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The Sprinkler System In Self-Propelled Sweepers,Neutralizing PM10 Dust Formation

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ABSTRACT: the article presents the method of application, the original implementation, of the PM10 system for a selected road sweeper model. The components and method of cooperation of this system are presented. In addition, the technique of summer road and street cleaning was presented and the benefits resulting from the use of PM10 systems in self-propelled sweepers.
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I. INTRODUCTION

Along with the progressing environmental pollution, as a result of small emissions of PM10 and PM2.5, it is very important to introduce all measures aimed at reducing the emission of these dusts. As is known, these dusts are formed mainly when burning low-quality solid fuels in old type boilers, but also during road works including road and street sweeping.

The amount of dust, mainly PM10, during mechanical sweeping of streets can be significant, thus exceeding the applicable standards [2], especially in the spring, when the materials used for sprinkling roads and streets in winter are collected from roads. These dusts are very often silica dusts, which are very harmful to human health, because they tend to settle in the human lungs, which may contribute to the onset of cancer.

In view of the above problem, more and more factory-new street sweepers are equipped with systems reducing PM10 dust generation. These systems are usually designed based on two assumptions:

- through the use of paper or fabric filters, on the surfaces of which PM10 particles will settle,
- through the use of high-pressure water sprinklers, supporting the sweeping process and at the same time cleaning the surface.

In the case of small sweepers whose permissible total weight does not exceed 4 ÷ 5 tonnes, and the capacity of the pollution tank does not exceed 3 m^3, it can be seen that the manufacturers of these machines use the first of assumptions. However, the manufacturers of sweepers from the permissible total weight from 5 to almost 26 tons and the capacity of tanks for pollutants from 4 to more than 10 m^3 apply the second of the assumptions, that is neutralization of harmful dust based on the action of water.

However, the question arises as to what to do with municipal equipment, such as road sweepers, which have been produced before, i.e. before the introduction of standards and directives, establishing the formation of maximum amounts of dust included in the so-called small emissions. We mean sweepers that are not equipped with paper or cloth filters, or high-pressure water sprinklers.

The answer to this question will be given in the content of this article, where the original system was presented, the aim of which is to prevent the formation of harmful PM10 dust. At the time of writing this article, the system was built on a selected road sweeper model, tested and prepared for certification by an independent certifying company.

II. PROBLEMS OF MECHANICAL CLEANING OF PAVED SURFACES

One of the most important tasks of cleaning cities and rural areas is to keep streets, squares, sidewalks, bridges, underground passages, aboveground and above-ground passages clean. Purification of streets depends on weather conditions and is seasonal. In summer, the functions of street cleaning, types of pollution and the way they are removed change over the summer. In the summer, cleaning is essential in ensuring the sanitary and hygienic condition, order and aesthetic appearance of urban and rural settlements. The pollution of the street surface with snow and ice, from a sanitary point of view, is not dangerous, but it is a burdensome obstacle to road traffic. In winter, the communication functions of street cleaning acquire the dominant meaning, since

ensuring passability is of fundamental importance [7, 8, 12].

Various impurities and wastes accumulate on the streets and squares. The summer cleansing covers sweeping, washing and pouring, while keeping winter through is ensured by skimming and removing snow and preventing and fighting against winter slippery [4].

Street surfaces are appropriately contoured longitudinally and transversely to allow water outflow. Removal of liquid contamination is carried out automatically, thanks to gravitation flow from the surface. The tasks of urban cleaning are reduced to removing solid contaminants. There are two basic types:

- street pollution (sweeps),
- atmospheric water in solid form (snow and ice).

In the waste catalog, they were marked out with the code 20 03 03 from streets and squares purification.

The intensity of accumulation of various types of solid pollutants and pavements depends on [3]:

- technical condition of road surfaces,
- seasons,
- traffic intensity,
- technical condition moving on the roads of the rolling stock,
- the location of a given street in a spatial arrangement of the city,
- the state of afforestation and the type of street greenery,
- population, its concentration and social discipline in terms of maintaining cleanliness,
- concentration of buildings.

