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STANISŁAW KUŹMIŃSKI*, ANNA SZAYNOK**, MIECZYSŁAW TEISSEYRE***

DUSTMETERS FOR CONTINUOUS MONITORING OF INDUSTRIAL GASES

The application of automatic dustmeters is discussed and the operation principle of optical and radioisotopic dustmeters constructed in the Wrocław Technical University, given.

1. CHARACTERISTIC OF INDUSTRIAL DASTMETERS

The growing interest in the development of apparatuses for automatic measurements of dustiness in gases emitted to atmosphere has been observed recently. The evidence is given by publications in which numerous types of dustmeters are being offered. These dustmeters differ with respect to construction and operation principle, their measuring systems being rather complicated. As a rule the dustmeters used for automatic measurements are based on indirect measuring methods.

Indirect methods take advantage from the relations between some physical phenomena and gas dustiness concentration, e.g.:

1. Dynamic effect of solgas stream on pressure drop in measuring reducers;
2. Occurence of electrostatic charges on the surface washed by solgas stream;
3. Increased absorption and dissipation of the energy of acoustic waves, light and ionizing radiation passing through a dusted medium;
4. Increased surface density of filtering medium.

While reviewing the technology in concerning automatic dustmeters it has been stated that measuring reducers have not found a wide application. Of electrostatic dustmeters the most known and actually produced in series by I. C. Echaedt in Stuttgart is "Konitest" developed by E. FEIFEL and R. PROHAŻKA [10, 12, 14].

* S. KUŹMIŃSKI, Master of Sci., Institute of Physics of Wrocław Technical University, Wrocław, Poland.

** A. SZAYNOK, Assistant Professor, Institute of Environment Protection Engineering of Wrocław Technical University, Wrocław, Poland.

*** M. TEISSEYRE, Assistant Professor, Institute of Power Engineering and Fluid Mechanics of Wrocław Technical University, Wrocław, Poland.

Simple structure of electrostatic dustmeters belonging to the second group is their great advantage, nevertheless numerous defects can be also shown, e.g. the fact that indications of the instrument depend on the kind of dust, its granular composition, and changes in flow rate. These dustmeters being, moreover, exposed to erosion are relatively easily choked by dust.

The third, most numerous group is constituted by optical dustmeters. They are constructed in several variants by a number of firms all over the world. The most known are the instruments offered by Siemens, Visomat, AEG, Durag, Dr. Lange and Leads and Northrup Co. Investigations on optical dustmeters are continued [3, 9, 11]. Some results published in [4] have shown that the dustmeter RM-4 produced by Sick have good metrologic and functional properties, although some deffects have been also observed. E.g. it is difficult to keep optical system in cleanliness and the indications are conditioned by granular composition and kind of dust. The investigations performed in Poland are concentrated chiefly on the development of optical dustmeters. Some investigations on the application of attenuation of ultra sounds to the measurements of dust concentration are also carried out in the Wrocław Technical University.

Dustmeters belonging to the group 4 are based on the measurements of changes in surface density of filtrating bands through which the sample of solgas is flowing seem to find wide industrial applications, because of the increasing application of radioisotopic methods to measuring purposes such dustmeters have the best developmental chance. With beta radiation source the variation in surface mass of measuring filter on which the dust was deposited may be measured with a relatively high accuracy, and hence the concentration of solgas dustiness determined.

The most essential advantage of radioisotopic dustmeters is their relatively simple structure, high operation reliability, the fact that the indication does not depend on the kind of dust within a relatively large range and that the essential elements of the device need not be protected against dustiness [20]. As it follows from the investigations [20] radioisotopic dustmeters can be successfully applied to various branches of the industry. The measurement accuracy is of the same order as in optical dustmeters. According to the authors' opinion the research works in Poland should in this field be concerned with optical radioisotopic dustmeters.

