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SHIELDING IN NUCLEAR ENGINEERING. COLLECTION OF ARTICLES.

(SELECTED ARTICLES)

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EDITED TRANSLATION

SHIELDING IN NUCLEAR ENGINEERING.
COLLECTION OF ARTICLES.
(SELECTED ARTICLES)

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09 English Title
THE ROLE OF PROTECTIVE SHIELDING IN RADIATION SAFETY SYSTEMS

43 Source
ZASHCHITNYYE POKRYTIYA V ATOMNOY TEKHNIKE. SBORNIK STATEY (RUSSIAN)

42 Author GOROBINSKIY, S. M.	**98 Document Location**
16 Co-Author NONE	**47 Subject Codes** 18
16 Co-Author NONE **16 Co-Author** NONE **16 Co-Author** NONE	**39 Topic Tags:** nuclear engineering, nuclear radiation, radiation, reactor shielding, contamination

ABSTRACT: The author discusses the organization of a reliable system of radiation safety in its very broadest terms, pointing out the importance of the strict observation of permissible contamination levels. The entire range of the problem of surface contamination is examined and the causes for such contamination are listed and discussed. Particular attention is given to the relation which exists between the degree of contamination of equipment and structural surfaces and aerosol activity in the air. The views of different authors on this problem are examined and criticized. The author advances the premise that one of the fundamental postulates of radiation security must be the radical reduction of the possibility of contamination of the surfaces of production shops and equipment. It is pointed out that, at the present-day state-of-the-art, the primary emphasis in this direction must be layed on the utilization of such construction and finishing materials, from which contamination can be easily removed. The fundamental requirements of good shielding materials are discussed, with the author calling for the replacement of stainless chrome-nickel steel by more accessible and more easily deactivated materials. The shielding potential of different polymer and lac dye materials are discussed and the advantages of formula 57-40 masticated rubber for this purpose are analyzed briefly. English translation: 7 pages.

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09 English Title
ADHESIVE LAYER AS PROTECTIVE COATING AGAINST RADIOACTIVE CONTAMINATION

43 Source
ZASHCHITNYYE POKRYTIYA V ATOMNOY TEKHNIKE. SBORNIK STATEY (RUSSIAN)

42 Author IVANOVA, T. G.	**98 Document Location**
16 Co-Author GUS'KOVA, N. I.	**47 Subject Codes** 18, 11
16 Co-Author NONE **16 Co-Author** NONE **16 Co-Author** NONE	**39 Topic Tags:** radioactivity, radioactive contamination, radiation shielding, adhesive, nuclear shielding, epoxy adhesive

ABSTRACT: One of the types of films used for surface shielding is roll-film material with a non-drying, adhesive layer applied to one side. The use of films is said to simplify considerably the technology of gluing the surfaces to be protected, while eliminating the use of harmful and flammable solvents. As a result of experimental work, such roll-film materials for shielding purposes against radioactive contamination were developed on a polyethylene and polyvinylchloride base. The following considerations were considered fundamental: 1) the formula of the base film must provide minimal sorption and easy desorption (deactivation) of radioactive contaminants; 2) the formula of the non-siccative glue must have good adhesion to various construction materials: concrete, metal, plaster; 3) the films with the adhesive layers must be capable of easy application to the surfaces to be shielded and, in case of necessity, easy removal and replacement. The authors discuss other specifications both of the films and of the adhesive glue layers, with special attention to a polyethylene film (0.1 - 0.14 mm in thickness), which may be washed free of radioactive contamination very easily, and an easily deactivated polyvinylchloride film (0.2 - 0.29 mm in thickness) of a specially selected formula. On the basis of experiments, the authors reached the following conclusions: 1) Polyethylene and polyvinylchloride films with an adhesive layer may be recommended for use, in working with radioactive materials, as temporary, easy-to-replace, shielding for vertical surfaces and for laboratory equipment, as a protection against radioactive contaminants and corrosion; 2) The formulas chosen for the base film provide deactivation of the protective shielding up to maximum permissible levels with mean levels contamination. The polyethylene films showed particularly good deactivation capability; 3) The formula selected for the glue layer provides good strength of adhesion of the films to metallic surfaces and satisfactory adhesion to cement and plastered surfaces, if these surfaces are prepared in accordance with certain recommendations discussed in the article. Orig. art. has: 1 figure. English Translation: 6 pages.

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0 **English Title** INVESTIGATION OF ORGANIC COATING MATERIALS FOR PROTECTIVE COATING FROM RADIOACTIVE CONTAMINATIONS

43 Source
ZASHCHITNYYE POKRYTIYA V ATOMNOY TEKHNIKE. SBORNIK STATEY (RUSSIAN)

42 Author GOROBINSKIY, S. M.	**98 Document Location**
16 Co-Author PANFILOVA, Z. YE.	**47 Subject Codes** 11, 18
16 Co-Author SPIRIBONOV, A. D.	**39 Topic Tags:** hydrogen atom reaction, radioactive contamination, nuclear shielding, reactor shielding, radiation shielding, lacquer
16 Co-Author NOSOVA, L. M.	
16 Co-Author SHUBR[illegible]KO, N. A.	