Pollution of street surfaces, depending on the place of manufacture or source of origin can be divided into [9]:

- produced by the street environment itself in a natural (endogenous) and cultural manner, resulting from its use,
- derived from the external street environment (exogenous), i.e. imitated by it without the physical possibilities of ecological protection.

Effective cleaning of the surface of streets and squares in the summer requires the use of appropriate technology and appropriate equipment in order to obtain at the lowest financial costs, optimal treatment conditions [8].

The summer cleaning of streets and squares consists primarily of [13]:

- reducing the degree of street pollution by washing with a stream of water,
- reducing the degree of contamination of the surface by simultaneous washing and polishing with mechanical brushes,
- reducing the degree of pollination of streets and air layer to a height of about 1 meter by pouring (sprinkling),
- reduction of the degree of contamination of the road surface and squares by sweeping with simultaneous collection of pollutants and their loading by pneumatic or mechanical method to the tanks located on the clearing machine.

The purification takes place under conditions where the ambient temperature does not fall below 0 ° C, although there may be deviations from this rule. An example is sweeping dry streets at a temperature below 0 ° C, using self-propelled sweepers working without using water. As you can see, the concept of summer treatment can also be used in certain winter conditions [8].

2.1. Ways of street cleaning

Removal of dust and dirt from hardened surfaces takes place by applying sweeping. Modern sweeping technology is connected with the process of collecting pollutants to the container (Figure 1) placed on the sweeper.

Fig. 1. The container is designed to collect impurities in self-propelled vacuum sweeper

In the past, sweeping was done with sweepers with cylindrical rotating brushes that scraped the contamination of the roadway, from where they were removed by hand [8].

This type of sweeping is no longer used. Sweeping combined with automatic collection of dirt by sweeper is common. Hence, sweepers used for this purpose are called self-propelled sweepers.

Due to the fact that pollutants on the road are rejected by the vehicle traffic and accumulate near the curb or shoulder, the side lanes and curb

sideways are mainly covered by the curbs. Mechanical sweeping should also be treated as a complementary and finishing operation after cleaning the road with water [7, 8].

The automatic collection of pollutants can take place mechanically, as is the case in elevator sweepers (Figure 2) or pneumatically - as in vacuum sweepers (Figure 3), the sweeping operation itself is carried out either wet or dry.

Fig. 2. An elevator sweeper, adapted for towing a tipper truck

Fig. 3. Vacuum self-propelled sweeper

In sweepers with mechanical loading of pollutants (Figure 2), the brush bristles bend on contact with the cleaned surface, then straighten throwing scraped dirt onto the scraper conveyor and then into the tank or conveyor belt, if it is a sweeper towed by a car tipper, on the box where the impurities from the conveyor belt are discharged.

In vacuum sweepers (Figures 1 and 3), thus sucking in dirt, the fan sucks air from the hopper into dirt, so that they are sucked in by the suction nozzle and guided through the suction line to the said container.

When wet sweeping the surface and air in the sweeping area are sprinkled with water drawn from the water tank of the sweeper. Sweeping is usually combined with intensive dust generation. The sprinkling process prevents the generation of dust. The water expense for spraying, without the participation of the PM10 system mentioned in the introduction of this article, is from 0,01 to 0,05 dm^3 / m^2 [10]. Wet sweeping can be performed only at positive air temperatures and road surface. With a dry sweep in the sweeping area, a negative pressure is created by the suction nozzle directing the air contaminated with dust to the sweeper filters. This process should prevent the spread of dust.

Dry sweeping can be carried out on dry and paved surfaces, also on days with negative temperatures. Sweeping the road surface with a sweeper should take place using the first gear at a speed of 5 to 12 km / h [10]. The sweeping width depends on the sweeper's construction and is usually between 1,0 and 3,5 meters. Sweeping usually takes place in the early morning hours or in the evening and night hours, this applies mainly to streets with high traffic. Road sweeping should take place after completion of the cleaning of adjacent pavements to avoid contamination of the cleaned road surface with dirt from pavements. When sweeping large areas of roadways and yards, a team work of sweepers should be introduced [7, 8, 12].