2. OPTICAL DUSTMETERS CONSTRUCTED IN THE WROCŁAW TECHNICAL UNIVERSITY

2.1. DESCRIPTION OF THE STRUCTURE

Automatic dustmeters consist of optical and electronic units (Fig. 1). Scheme of optical system is given in Fig. 2. Reflector which is a separate element of the device contains a source of light (*1*), condenser (*2*), and objective (*3*). Light beam emitted by the reflector travels along the canal (*4*), filled with solgas. Two telescopes (*5*) and (*6*) are placed in the plane of measuring device cross-section, their symmetry axes are perpendicular to trace

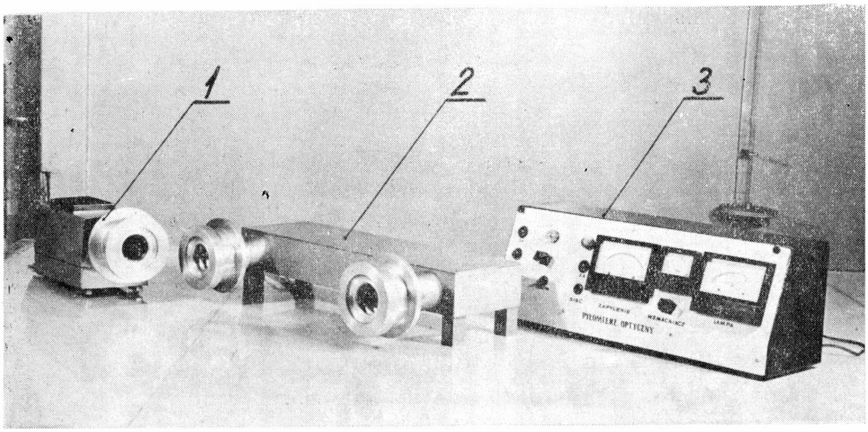

Fig. 1 Optical dustmeter IFT

1 — reflector; *2* — optical unit; *3* — electronic unit

Rys. 1. Pyłomierz optyczny IFT

1 — reflektor; *2* — część optyczna; *3* — część elektroniczna

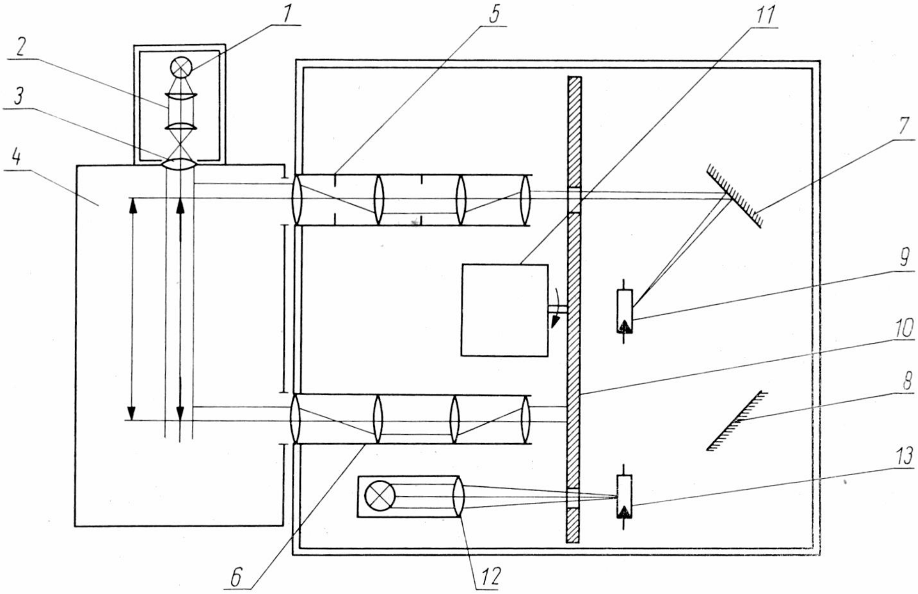

Fig. 2. Schematic representation of optical unit

1 — light sources; *2* — condenser; *3* — objective; *4* — flow canal of the solgas investigated; *5,6* — telescopes; *7,8* — mirrors; *9* — measuring photoelement; *10* — modulator; *11* — propulsion motor; *12* — illuminator; *13* — synchronizing photoelement

