6

SUPPLY SYSTEM OF FLY ASH FOR MINING PLANTS – ANALYSIS OF THE PROBLEM

6.1 INTRUDUCTION

In Poland, a leading source of heat and electricity is a coal. More than 90% of energy comes from combustion of coal, and therefore Poland is the one of the leading manufacturers of coal combustion products (CCPs) in Europe [19]. The main coal combustion product is the fly ash from black coal, which increasingly is treated as a full blown product, which could be an alternative to the aggregates. It is used in many areas, especially in coal mining and construction industry. Use of this material is essential for economic and ecological reasons, because it allows to elimination of landfills and to protect the other resources.

However, delivery of fly ash to operational places (mines) is a complex system, in which may arise the numerous difficulties both technical and organizational nature, and related to the environmental aspects and health and safety at work. The most important problems in currently existing supply system are, among other:

- the problem of secondary dust emission during loading, transport and unloading of products,
- reliability of supplies,
- choice of mode and means of the transport,
- and the problem of warehousing of fly ashes.

These issues make it necessary to modify existing supply system and seek for alternative solutions, which may allow to reduce or completely eliminate existing difficulties.

6.2 RECOVERY OF FLY ASH IN MINING PLANTS

The characteristics of coal combustion products (CCPs)

The coal combustion products (CCPs) are called fixed products created in the course of transformation of chemical energy of fuel to thermal energy in power plants and CHP plants [21]. These include, in particular:

- fly ash,
- slags,
- mixture of ash and slag.

Depending on the type of fuel and furnaces and also combustion conditions, the form and properties of the waste may be different. According to the Decree of the Minister of environment on the catalogue of waste (OJ 2001.112.1206), all of energetic waste are classified as a group of 10 01 – „wastes from power plants and the other fuels combustion plants" (with the exception a group of 19) [12].

Table 6.1 Selected energetic waste used in underground mining technologies

10 01 – Wastes from power stations and other combustion plants (except 19)	
10 01 01	Bottom ash, slag and boiler dust (excluding boiler dust mentioned in 10 01 04)
10 01 02	Coal fly ash
10 01 05	Calcium-based reaction wastes from flue-gas desulphurization in solid form
10 01 80	Mixture of ash and slag
10 01 82	Mixtures of fly ash and solid waste with calcium-based flue gas desulphurization (dry and semi-dry method of flue gas desulphurization and fluidized bed combustion)

Source: [12]

Selected energetic waste, which can be used in underground mining technologies presents Table 6.1. The largest group of energetic waste is fly ash (about 80-90%). It is the remnant from the coal or lignite combustion in boilers, that of emissions, in which mineral grains of less than 0,075 mm is more than 50% [7] of all grains. Fly ash is captured by electrostatic precipitators placed on boilers. It has dust form in gray or light brown color and its main components are oxides of aluminium, silicon and iron. Due to the participation of basic components of fly ash, it can be divided into three groups: silicate ashes, aluminum ashes and calcium ashes [16].

In Poland, in 2012 have been produced about 21 million tones energetic waste of which 4,6 million tones was coal fly ash (code 10 01 02) and 3,8 million tones were mixtures of fly ash and solid waste with calcium-based flue gas desulphurization (10 01 82) [11]. A large number of coal combustion products is forcing the Polish Industry to take action aimed at their recovery. Recovery - all activities that do not pose a threat to human life and health or the environment consisting in the use of waste (in whole or part) or leading to the recovery of substances, materials or energy from waste and its use[4]. The duty of disposal or recovery of energetic waste is based on the law of 14 December 2012 on the waste. In Poland, popularization of the energetic waste management deals with Polish Union of Coal Combustion Products which comprising representatives of heat and power plants, enterprises, scientific institutes and research laboratories [16].

The use of fly ash in mining plants

To fly ash can be used it has to meet certain quality standards. Possibilities of the use a wastes are dependent on their properties, e.g. grain size, chemical composition, content of sulphur compounds and, above all, the amount of free CaO. The content of calcium oxides (CaO) of less than 3,5% are classified ash as inactive, 3,5-14% as low active, and over 14% as active [7]. Activity of fly ash is a measure of its fitness to chemical stabilization.

Fly ashes are used primarily in building materials industry, road construction and in underground mining technologies. In recent years, mining industry has become a mass consignee of fly ash, mainly due to implementation a lot of new technologies (e.g. preparation of ash-water slurries) [7]. Currently about 85% of all waste, which are located in mines, is the fly ash and mixtures of fly ash and solid waste with calcium-based flue gas desulphurization.

