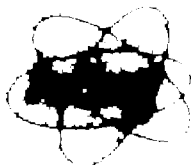


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**INSTITUTE OF NUCLEAR CHEMISTRY  
AND TECHNOLOGY**

INIS-mj--13440



**APPLICATION OF RADIOISOTOPE  
TECHNIQUES IN INDUSTRY  
AND  
ENVIRONMENT PROTECTION**

**Part II**

**RECEIVED 1988**

**APPLICATION OF RADIOISOTOPE  
TECHNIQUES IN INDUSTRY  
AND  
ENVIRONMENT PROTECTION**

**Part II**

**Institute of Nuclear Chemistry and Technology  
ul. Dorodna 16, 03-195 Warszawa, Poland  
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## GENERAL INFORMATION ABOUT THE INSTITUTE

Institute of Nuclear Chemistry and Technology established in 1983 as a successor of the Żerań Division of former Institute of Nuclear Research. The INCT has adopted over thirty years' heritage of nuclear science in Poland.

The Institute consists of the following nine Departments:

- I - Department of Nuclear Methods of Material Engineering;
  - II - Department of Structural Research;
  - III - Department of Radiotope Instruments and Methods;
  - IV - Department of Chemical Nuclear Engineering;
  - V - Department of Radiochemistry;
  - VI - Department of Nuclear Methods of Process Engineering;
  - VII - Department of Radiation Chemistry and Technology;
  - VIII - Department of Analytical Chemistry;
  - X - Department of Radiobiology and Health Protection;
- plus Experimental Establishment of Electronic Equipment.

The research conducted at the INCT concentrates around the following topics:

- radiation chemistry, physics and technology;
- radiochemistry;
- nuclear chemical engineering;
- chemical and physical analytical techniques, particularly those based on nuclear methods;
- radiometric methods and nuclear apparatus;
- nuclear methods applied to material engineering, process engineering, industry, hydrology and environment protection:
  - radiobiology and medical aspects radiological protection;
  - special methods of elements separation, development of technologies aimed at obtaining new materials of required properties as well as high purity materials.

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## DEPARTMENT OF RADIOISOTOPE INSTRUMENTS AND METHODS

The activities of the Department is aimed at the design and development of radioisotope instruments and methods for measurement and control. In particular:

- acid concentration gauges intended for on-line determination of sulfuric, hydrofluoric, nitric and boric acids concentration. The principle of operation is based on the absorption of slow neutrons and slowing down fast neutrons from sealed neutron sources;
- X-ray fluorescence and  $\beta$ -ray backscattering coating thickness gauges;
- low resolution X-ray fluorescence analysers;
- measurement of physical and chemical properties of coals by radiometric methods;
- radioisotope instruments for control of dust pollution in air;
- electronics for radiometric and industrial measuring instruments;
- conventional radioisotope instruments for measurement and control.

### Managing staff of the Department

Piotr Urbański, Ph. D. - Head of the Department

Bronisław Machaj, Ph. D. - Laboratory of Electronics

Jan Strzałkowski, Eng. - Laboratory of Industrial Sensors



## NEUTRON GAUGES FOR ACID CONCENTRATION MEASUREMENTS IN INDUSTRIAL INSTALLATIONS

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### ABSTRACT

The principle of operation and more important parameters of neutron gauges for measuring acid concentration in industrial installations are given in the paper. The gauges for measuring concentration of sulphuric acid  $H_2SO_4$  proved to be reliable and satisfactory during a few years operation in industrial installations. Their utility to measure concentration of other acids, eg. hydrofluoric acid HF and boric acid  $H_2BO_3$ , as well as to measure concentration of chlorine in water solutions was checked in laboratory or in experimental installations. The measuring heads of the gauges employ transmission geometry or immersed geometry of measurement. The gauges in transmission geometry are bolted onto the pipe containing the measured acid. In submersion geometry, the measuring head consists of a flow tank inside of which fast neutron source and thermal neutron detector are placed.

The gauges can also be used to measure concentration of other acids, anywhere variation of acid concentration is accompanied by variation of concentration of hydrogen atoms in the solution. They can also be used to measure content of elements strongly absorbing thermal neutrons such as: Li, Cd, Rh, In, Gd, Pa and others.

### INTRODUCTION

The investigations aimed for elaboration of neutron gauges to measure acid concentration started on the demand of the Institute of Inorganic Chemistry in Gliwice. At that time this Institute was looking for new methods for measuring of sulphur acid concentration instead of conductometric ones. The electrodes of conductometric gauge immersed into the acid and subjected to corrosive environment are rapidly demaged /once a month on average/ what is tedious for the user. Another serious disadvantage of a conductometric gauge is its sensitivity to acid impurities and connected with that dependence of indication of the gauge.



Since the first publication on neutron gauge for measuring sulphuric acid concentration, some improvements have been introduced to the gauge construction and additional investigations have been carried out. The investigations were aimed to widen the range of applications of neutron gauges, employing the fast neutron slowing down principle and absorption of thermal neutrons principle to measure concentration of other acids. Results of these investigations and achieved results are presented in the paper. Since that time also, many gauges for measuring sulphuric acid concentration were produced and installed in chemical plants producing sulphuric acid. The gauges installed in a loop of automatic control of acid concentration are working there since many years, showing high reliability of operation.

### SULPHURIC ACID CONCENTRATION GAUGE

Measuring head of the sulphuric acid concentration gauge  $\text{H}_2\text{SO}_4 + \text{H}_2\text{O}$ , denoted as MSK-4 type, is shown in Fig. 1. Fast neutrons from Pu-Be neutron source penetrating into the

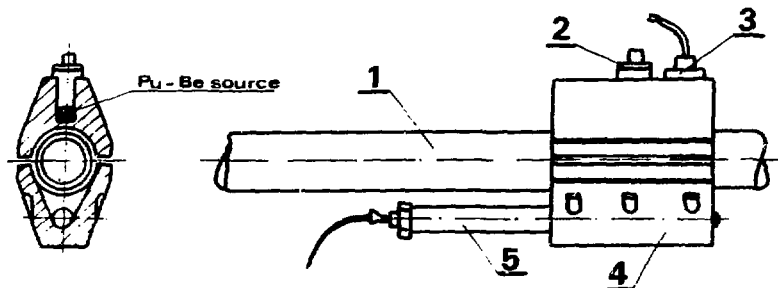


Fig. 1. Measuring head of sulphur acid concentration gauge in transmission geometry: 1 - pipe containing sulphuric acid, 2 - Pu-Be neutron source holder, 3 - temperature sensor, 4 - measuring head trunk, 5 - measuring probe containing slow neutron detector and pulse preamplifier

acid solution inside the pipe are slowed down. From the three elements H, S, C constituting the acid solution, the slowing down properties are practically determined by the concentration of hydrogen atoms. The weight concentration of hydrogen atoms is closely related to the concentration of sulphuric acid. Thus measuring the concentration of hydrogen, one can determine the concentration of sulphuric acid. Fig. 2 shows pulse count rate at the output of thermal neutron detector against acid concentration at  $23^{\circ}\text{C}$  and  $63^{\circ}\text{C}$  of the solution.