Rys. 2. Schemat części optycznej pyłomierza

1 — źródło światła; *2* — kondensator; *3* — obiektyw; *4* — kanał przepływowy badanego solgazu; *5,6* — lunety; *7,8* — zwierciadła; *9* — fotoelement pomiarowy; *10* — modulator; *11* — silnik napędowy; *12* — oświetlacz; *13* — fotoelement synchronizujący of light beam. Light dispersed on dust particles present in gas being tested passes through the telescope and falls on the mirrors (*7*) and (*8*). Reflected beams are convergent. The measuring photoelement (*9*) is located at their intersection point. Between eyepieces of the telescopes (*5*) and (*6*) and the photoelement there is a modulator (*10*) driven with a constant angular speed by an electric motor (*11*). Modulator is formed by a disk with two rows of notches and its circumference situated concentrically with respect to its centre. Each row consists of 3 notches shifted angularily with respect to one another so that their initial portions in one raw overlap the final parts of the notches in the second row. The dustmeter is moreover equipped with an illuminator (*12*) and synchronizing element (*13*) whose location enables the light beam emitted by the illuminator to fall on it after having passed through the modulator apertures more distant to its centre.

Block diagram of electronic unit is shown in Fig. 3. The input of preamplifier (*14*) is equipped with a measuring element, while main amplifier (*15*), rectifier (*16*) and polarized

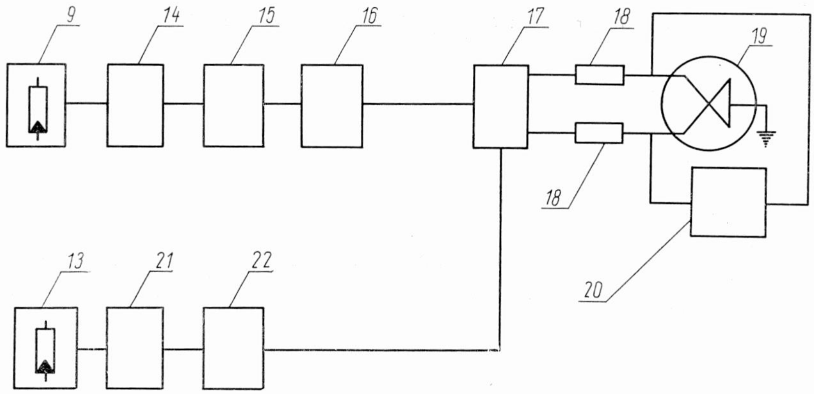

Fig. 3. Schematic representation of electronic unit

9 — measuring photoelement; *13* — synchronizing photoelement; *14* — preamplifier; *15* — main amplifier; *16* — rectifier; *17* — polarized transmitter; *18* — integrating elements; *19* — logometer; *20* — register; *21* — amplifier; *22* — rectifier;

Rys. 3. Schemat części elektronicznej pyłomierza

9 — fotoelement pomiarowy; *13* — fotoelement synchronizujący; *14* — przedwzmacniacz; *15* — główny wzmacniacz; *16* — prostownik; *17* — spolaryzowany przekaźnik; *18* — układy całkujące; *19* — logometr; *20* — rejestrator; *21* — wzmacniacz; *22* — prostownik

transmitter (*17*) are installed on the output. The transmitter output is connected with logometer (*19*) and register (*20*) by means of integrating elements (*18*). Synchronizing photoelement (*13*) is connected with controlling input of the polarized transmitter (*17*) by means of the second amplifier (*21*).

2.2. DUSTMETER OPERATION

Light beam emitted by the reflector and scattered on dust particles present in gas investigated fall on the telescope objective (*5*). Its intensity is then I_0 being higher than the intensity I of light beam falling on the objective of the telescope (*6*). The attenuation of the light on the distance L between the objectives of the telescopes depends on the concentration and kind of dust particles present in gas on which the light is scattered. The energy of scattered light is transformed by measuring element into the energy of electric impulses. The impulses coming from both light beams are separated by modulator and electric circuit and transmitted to logometer whose indications are proportional to the intensity ratio I_0/I. Dust concentration in gas can be determined by measuring this ratio using dustmeter callibrated for the given kind of dust.

Optical dustmeter is used to a continuous measurement of gas dustiness in pipes, or, after some modifications, in workshops and factories. It can be also used in canals, in which the pressure is below the atmospheric one or in canals in which the pressure is above the atmospheric pressure; in the latter case blower should be applied. Maximal distance between electronic and optical units amounts to about 200 m.