The main directions of management of fly ash in mines, among other, are [4]:

- grouting of mine carvings,
- liquidation and filling of unnecessary mining workings,
- solidifying backfill,
- preventive fire protection and fire fighting in mines.

Characteristic application of fly ashes in Poland, in mining underground, is their use as a component of materials to filling mining workings where they replace valuable quartz sands. However, they are also used in the form of water slurries to perform anti-explosion dams, to build fields for the recovery of methane, to braking explosions and to liquidation of fire risks [19], which level in Poland is still very high despite the use of increasingly perfect technique for early detection of fires and more effective prevention [10]. All of components, endogenous fire arises in the presence of combustible material, inflow of oxygen and a temperature capable to ignite a coal, through which it comes to the creation of endogenous fire, are present in mine cavings – therefore, it is necessary to their grouting.

Nevertheless, to the recovery of any type of wastes in mines should be approached in an individual way, because depending on the technologies of waste generation, their properties are variables. Lack of proper precautions can lead to serious consequences. The way of the use of waste is determined by the technical services of particular mine which accept waste for recovery. The way of their use in mine works require also relevant records, among others, in plan of mining plant operations. In recent years, the demand of mines for fly ash is gradually increases, therefore it is necessary to use the efficient supply system of this product, which meet the requirements of mine plant as best as possible.

6.3 THE STRUCTURE OF SUPPLY SYSTEM OF FLY ASH

Generally, the system is a collection of mutually and deliberately interrelated elements. The term of supply system should be understood as all elements which are present during physical flow of product from place of origin to place of receipt along with the accompanying the flow of information.

The most important elements of the system are [2]:

- physical flow of goods (transportation),
- organization and flow of information,
- storage/stock management,
- infrastructure,
- costs of the supply chain.

Supply systems can have a different structure depending on number of brokers between the supplier and the consignee. In case of absence of brokers between the links in the supply chain is said to be about the direct system, but if there is at least one broker says about indirect system or mixed system (combined system). Division of supply systems according to their structure, illustrated Figure 6.1.

Analyzed supply system, in which the fly ash flows between power plants and mining plants, has a direct structure. There are three types of flows between links of supply chain: physical flow of goods, flow of information and flow of finance. Organization of physical flow of goods is focused, primarily, on the choice of appropriate mode and means of transport, organization of transport and planning of supplies. This type of flow is assisted by information flow both before, during and after delivery. In turn, the organization of information flow consists in gathering and exchange of information about future demand for fly ashes (their quantity, time and way of delivery). Close cooperation in field of the exchange of information between power plants and mining plant determines the correct realization of supply chain processes. This is very important mainly due to the seasonality of the fly ashes.