It can be seen from the diagram, that for a narrow span of acid concentration the count rate against acid concentration can be approximated with a straight line. It can also be seen



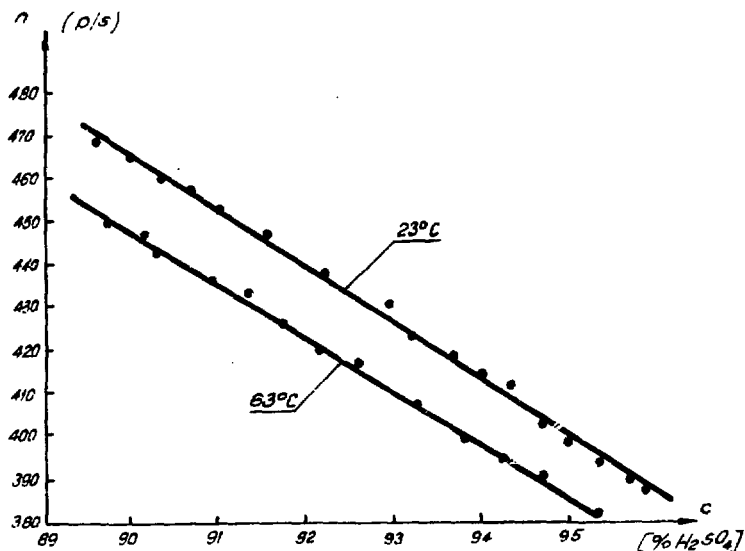


Fig. 2. Pulse count rate at the output of neutron detector against temperature of sulphuric acid at  $23^\circ C$  and  $63^\circ C$

that compensation of variation of acid temperature is a necessity. This is done by means of a temperature sensor placed in the measuring head. The gauge is adapted to measure concentration of sulphuric acid in two subranges: 90% - 99.9% and 60% - 70% of  $H_2SO_4$ . More detailed data are given in Table 1.

Table 1. Technical data of MSK-4 sulphuric acid concentration gauge

| Description  | Units | Mod. A          | Mod. B          |
|--|-------|-----------------|-----------------|
| Measuring range of $H_2SO_4$                             | %     | 90-99.9         | 60-70           |
| Error of statistical fluct. at conf. level 0.95          | %     | $\pm 0.15$      | $\pm 0.5$       |
| Switchable double time const. /for slow/fast variations/ | sec   | 200/25          | 200/25          |
| Indication of concentration                              | %     | digital display | digital display |
| Standard analog output                                   | V     | 0-10            | 0-10            |
|  | mA    | 0-5             | 0-5             |

Table 1.

| Description                               | Units | Mod. A     | Mod. B       |
|---|-------|------------|--------------|
| Optional analog output                    | mA    | 0-10       | 0-10         |
|   | mA    | 0-20       | 0-20         |
|   | mA    | 4-20       | 4-20         |
| Standard acid temp. range                 | °C    | 90±20      | 90±20        |
| Short period acid temp.                   | °C    | 140        | 140          |
| Diameter x thickness x length of the pipe | mm    | 100x4x1100 | 100x3.5x1100 |
| Sensitivity, S                            | -     | 3.3 - 5.0  | 1.8-2.2      |

The sensitivity  $S$  given in the Table 1 and given also later in the paper for other gauges is determined as the ratio  $S = \Delta n/n/1\%$ , where  $\Delta n/n$  denotes relative variation of count rate. Thus the sensitivity  $S$  determines for how many percent changes the count rate, when variation of sulphur concentration is equal to 1%.

The fact that slowing down of fast neutrons is practically dependent on the hydrogen concentration in the solution measured, permits for use of the same principle of operation to measure concentration of other acids wherever variation of acid concentration is accompanied by sufficiently large variation of hydrogen concentration in the acid solution. As an example, technical data of oleum concentration gauge and hydrofluoric acid concentration gauge, employing the same principle of operation, are presented below.

#### OLEUM CONCENTRATION GAUGE

The oleum concentration gauge  $H_2SO_4 + SO_3$  employs the same principle of operation as sulphuric acid concentration gauge, as well as the same measuring head. Laboratory investigation were carried out with the gauge. Basing on these investigations, achievable parameters of the gauge have been estimated, and are presented below.

- Measuring range 2.5-6.5%  $SO_3$
- Error of statistical fluctuations at confidence level 0.95 0.2 - 1%  $SO_3$
- Diameter x thickness of the pipe containing acid 100 x 4 mm
- Time constant of the gauge 100 sec
- Pu-Be neutron source yield  $1.10^6$  n/sec
- Gauge sensitivity 4.03 - 1.55



The count rate at the output of thermal neutron detector against oleum concentration in the range 25% - 65%  $\text{SO}_3$  is non-linear one and is determined by the equation:

$$R = R_{25} \cdot w_{01}^{-1.0087}$$

R - pulse count rate from/sample measured,

$R_{25}$  - pulse count rate from sample  $w_{01}=25\%$   $\text{SO}_3$  concentration,

$w_{01}$  - concentration  $\text{SO}_3$ , %.

### HYDROFLUORIC ACID CONCENTRATION GAUGE

The hydrofluoric acid concentration gauge HF +  $\text{H}_2\text{O}$  employs the same principle of operation and uses the same measuring head as the sulphuric acid concentration gauge in Fig. 1. The technical data estimated on the base of laboratory measurements and investigations are the following.

|  |                        |
|--|------------------------|
| - Measuring range  | 70 - 85% HF            |
| - Error of statistical fluctuations at confidence level 0.95 | 0.24 - 0.28% HF        |
| - Diameter of pipe containing acid                           | 57 mm                  |
| - Pu-Be fast neutron source yield                            | $5.3 \cdot 10^5$ n/sec |
| - Time constant of the gauge                                 | 200 sec                |
| - Gauge sensitivity S  | 1.53 - 2.05            |

The principle of operation of boric acid concentration gauge and chlorine concentration gauge is different, although the measuring head of these gauges can be the same as the head for sulphuric acid gauge.