The dustmeter has three measuring ranges: The first with the highest sensitivity is used for the measurement of low dust concentrations. It is particularly useful in case of coarse grained dust. The second and third ranges are used in measurements of higher dust concentrations, especially of fine-grained and very fine-grained dust. The measuring ranges are the following:

Range I 0– 800 mg/mm^3,
Range II 0–3000 mg/mm^3,
Range III 0–6000 mg/mm^3.

Results of measurements are presented graphically in Fig. 4. From the analysis of curves shown in the graph it follows that the dustmeter can be also used to measurement

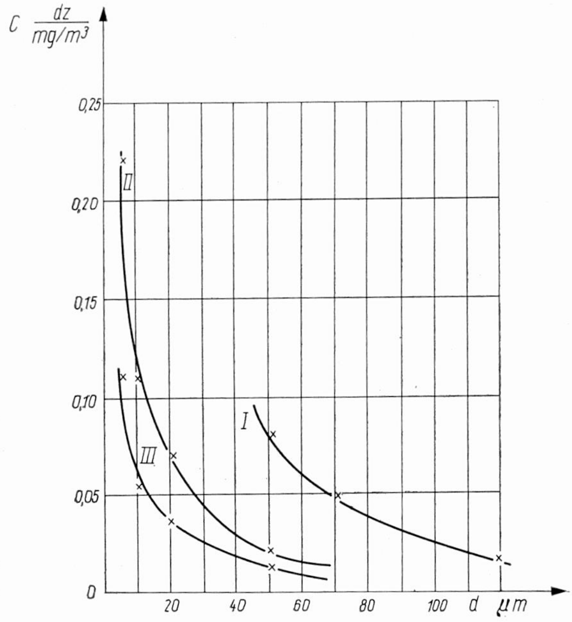

Fig. 4. Senstivity of optical dustmeter vs. virtual diameter of dust grain

Range I — to 800 mg/mm^3; Range II — to 3000 mg/mm^3 Range III — to 6000 mg/mm^3

Rys. 4. Zależność czułości pyłomierza optycznego od średnicy zastępczej ziaren pyłu

I. zakres — do 800 mg/mm^3; II. zakres — do 3000 mg/mm^3; III. zakres — do 6000 mg/mm^3

of low concentrations of very fine-grained dust. Such dust is observed in dusty and smoky halls in factories.

The dustmeter described in this paper has been also used to measurement of attenuation cross-section of quartz dust in function of its grain diameter. The attenuation cross-section is

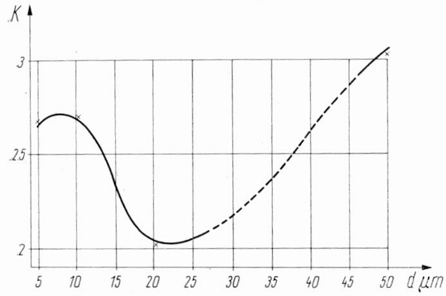

Fig. 5. Attenuation cross-section for monochromatic light $\lambda = 0.6\,\mu m$ vs. virtual diameter o quartz dust grain

Rys. 5. Przekroje osłabienia dla światła monochromatycznego o długości fali $\lambda = 0{,}6\ \mu m$ w zależności od średnicy zastępczej ziaren pyłu kwarcowego

determined by the ratio of light attenuation coefficient to the area of dust particle. Results of measurements performed for monochromatic light $\lambda = 0.6\ \mu m$ are presented in Fig. 5. The dustmeter has been patented (No P-155573).

3. RADIOISOTOPIC DUSTMETER CONSTRUCTED IN THE WROCŁAW TECHNICAL UNIVERSITY

3.1. STRUCTURE AND OPERATION

Structural design of radioisotopic dustmeter was based on measuring method given by DRESIA [7, 8]. It can be considered as an original solution. The dustmeter is characterized by automatic compensation of measurement errors resulting from changes in properties of filtering band, temperature, humidity and ageing of electronic elements. Measuring unit of the dustmeter (Fig. 6) consists of a measuring head with a source of nuclear radiation, nuclear radiation detectors and of electronic functional blocks. Filtration band shifting periodically is located between the source and detector. Part of the band is covered with dust in a special cell (chamber) filled with succeed sample of the gas tested. One of the detectors (in measuring path) is located over the part of band covered with dust, the second one (in compensation path) being located over the uncovered part. Both detectors are close to each other. Measuring head is beyond the region (in the direction of band shift) in which the dust is deposited. In this head radiation affects the part of band with dust and a part without dust.