ABSTRACT : Lacquered materials are widely used for finishing processes in factories and technical equipment. The advantage of lacquered materials for the shielding of construction materials and technological equipment from radioactive contamination is the continuous, jointless coating of the surface during any of its configurations. The present investigation showed that the desorptive properties of lacquer coatings depend primarily on their chemical composition. Lacquers with oils and alkali-oil should not be used for surfaces contaminated by radioactive waste. It is advisable to use 1-20-61 enamels on an SVKh-40 base and commercial enamels on an SVKh-40 base with lacquer coatings. The most efficient protection of concrete against contamination is a shielding on a base of the high-molecular epoxy resins E-40, E-41, E-49 and ET-8. (see Fig. 1 of the Enclosure). It is possible to make shielding compounds consisting of lacquer coatings which ensure easy and complete decontamination (washing away of radioactive waste). Orig. art. has: 3 figures and 4 tables. English translation: 13 pages.

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Transliterated Title PRIMENENIYE EPOKSIDNYKH POKRYTIY DLYA ZASHCHITY METALLICHESKIKH I BETONNYKH POVERKHNOSTEY

09 English Title THE APPLICATION OF EPOXY COATINGS FOR PROTECTION OF METALLIC AND CONCRETE SURFACES

43 Source
ZASHCHITNYYE POKRYTIYA V ATOMNOY TEKHNIKE. SBORNIK STATEY (RUSSIAN)

42 Author TIKHOMIROV, V. B.	**98 Document Location**
16 Co-Author PANEVKINA, YE. A.	**47 Subject Codes** 11, 18
16 Co-Author NONE	**39 Topic Tags:** epoxy resin, corrosion, nuclear shielding, shielding, epoxy shielding, radiation protection
16 Co-Author NONE	
16 Co-Author NONE	

ABSTRACT : Shieldings made of epoxy resins are the most widely used protection against corrosion for buildings, communications, and equipment, including nuclear devices. In the U.S.A., epoxy shieldings are used to protect steel and concrete surfaces from a radiation of 10^9 rad and the simultaneous action of boiling water. Of the resins being manufactured in the Soviet Union, the high-molecular epoxy resins can be used for nuclear shielding. This type of epoxy resin has the best physical and mechanical properties. Different compositions of epoxy resins and solvents are listed in the article. Both air and heat drying can be used for them. An additon of 1% of melamino-formaldehyde resin is used to lower the surface tension of the epoxy compound, thus improving the coating. The viscosity of the resin is also important for the coating method. Common spray guns can be used for epoxy spraying. Orig. art. has: 3 tables. English translations: 6 pages.

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09 English Title METERS AND DOSIMETERS FOR STUDY OF PROTECTION AND THE PROTECTIVE PROPERTIES OF MATERIALS

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42 Author AVAYEV, V. N.	**98 Document Location**
16 Co-Author VASIL'YEV, G. A.	**47 Subject Codes** 18, 11
16 Co-Author YEGOROV, YU. A.	**39 Topic Tags:** radiation, concrete, neutron, gamma radiation, reactor shielding, radiation shielding, cement
16 Co-Author KUCHERYAYEV, V. A.	
16 Co-Author ORLOV, YU. V.	

ABSTRACT : Investigations that were conducted showed that heavy concrete gives more effective protection against neutrons and gamma-radiation. The addition of magnesium to the concrete somewhat increases the shielding properties as compared to concrete of Portland cement in the same density. The introduction of Boron compounds into the concrete greatly reduces the flow of thermal neutron. English translation: 19 pages.

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THE ROLE OF PROTECTIVE SHIELDING IN RADIATION SAFETY SYSTEMS

S. M. Gorobinskiy

In many instances the organization of a reliable radiation safety system in processing installations presents an opportunity for the practical utilization of radioactive substances and ionized emission. In a radiation safety system the maintenance of allowable standards of contamination by radioactive substances on the surfaces of building structures and equipment is of the highest significance.

The contamination of surfaces is dependent fundamentally on the nature of the work done with the radioactive substances and results from the following causes:

1) inadequate technological processes and equipment for working with radioactive substances, in particular, insufficient hermeticity of equipment and inadequate fueling arrangements with respect to compartments and isolation chambers;

2) performance of various maintenance and emergency jobs under conditions (when the hermeticity of the equipment is disturbed) in which the technological process either spills radioactive products or throws off radioactive gases or aerosols;

3) inadequate functioning of vacuum duct ventilation, violating the rules for transporting the product;

4) contamination of containers, instruments and protective clothing used by personnel, particularly of gloves and footwear, because of safety technique violations in working with radioactive substances.