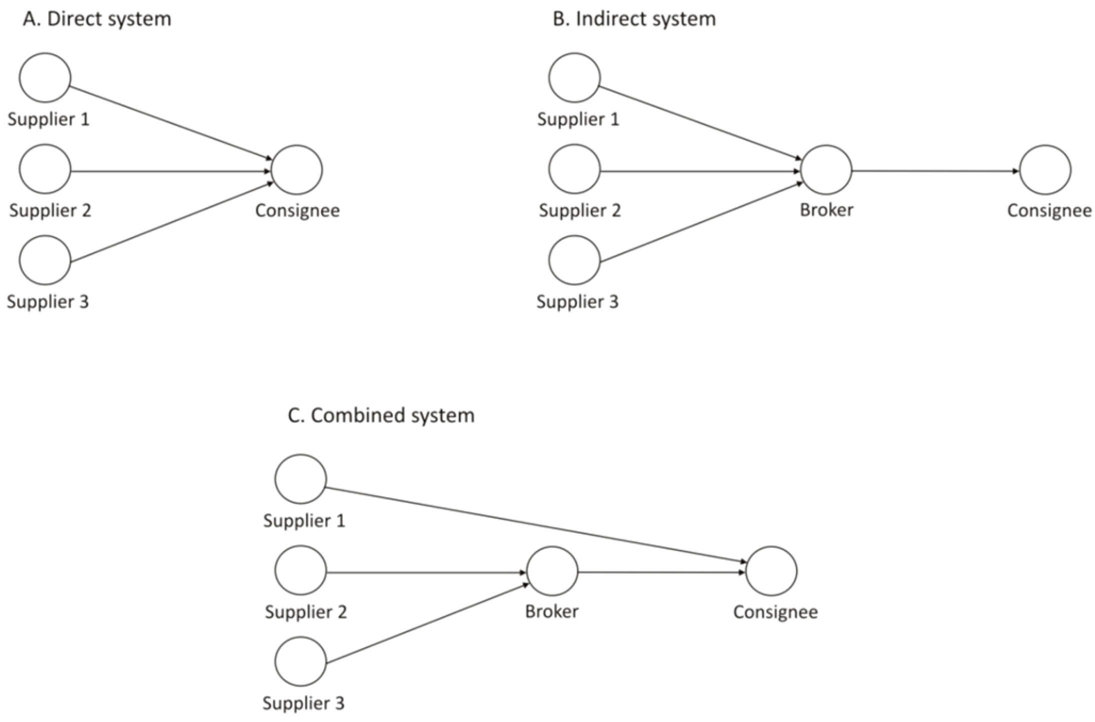

Fig. 6.1 Division of supply systems according to their structure

Source: own work based on [5]

During the heating season (from November to March) there are produced significant quantities of ashes which must be received from power plants due to limited retention of tanks. But while the off-season there is a risk, that need of the mines on the fly ash will not be met. In connection with above situation, the power plants and mines must assist each other. When total synchronization of inflow and outflow of streams is not possible and there are random cases (e.g. endogenous fire), a good solution may be to keep a certain quantity of stock of fly ash on the area of mine.

The whole supply system is burdened with cost of resource consumption of this system, first of all, there are cost of transport, maintenance of stock and processing of information related to these activities.

Example of supply system of fly ash presents Figure 6.2.

Physical flow of product starts in power plants, where the fly ashes from coal are generated. From there, they are transported by pipeline over short distances to retention tanks (silo) where they are temporarily stored. From silos, fly ashes are loaded, by charging sleeves, to the appropriate means of transport, wherein overcomes the main part of route. Transport is organized mostly by external carriers (outsourcing) who have specialized means of transport which are adapted for the carriage of fine-grained materials, as well as they have license to transport of these materials (decision of the Mayor of the city on the authorization for the transport of waste). There are several variants of the carriage depending on the used modes of transport. Each mode of transport has both advantages and disadvantages and the choice of variant is depends on various factors, among others: the location of dispatch and receipt points, costs, access to infrastructure and individual preferences of customers.

After delivery of the product to the customer, follows pneumatic unloading into the place of temporary storage (closed silos) or directly to the places of application of fly ash. According to environmental protection requirements the fly ashes cannot be stored at the opened landfills because of their dusting.

