} \quad (20)$$

The segment AB will be the radius for this conical umbrella, R_z = 25 cm.

The length of the electric and gas welder's workplace is 150 cm (Figure 8), and the length of the hood is 50 cm.

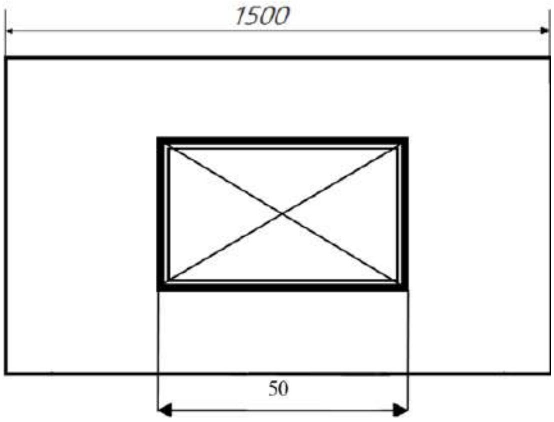

Figure 8. Layout of the table and hood when viewed from above.

The surface area of the technological table:

$$S_{TC} = b_{TC} \cdot c_{TC} = 1{,}5\ m \cdot 0{,}6\ m = 0{,}9\ m^2 \qquad (21)$$

For these conditions, we will use a system with conical hoods at each workplace electric welder with a reception opening of radius R = 0,5 m, the angle of inclination φ = 60° (Figure 9).

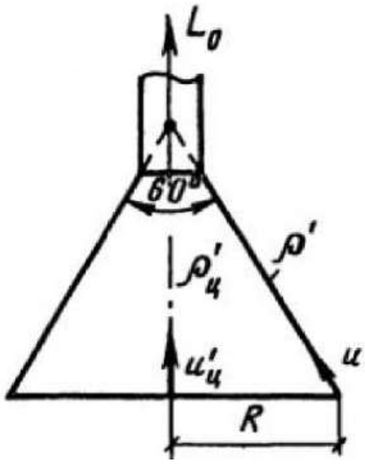

Figure 9. Schematic diagram of a conical exhaust hood

With the help of this device harmful substances can be removed from the air of the working area.

Calculation of the design parameters of the hood.

Body angle:

$$\gamma = 2\pi(1 - \cos\phi/2) = 2\pi(1 - \cos(60/2)) = 2 \cdot 3{,}1416\ \ (1 - 0{,}866) = 0{,}842 \qquad (22)$$

The length of the formative cone:

$$c_o = R/(\sin\phi/2) = 0{,}25\ m\ /(\sin\ (60/2)) = 0{,}5\ m \qquad (23)$$

The distance from the center of the umbrella to the pole (height of the cone):

$$c_ц = R/(tg\phi/2) = 0,25 \text{ m} /(tg\ (60/2)) = 0,43 \text{ m} \qquad (24)$$

If the airflow rate at point u (at the point where the human body is deflected by 15°) should be at least 0.9 m/s, we can find the airflow rate that will provide this speed (Figure 10).

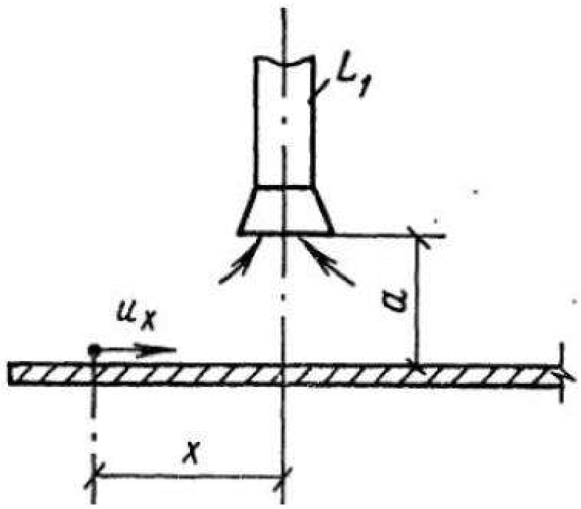

Figure 10. Schematic representation of the work table with the drafting.

The drafting performance, which provides at point x a velocity of 0.9 m/sec:

$$Q_u = 2\pi u_x (x^2 + a^2)^{3/2} / x = 2\pi \cdot 0,9 \cdot (0,1313^2 + 0,3^2)^{3/2} / 0,1313 = \qquad (25)$$

$$= 1,5 \text{ m}^3/\text{sec}$$

where x is the maximum horizontal distance at the inclination of the body at 15°, m.

Thus, according to mathematical calculations, to remove dust from the most extreme point of human breathing zone it is necessary to provide a flow rate of 1,5 m^3/sec.

Since the repair-mechanical site of "Shakhtinskaya ceramics" (Figure 11) 4 similar jobs and each has a local suction, let's determine the total flow rate for all extractions:

$$Q_{1\text{-}4} = 4Q = 4 \cdot 1,5 \text{ m}^3/\text{sec} = 6 \text{ m}^3/\text{sec} \qquad (26)$$

Ventilation network of the shop (Figure 12) consists of 4 suction holes (inlets number 1,3,5,7), pipelines, bag filter (11-12) and fan 13.

Air will flow through the ventilation network piping (Figure 12), the diameter of which is d = 0.5 m throughout the network.