### BORIC ACID CONCENTRATION GAUGE

Boric acid concentration gauge  $\text{H}_3\text{BO}_3 + \text{H}_2\text{O}$  is produced with two types of measuring heads. One of the versions of the boric acid gauge is equipped with the same measuring head as the head of sulphuric acid concentration gauge in Fig. 1. The other version is a gauge with an immersion type measuring head. The principle of operation of the gauge, in both cases, is the following. Fast neutrons from neutron source penetrating the solution of the acid are slowed down mainly by hydrogen atoms from water molecules. Slowed down neutrons are then absorbed by boron atoms having high absorption cross section of the thermal neutrons (757 barns for natural boron and 3838 barns for  $^{10}\text{B}$ ). The higher the concentration of boric acid the smaller the ther-

mal neutron flux. Measuring thus the thermal neutron flux one can determine the concentration of boric acid. Fig. 3 illustrates pulse count rate at the output of thermal neutron detector

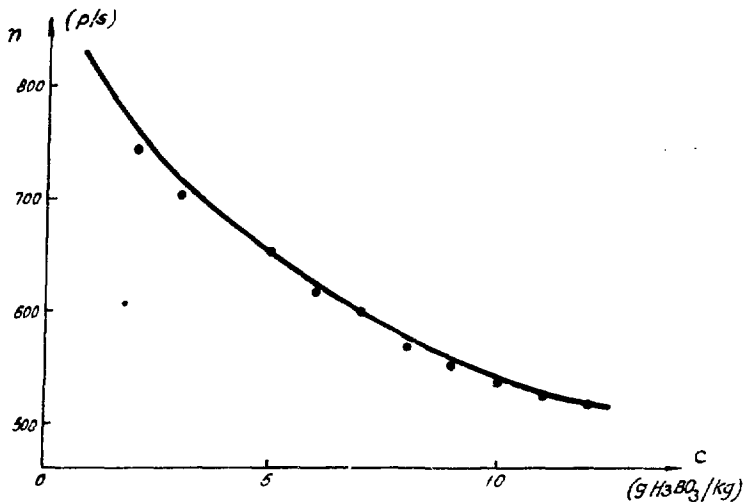


Fig. 3. Pulse count rate at the output of neutron detector against concentration of boric acid. Pipe diameter containing acid  $\varnothing$  80 mm. Pu-Be fast neutron source  $5.3 \cdot 10^5$  n/sec. Thermal neutron detector NEM 525A1ST

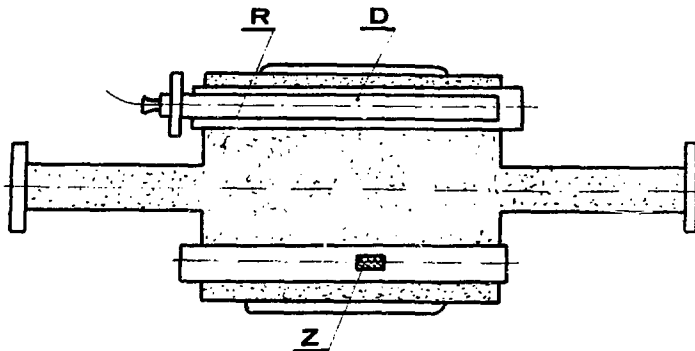


Fig. 4. Measuring head of boric acid concentration gauge in immerse geometry; Z - fast neutron source, D - thermal neutrons detector, R - boric acid solution

against the concentration of boric acid in measuring geometry as shown in Fig. 1. Laboratory investigations and measurements carried out at experimental installations show that such a mesu-

ring geometry ensures sufficient accuracy of measurement in the range 2 - 40 g  $H_3BO_3$  in 1 kg of boric acid solution. Additionally, to ensure sufficient accuracy diameter of the pipe containing boric acid must be of proper size. The gauges with the measuring head as in Fig. 1 are denoted as type MSB-3 model A or B depending on the diameter of the pipe, and in consequence depending on measuring range of acid concentration, see Table 2. For measurements of low concentration of boric acid the immerse measuring geometry is employed, see Fig. 4. The principle of operation of the gauge in immerse geometry is similar, i.e. slowing down of fast neutrons in water solution of boric acid and then absorption of thermal neutrons by boron atoms.

Table 2. Technical data of boric acid concentration gauge in immerse geometry

| Description               | Units | MSB-3  |        | MSB-4    |          |
|---------------------------|-------|--------|--------|----------|----------|
|                           |       | Mod. A | Mod. B | Mod. A   | Mod. B   |
| Measuring range $H_3BO_3$ | g/kg  | 2-14   | 10-40  | 1-6      | 10-40    |
| Accuracy, relative        | %     | 5      | 10     | 5        | 10       |
| Time constant, double     | sec   | 120/20 | 120/20 | 120/20   | 120/20   |
| Analog output             | V     | 0-10   | 0-10   | 0-10     | 0-10     |
| Pipe diam. x thickness    | mm    | 102x10 | 57x10  |          |          |
| Container dimensions      | mm    | -      | -      | ∅218x280 | ∅218x280 |

Immerse type boric acid concentration gauges can also be used to measure higher concentrations of boric acid and are also produced in two versions, see Table 2. The immerse measuring geometry ensures better conditions of measurement from the point of view statistical error and of decrease of influence of the nearest environment on the indication of the gauge. Such measuring geometry can not however be used in installations with high acid pressure because of constructional reasons. The immerse version of gauges are denoted as MSB-4 type and are also made as model A and model B depending on the concentration of boric acid to be measured.

### CHLORINE CONTENT IN WATER SOLUTIONS

The gauge of chlorine content in water solutions operates on the same principle as boric acid concentration gauge. Laboratory investigations have been carried out with a gauge equipped with the measuring head as in Fig. 1. The measured solutions were:  $NH_4Cl + H_2O$  and  $NaCl + H_2O$ . Estimated during these investigations parameters achievable are presented below.

|  |                        |
|--|------------------------|
| - Measuring range  | 0 - 10% NaCl           |
| - Error of statistical fluctuations at confidence level 0.95 | 0.95 - 0.15% NaCl      |
| - Time constant of the gauge                                 | 100 sec                |
| - Pu-Be neutron source yield                                 | $5.3 \cdot 10^5$ n/sec |

Estimated parameters for a gauge measuring water solution of  $\text{NH}_4\text{Cl} + \text{H}_2\text{O}$  are very similar to that presented above.

The gauges employing the principle of absorption of slowed down neutrons can be successfully used for measurements of content of elements highly absorbing thermal neutrons such as: Li, Cd, Rh, In, Gd and others.