Depending on the character and form of the radioactive contamination, radiation safety can concern the most diverse levels. Contamination can be localized on separate portions of the surface of the premises and equipment. Contamination of such character, for instance, is observed in leakage around atomic reactor steam generators. In other cases large surfaces can be subject to contamination by radioactive substances. This takes place either as the result of an accident, or following the spread of radioactive contamination by shoes and clothing from one area to another.

Depending on the character of the process, the isotopic composition of surface radioactive contamination can be extremely diversified which also, in significant measure, determines the radiation danger of the contamination. Surfaces contaminated by radioactive substances from the fission groups of isotopes with large half-life periods and large periods of semi-decomposition from the base substance present a danger as sources of surface beta and gamma rays. Such contamination leads to an increase in radioactive background in the processing plant and in all cases becomes a source of contamination to the arms, body and clothing of the workers.

The level of contamination of apparatus and surfaces of structural members is closely related to atmospheric contamination. These two factors have a mutual influence upon each other. The greater the contamination of the air by aerosols and gases, the more intensive is the contamination of surfaces. On the other hand, contamination of surfaces causes contamination of the surrounding air. Cross contamination occurs due to transfer of the minutest particles by abrasion from the surface in suspension, movement of air currents, and by the fall-out from aerosols; the transfer of contaminants by means of contact has important significance.

In the native and foreign literature there are works which explore the relationship between the activity of aerosols in the atmosphere of the premises and the radiactivity on the surfaces.

Several authors point out that a direct connection exists between the level of surface contamination and the content of radioactive material in the air, which depends on the nature of the surface coatings, the frequency of air exchanges, the general dust content in the air of the premises, and the chemical and physical properties of the radioactive contamination.

Chamberlin and Sterberi established that during dusty operations in a sealed area, surface contamination of one unit per square meter gives rise to a volume concentration of dust in the air of 4×10^{-5} units per cubic meter (for example, a microcurie/m^2 of surface gives 4×10^{-5} microcuries/m^3 of air).

The same authors indicate that during ordinary dusty operations in the open air, this magnitude decreases to 2×10^{-6} units/m^3 of air.

G. M. Parkhomenko and co-workers proposed a representation of the correlation between the levels of contamination of the surface and the air as the relationship between the MAC quantity (maximum allowable dose concentration) in the air to the level of surface contamination, expressed in 1000 alpha particles/150 cm^2·minutes. They found that this relationship under production conditions fluctuated within wide limits from 0.009 to 0.38, i.e., almost 40 times. The authors come to the conclusion that in the absence of external contamination sources of the surrounding air and given the dust content, the mean surface contamination equals 4200 beta particles/150 cm^2·minutes, giving rise to a concentration of 0.34×10^{-14} curies/liter of radioactive dust in the air. Given the mean level of surface contamination this is equal to 12,000 beta particles/150 cm^2·minutes; the concentration of radioactive dust in the air reaches the maximum allowable.

In the same case, when the radioactive contamination is comprised of beta and gamma active isotopes, this can lead to additional external radiation of the personnel. Thus Danster reached the conclusion that the dosage from a plane source of beta particles with energies from 0.5 to 1.2 MEV equals 7 rads/hr from 1 microcurie/cm^2. Taking an allowable value of dosage as 1.5 rads/week and allowing that the contamination need not exceed 0.1 the maximum allowable dose, he established a level of contamination equal to 4×10^{-4} microcuries/cm^2.

Therefore, surfaces contaminated by radioactive substances present an additional factor concerning the influence of radiation on the work force. Because of this one of the basic principles in radiation safety must be radical minimization of the possibility for contamination of the surfaces of the production premises and equipment. This is achieved either by eliminating the possibility for surface contamination, which at the present time is not always achievable in practice, or by utilizing materials of a design and finish that can be easily cleansed of radioactive contamination.

It is similarly essential to note that the utilization of difficult-to-deactivate coatings may prove to be the reason for an increase in the quantity of solid and liquid radioactive fall-out. This necessitates frequent changing of the floors, walls of the premises and of various equipment. Besides this, difficult-to-deactivate surfaces require a significantly greater expenditure of decontaminating solutions which, in addition, also produce an increase in the volume of liquid radioactive fall-out.

The utilization of ordinary traditionally designed and finished materials (poured concrete, brick, carbon steel, alkyd and oil paints) leads to the necessity for frequent removal and change of significant portions of the floors and walls.

In the past the lack of shielding materials possessing minimum sorption, good deactivation and wide availability forced the utilization of difficult-to-acquire chrome-nickel stainless steels as protective shielding for the floors and walls. Nevertheless, stainless steel does not completely satisfy the most important requirements of the shielding material problem since in many instances it is deactivated only with difficulty to established maximum allowable levels.

These enumerated conditions dictated the need for the development of materials which would guarantee the satisfaction of the following requirements:

1) replacement of chrome-nickel stainless steels and other structural building materials by products which are more available and easily deactivated;

2) cleanliness of working conditions resulting in decreased contamination of the manufacturing premises.