The cross-sectional area of the pipeline:

$$S_{тр} = \pi R^2 = \pi d^2/4 = 3,14 \cdot 0,5^2/4 = 0,196\ m^2 \quad (27)$$

where d is the pipeline diameter, m.

The perimeter of the pipeline:

$$P_{тр} = 2\pi R = \pi d = 3,14 \cdot 0,5^2\ m = 0,785\ m \quad (28)$$

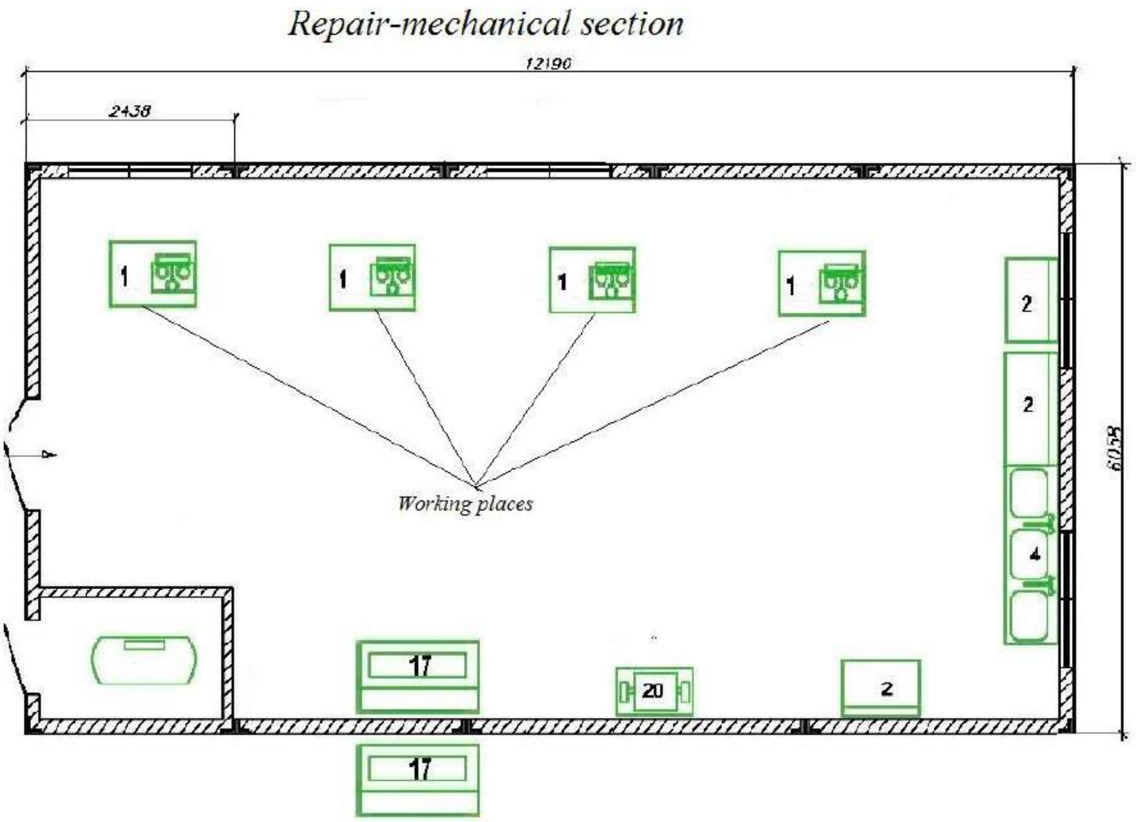

Figure 11. Scheme of the repair-mechanical section of "Shakhtinskaya Ceramics".

Air velocity in the pipelines:

$$v = Q/S_{тр} = 1,5\ m^3/sec\ /\ 0,196 = 7,65\ m/sec \quad (29)$$

Reynolds number according to the formula for each duct:

$$Re = v \cdot d/\vartheta = 7,65\ m/s \cdot\cdot\ 0,5\ m\ /\ 1,5 \cdot\cdot 10^{-5}\ m^2/s = 255\ 000 \quad (30)$$

where ϑ is the kinematic viscosity of air, $\vartheta = 1.5 \cdot 10^{-5}\ m^2/s$;

Since the Reynolds number is greater than 2000, it means that the mode is turbulent.