### CONCLUSIONS

The gauges presented in the paper ensure contactless measurement of concentration of acid, or a content of some elements in water solutions. Thanks to contactless principle of measurement high reliability of operation of the gauges is achieved in heavy industrial environment. Experience gained during few years operation of sulphuric acid concentration gauges in chemical plants justify such opinion.

Contrary to conductometric gauges commonly used for measurement of sulphuric acid concentration, the neutron gauges are insensitive to the impurities occurring in sulphuric acid. Finally the neutron gauges ensure measurement of acids at high pressure and considerable temperatures.

## RADIOISOTOPE METHODS AND DEVICES FOR COATING THICKNESS MEASUREMENTS AND ANALYSIS

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### ABSTRACT

Radioisotope instruments based on beta-rays backscattering and XRF technique intended for coating thickness gauging and analysis are presented and some examples of their application are described.

### INTRODUCTION

Radioisotope instruments for coating thickness gauging and analysis generally are based on such effects as X-ray fluorescence or beta-rays backscattering. The measurements performed with these instruments are nondestructive, need neither special treatment of measured sample nor high skilled personnel for interpretation of obtained results. Radioisotope sources applied in the instruments have relatively low penetrating ability so the hazard for operating personnel is negligible.

The aim of this paper is to present developed in INCT instruments for coating thickness measurements and analysis, show their basic features and some examples of application.

### COATING THICKNESS GAUGES

Radioisotope coating thickness gauges are represented by beta - backscattering device type GIL and XRF instrument. The both devices are intended for laboratories and some examples of their application are listed in Tables 1 and 2.

Beta - backscattering coating thickness gauge is a versatile instrument applicable when atomic number difference between coating and base materials is not less than 5. Range of measurement



Table 1. Some examples of application of beta - backscattering coating thickness gauge

| Coating                         | Base  | Range [ $\mu\text{m}$ ] | Source                    |
|---------------------------------|---|-------------------------|---------------------------|
| Gold                            | Fe, Ni, Cu, Ag<br>brass, bronze,<br>kovar, laminate | 0-3<br>0-9<br>0-30      | Pm-147<br>Tl-204<br>Sr-90 |
| Silver<br>Cadmium<br>Tin        | Fe, Ni, Cu<br>kovar, bronze<br>laminate             | 0-4<br>0-25<br>0-70     | Pm-147<br>Tl-204<br>Sr-90 |
| Nickel<br>Copper                | ABS   | 0-25                    | Tl-204                    |
| Alloy Sn-Pb<br>/30% Sn, 70% Pb/ | Fe, Cu, brass<br>bronze<br>laminate                 | 0-20                    | Tl-204                    |
| Alloy Sn-Pb<br>/60% Sn, 40% Pb/ | Fe, Cu, brass<br>bronze<br>laminate                 | 0-25                    | Tl-204                    |
| Chromium                        | Copper  | 0-2.5<br>0-10<br>0-50   | C-14<br>Pm-147<br>Tl-204  |
| Gold                            | Titanium  | 0-10                    | Tl-204                    |
| Silicon-Carbide                 | Carbide   | 0-10<br>0-100<br>0-300  | Pm-147<br>Tl-204<br>Sr-90 |

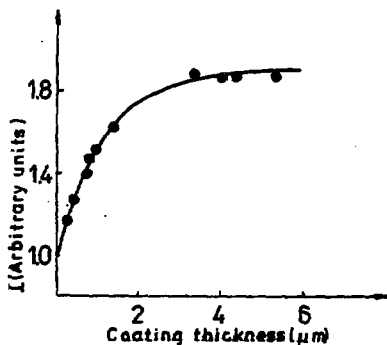


Fig. 1. Calibration curve for beta backscattering determination of gold thickness deposited on copper base /with Pm-147 source/



Table 2. Some examples of application of XRF coating thickness gauge

| Coating  | Base     | Range [ $\mu\text{m}$ ] | Source | Excited radiation |
|----------|----------|-------------------------|--------|-------------------|
| Gold     | Ag       | 0-7                     | Cd-109 | Au L              |
|          | Ag       | 0-12                    | Am-241 | Ag K              |
|          | Cu       | 0-7                     | Cd-109 | Au L              |
|          | Cu       | 0-3.5                   | Cd-109 | Cu K              |
| Chromium | Cu       | 0-15                    | Cd-109 | Cu K              |
|          | Cu       | 0-15                    | Cd-109 | Cr K              |
|          | Steel    | 0-10                    | Cd-109 | Fe K              |
| Nickel   | Steel    | 0-20                    | Cd-109 | Fe K              |
|          | Brass    | 0-10                    | Cd-109 | Ni K              |
|          | Ceramic  | 0-20                    | Cd-109 | Ni K              |
| Silver   | Brass    | 0-8                     | Cd-109 | Cu K              |
|          | Brass    | 0-50                    | Am-241 | Ag K              |
|          | Ceramic  | 0-50                    | Am-241 | Ag K              |
| Rhodium  | Cu       | 0-2                     | Cd-109 | Cu K              |
|          | Kovar    | 0-2.5                   | Cd-109 | Fe K              |
|          | Au/Kovar | 0-2.5                   | Cd-109 | Fe K              |
| Zinc     | Steel    | 0-20                    | Cd-109 | Zn K              |
| Copper   | Steel    | 0-20                    | Cd-109 | Cu K              |

depends on energy of beta - rays and can be changed by selection one of three radioisotope sources /Pm-147, Tl-204 and Sr-90/. User can also choose size and shape of measured area changing apertures delivered together with the instrument. Built in microcomputer performs signal processing and allows results to be displayed on small 4-digit display as well as typed by printing device.

X-ray fluorescence coating thickness gauge is more expensive and more sophisticated instrument, but allows also to perform measurements of platings when difference in atomic numbers between coating and base is too small for beta - backscattering gauge. The XRF gauge is particularly applicable when composition of coating and base materials is not constant /e.g. alloys coatings or ceramic base/ or when between measured coating and base a thin sub-layer of additional material is plated. Examples of such applications are shown on Fig. 2-4. Main disadvantage of application of XRF technique for thickness measurements of alloy platings is need for determination of separate scales for various alloys compositions. The main advantages are: non-destructive method of measurement, relatively high speed and possibility of automatic processing displaying or typing obtained results.