2.2. Brush as the basic working element of the sweeper

The basic working tool of the sweeper is a brush. From her conditio and the cleaning efficiency depends on the setting.

The brushes should be positioned at the right angle to the longitudinal axis of the vehicle and to the surface of the road surface and suspended at the appropriate height. Too high suspended brushes do not allow their proper contact with the road surface, which leads to a reduction in cleaning efficiency. Brushes that are suspended too low and too tight against the road surface are quickly used. The brushes are divided into the main ones - cleansing the wide surface strip and collecting debris to the sweeper tank and the auxiliary (curb) - sweeping debris from under the curb and feeding them under the main brush. Depending on the design, the roller brushes (Figure 4), belt brushes (Figure 5) and disc brushes (Figure 6) are distinguished. Plastic fibers or steel wires are put on the brush body and replaced with new ones after use. Adequate fiber selection is important for sweeping [8].

Fig. 4. Roller brush [14]

Fig. 5. Belt brushes, also known as batten [14]

Fig. 6. Disc brush [14]

III. EQUIPMENT USED FOR MECHANICAL ROAD CLEANING

Vehicles used for mechanical street cleaning can work both day and night. In contrast to machines used for winter maintenance of road and street traffic, these vehicles do not have to clean up all streets in their area within a few hours, while they should perform their tasks as cheaply as possible. Usually only the main and representative city streets are cleaned daily. The remaining streets are operated periodically - usually every few days. That is why rolling stock for the summer cleaning of streets is often smaller than the rolling stock used for winter maintenance of streets or its efficiency is not fully used [6].Street cleaning can be done by washing itself, washing - sweeping or self-propelled sweeping.

Sweeping the self-propelled - it is admittedly less efficient and more expensive than the toppings, but has the advantage of allowing the collection of pollutants from the treated surface.

In truth, in large self-propelled sweepers, there is a standard water system for sprinkling the brush work area, however, they consume much less water than road dishwashers and therefore there are no prohibitions for refueling sweepers with water coming from city hydrants. As a result, many companies dealing with road and street cleaning considered that the prevalence of self-propelled sweepers could provide mechanization beyond winter street cleaning.

As mentioned before, self-propelled sweepers are divided depending on the method of collecting pollutants on [6]:

- suction sweepers (so-called vacuum sweepers),
- sweepers with mechanical loading of pollutants.

The first group includes sweepers, in which the fan sucks the air from the container intended for collecting impurities, thanks to which they are sucked in by the suction nozzle and conducted by the suction line. In this group of sweepers, the author of this article decided to apply a sprinkler system to prevent the formation of PM10 dust.

On the other hand, sweepers with mechanical pollution loading are sometimes equipped with a fan (eg Europa or Gothia elevator sweeper from the Brodd Group), but its task is only to dust the air suction from the collecting brush working area [6].

In addition, self-propelled sweepers are divided into car, self-propelled and drawn. The car sweeper is mounted on the car chassis, while the self-propelled vehicle, like the towed one, does not have the characteristics of a special car, although its driving and driving mechanisms can be made of car chassis assemblies [6].

IV. PM10 SYSTEM APPLICATION IN SELF-PROPELLED VACUUM SWEEPERS

The PM10 system presented in this article was applied to Bucher Schörling sweeper, equipped with a 7 m3 pollution tank and DAF LF truck mounted on the chassis with a maximum weight of 18 tons. The sweeper is a two-sided sweeper equipped with two disc brushes placed on the left

and right side of the machine and a roller brush placed between the disc brushes. It is worth mentioning that the roller brush is placed on a movable mechanism that changes its position relative to the road axis depending on whether the left or right side of the road is swept. The sweeping unit of the sweeper with the standard water pump and the main pump of the PM10 system is supplied from a separate engine, called the upper engine, which works regardless of the bottom engine, which is the DAF truck engine, which is the carrier of the described sweeper. Water for the PM10 system is taken from the water tank built in the sweeper.