In past years the solution of this complex problem was attempted by creative collaborations of various specialists; chemists, hygienists, physicists.

The foundations of the work accomplished were several theoretical assumptions and principles which were developed as the result of a multitude of experimental investigations. An investigational task was carried out which allowed the principles for creating and evaluating materials for safety technology to be worked out. As a basic criterion (under the conditions of conserving the entire complex of essential material properties) the sorption and desorption properties of materials under conditions of frequent exposure to radioactive contamination were studied. A special methodical investigatory procedure was developed for this purpose. Investigation of a wide group of polymerized substances and their compounds with various components (plasticizers, stabilizers, fillers and others) under various conditions and by various methods preceeded the practical resolution of the question. This permitted disclosure of basic principles identifying the relationships of sorption-desorption properties (via the structural composition of a polymeric material) for the radioactive isotopes of various elements, and similarly the mechanism of change in the properties of materials under the influence of nuclear radiation. Based on the results of the conducted investigations a new principle was proposed for improving the desorption properties of polymerized shielding materials. It was founded on the introduction of an additive to the material which reacts on the material's surface as a self-regenerating exudation layer. This principle found its practical embodiment in the created formula for polyvinyl chloride - rubber mastic of composition 57-40 and 80, and similarly in other widely implanted compositions of polymerized materials.

The created materials satisfied the requirements by their general physico-mechanical and chemical properties, ease of deactivation, raw material availability and possibility of being manufactured in existing facilities.

Works concerning the creation of organic coating materials possessing special properties have great significance. Among the organic coatings worth note are compositions based on epoxy, polyester, polyvinyl chloride resins and several silicon organic compounds. These materials, to a significant degree, supplement the development of the previously-noted polymeric coatings and create the opportunity to reliably shield vertical structural members and several types of equipment.

At the present time in the USSR an assortment of polymerized and organic coating materials have been created which can be successfully adapted to serve as protective shielding in structural members and equipment. Similarly of significant importance are works in the area of perfecting methods of deactivation. These efforts are directed towards the creation of deactivating solutions for various materials independent of their sorption properties.

In this manner two routes of investigation were projected which must, in our opinion, supplement each other: on the one hand the immediate creation of easily deactivated polymerized materials; on the other, the development of deactivation methods fully applicable to structures and to the fabrication of materials.

It is particularly worthwhile to note that the quality and effectiveness of protective shielding exploitation in building structures depend not only on the use of the proper shielding materials, but also on the correct technique of applying these protective coatings. The connecting seams between the sections of protective coating must be hermetic and must possess the same properties as the basic shielding materials. This is important for reasons of cleanliness since it determines the possibility of effectively cleaning the applied shielding.

It is worth pointing out that high frequency bonding of rubber mastic of composition 57-40 gives a joint of generally higher quality than heated-air bonded installations which offer a significantly lower quality of protective shielding and necessitate its rapid replacement. The application of corresponding protective shielding lowers the radioactive influence on work areas by a significant level to maximum allowable limits, which evidences the important role of protective shielding in the overall field of radiation safety.

For long range successful application of protective shielding to building structures and equipment, answers to many questions are required ranging from the field of polymeric materials yet to be developed to the field of methodical procedures for their evaluation. Special attention should be paid to correct practical utilization of experimental results. One of the important problems in performing long range investigations on the development and evaluation of materials for protective shielding is the standardized and unified methodical acceptance of such investigations. It is essential, similarly, to establish standard radiometric instrumentation which would allow a massive quantity of evaluation to be performed on the deactivation of materials for protective shielding. Major significance is attached to the adoption of industrial processing technology to develop the highest quality polymer materials for protective shielding. Special attention should be directed to the overall coordination of investigative and constructional experiments carried out by various institutions concerned with the creation of protective shielding.

The resolution of the foregoing questions will accelerate practical realization of the efforts carried out in the area of protective shielding, and will make possible the widening of investigation in this field, essentially allowing the development of an effective system of radiation safety while utilizing radioactive materials.

USE OF SHEETS WITH AN ADHESIVE LAYER AS PROTECTIVE COATING AGAINST RADIOACTIVE CONTAMINATION

T. G. Ivanova and N. I. Gus'kova

One of the possible film forms for the protective shielding of surfaces is rolled sheet material with a nondrying adhesive layer preapplied on one side. The adaptation of sheets with a single-sided adhesive layer considerably simplifies the technology for bonding the protective surfaces and does away with the necessity for using harmful and flammable solvents in this operation.

As a result of experimental efforts, coating materials of this type for protective shielding from radioactive contamination were developed with polyethylene and polyvinyl chloride bases.

During development of the referenced materials, the following basic assumptions emerged:

1) the composition of the coating base must guarantee minimum sorption and easy desorption (deactivation) of radioactive contamination;

2) the composition of the nondrying adhesive must have good adhesion (stickiness) to varied structural materials, concrete, metals and plaster;

3) the sheets with adhesive layers must be readily appliable to the protective surfaces and when necessary must be easily removable for replacement with new ones.