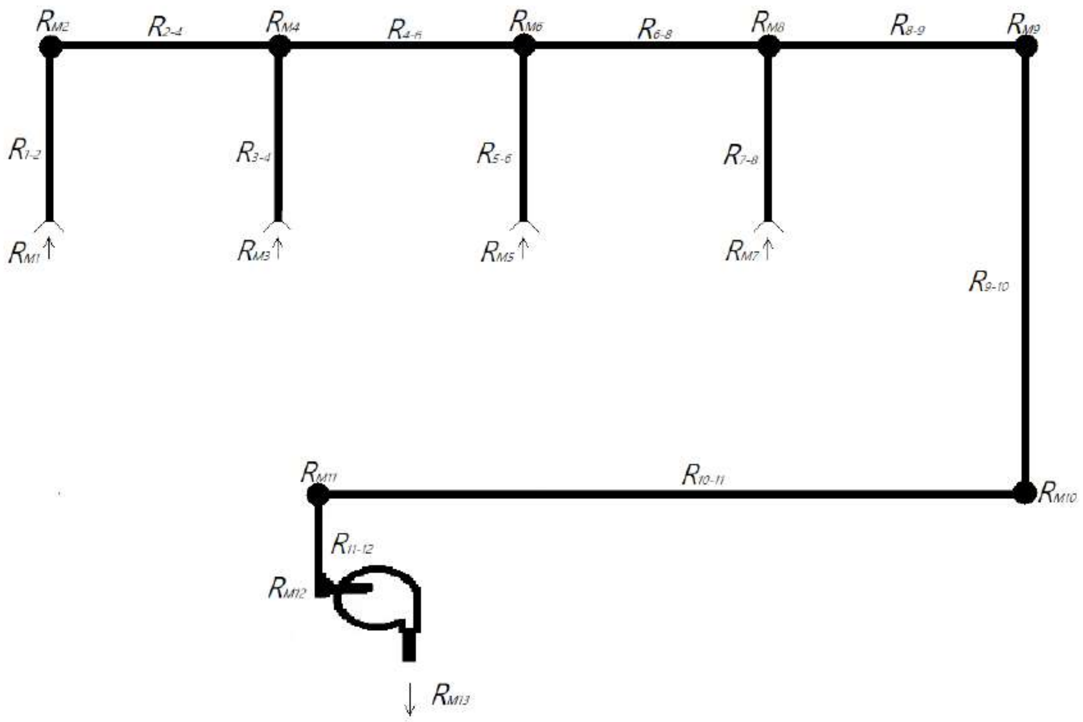

Figure 12. Schematic diagram of the ventilation network of the repair-mechanical section.

The coefficient of friction resistance:

$$\lambda = 0{,}11 \sqrt[4]{68/\mathrm{Re} + \mathrm{k/d}} = 0{,}11 \cdot \sqrt[4]{68/255\ 000 + 0{,}001/0{,}5} = 0{,}024 \qquad (31)$$

where k is the roughness of the pipe walls k = 0.1 mm for pipes.

The obtained values of friction resistance coefficients are given in appendix 1.

To select the fan, it is necessary to know the resistance and depression of the ventilation network. Let us perform the calculation:

Calculation of the total resistance of the section 1-5:

Local inlet resistance at point 1:

$$R_M{}^1 = \xi\rho/2S^2_{Tp} = 0{,}4 \cdot 1{,}225/(2 \cdot 0{,}196^2) = 6{,}38 \text{ ns}^2/\text{m}^8 \qquad (32)$$

where ρ - specific weight of air, assumed for the operating conditions of the installation of 1,225 kg/m^3.

ξ - coefficient, taking into account local resistances.

Aerodynamic friction resistance of straight section 1-2:

$$R_{1-2} = \lambda L\rho/2dS_{Tp}{}^2 = 0{,}024 \cdot 1{,}5 \text{ m} \cdot 1{,}225 \text{ kg/m}^3/(2 \cdot 0{,}5 \text{ m} \cdot 0{,}196^2 \text{ m}^2) = 1{,}15 \text{ ns}^2/\text{m}^8 \qquad (33)$$

where L is the length of a particular section of the pipeline, m.

Local resistance at the turn in point 2:

$$R_м^2 = ξρ/2S^2_{тр} = 1{,}4 \cdot 1{,}225\ kg/m^3 /(2 \cdot 0{,}196^2) = 22{,}32\ ns^2/m^8 \quad (34)$$

Aerodynamic friction resistance of straight section 2-4:

$$R_{2\text{-}4} = λLγ/2dS^2 = 0{,}024 \cdot 3\ m \cdot 1{,}225\ kg/m^3/ (2 \cdot 0{,}5\ m \cdot 0{,}196^2\ m^2) = \quad (35)$$

$$= 2{,}3\ ns^2/m^8$$

Total resistance of section 1-4:

$$R_{общ}^{1\text{-}4} = \ = R_м^1 + R_м^2 + R_{1\text{-}2} + R_{2\text{-}4} = 6{,}38 + 1{,}15 + 22{,}32 + 2{,}3 = \quad (36)$$

$$=32{,}15\ ns^2/m^8$$

In section 11-12 there is a unit with a bag filter. During operation of the unit on the surface of the bags there is a dust accumulation due to which the aerodynamic resistance of the filter also increases.

Cleaning (regeneration) of sleeves from dust is carried out without switching off the unit separately for each row of sleeves and lasts for 0.2 - 0.3 s by giving a pulse of compressed air through nozzles in the diffuser part of each sleeve. The air jet entering the hose through the diffuser sucks (injects) cleaned air from the chamber and creates increased pressure in the hose. At the same time, the sleeve inflates, destroying the dust layer, which is separated from the fabric by the reverse pulse air flow and dumped into the hopper. (Architectural Encyclopedia 2021)

Then, taking into account the values of aerodynamic resistance of the filter cleaned $R_{min\ filter}$ = 1000 Pa and dirty R_{max} filter = 2000 Pa, the resistance will be:

$$R_{min}^{11\text{-}12} = R_{min}^{fil} / Q^2 = 1100\ Pa / 6^2\ m^3/s = 30{,}56\ ns^2/m^8 \quad (37)$$

$$R_{max}^{11\text{-}12} = R_{max}^{fil}/ Q^2 = 2000\ Pa / 6^2\ m^3/s = 55{,}56\ ns^2/m^8 \quad (38)$$

The total aerodynamic resistance of the entire ventilation piping system for the existing and projected systems was determined by the formula:

$$R_{общ} = ΣR + ΣR_M + ΣR' = 134{,}38\ ns^2/m^8 \quad (39)$$

where ΣR is the total aerodynamic resistance of the straight sections of the pipeline.