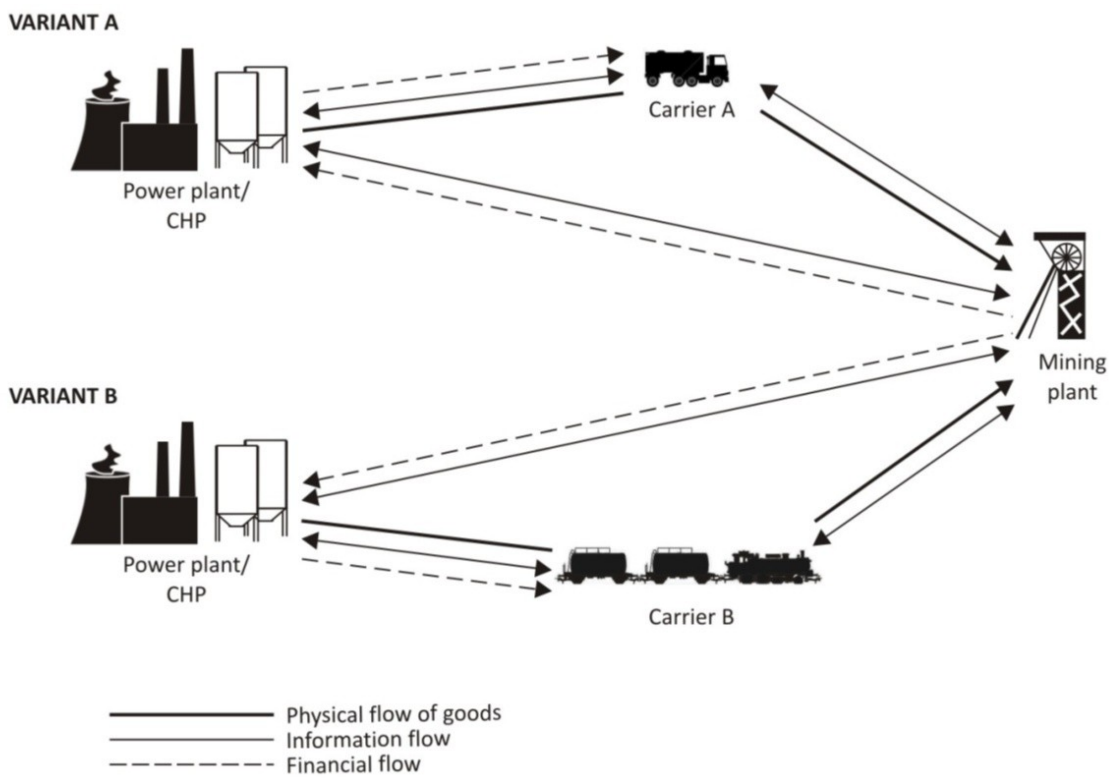

Fig. 6.2 Example of supply system of fly ash for mining plant

6.4 CHARAKTERISTICS OF THE MODES AND THE MEANS OF TRANSPORT USED IN SUPPLY SYSTEM OF FLY ASH

The choice of the modes and the means of transport

The most important point in supply system is the transportation, because it allows for physical flow of product between the supplier and the consignee. Furthermore, the transportation determines to a large extent on the costs of the entire system. Whereas the costs and level of customer service, the companies need to make different decisions related with the transportation. They are focused on the choice of mode, means of transport and the carrier. However, in practice, there is rarely an opportunity of the free choice among all available mode of transport, mainly due to the nature of transported materials and even specificity of same mode of transport [6]. This choice is very limited. Moreover, the important issue is the negative impact of fly ash transport on the environment. It is, above all, problem of dust ashes during their transport, what forces the use of such means of transport which significantly reduces or completely eliminates the problem.

At present, to transport of fly ash, there is used two mode of transport: road transport and rail transport. The choice of mode of transport and the carrier is dependent on many factors, which presents Table 6.2.

An additional, the criterion of the choice, in case of transport of fly ash, may be quantity and systematicity of supplies. In event of lower demand for fly ashes, the good solution can be the used road transport, however, its cost is significantly higher compared to rail transport. This type of transport are characterized by high availability – on the market works much more road carriers than rail carriers. Moreover, road transport may provide the transported goods in any place of destination, because it is not restricted by presence of railroad. The next advantage of road transport is shorter time of fly ash carriage, because it is not require e.g. compilation of long sets of wagons [1].

However, negative aspects of the choice of road transport are dependence of weather conditions and of the intensity of road traffic which can affect on reliability of delivery time. The used of this type of transport raises also social and environmental consequences in the form of air pollution by exhaust fumes and erected dust, communication noise and it causes of congestion (Congestion - coll. traffic jam) in the cities, thus result in decrease of quality of the inhabitants life of this area.

Taking into account the environmental costs, significantly better is rail transport, which does not emit as much harmful compounds in the atmosphere, and additionally does not participate and contribute to formation of congestion, because it move at the dedicated lanes. Another advantage of rail transport is the possibility of the mass transportation over long distance [1] at relatively low cost. Unfortunately the time of carriage by rail is significantly longer than road transport, and additionally its availability is heavily restricted.

Table 6.2 Determinants of the choice of carrier

Criterion	Description
Costs of transport	There are the resultant of such components as: freight rates, minimal weight of cargo, loading and unloading equipment, damage during transport. The costs of components will vary depending on means of transport.
Time of transport	This is the total amount of time that elapses from the moment of release of the product by the supplier until the delivery to the consignee. Includes: the length of time required to pick up and delivery, time of handling and time of loading and unloading.
Reliability of supply	Refers to the regularity of the transport time, which the carrier is able to provide. This is particularly important in the case of the endogenous fire in mine.
Costs of stock	In the case of an irregular of the service, related with time and reliability of the supply, the consignee need to obtain in certain quantity of stock, and thus bear the costs of their storage.
Capacity of transport	The ability of the carrier to provide equipment and device necessary for movement of specific goods, as the fly ashes are.
Spatial availability	The ability of the carrier to provide the service on the desired route. It refers to physical access of the carrier to different objects, e.g. railroad are limited due to natural causes, and they have official approved operating range.
Safety of product	In the carriage time the carrier should protect the transported products against quantitative and qualitative losses.

Source: own work based on [1]

Regardless of which mode of transport will be chosen to carriage of fly ash, it is necessary to use the appropriate means of transport, which must be closed type, due to dusting during the transport. The example of means of transport, which are used to transport of fly ash is illustrated in Figure 6.3.