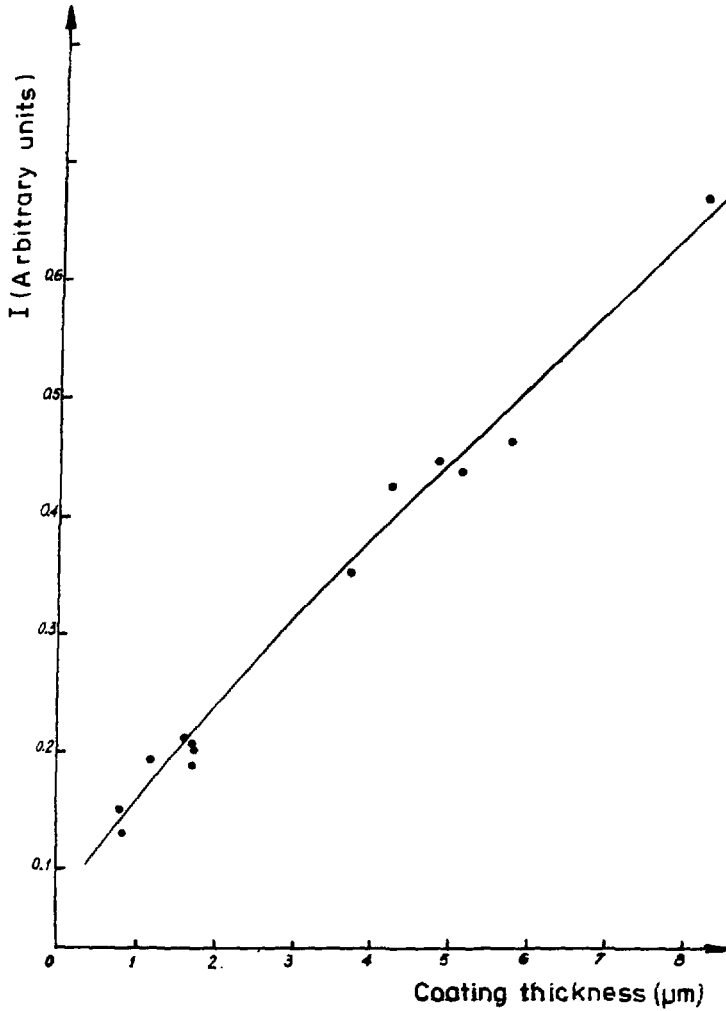


Fig. 2. XRF determination of nickel thickness deposited on ceramic base

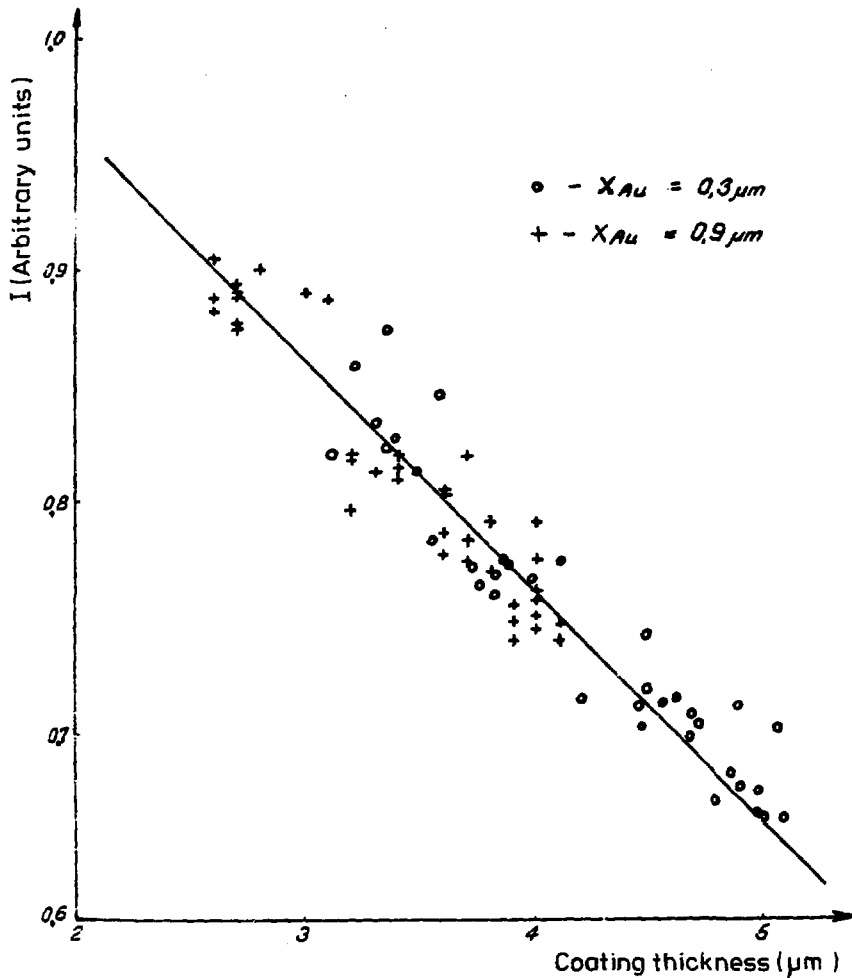


Fig. 3. XRF determination of rhodium thickness coated on Kovor base with thin gold sublayer of various thickness

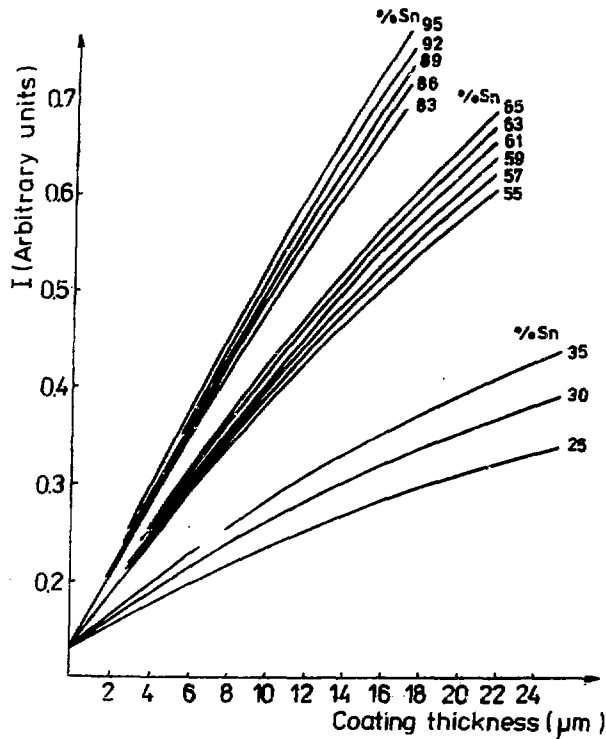


Fig. 4. Diagram of thickness determination of Sn-Pb plating

#### RADIOISOTOPE ANALYZERS

The main advantages of radioisotope analyzer applications are those features which allow to perform measurements by nondestructive way, in short time, using relatively cheap and easy in operation instrumentation. The most widely used are XRF analyzers designed either as simple, sometime portable gauges, as well as sophisticated, fully computerized analytical systems. Both types of instrumentation are available in Poland. Application of low-resolution XRF technique realised in INCT are based on various types of AF fluorescence analyzers. They consist of measuring heads with radioisotope source, proportional counter, preamplifier and sometime a device for changing positions of balanced filters. The control unit which lately was being computerized, process signal delivered from measuring head and displays or types final result. Exchangeable