ΣR_M is the total aerodynamic resistance of the local resistance sections of the pipeline.

$\Sigma R'$ - total aerodynamic resistance of the equivalent sections of the pipeline.

The depression of the whole system was determined by the formula:

$$H_{min} = 1{,}1\ R_{общ}\ Q_{общ}^2 = 1{,}1 \cdot 164{,}94\ ns^2/m^8 \cdot 6^2\ m^3/s = 6\ 532\ Pa \quad (40)$$

$$H_{max} = 1{,}1\ R_{общ}\ Q_{общ}^2 = 1{,}1 \cdot 189{,}94\ ns^2/m^8 \cdot 6^2\ m^3/s = 7\ 522\ Pa \quad (41)$$

where 1,1 is the coefficient that takes into account the underbalance losses on unaccounted resistances.

The obtained data are summarized in Appendix 1,2,3.

Using the obtained values of depression, as well as the flow rate of air from the calculation of formula 26 (Q = 6 m^3/s = 21 600 m^3/h), we select the fan VTs6-28. according to the aerodynamic characteristic (Figure 13).

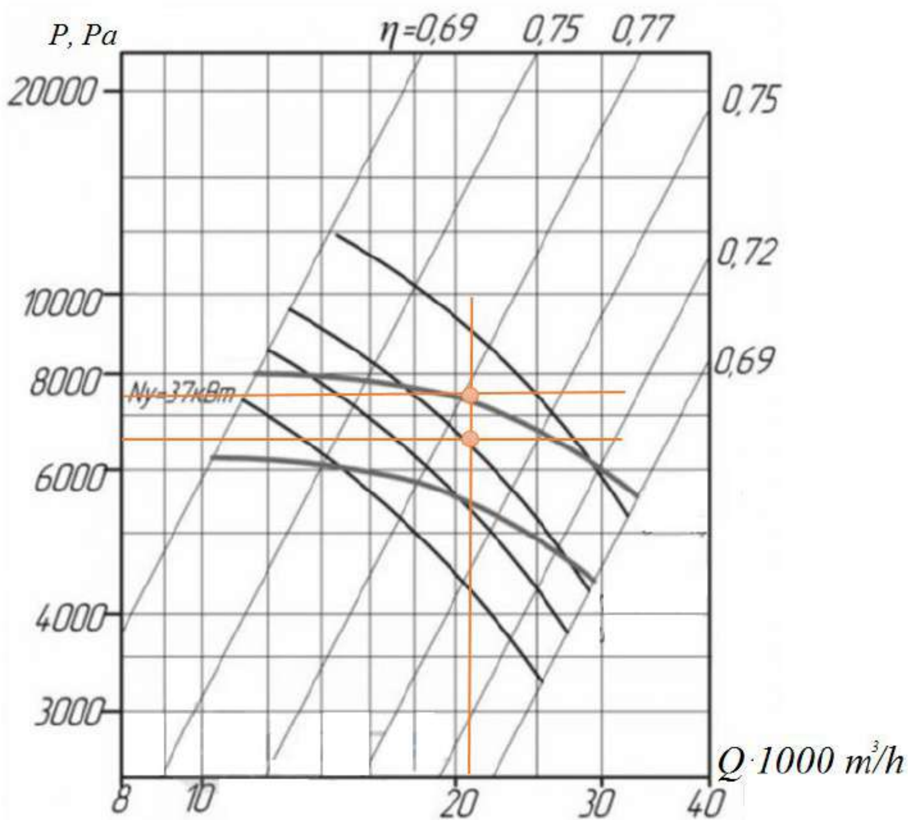

Figure 13. Aerodynamic characteristic of the fan VTs6-28

2.8. Selection of the most effective dust collector for the given conditions

A bag filter is one of the types of equipment, the principle of operation of which is based on protection of production and people working there against dust and polluted air. The following six types of bag filters are produced by domestic manufacture:

- With reverse sectional blowdown;
- With piece-by-piece jet blowing;
- With pulse blowing;
- With regeneration by mechanical action;
- With aerodynamic shaking in combination with reverse sectional blowing.

For efficient operation of the bag filter unit, it is necessary to consider the design features of the unit. Therefore, it is necessary to calculate the characteristics necessary for the selection of the unit. (Brakovich and Sizov 2011, 24)

Specific gas load:

$$q = q_n \cdot c_1 \cdot c_2 \cdot c_3 \cdot c_4 \cdot c_5 = 2{,}6 \cdot 1 \cdot 1 \cdot 0{,}9 \cdot 1 \cdot 0{,}92 = 2{,}15\ m^3/(m^2 \cdot min) \quad (42)$$

q_n - normative specific load, depending on the type of dust and its tendency to agglomeration. For alumina, cement, ceramic dyes and limestone it is equal to 2.6.

c_1 - coefficient, characterizing the ability to regenerate the filtering elements. For this coefficient a filter with pulse blowing by compressed air with fabric sleeves is taken as a basic variant. For this apparatus the coefficient c_1 = 1.

c_2 - coefficient, taking into account the influence of dust concentration on the specific gas load.

c_3 - coefficient, taking into account the influence of dispersed dust composition in gas, the data are given in Table 3 (d_m - median particle size, microns).

d_m, мкм	< 3	3 - 10	10 - 50	50 - 100	> 100
c_3	0,8	0,9	1,0	1,1	1,3

Table 3. Change of coefficient c_3 depending on particle diameter

c_4 - coefficient, taking into account the effect of gas temperature, the coefficient values are given in Table 4.

t, ^{0}C	20	40	60	80	100
c_4	1	0,9	0,84	0,78	0,75

Table 4. Change of coefficient c_4 depending on gas temperature

The filtering surface of the apparatus:

$$F_ф = V_п /60q = 370\ m^3/60 \cdot 2,15 = 2,87\ m^2 \quad (43)$$

According to Appendix 4, we find the most suitable industrial bag filter of FRU brand (Figure 14) with the filtering surface area of 2.5 m^2. The design of this unit assumes that there are 14 bags in a section.