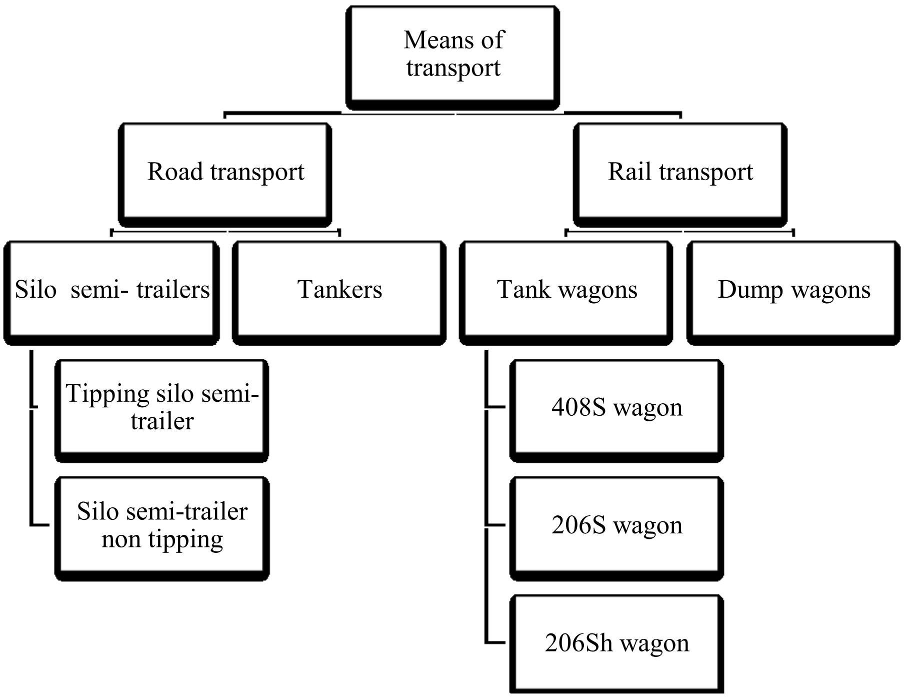

Fig. 6.3 The means of transport which are used to carriage of fly ash

In the road transport are used the tankers and two kinds of semi-trailers. There is the tipping silo semi-trailers and silo semi-trailers non tipping. Both of them are loaded from the top by several manholes. However, they differ by the method of unloading. The tipping silo semi-trailer is adapted to the unloaded by raising the entire silo to the top, and then the cargo is emptied by back channel under pressure through the valve cone [18]. In turn, the unloading of silo semi-trailer non tipping is followed by the holes in the valve cone, which are equipped in vibrating system and the ball valve which supply the compressed air [18]. Everything is linked by a pipe which leads to the rear of the vehicle between its axles. The example of the construction of the silo semi-trailer non tipping is shown by Figure 6.4.

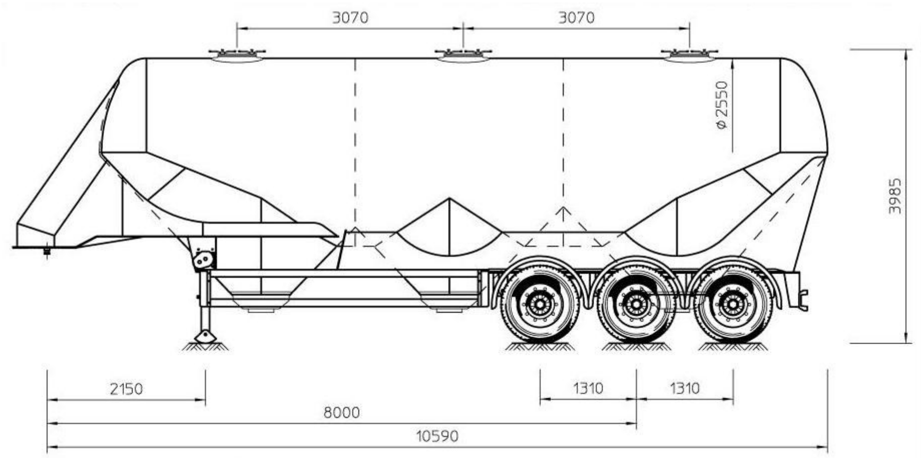

Fig. 6.4 The silo semi-trailer non tipping with a volume of 49 m^3 and a capacity of 28,7 t

Source: [15]

The means of transport have a different construction, volume and capacity (from 31 m^3 up to 65 m^3) which gives the possibility to adapt the mean of transport to the needs and requirements of the customer. An example of construction of tipping silo semi-trailer is presented on the Figure 6.5.