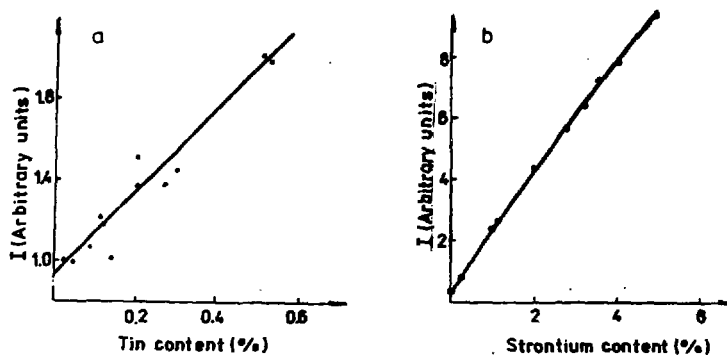


Fig. 5. Determination of tin /a/, and strontium /b/ in geological samples

sources and counters, as well as possibility of filters application allows to use those instruments for solving most of analytical problems where low resolution XRF technique is applicable. Some examples of applications are listed in Table 3.

Table 3. Some examples of application of AF fluorescence analyzer

| Analysed element | Matrix  | Range                      | Intrinsic error               |
|------------------|---|----------------------------|-------------------------------|
| Manganese        | fusion  | 30-45% MnO                 | 0,25% MnO                     |
| Iron             | fusion<br>blood                                     | 0-3,5% FeO<br>60-700 ppm   | 0.15% FeO<br>30 ppm Fe        |
| Zinc             | ores  | 45-57%                     | 2% Zn                         |
| Strontium        | geological materials                                | 0-5%                       | 0,1% Sr                       |
| Silver           | waste products                                      | 0-2,5%                     | 0.03% Ag                      |
| Tin              | geological mat.<br>Sn-Pb alloys<br>Sn-Pb galv. bath | 0-3%<br>55-95%<br>5-25 g/l | 0.05% Sn<br>1% Sn<br>1 g/l Sn |
| Tungsten         | galvanic bath                                       | 10-50 g/l                  | 0.5 g/l W                     |
| Lead             | Sn-Pb galv. bath<br>ores                            | 5-25 g/l<br>1.5-8%         | 1 g/l Pb<br>0.3% Pb           |

Low resolution XRF analyzers are particularly useful for analysis of geological materials, galvanic bath and alloys. Some results their applications for tin and strontium determination in geological samples are shown on Figs 5a and 5b. Measurements were performed on powdered

D

samples in time ca 300 s. Presented instruments can also be used for analysis of liquid samples and were successfully applied for determination of some elements in galvanic bath. On Fig. 6

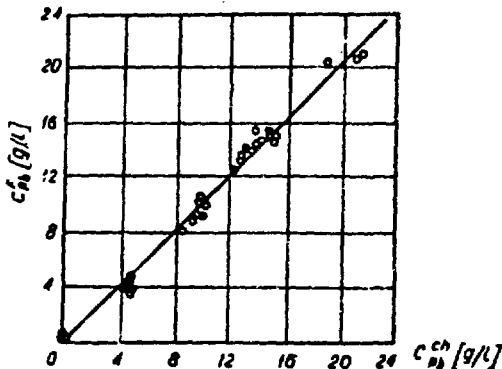


Fig. 6. Comparison of chemical and XRF analysis results of lead determination in galvanic bath

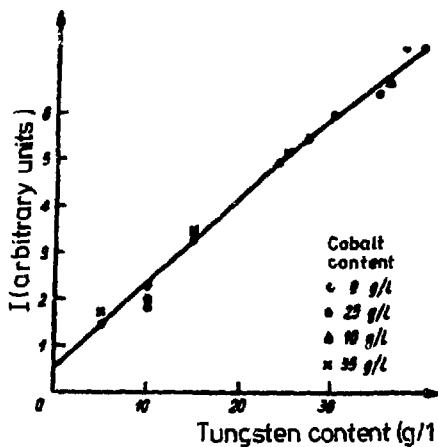


Fig. 7. Determination of tungsten in galvanic bath with various cobalt concentrations

comparison of lead content analyzed by XRF and chemical methods is shown, and Fig. 7 shows calibration line for tungsten determination. As example of application of above instruments for alloys analysis some results of Sn determination in Sn-Pb alloys are presented on Fig. 8. An interesting example of application of low resolution XRF technique is determination of iron in blood /Fig. 9/. The sample of 100  $\mu$ l blood is deposited on paper filter and after drying measured by analyzer. Results are obtained after ca 300 s.

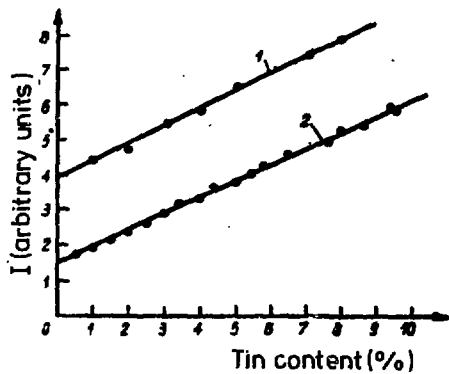


Fig. 8. Determination of tin content in Sn-Pb alloys: 1/ Sn L X-rays, 2/ Sn K X-rays

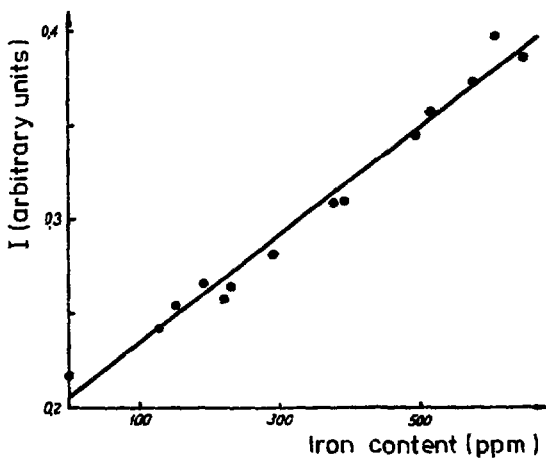


Fig. 9. XRF determination of iron in human blood

### CONCLUSIONS

Presented above brief review of radioisotope methods and instrumentation for coating thickness gauging and analysis gives a scope of possible fields of application of this technique. It can be hoped that existing experience as well as instrumental base will lead in near future to wider application of these methods in industry, whereas development of new computerized instrumentation will result in further improvement of their performance.