Body of this bag filter is equipped with ladders, platforms and barriers to provide access to mechanical equipment.

Capacity of FRU-M bag filters varies in the following range:

- Single module - from 3 500 to 25 000 m^3/h, with maximum filtration rate of 1.4 m/min.

- Two-module - from 30 000 to 60 000 m^3/hour, with a maximum filtration speed of 1.4 m/min.

- Four-module units - 65,000 to 125,000 m^3/hour, with a maximum filtration rate of 1.4 m/min. (Rogunov 1985, 17)

Due to the high capacity of this model, the mechanical wear of the bag filter material is caused by the repeated occurrence and disappearance of folds, i.e. frequent alternating bending. This phenomenon occurs to a greater extent during filter regeneration, which causes mutual abrasion of the fibers.

Since there is no normative documentation regulating the resistance of filter materials to wear (abrasion), then, based on the physical and mechanical parameters of textile fibers, namely, the breaking strength, we can conclude that during the filtration of dusty and gassy air, the material with the highest breaking strength will be more resistant to wear (mechanical effects). (Rogunov 1985, 17)

Figure 14. Industrial bag filter (Sourse Fakel)

Thus, according to some data for wool fabrics, for example, the service life is usually 9 - 12 months, nitron - up to 14 months, and the service life of glass fabrics varies in a wide range up to 24 months. This variation can be explained by the fact that the breaking strength of glass fabrics is about 3000 MPa, which is 3 times higher than that of many other filter materials.

Based on the data obtained, we can see Dependence between filtering material's lifetime and tensile and torsional strength of the material (Figure 15 and 16).

According to the graph, an increase in the tensile strength of the filter material leads to an increase in the service life of this material.

However, in order to develop a technical solution to improve the efficiency of filter bag materials used, additional laboratory research is needed, which will make it possible to contribute a practical point of view in this direction.

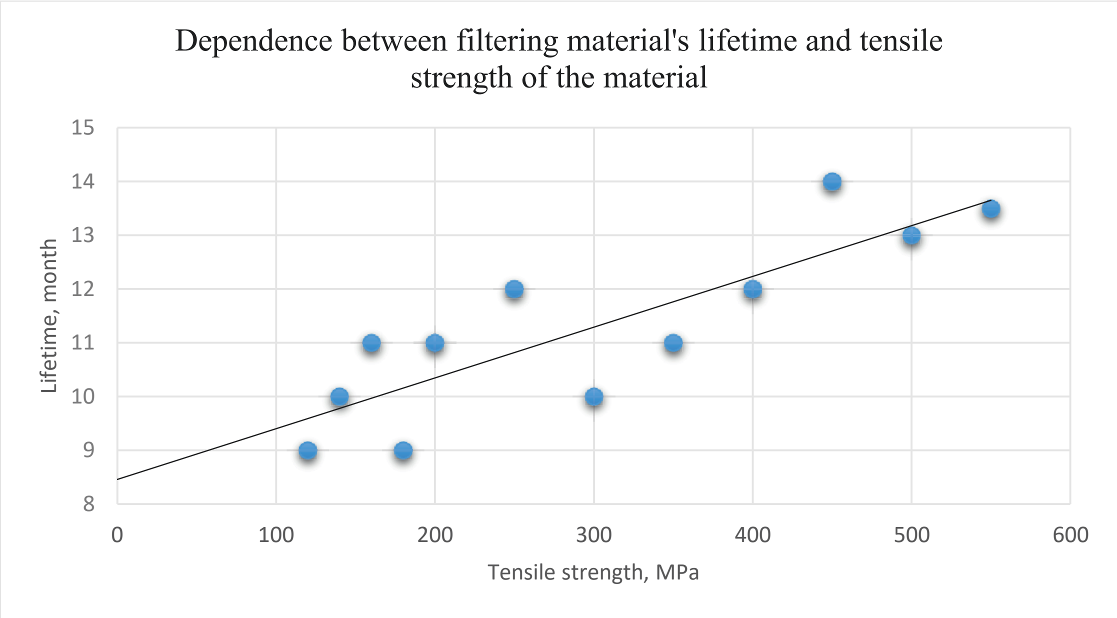

Figure. 15. Dependence between filtering material's lifetime and tensile strength of the material