As a result of this, a sheet of polyethylene (0.1-0.14 mm thick), from which radioactive contamination washes off exceptionally well, and a sheet of easy-to-deactivate polyvinyl chloride (0.2-0.29 mm thick) of specially chosen composition were selected to act as a base for the given materials.

Sheets of polyethylene are presently manufactured uncolored, while polyvinyl chloride is available in white, cream, pale blue and other colors.

The following basic requirements are set forth for the nondrying (nonhardening) adhesives used in adhesive tapes: preservation of adhesiveness over time, no constituent migration into the base sheet, high adhesive properties, and others. Nondrying adhesives based on raw low-molecular rubbers most completely satisfy these requirements. Therefore for the adhesive layer a composition of low-molecular polyisobutylene (molecular weight, 20,000) with the addition of high-molecular polyisobutylene (molecular weight, 118,000) was used for preservation of the essential cohesive properties. A thickness of 40-60 microns was adopted as the optimal thickness for the adhesive layer.

Polyethylene and polyvinyl chloride sheets with an adhesive layer are manufactured in the form of rolls. As a result of the high stickiness of the adhesive on the base sheet and the significant width of the panels (50 cm and more), unrolling the rolls required a great deal of effort. Besides this, while working with long (up to 3 m) panels in the gluing process, various sections of the sheeting tended to adhere to each other, which significantly complicated installation and degraded the quality of the coating.

During the first stage of our work a special dereeling apparatus was designed and built for application of adhesive sheets on walls which completely eliminated the occurrence of wrinkles and the accidental sticking of separate areas of the sheets to each other. Nevertheless, work with the apparatus required a great deal of physical effort for dereeling the rolls and did not simplify the gluing process.

One of the roads toward elimination of the cited technological weaknesses of adhesive sheets is the application of special interlayers to which the adhesive layer only minimally adheres. A large number of polymerized sheets and coatings on paper were investigated with the objective of selecting an appropriate composition. As a result of the investigation, the best interlayer was conceded to be paper with a nitrocellulose coating of a specially selected composition (a type of imitation leather on paper). At present, production processing has started using polyethylene sheeting with an adhesive layer (STU 30-12055-61) for protective coating with application of the mentioned paper interlayer (TU-35 LP No. 43-62).

The presence of a paper interlayer in adhesive sheets significantly simplifies the work of installation, which can be performed by two workers. When covering walls, one of the workers, having attached the upper end (from which the paper had been stripped) to the wall, continues to gradually attach the coating from the top down, smoothing it to the protective surface, during which the second worker strips the paper from the coating (see drawing).

Installation of a sheet with an adhesive layer on a vertical surface.

The coating of structural surfaces and appurtenances (enclosures, exhaust hoods, etc.) with adhesive layered sheets has been expertly performed. Coatings located in facilities over the course of three years were responsible for significantly lowering general contamination and radioactive background in the buildings. When coating the internal surfaces of enclosures, application of white-colored sheets also improves lighting. Adhesive sheets were used for covering the interior of a sanitary sluice where the coating was under conditions of high humidity and temperature. After two years of use, the maximum contamination of the coating reached 40,000 beta particles/150 $cm^2 \cdot min$. Following weekly deactivation with a 10% solution of nitric acid or with a solution of Petroff's catalyst (mixture of naphthalene-sulfonic acids and alkyl-aryl sulfonic acids), the residual activity level of polyvinyl chloride coatings (along the smear) consisted of 2-4000 beta particles/150 $cm^2 \cdot min$ while the polyethylene coating was cleansed practically to the background level. It is worth noting the specialized requirements in the preparation of undersurfaces for sticky coatings as opposed to preparation of undersurfaces for ordinary coatings with solidifying adhesives. In the latter case, best adhesion is achieved if the materials to be coated have a rough surface. To achieve this they are sandblasted, abraded with rough emery cloth, etc.

In sticky coatings, the reliability of adhesion increases in relation to the area of contact of the adhesive layer with the surface. Therefore, with such coatings in contrast to ordinary adhesives, the surface to be coated must be of maximum smoothness. Experience in coating various surfaces with sheets of adhesive layers on a polyisobutylene base showed that the sheets exhibit optimal adhesion to unpainted or painted metallic surfaces (stainless and carbon steel, dural and other metals).

When coating concrete surfaces the best results were obtained on rolled concrete and on surfaces after metallic sheathing. When wooden sheathing was used, it is essential to smooth the surface with a cement or some form of plaster. After such finishing, the surface must be level and smooth; the waviness of the surface must be no more than 10 mm for a wavelength of no less than 1 m, and the roughness -- no more than 0.2 mm.