## RADIOISOTOPE DUST POLLUTION MONITOR

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### ABSTRACT

Measuring principles and specification of two dust monitors for ambient air pollution: station-type AMIZ and portable-type PK-10 are presented. The first one, a fully automatic instrument is intended for permanent monitoring of air pollution in preset sampling time from .25 to 24 hours. The second one was developed as a portable working model. Both instruments display their results in digital form in dust concentration units.

### DUST MONITOR AMIZ

The instrument is designed for application in permanent or mobile stations of the air pollution monitoring network. The principle of operation is as follows: dust particles from known volume of ambient air are deposited on filter tape made from fiber glass. The air flow is stabilised on constant level of  $1 \text{ m}^3/\text{h}$ . Mass of the collected dust particles is determined by absorption of low energy beta radiation. Two measurements of transmitted beta rays at exactly the same place of the filter tape are performed. First - before the dust deposition and second - after dust deposition.  $\text{Pm-147}$  is used as beta-ray source and G-M tube as radiation detector.

The dust monitor operates in preset cycles, which have to be selected prior to start of the measurement. Algorithm of each cycle consists of 14 operation steps controlled by a microprocessor. At the beginning of each cycle is step "zero", in which the instrument waits for a starting signal from internal quartz clock generated according to measuring cycle setting. Date and time of the starting moment /day, hour and minutes/ of the cycle is typed on the printer. Then step by step all such operation as measurement of radiation, air pumping, results typing, generation of internal control signals, tape shifting and others are realised.

At the end of each cycle the date /day, hour and minutes/ together with measured dust concentration are also typed by the printer. Then the monitor waits for the next starting signal from the internal clock to start a new measuring cycle.

The dust monitor AMIZ consists of 5 unit /Fig. 1/: 1 - pumping unit, 2 - measuring head, 3 - air inlet head, 4 - electronic control unit and 5 - printer. The units 1, 2 and 3 are installed in a kiosk at the open air. The units 4 and 5 can be placed in some distance from the kiosk. Measuring head /2/ and electronic control unit /4/ are fed from mains 220 V, 50 Hz.

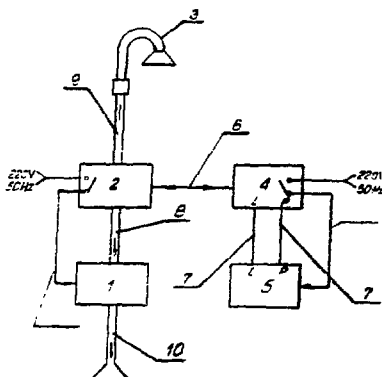


Fig. 1. Block diagram of dust monitor AMIZ: 1 - pumping unit, 2 - measuring head, 3 - air inlet head, 4 - electronic control unit, 5 - printer, 6,7 - cable, 8, 9 - air ways

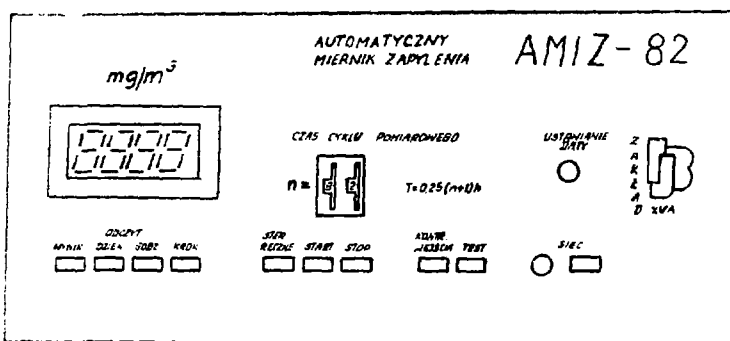


Fig. 2. Electronic control unit of dust monitor AMIZ

After a suitable subrange was selected and button "START" pressed, the dust monitor can work automatically up to the end of filter tape. The store of the filter band on the reel is sufficient for 2000 independent measurements.

The dust monitor was calibrated by the gravimetric method, and its indications were compared with those of the Aspirator for a long time by Environment Protection Establishment /Fig. 3/.

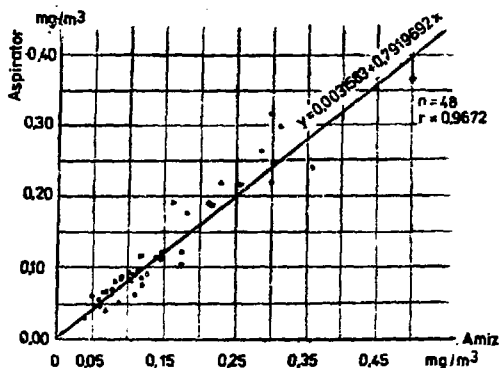


Fig. 3. Correlation between dust monitors ASPIRATOR and AMIZ

This test has shown very high correlation factor  $r = 0.9672$  between results obtained with both instruments.

Standard error of the monitor AMIZ is  $\pm 0.005 \text{ mg/m}^3$ , if cycle selector was set in position  $n = 1$ . This is theoretical figure only, since usually  $n$  is greater than 1 and practical accuracy is much better. For instance, if  $n = 4$  /it corresponds to the duration of measuring cycle 1 hour/ and dust concentration of  $5 \text{ mg/m}^3$ , accuracy of obtained results can be estimated as 2.5%. The best accuracy can be expected in these cases when mass of the deposited dust varies from 100 to 500  $\mu\text{g}$ .

#### PORTABLE DUST MONITOR PIK - 10

The portable dust monitor PIK is intended for air monitoring in open areas and also in closed rooms at working places. The instrument measures the total mass of airborne dust particles of which collects non-respirable fraction of the dust.

The principle of determination of the mass concentration is the same as in the station monitor AMIZ, i.e. absorption of beta rays by the dust layer deposited on a thin mylar film /Fig. 4/. Dust is collected by mini-conimeter /23/ which impact nozzle is also used for collimation of the beta rays.