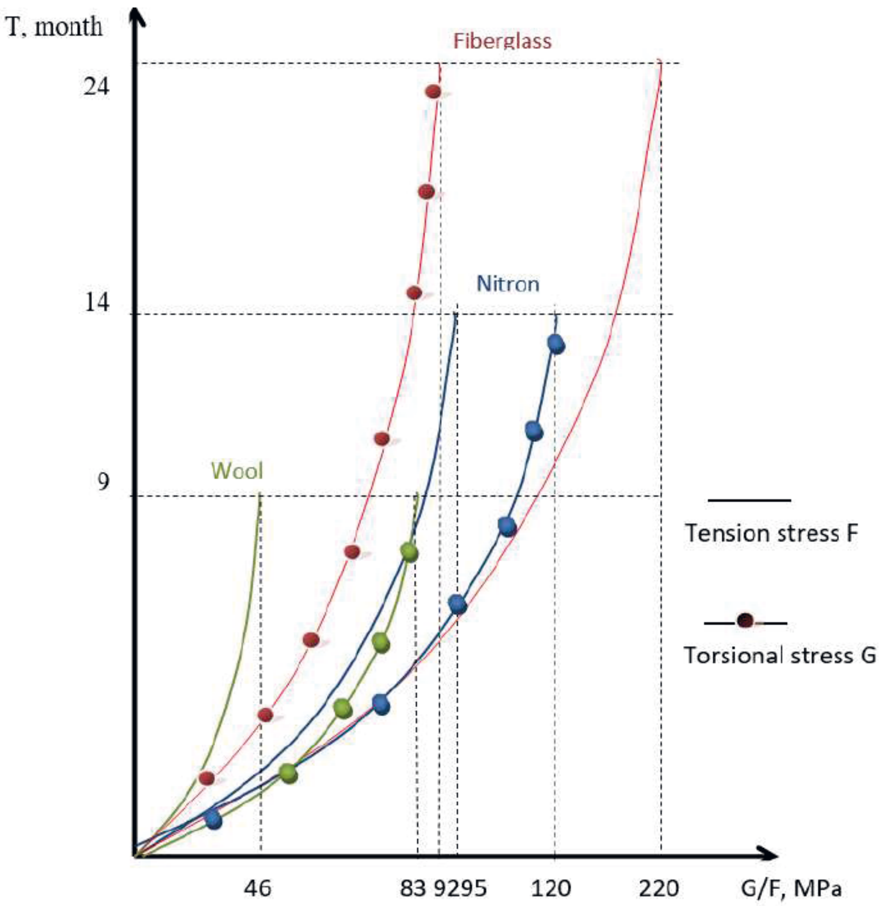

Figure 16. Dependence between filtering material's lifetime and tensile and torsional strength of the material

2.9. Economic evaluation of proposed technical and organizational solutions

There are some filtering materials for comparison: niton, wool and fiberglass fabric. The cost of the material is taken from the online store. (Sibelcon 2021)

Table 5.

Technical characteristics of filter bags

Material	Nitron (polyacrylonitrile)	Wool	Fiberglass fabric
Operating time, month (OP)	14	10	24
Price per unit, rub	400	650	1600
Unit cost of use (UC)	28,6	65	66,5
Coefficient of relative efficiency of use	2,3		0,97

Unit cost of use of filter’s bag made from nitron:

$$UC_1 = P_1 / OP_1 = 400 \text{ rub} / 14 \text{ month} = 28{,}6 \quad (44)$$

Unit cost of use of filter’s bag made from wool:

$$UC_1 = P_2 / OP_2 = 650 \text{ rub} / 10 \text{ month} = 65 \quad (45)$$

Unit cost of use of filter’s bag made from fiberglass fabric:

$$UC_3 = P_3 / OP_3 = 1600 \text{ rub} / 24 \text{ month} = 66{,}5 \quad (46)$$

Coefficient of relative efficiency of use:

$$K^1_r = UC_2/UC_1 = 65/28{,}6 = 2{,}3 > 1 \quad (47)$$

The use of a nitron filter bag is more feasible than a wool filter bag.

$$K^2_r = UC_2/UC_3 = 65/66{,}5 = 0{,}97 < 1 \quad (48)$$

The use of a wool filter bag is more feasible than a fiberglass filter bag.

Costs for the purchase of a nitron filter bag for 1 unit of FRI:

$$C_1 = OP_1 \cdot N \cdot n = 400 \text{ rub} \cdot 14 \cdot 1 = 5\ 600 \text{ rub} \quad (49)$$

where n is the number of filtering units at Shakhtinskaya Keramika;

N - number of filtering hoses in the section according to Appendix 4.

Costs for the purchase of a wool filter bag for 1 unit of FRI:

$$C_2 = OP_2 \cdot N \cdot n = 650 \text{ rub} \cdot 14 \cdot 1 = 9\ 100 \text{ rub} \quad (50)$$

Costs for the purchase of a fiberglass filter bag for 1 unit of FRI:

$$C_3 = OP_3 \cdot\cdot N \cdot n = 1600 \text{ rub} \cdot 14 \cdot 1 = 22\ 400 \text{ rub} \quad (51)$$

1 year benefit with nitron material:

$$Э=(З_1 – З_3)(D/OP_1)=(9\ 100 \text{ rub} – 5\ 600 \text{ rub})(358 \text{ days} /425 \text{ days}) = 4\ 155 \text{ rub} \quad (52)$$

where D is the number of working days in the year.

So, the use of Nitron filter material is more economically advantageous for the company.

Installation costs:

$$M = c \cdot a = 2\ 587 \text{ rub} \cdot 3 \text{ h} = 7\ 761 \text{ rub} \quad (53)$$

where s is the average rate of an employee, rubles;

a - number of hours to replace all filter bags, h.