Of the two obtained signals one contains information on the measured value and on measurement errors, while the second signal contains only the information on measurement errors. Fusion of both signals in function blocks of measuring unit yields compensation

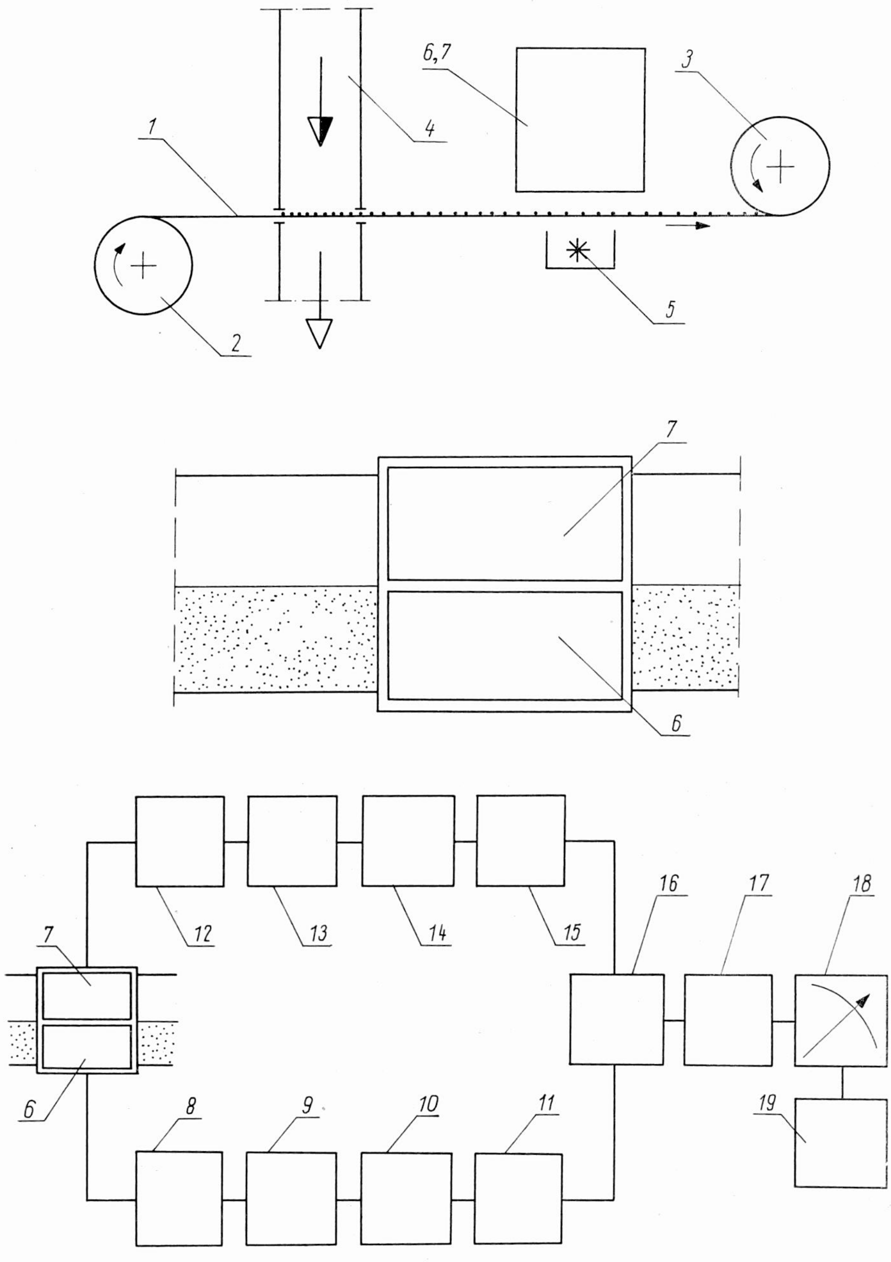

Fig. 6. Schematic structure of radioisotopic dustmeter ITCiMP

1 — filtration band; *2* — outlet drum; *3* — receiving drum; *4* — solgas supplying duct; *5* — radiation source; *6* — radiation detector of measuring route; *7* — radiation detector of compensation route;
Compensation path: *8* — input system; *9* — forming system; *10* — integrator; *11* — fitting system;
Measuring path: *12* — input system; *13* — forming system; *14* — integrator; *15* — fitting system; *16* — differential system *17* — converter; *18* — dust content meter; *19* — recorder

Rys. 6. Zasada budowy pyłomierza radioizotopowego ITCiMP

1 — taśma filtracyjna; *2* — bęben zdawczy; *3* — bęben odbiorczy; *4* przewód doprowadzający próbkę badanego solgazu; *5* — źródło promieniowania; *6* — detektor promieniowania toru pomiarowego; *7* — detektor promieniowania toru kompensacyjnego
Tor pomiarowy: *8* — układ wejściowy; *9* — układ formujący; *10* — integrator; *11* — układ dopasowujący
Tor kompensacji: *12* — układ wejściowy; *13* — układ formujący; *14* — integrator; *15* — układ dopasowujący; *16* — układ różnicowy (ilorazowy); *17* — przetwornik; *18* — miernik stężenia zapylenia; *19* — rejestrator

of the measurement errors resulting due to changes in the band properties temperature and ageing of the particular elements of the device, as well as of errors resulting from the change in density, efficiency of nuclear radiation sources and of detectors, temperature of the measured region etc.

The presented above device is expected to be modified in order to increase its applicability. This modification would allow to measure the dustiness concentration together with the efficiency of the electrofilter.