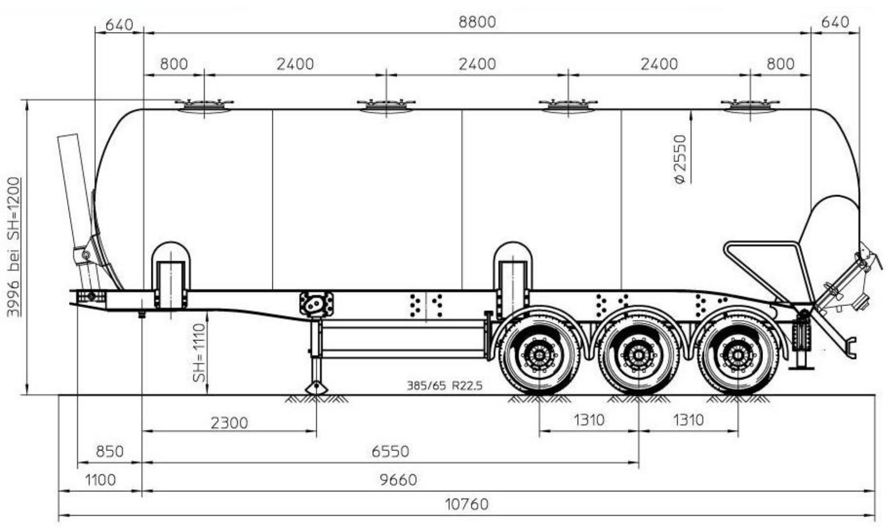

Fig. 6.5 Tipping silo semi-trailer with a volume of 48,3 m^3 and capacity of 28,1 t

Source: [15]

Another means of transport are tankers. Their loading is done through charging sleeves, but the unloading is set by the pressure installation that causes the formation of pressure in the tank and supplies the air necessary for unloading [20].

The rail transport of fly ash takes place in a dump wagons with removable roof or in tank wagons. The loading of various types of dump wagons is done usually by loading hole (tilting roof), while they are unloading by gravity after opened the unloading valves [14]. Tank-wagons (206S, 206Sh, 408S) have mostly two, three or four tanks positioned vertically on the axis [8]. Example structure of tank-wagon is illustrated on the Figure 6.6.

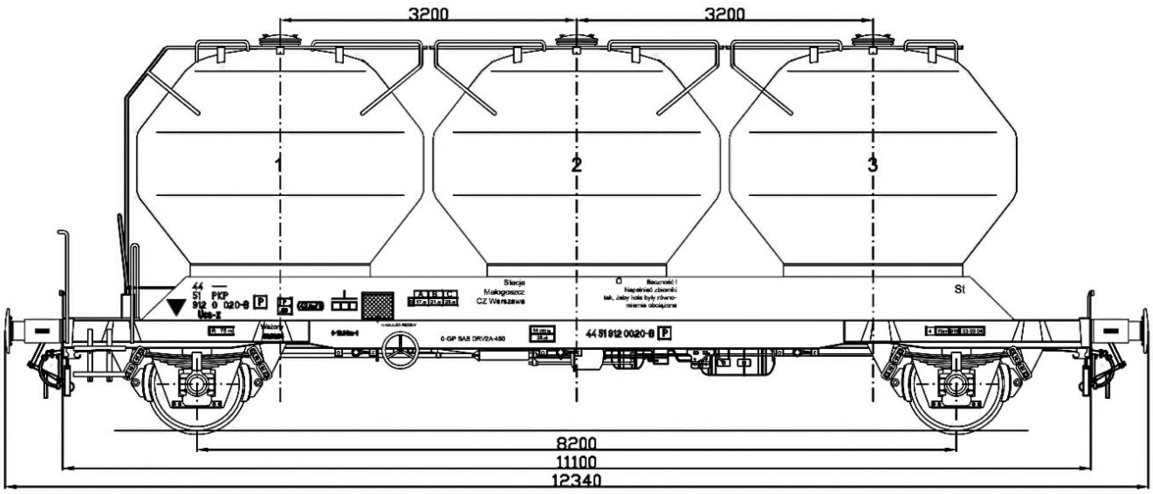

Fig. 6.6 Tank-wagon 206Sh with the volume of 3 x 14 m^3 and capacity of 25 t

Source: [13]

The loading of each type of tank-wagons is done by gravity through charging holes placed on top of tanks. Wagon unloading is achieved by pneumatic installation in over-pressure generated in the interior [8]. The construction of unloading system of wagon allows individual unloading of each tank, or all tanks at the same time [13].