Capital investments:

$$I_c = C_1 + Tr + M + C_f = 5\ 600 + 0 + 7\ 761 + 1\ 450\ 000 = 1\ 463\ 361 \text{ rub} \quad (54)$$

where Tr = 0 - delivery cost (included in the purchase price), rubles

C_f – cost of bag filter, rub.

Total costs for the installation of the bag filter

$$C_t = E_n \cdot I_c = 0 + 0{,}08 \cdot 1\ 463\ 361 \text{ rub} = 117\ 069 \text{ rub} \quad (55)$$

where E_n - normative coefficient of economic efficiency of capital investments for the implementation of measures to improve labor protection conditions.

3. Conclusion

The master's thesis is devoted to the development of the solution to the urgent problem of industrial safety for normalization of the working area atmosphere in the presence of harmful substances that have a negative impact on the human body.

The explanatory note provides information about the relevance of the problem at the moment, gives a general description of the design object, a description of the production technology and assessment of the level of hazardous and harmful factors.

In the course of the work the objectives were achieved, namely:

1. The analysis of technological and organizational factors that lead to the formation of dust at the working places of ore-dressing and processing plants has been made.

2. The condition of the air environment in terms of dust factor for "Shakhtinskaya Ceramics" has been evaluated.

3. The measures aimed at minimizing the impact of dust factor on the personnel of "Shakhtinskaya Ceramics" were selected.

As at "Shakhtinskaya Ceramics" dust by dispersed composition cannot be removed by existing methods at the enterprise, and it is not rational to increase air inflow, therefore it is necessary to take measures to improve index of working conditions class by chemical factor for electric welder and manual welder working places at several sites of the enterprise.

To improve the existing measures at "Shakhtinskaya Ceramics", modernization of such dust-collecting installation as a bag filter is proposed, which is the selection and installation of the most effective material of the filter bag.

In the conclusion of the final qualification work, we can conclude that the bag filter design filter bag material is one of the most important components in the fight against dusty and polluted air in the work area, without which the system can not work. Therefore, it is so important that this filter element performs its function well and reliably.

When choosing a filtering material for a bag filter, it is suggested to take into account such fiber parameter as tensile strength in order to increase filtering material service life and avoid expenses for purchase and replacement of other cheaper variants.

However, to develop a technical solution to improve the efficiency of the filter bag materials used, it is necessary to conduct additional laboratory research and on the basis of the data obtained, conduct a dependence of the durability of the materials on their physical and chemical properties.

After the introduction of the measure is expected not only to reduce the negative impact on workers, but also economic benefits from the proposed measure.

4. Bibliography

1. Brakovich I.S. Calculation of the bag filter / I.S. Brakovich, V.D. Sizov. - Minsk, BNTU, 2011. - 27 с.

2. Morgulis L.M. Bag filters / L.M. Morgulis, M.G. Mazus. - M.: "Machine Industry", 1977. - 256 с.

3. Muratov, P.P. Bag filters / P.P. Muratov - M.: Respublika, 2007. - 231с.

4. Rogunov O.A. Gas-cleaning equipment. Bag filters. Catalog / O.A. Rogunov. - Moscow: CINTIHIMNEFTEMASH, 1985 - 17 p.

5. Torgovnikov B.M. Design of industrial ventilation. Handbook./ BM Torgovnikov - Kiev: Publishing House "Budivelnik" 1983 - 256 p.

6. Interstate standard GOST 31826 - 2012. Gas cleaning and dust-collecting equipment. Bag filters. Wet dust collectors. - Moscow: Standardinform, 2013 - 23 p.

7. GOST 12.1.007-76. "SSBT. Hazardous substances. Classification and general safety requirements:

8. Vladimirovsky quarry of refractory clays, OJSC [Electronic resource]. URL: https:// studwood.ru/1645520/tovarovedenie/vladimirovskiy_karer_tugoplavkih_glin

9. Company "HITACHI" [Electronic resource]. URL: https://www.hitachicm.ru

10. Group of companies "Unitil" [Electronic resource]. URL :http://www.unitile.ru

11. Mogilev automobile plant named after S.M. Kirov [Electronic resource]. URL: http://www.moaz.by

12. Labor protection and life safety [Electronic resource]. URL:http://ohrana-bgd.narod.ru/pil1.html

13. Hazardous and harmful production factors [Electronic resource]. URL:https://www.protrud.com/опасные-и-вредные-производственные-факторы/

14. "Fakel" - production of dust-collecting units for air purification. [Electronic resource]. URL:https://fakel-f.ru/blog/30-01-20

15. Ventilation and air conditioning [Electronic resource]. URL:https://venteler.ru/chem-otlichayetsya-aspiratsiya-ot-ventilyatsii/

15. Analysis of harmful and hazardous factors during electric and gas welding work [Electronic resource]. URL:https://novainfo.ru/article/5253

16. Architectural Encyclopedia [Electronic resource]. URL: https://arxipedia.ru/proizvodstvo-izvesti/rukavnye-filtry-2.html#:~:text=Rope%20filters%20are%20used%20for%20full,is%20in%20the%20range%200%2C6-1%2C2%20kPa

17. Sibelcon. Industrial ventilation. [Electronic resource]. URL: https://sibelkon.ru/produkcziya/filtruyushhie-elementyi/rukava-filtrovalnyie/?utm_source=yandex&utm_medium=cpc&utm_campaign=37266867&utm_content=6305762457&utm_term=фильтровальные%20рукава&yclid=3007377490560442014.