Sprinkler system, neutralizing PM10 dust formation (see markings from Figures 7 and 8, additionally given in the text), it is characterized by the fact that the high-pressure water pump (11) is driven through the clutch (5) together with the drive shaft (4), through a hydraulic motor (8), whereby the engine hydraulic (8) is supplied with hydraulic oil pumped from a hydraulic pump (6), equipped with a hydraulic motor safety valve (9), while a hydraulic pump (6) is driven through a coupling (5) with a drive shaft (4), through a wheel a passive drive (2) which cooperates with an active drive wheel (1), the passive power wheel (2) and the active drive wheel (1) being pulleys, the active drive wheel (1) being driven directly from the upper sweeper motor (SG), moreover a high-pressure pump (11), which is equipped with a water pump safety valve (12), sucks water from the sweeper water tank (13) into the water conduit (PW), after which water is supplied from the pressure to the valve shutting off high pressure water supply nozzles in the strip under the front bumper (14A), and / or the valve cutting off the high pressure water supply nozzles over the roller brush (14B), and / or the valve shutting off the high pressure water supply nozzles in above the disc brushes (14C), and / or the valve cutting off the high-pressure water supply nozzles in the suction nozzle (14D), and / or the valve cutting off the high pressure water supply of the hand lance (14E) (depending on the needs), to the water conduit (PW), through the valve in the pneumatic conduit (15), compressed air is supplied from the air compressor (16), pumping air into the vehicle's braking system, and / or a separate compressed air tank (17), for blowing water, remaining in the water pipe (PW), to avoid freezing at subzero temperatures.

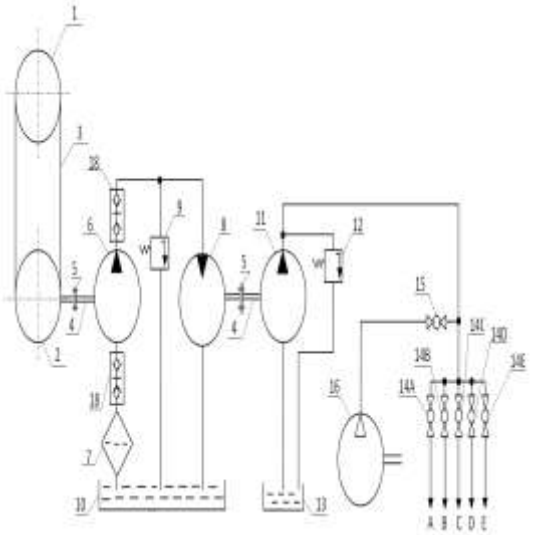

Fig. 7. Scheme of the PM10 system hydraulic system, where: 1 - active drive wheel, 2 - passive driven wheel,
3 - belt transmission, 4 - drive shaft, 5 - clutch, 6 - hydraulic pump, 7 - strainer, 8 - hydraulic engine, 9 - hydraulic engine safety valve, 10 - hydraulic oil tank, 11 - high-pressure water pump, 12 - water pump safety valve, 13 - water tank of sweeper, 14A - valve blocking water supply under high pressure nozzles in a strip under the front bumper, 14B - shut-off valve for high-pressure water supply over nozzles over the roller brush,
14C - shut-off valve for high-pressure nozzle water supply, over disc brush, 14D - shut-off valve for high-pressure water supply in nozzles, 14E - high-water shut-off valve pressure of the hand-operated lance, 15 - valve in the pneumatic conduit, 16 - air compressor, 17 - compressed air tank, 18 - quick coupe