Before applying adhesive sheets to finished or unfinished concrete surfaces, the top dustlike layer of the concrete or plaster is primed with an undercoat. Natural linseed oil, graphite-based undercoatings, synthetic latexes (for example, polyvinyl-acetate emulsion) or synthetic resin (perchloride, alkyd or other) can be used for undercoatings. Adhesive layers stick badly to surfaces coated with "Oxol" linseed oil.

If, after finishing, the surface remains rough with deep fissures from coarse sand fractures, additional spackling up to complete levelling is essential, followed by polishing, so that the surface is completely smooth.

The best spackling compounds for surfaces to be covered with adhesive polyisobutylene based sheets are: gypsum-cement, perchlorovinyl, water base latexes (cellulose type spackles), alkyd lacquers (spackle ASH-1) and natural linseed oil.

Colored opaque sheets with an adhesive layer can be applied to concrete surfaces with the aforementioned undercoats or spackling. Uncolored sheets, in particular the currently-produced uncolored polyethylene sheets, are preferably applied to painted, carefully prophylacticized surfaces. The final paint coat is best applied to the very same bonding agents that are indicated above for undercoating.

When the indicated requirements for preparing the surfaces were not observed, there was poor adhesion of sheets.

When experimentally coating with polyvinyl chloride sheets with an adhesive layer, significant shrinkage of the sheets was observed, as high as 5-7%, which led to a peeling away of the protective surfaces on concrete and spackled surfaces, despite the additional stickiness offered by the adhesive layer. Shrinkage was significantly less with polyethylene sheets with adhesive layers.

At present, mass production technology is being perfected for polyvinyl chloride sheets (to decrease stretching in the process of applying the adhesive layer), nevertheless it has still not proved possible to significantly decrease the shrinkage of the sheets following installation.

As was shown by experimental coating, a noticeable decrease in shrinkage of polyvinyl chloride sheets can be achieved during coating at the expense of preshrinking the sheets one by one before their installation on protective surfaces.

Thanks to their chemical stability, polyethylene and polyvinyl chloride sheets safeguard laboratory facilities not only from radioactive contamination, but also from the destructive properties of various chemical agents (corrosion). For example, for corrosion prevention an exhaust ventilation duct (of galvanized iron) in an analytic laboratory was coated with a polyethylene sheet with an adhesive layer. After three years of use, the duct showed no noticeable corrosion. Without this sheet coating, the duct needed replacement after several months.

Sheets with adhesive layers were used in a mill, with stationary shields as temporary, easily-removable coatings in order to protect structural members from radioactive contamination during maintenenace operations.

On the basis of experience in applying adhesive layered sheets as protective coating from radioactive contamination, the following conclusions can be drawn:

1. Polyethylene and polyvinyl chloride adhesive layered sheets can be expediently used during work with radioactive substances as temporary, easily-removable protective coatings from radioactive contamination and corrosion for vertical surfaces and laboratory facilities.

2. The selected compositions for the sheet bases (polyethylene and polyvinyl chloride) guarantee the deactivation of coatings up to allowably limited levels during medium degrees of contamination. Polyethylene sheets are particularly easily deactivated.

3. The selected composition of the adhesive layer guarantees durability of the adhesive properties of the sheet to metal surfaces and additional adhesiveness to concrete and spackled surfaces when these surfaces are prepared in accordance with the above mentioned requirements.

INVESTIGATION OF ORGANIC COATING MATERIALS FOR PROTECTIVE COATING FROM RADIOACTIVE CONTAMINATION

S. M. Gorobinskiy, Z. Ye. Panfilova, A. D. Spiribonov, L. M. Nosova and
N. A. Shubrenko

Of the materials usable at present for finishing manufacturing buildings and facilities, organic coating materials have a high specific gravity.

Application of organic coating materials as protective coating of structural members and technological facilities from radioactive contamination has priority over other materials, since they guarantee continuous seamless coating of the surface regardless of its configuration.

One of the basic requirements set forth for organic materials for use as protective coating for the surfaces of operating plants and laboratories and to further work with radioactive substances is minimal sorption of radioactive substances and washing them off as easily and completely as possible.

First attempts at investigating desorptive substances serially applied to enamels and lacquers showed that various organic coating materials have markedly different desorption characteristics.

Thus, widely used oil paints and, similarly, pentatal and glyptal enamels are practically nonwashable with reference to radioactive contamination. Their residual activity after the fifth contamination wash cycle remains at 60-70%.

Under identical conditions of use, enamels based on polyvinyl chloride resin and nitrocellulose lacquers wash off significantly better (residual activity after the fifth contamination wash in most cases does not exceed 9-13%).

In the foregoing works on the development of compositions of polyvinyl chloride rubber mastic and, similarly, compositions of rubber mixtures, it is shown that the desorption properties of materials depend to a large extent on their components, and interchange of one component with another of the same function often brings with it a change in the desorption properties of the material. Therefore it proved natural that even organic coating materials, depending on their components, have various desorption characteristics.