The optimization of filtration system in dustmeter by substituting of other dust depositing elements for the periodically renovated band is also forseen.

CONCLUSIONS

Measuring systems of dustmeters presented in the paper are characterized by good metrologic properties. Their suitability to industrial measurements depends, however, on further investigations on their reliability. Considering a simple structure and the independence of results of dust concentration measurements of the kind of dust, the dustmeters based on radioisotopic method, seem to deserve a special attention.

PYŁOMIERZE DO CIĄGŁYCH POMIARÓW ZAPYLONYCH GAZÓW PRZEMYSŁOWYCH

W artykule omówiono zastosowanie automatycznych pyłomierzy przemysłowych. Podano zasadę działania pyłomierzy opracowanych na Politechnice Wrocławskiej, tj. pyłomierza optycznego i radioizotopowego. Układy pomiarowe tych pyłomierzy odznaczają się dobrymi właściwościami metrologicznymi. Na szczególną uwagę zasługują pyłomierze oparte na zasadzie radioizotopowej ze względu na prostotę układu i niezależność wyników pomiarów stężenia zapylenia od rodzaju pyłu.

STAUBMESSGERÄTE DER STÄNDIGEN KONTROLLE VON INDUSTRIEGASEN

Die Messsysteme von Staubmessgeräte, die in dieser Arbeit gezeigt sind, besitzen gute metrologische Eigenschaften.

Ihre Angewandheit in der Industriemessung hängt doch von weiteren Versuchen in ihrer Zuverlässigkeit ab.

Mit unkomplizierter Bau und Unabhängigkeit der Messergebnissen in Gaskonzentrationen vom Gasart, wurden hergestellte Staubmessgeräte auf der radioisotopischen Methode von grosser Bedeutung.

КОНИМЕТРЫ ДЛЯ НЕПРЕРЫВНОЙ ПРОВЕРКИ ПРОМЫШЛЕННЫХ ГАЗОВ

Обсуждаемые в статье измерительные системы кониметров обладают хорошими метрологическими свойствами, однако указания относительно их пригодности для промышленных измерений зависят от результатов дальнейших исследований их надежности. Из-за несложности устройства а также независимости результатов измерений концентрации газов от вида газа, конимеры, основанные на радиоизотопном методе, заслуживают особенново внимания.

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