The safety in the transport process

A very important issue during organization of transport process of fly ash is the safety of both humans involved in this process as well as the environment. Road or rail carrier should have experienced staff, which is able to adequately prepare the transportation and predict eventual difficulties which may occur in this process. In the transport process the means of transport may be damaged in an accident or collision, which may cause the escape of cargo on the outside. Equally important is the loading and unloading at the point of destination. Lack of tightness of loading and unloading installations (hoses, valves, etc.) is responsible for quantitative and qualitative losses of cargo (and thus for dusting of the fly ash) therefore, it should be prevented.

Observance of principles of health and safety at work is especially important in case of tipping silo semi-trailer unloading. A person who engaged in the unloading should be equipped in appropriate personal protective equipment and take care of their own safety during opening the upper manhole, e.g. by pinning the harnesses and ropes which protect against possible fall from the upper deck of the silo. In addition, while tipping silo is lifted up, it is worth paying attention to wind, because it can cause roll over the silo. This type of silo is equipped in additional folding rear props for stabilization during lifting of tank. The construction of the tank should be very durable to prevent the unseal, in case of roll over the silo [17].

Another important requirement is to preserve the purity of the inside of the tank wagons and silos (and they unloading system) to avoid contamination of cargo by the remnants of the previous cargo [18]. It is important especially when there is a change of type of transported materials. The safe solution is the carriage of the same or similar products which tolerates each other. Depending on the type of transported products and the mean of transport, there are used a different washing procedure, e.g.:

- washing with the special cleaning agents (e.g. foam to washing the vehicles),
- cleansing in vapor,
- disinfectants based on the acids and alcohols.

The appropriate condition of purity can be achieved only by cleansing in special washes. Service of washes issue a certificate of purity, which is signed by the driver who thus certifies that the visual control was carried, and states that all parts (tank, hoses, pneumatic system) of vehicle are clean [18].

6.5 IDENTIFICATION OF THE PROBLEMS AND THE PROPOSALS FOR IMPROVEMENT THE EXISTING SUPPLY SYSTEM

Efficient management of supply system is focused on appropriate planning, organizing and controlling of flow of goods. Therefore, in each supply chain it is important to right organization of physical flow of goods and flow of information. Information should be quick and precise in order to facilitate making a good decisions and thus fully satisfy customers needs and requirements. However, the physical supply should characterized by reliability which is, unfortunately, dependent on unforeseen random events and technical and organizational conditions. Currently existing structure and functioning of the supply system of fly ash requires the introduction of changes and improvements or seek for new, alternative solutions.

Identification of the problems of supply system

In general, the problems in the supply system of fly as are related with variable demand for fly ash, retention of storage tanks, flow of information and, above all, with the process of transport. Due to the limited retention of the tanks, the power plants must be in constant contact with consignees and manage the receipts. It requires considerable organizational effort, the more that demand of consignee is variables. Variability of demand is causes e.g. unplanned situations or random events. As far as possible, the suppliers should predict future demand for fly ash, while the consignees should predict future demand for raw materials and, as far as possible, keep a certain amount of safety stock. The most problems in entire supply system generate the process of transport. Each of the conventional modes of transport usually used in supply system of fly ash has advantages and disadvantages which are contribute to a reduction efficiency of entire supply system. The most important problems related with the process of transport are described in Table 6.3.

Table 6.3 Identification of the problems related with the transport process of fly ash

Modes of transport	Identification of the problems
Road transport	The relatively high cost of delivery compared to rail transport, Create and participate in road congestion, what may negative influence on the reliability of supply, Supplies are dependent on the weather conditions on the road, Generation of environmental and social costs (communication noise, air pollution, exhaust fumes and dust)
Rail transport	Long time of delivery, loading and unloading, Limited spatial availability, The necessity to have access to the rail infrastructure (by the consignee)
Common to both modes of transport	The necessity to clean the means of transport after each carriage, Possibility of dusting during transport, loading or unloading e.g. By leaky installation or in case of traffic accident, Waiting in line for unload in the case of several deliveries at the same time, Aspects of health and safety at work related with process of transport.

Problems indicated in the table have a different nature. Some of them require only appropriate organizational solutions (such as waiting in line for unloading) while other are related for risk of distortions in supply chain, which may include operational random events (e.g. equipment failure) or natural disasters and weather conditions on which the participants of supply chain have no affects.