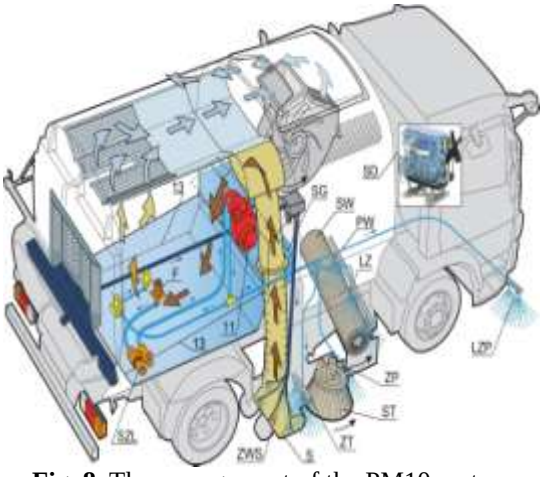

Fig. 8. The arrangement of the PM10 system components in the sweepers, where: 13 - sweeper water tank,
F - filter placed in the water tank, LZ - spray brush sprinkler strip, LZP - front spray bar, P - high

pressure pump, PW - water hose, S - suction pipe, SD - lower car engine, SG - engine upper sweepers, ST - disc brush,
SW - roller brush, SZL - quick-coupling for hand lance, ZP - front disc sprinkler, ZT - rear disc brush sprinkler, ZWS - internal sow sprinklers

It is worth mentioning that the high-pressure water pump (11), shown in Figure 9, in the described sweeper is a piston pump equipped with three ceramic pistons. This is a pump from the Italian company Interpump, pump type: WS-104. The pump, as already mentioned, is driven directly from the hydraulic motor shaft. The high-pressure water pump (11), which is the heart of the PM10 system, produces a water pressure of 100 bar, ultimately the WS-104 pump is to be replaced by a pump from the same manufacturer, but it will be a WS-153 pump giving a pressure of 150 bar. Both pumps WS-140 and WS-153 are characterized by a capacity of 30 l / min.

Fig. 9. WS-104 high-pressure water pump, Interpump company

Figure 10 shows the view of the WS-140 pump, working on the sweeper, and so in real conditions. In turn, Figure 11 shows a hydraulic motor, which is responsible for transferring the drive to the shaft of the main hydraulic pump (11), which is the WS-104 pump, shown in Figures 9 and 10.

Fig. 10. WS-104 pump, mounted on Bucher Schörling sweeper, forcing water into the PM10 system

Fig. 11. Hydraulic motor, driving the WS-104 pump

There are really many ways to transfer the drive to the main pump (11), but from a typically operational point of view, the best and least problematic is the use of a hydraulic drive due to, among other things, the operating conditions in which the pump must operate.

The shut-off valves for the water supply to the individual elements of the sweeping unit sweepers can be controlled by manual ball valves or solenoid valves whose coils are supplied from the electric system of the sweeper, that is the voltage of 24 Volts.

After establishing the general concept of the PM10 system and the arrangement of its components in the sweepers (Figure 8), the system design started with the choice of sprinkler slats, setting the parameters of their operation (pressure and water flow), because these parameters influenced the diameters of the ducts and the pressure generated through the main water pump.

V. THE BENEFITS OF USING THE PM10 SYSTEM

The first and most important benefit of using the PM10 system is the elimination of dust to a large extent, resulting from the operation of the sweeping sweeping unit. In addition, the PM10 system, in very difficult conditions, i.e. when there are a lot of impurities on the roads, can be assisted by a standard sprinkler system, factory mounted in the sweeper. The elimination of dust, that is, the raising of fine dust in the air, and in particular silica dusts, which are the remnants of roughing materials used for the winter maintenance of road surfaces, are very harmful to human health, because these dusts tend to settle and accumulate in the human lungs, which may be the beginning of cancer. In addition,

excessive dusting is harmful to the natural environment, and therefore to greenery growing in road lanes and for animals.