The sorption properties of systems of organic coatings, applicable for protecting surfaces from contamination by radioactive substances are basically established in the upper or coating layer. The coating layer in a system of organic coatings, as a rule, appears as an enamel or lacquer.

As is known, the basic component of enamel or lacquer is a film-forming substance; besides this they may contain plasticizers, and in enamels perhaps dyes, pigments or fillers. In order to identify the influence of each component added to one or another composition on the desorption properties of the coating, special investigations were conducted.

Basic examples of film-forming substance from various classes were submitted to test; initially, bonding agents were used in which film forming occurs under normal temperatures (18-20°C), i.e., without special heating. Sorption-desorption characteristics of the investigated film-forming substances are shown in Figure 1.

Following from the graph, films based on oil and alkyd-oil film-forming substances, after the first cycle of contamination-washing already have a residual activity above 2%, while after the fifth contamination, residual activity reaches 36%. Besides, the worst results were exhibited by films of linoleic natural boiled oil, lacquer based on PFL-3 resin, lacquer 170 and resin FKHT 15/02.

Unsatisfactory desorption characteristics are also shown by films of polyvinyl butyryl, butadiene styrene latex SKS-65, low viscosity polyvinyl chloride resin KHV and resin 101.

One group of film-forming materials with good desorption characteristics consists of epoxy lacquer resins E-41, E-49, ET-8, copolymer SVKH-40, polyvinyl chloride resin SPS, copolymer BMK-5, resin AS, fluorpolymers 32L and 42L, polystyrene, silicon organic lacquers K-55 and K-57, lacquer OUR-930, and polyester lacquer KHKL. The residual activity of samples of these materials does not exceed 1% after five investigative contamination-wash cycles.

For checking out the influence of plasticizers, pigments and fillers on the desorption characteristics of a lacquer film, polyvinyl chloride resin SPS was selected as a reference substance. Selection of this resin was based on the fact that it combines well with various plasticizers, pigments and fillers, and lacquers using it as a base dry quickly at normal temperature.

The influence of the most commonly used plasticizers and fillers was investigated.

The plasticizers diphenyl chloride, tricresylphosphate, chloroparaffin and dibutyl phthallate, when introduced into film-forming substances in quantities up to 20-30%, do not evidence noticeable influence on the desorption properties of the film. Introduction of plasticizers in quantities in excess of 30% decrease the washability of the coating somewhat.

The investigation results of the effect of pigments on the desorption properties of a lacquer film are shown in Figure 2. From this figure, it follows that introduction of any of the checked-out pigments to some extent or other will degrade the desorption properties of lacquer films. In examining the dynamics of residual activity accumulation on pigmented films, it can be seen that investigations on pigments for degrees of influence on the desorption characteristics of lacquer films separate into several groups. Red oxide, chromic oxide, graphite, ash, titanium dioxide in rutile form and in the form of hydrotitanite, ferrous minium, lead oxide,

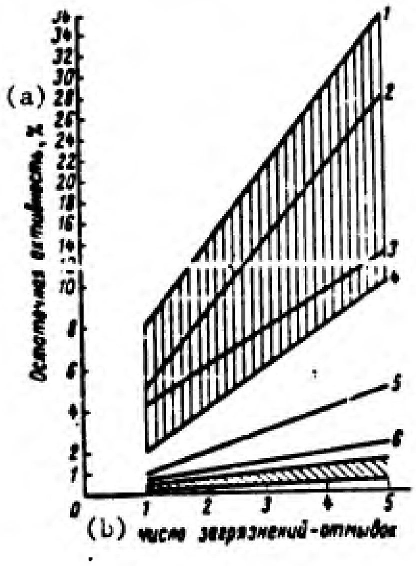

Figure 1. Sorption-desorption properties of film-forming substances. Key: (a) = residual activity,%; (b) =number of contamination-wash cycles; 1 = linseed oil; 2 = polyvinyl butyryl; 3 = butadiene styrene latex SKS-65; 4 = lacquer FL-02; 5 = low viscosity polyvinyl chloride resin KHV; 6 = lacquers SVM-515 and MS-25; vertical cross-hatching = lacquer 6 s, lacquer 4 s, lacquer based on resin PFD-4, lacquer based on resin PFL-3, lacquer FL-2, lacquer 170, resin FKHT 15/02; diagonal cross-hatching = copolymer SVKH-40, polyvinyl chloride resin SPS, copolymer BMK-5, resin AS, fluorpolymers 32L and 42L, ternary copolymer, polystyrene, lacquers K-55 and K-57, lacquer OUR-930, lacquer KHKL, lacquers based on epoxy resins E-41, E-49 and ET-8.