5. List of figures

6. List of tables

7. Annex table of contents

1) Table 1. Summary table on the local resistance of the ventilation network of the repair-mechanical site of "Shakhtinskaya Ceramics".

2) Table 2. Summary table on the aerodynamic friction resistance of the ventilation network of the repair-mechanical site of "Shakhtinskaya Ceramics".

3) Table 3. Summary table.

4) Table 4. Technical characteristics of bag filters.

Appendix 1.

Table 1. Summary table on the local resistance of the ventilation network of the repair-mechanical site of "Shakhtinskaya Ceramics"

Resistance	Site	Sectional area	Local resistance coefficient	Local resistance, R_M
R_{M1}	Inlet to the pipe	0,196	0,4	6,37755102
R_{M3}	Inlet to the pipe	0,196	0,85	13,55229592
R_{M5}	Inlet to the pipe	0,196	0,85	13,55229592
R_{M7}	Inlet to the pipe	0,196	0,85	13,55229592
R_{M2}	Turning 90^0	0,196	1,4	22,32142857
R_{M4}	Mating under 90^0 with side jet	0,196	2,6	41,45408163
R_{M6}	Mating under 90^0 with side jet	0,196	2,6	41,45408163
R_{M8}	Mating under 90^0 with side jet	0,196	2,6	41,45408163
R_{M9}	Turning 90^0	0,196	1,4	22,32142857
R_{M10}	Turning 90^0	0,196	1,4	22,32142857
R_{M11}	Turning 90^0	0,196	1,4	22,32142857
R_{M12}	Turning 90^0	0,196	1,4	22,32142857
R_{M13}	Entering the atmosphere	0,196	1,4	22,32142857

Appendix 2.

Table 2. Summary table on the aerodynamic friction resistance of the ventilation network of the repair-mechanical site of "Shakhtinskaya Ceramics"

Resistance	Section length, m	Pipe diameter, d	Sectional area, S	Friction coefficient, λ	Aerodynamic friction resistance R, n s^2/m^8
$R_{тр1-2}$	1,5	0,5	0,196	0,024	1,147959184
$R_{тр2-4}$	3	0,5	0,196	0,024	2,295918367
$R_{тр3-4}$	1,5	0,5	0,196	0,024	1,147959184
$R_{тр4-6}$	3	0,5	0,196	0,024	2,295918367
$R_{тр5-6}$	1,5	0,5	0,196	0,024	1,147959184
$R_{тр6-8}$	3	0,5	0,196	0,024	2,295918367
$R_{тр7-8}$	1,5	0,5	0,196	0,024	1,147959184
$R_{тр8-9}$	3,15	0,5	0,196	0,024	2,410714286
$R_{тр9-10}$	5,5	0,5	0,196	0,024	4,209183673
$R_{тр10-11}$	9	0,5	0,196	0,024	6,887755102
$R_{тр11-12}$	0,5	0,5	0,196	0,024	0,382653061
$R_{тр12-13}$	1,5	0,5	0,196	0,024	1,147959184

Appendix 3.

Table 3. Summary table

<table>
<tr><th>Site</th><th>Local resistance</th><th>Friction resistance</th><th>Total resistance</th><th>Equivalent resistance</th><th>$\sum R$</th></tr>
<tr><td>1-4</td><td>6,37755102
22,32142857</td><td>1,147959184
2,295918367</td><td>32,14285714</td><td rowspan="4">10,5975
8,97102
7,73526</td><td></td></tr>
<tr><td>3-6</td><td>13,55229592
41,45408163</td><td>1,147959184
2,295918367</td><td>58,4502551</td><td></td></tr>
<tr><td>5-8</td><td>13,55229592
41,45408163</td><td>1,147959184
2,295918367</td><td>58,4502551</td><td></td></tr>
<tr><td>7-8</td><td>13,55229592
41,45408163</td><td>1,147959184</td><td>56,15433673</td><td></td></tr>
<tr><td>8-9</td><td>22,32142857</td><td>2,410714286</td><td>24,732142</td><td>-</td><td>32,467382</td></tr>
<tr><td>9-10</td><td>22,32142857</td><td>4,20918</td><td>26,53061224</td><td>-</td><td>58,997995</td></tr>
<tr><td>10-11</td><td>22,32142857</td><td>6,887755102</td><td>29,2091</td><td>-</td><td>88,20709</td></tr>
<tr><td>11-12</td><td>22,32142857</td><td>0,382653061</td><td>22,70407</td><td>-</td><td>110,91116</td></tr>
<tr><td>12-13</td><td>22,32142857</td><td>1,147959184</td><td>23,4693877</td><td>-</td><td>134,38055</td></tr>
<tr><td colspan="5">Total</td><td>134,38055</td></tr>
</table>

Appendix 4.

Table 4. Technical characteristics of bag filters

Brand	filter surface area, m^2	Ammount of sections	Ammount of bags in each section	Diameter of bags, m	Hight of bags, m
FR-6P	18	1	6	390	2,5
FT-2M	20	1	12	300	1,8
FRI	2,5 – 5,0	1 - 4	14, 28, 42	125	0,9; 1; 2
FRN-20	20	2	32	130	1,6
CA-3804	4140	3	-	-	-
FTNS-4M	12,4	1	4	386	2,6
FTNS-8M	24,8	2	4	386	2,0
FTNS-12M	37,2	3	4	386	2,6