In general, sweepers are used in the post-winter period, primarily to remove one of the hardening material, which is a remnant of the work associated with winter road maintenance. The material is usually sand, gravel, finely grinded grit and unmelted road salt. Its lumps are characterized by sharp edges and large sizes, because the stiffening material tends to clump. It is also susceptible to dusting when it is separated by brushes with which the sweeper is equipped [11].

The idea of the PM10 system is additional sprinklers (sprinkler strips) whose task is to evenly distribute water in the form of drops on the irrigated road surface. The quality of the selected spray nozzles determines the value of sprinkling and its technological effect [1].

Under the front bumper of the vehicle on which the sweeper was installed, a curtain (water curtain) was applied, which is to effectively prevent the spreading of dust, the curtain should prevent:

- direct passage of dust through the veil [5],
- wet the part of the roadway on which the roller brush will move,
- breaking loose and hard dirt that adhere to the road surface,
- cooling the surface (this factor is important in periods when the ambient temperature is high).

Experimental studies show that the density of a water curtain (water volume in a volume unit of the curtain) plays a very large and positive role, the same applies to the wide range of droplet and pressure diameters. From here you can probably draw the indications regarding the type of sprinklers and the necessary pressures [5].

These indications are very important when transferring the PM10 system, mounted in the sweeper for the certification process, performed by a specialist external company.

Another very important benefit resulting from the fact of using the PM10 systemin self-propelled sweepers, after the ecological aspects, is to extend the service life of both roller brushes and disc brushes. The material from which these brushes are made is usually steel and plastic, and the brush working on the wet surface uses much slower than a brush working on a dry surface, so thanks to the material savings (in particular plastics) we also protect the natural environment.

Summing up, the original implementation of the PM10 system brings benefits, first ecological, related to respect for human life and health, as well as fauna and flora, and this system significantly improves, and improves the efficiency of self-propelled road sweepers, making the machines more friendly and less onerous in clusters of human settlements.

REFERENCES

[1]. Drupka S. Deszczownie i deszczowanie. Warsaw: Agricultural and Forestry Publishers, 1980.
[2]. Journal of Laws of the Republic of Poland. Warsaw, 18 September 2012, item 1031. Regulation of the Minister of the Environment of August 24, 2012, on the levels of certain substances in the air.
[3]. Karst Z. Infrastruktura komunalna. Warsaw – Wroclaw: PWN Publishers, 1982.
[4]. Krassowski K., Banach – Paszkiewicz H. Eksploatacja lokalnej infrastruktury technicznej. Warsaw: PWN Publishers, 1986.
[5]. Lidner J., Struś W. Przeciwpożarowe urządzenia i instalacje wodne. Warsaw: Arkady Publishers, 1977.
[6]. Pacelt J., Przewłocki J. Tabor i sprzęt do oczyszczania miast. Warsaw: School and Pedagogic Publishers, 1976.
[7]. Podemska M.: Utrzymanie dróg. Technologia robót i sprzęt. Krosno: KaBe Publishers, 2015.
[8]. Przywarska R. Podstawy oczyszczania miast i terenów wiejskich. Bytom: University of Economics and Administration in Bytom, 2003.
[9]. Rzeczyński B. Zanieczyszczenia nawierzchni ulic. EKO Problemy Utylizacji Odpadów Przemysłowych i Komunalnych − EKO Problems of Utilization of Industrial and Municipal Waste 1999, 4, 13-14.Sibiga J., Skalmowski K. Technologia oczyszczania miast. Warsaw: School and Pedagogic Publishers, 1977.
[10]. Stawowiak M. Optymalne sposoby wykorzystania sprzętu na wiosnę. Drogi Gminne i Powiatowe − Municipal and Poviat Roads 2017, 2(31): 45-55.
[11]. Stypułkowski B. Zagadnienia utrzymywania i modernizacji dróg i ulic. Warsaw: Communication and Communications Publishers, 2000.
[12]. Zieliński J., Przywarska R. Oczyszczanie miast i unieszkodliwianie odpadów. Gliwice: Silesian University of Technology Publishers,1977.http://www.szczotkitechniczne.pl/

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