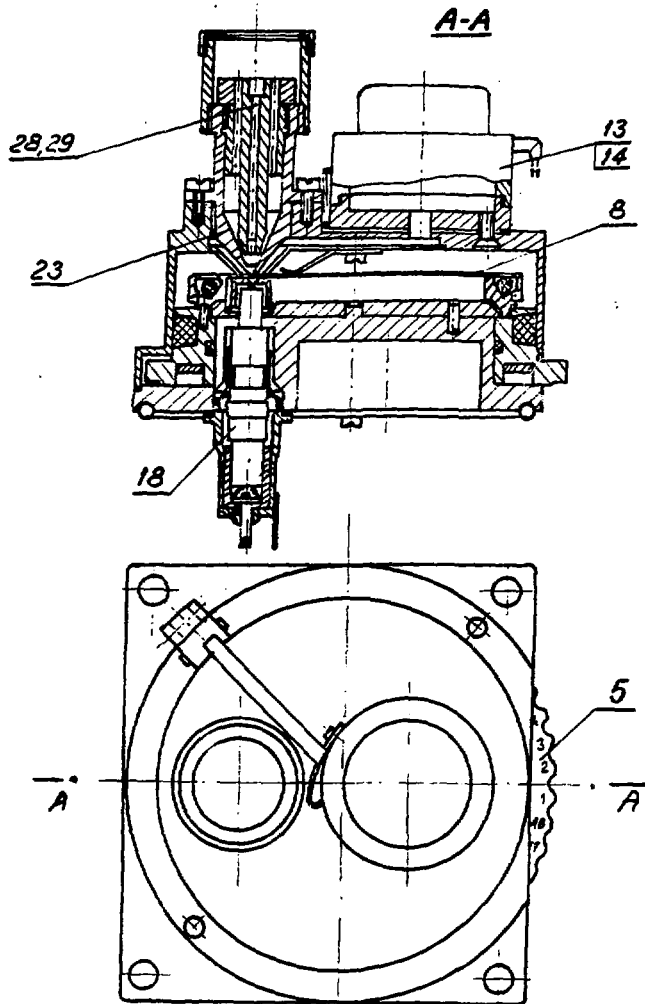


Fig. 4. Measuring head of dust monitor PIK

Air stream with great velocity passes through the impact nozzle of the conimeter and strikes the mylar film /8/ just under outlet of the nozzle. In such conditions the particles suspended in the air are deposited on the mylar, which is covered with thin layer of adhesive substance. The dust is collected on the mylar film in a circular area of well defined diameter of about  $5\text{ mm}^2$ . The mass of dust layer is of about few micrograms.

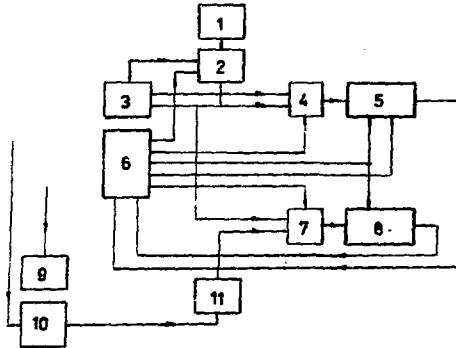


Fig. 5. Block diagram of dust monitor PIK: 1 - time selector, 2 - corrector, 3 - clock generator, 4, 7 - commutators, 5, 8 - counters, 6 - control unit, 9 - pump supply, 10 - H.V. supply, 11 - measuring head

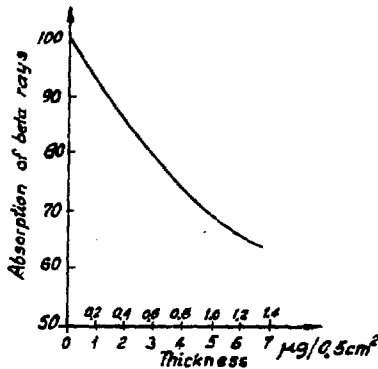


Fig. 6. Calibration curve of dust monitor

The air stream passing through the impact nozzle is forced by membrane pump /13, 14/. The air flow is constant and the standard time of dust sample collection is 30 min. Selection of measurement sub-ranges is accomplished by changing pumping time. The collected sample of the dust is irradiated by a collimated beam of beta rays from point source of  $\text{Pm-147}$  of activity  $74\text{ MBq} / 2\text{ mCi} /$  and active area of  $1\text{ mm} / 28, 29 /$ . Mini G-M tube type N 202 with the

window of diameter 3.2 mm and dead time  $50 \mu\text{s} / 18/$  is used as beta rays detector. Such radiometric arrangement assure sensitivity of measurements. In the developed model of dust monitor PIK-10 the lowest detectable mass of deposited dust is  $5 \mu\text{g}$ .

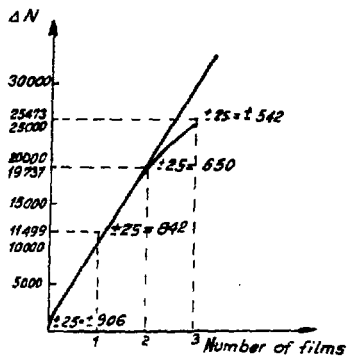


Fig. 7. Calibration curve as a function of number of mylar films

Operation of the instrument is very simple. Operator has only to select suitable measuring sub-range /connected with the time of air pumping/, change position of the disc /5/ with mylar film and switch on power supply. The instrument works automatically in 5 successive steps:

- 1/ measurement of the clean mylar film without dust/,
- 2/ air pumping,
- 3/ measurement of mylar film with deposited dust,
- 4/ data processing,
- 5/ display results in dust concentration units.

The disc from mylar film can be used for 48 independent measurements, and after being cleaned and covered with new adhesive layer can be used again.

## PERFORMANCE OF DUST MONITORS

### AMIZ

|                                      |                          |
|--------------------------------------|--------------------------|
| Measuring range:                     | $.005-4 \text{ mg/m}^3$  |
| Minimum detectable concentration:    | $.002 \text{ mg/m}^3$    |
| Mas of dust deposited on the filter: | min. 1 mg, max 1 mg      |
| Air flow rate:                       | $1 \text{ m}^3/\text{h}$ |
| Sampling time:                       | $.25 - 24 \text{ h}$     |

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Number of independent measurements: 2000  
Temperature range: 0 - 40°C  
Power supply: 220 V, 50 Hz, 400 VA  
Dimensions:  
    pumping unit 580x395x315 mm  
    measuring head 400x230x140 mm  
    control unit 570x350x180 mm

## PIK

Measuring range: .03-7 mg/m<sup>3</sup>  
Pumping time: 30 minutes  
Number of measurements: 48  
Power supply: 12 V, .5 A  
Dimensions: 250x110x95 mm

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