Another problem in the supply system can be improper communication or lack thereof. Exchange of information and collaboration between the links of supply chain plays a significant role in uncovering weaknesses and in preparation to effective management in case of crisis [9]. Actions should be coordinated both at the level of each link as well as at the level of entire chain. The lack of cooperation in the system impedes the efficient flow of goods and the possibility of forecasting future demand and planning actions.

Underground pipeline transport as an alternative for the existing supply system

One of the unconventional modes of transport is a pipeline transport, in which there are no means of transport and the cargo is moved through the pipelines. This type of transport is characterized by [3]:

- ability to mass movements of selected products,
- low costs of movements,
- high throughput,
- reliability of supplies,
- low spatial availability,
- high speed of transport,

- insusceptibility of cargo to weather conditions,
- low onerousness to the environment,
- high resistance to theft.

One of the essential advantages is that, in the case of pipeline transport there is no congestion, no cargo handling operations and no problem of the empty legs. Furthermore, this type of transport characterized by low onerousness to the environment compared to the others modes of transport [3]. This mode of transport is also a good solution from the viewpoint of the health and safety at work, because each network of pipelines serves only one type of product, thanks to which there is no need to washing the mean of transport, as in the case of other modes of transport, and also there is no risk related with the mutual interaction the transmitted goods.

Currently, pipeline transport is mainly used to the movement of liquid and gaseous goods, however, there is the possibility of its use also to the movement of the bulk materials and fine-grained materials such as fly ashes. Of course, this solution involves enormous financial outlays and a number of research (e.g. geological research or design of the terminal handling devices). At this point, there are two possibilities. The first option is to expand the existing road and rail infrastructure (which is obviously needed) and the fight against transport congestion, risk of distortions in supply chain and environmental degradation. In turn, the second solution is to invest in the development of pipeline infrastructure, which would relieve roads from lorries and from negative environmental impacts.

CONCLUSIONS

In recent years, in mining plants, the use of fly ash significantly increased and therefore so important is reliability of supply system of this product. Unfortunately, currently functioning supply system faces many problems of technical and organizational nature. This situation forces the introduction of changes in the current system or seek for new alternatives.

One of the important issues is the need to improve the flow of information and close cooperation in this field among participants in the supply chain. Better communication in the supply chain may significantly improve the physical flow of product. An essential component of the supply system should be the forecasting future demand and scheduling the supply cycle that would allow to solve the problems related to waiting of the means of transport for the unloading. Another significant problem is the organization of the transport process, which there are used the modes of transport that generate environmental costs and which contribute to create the transport congestion and the reliability of supplies is dependent on weather conditions.

An alternative to the currently used modes of transport can be an underground pipeline transport, which specificity would avoid the mentioned problems present in traditional supply system, however this solution is related to enormous financial effort, the carrying out a number of studies and the development of infrastructure.

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SUPPLY SYSTEM OF FLY ASH FOR MINING PLANTS – ANALYSIS OF THE PROBLEM

Abstract: *The article attempts to evaluate supply system of fly ash between power plants and mining plant. The main aim of this paper is to shown technical, organizational and environmental problems which are related to transport process of fly ash. This paper characterized the fly ash and its recovery. The article also described structure of delivery system, indicated carrier selection criteria, pointed out advantages and disadvantages various modes of transport used in supply chain and presents the possible risks to the safety of persons involved in the transport process. In addition, the paper presents possible improvements of the existing system and proposes an alternative solution.*

Key words: *Supply system, fly ash, waste logistics, transportation*

SYSTEM DOSTAW POPIOŁÓW LOTNYCH NA POTRZEBY ZAKŁADÓW GÓRNICZYCH – ANALIZA PROBLEMU

Streszczenie: *W artykule podjęto próbę oceny istniejącego systemu dostaw popiołów lotnych pomiędzy zakładami energetyki i ciepłownictwa oraz zakładem górniczym. Głównym celem było wskazanie problemów technicznych, organizacyjnych oraz środowiskowych związanych z procesem transportu popiołów lotnych. W pracy scharakteryzowano popioły lotne oraz wskazano miejsca ich zagospodarowania. Opisano również system dostaw i jego strukturę, przedstawiono kryteria wyboru środków transportu oraz przewoźnika, wskazano zalety i wady różnych gałęzi transportu wykorzystywanych w systemie dostaw, a także zaprezentowano możliwe zagrożenia związane z bezpieczeństwem osób uczestniczących w procesie transportu. Ponadto w artykule przedstawiono możliwe usprawnienia istniejącego systemu oraz zaproponowano rozwiązanie alternatywne.*

Słowa kluczowe: *System dostaw, popioły lotne, logistyka odpadów, transport*

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