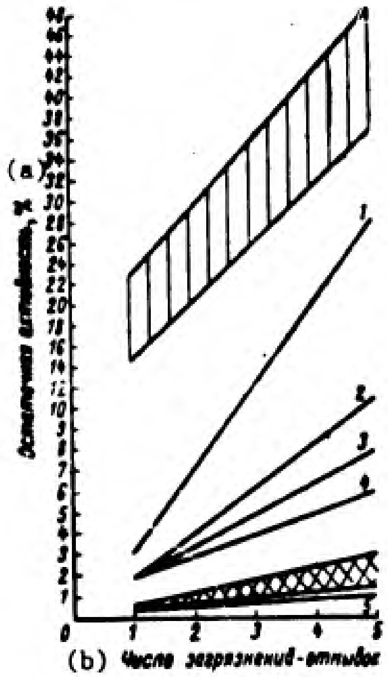

Figure 2. Influence of fillers and pigments on desorption properties of film-forming substances. Key: (a) = residual activity, %; (b) = number of contamination-wash cycles; 1 = zinc oxide; 2 = milori blue; 3 = ocher; 4 = kaolin, talc, ultramarine; 5 = polyvinyl chloride lacquer; vertical cross-hatching = strontium chromate, powdered aluminum, chalk, mica; diagonal cross-hatching - yellow lead chromate, red lead, ferrous minium, red oxide, ferric oxide pigment, titanium dioxide, magnesium titanate, chrome oxide and barite.

yellow lead chromate, magnesium titanate and red iron oxide pigment belong to the group of pigments whose introduction has little influence on the deactivatability of the lacquer films. The residual activation of lacquer films after the addition of pigment and following the fifth cycle of contamination-washing does not exceed 2.5%. The second group is comprised of pigments whose addition into lacquer raises the residual activity of such lacquer films to 10% following the fifth cycle. Monastral blue, lithopone, orange lead chromate, ultramarine, ocher, Milori blue and red cadmium belong to this group. Finally, addition of such pigments as zinc oxide, yellow zinc chromate, alumina powder and strontium chromate to the lacquer decreases to a significant degree the desorption properties of corresponding films. The residual activity after the fifth contamination reaches 30-50%, i.e., the films become practically undeactivatable.

Various fillers, which can be introduced during the preparation of paints, similarly proved different in regard to their influence on the desorption properties of colored lacquer films. The results of these investigations are presented in Figure 2. Introduction of kaolin and talc into the lacquer degrades it somewhat while chalk and mica significantly worsen the desorption properties of organic films. The residual activity in the latter case reaches 40% after the fifth contamination. Only films filled with barite have satisfactory desorption characteristics (their residual activity after the fifth contamination does not exceed 2.5%).

After having shown the effect of the individual components on the desorption properties of the coating, it appeared possible to select organic materials which would give easily deactivatable coatings with a uniquely necessary complex of general properties.

Among the number of film-forming materials manufactured at the present time satisfying all these requirements are such resins as epoxies, polyvinyl chloride, polyesters, silicon organics and copolymer SVKH-40.

Epoxy resin-based coatings are particularly suitable for protecting concrete surfaces, to which they adhere extremely well. Thanks to the fact that epoxy resins allow us to prepare enamels and lacquers with a large concentration of solids (up to 50%), they satisfactorily fill all the nonuniformities in the surface and allow a quality coating on concrete in three to four layers. Epoxy resins are also a fine protective material for metals. The coatings are characterized by high chemical and radiation stability, water repulsion, resistance to abrasion and exceptionally good adhesion to many structural materials: concrete, cement, cinder block, brick, spackling, stucco and others.

One of the valuable properties of several brands of epoxy resins is their resistance to organic solvents, particularly to ethers. Epoxy resin-based organic films endow surfaces with good properties: smoothness, hardness and glossiness. All of this guarantees their application under conditions where strong solutions are used for washing off radioactive contamination.

As indicated by Maslow [2], the walls of one wing of the Brookhaven National Laboratory (Long Island) are protected by a similar coating. With the object of eliminating radioactive contamination, the walls are subjected daily to deactivation with hot sodium hydroxide. The walls are then clean and the coatings are not damaged.

According to the data of Culshaw [3], epoxy resins give a single, air-drying coat of up to 500 microns thick for use in atomic power plants [Bradwell] which is satisfactory to resist abrasion, is stable under radiation and can resist the activity of strong acids and detergents.

Abroad at the present time, there is widespread application of epoxy resin- and coal tar-based substances for coating underground steam pipes, the internal lining of pipes, and cisterns [4]. Compositions based on epoxy resins with quartz powder used as a filler are outstanding because of their great stability to abrasion and are applicable as coatings for floors in mercantile and manufacturing buildings.

Native industry produces epoxy resins of brands ED-5, ED-6, E-30, E-40, E-41, E-49, ET-8 and others.

Depending on the hardening conditions (nature of the hardener, temperature and time of hardening), the very same resins develop coatings differing in both their general and specific properties. Epoxy resins, under conditions of hot curing, give more chemically stable, thermostable and water stable coatings than under conditions of cold curing. High molecular weight resins give higher quality coatings than low molecular weight resins [5].

In the present work the sorption-desorption properties of lacquer coating based on resins ED-5, ED-6, E-40, E-41, E-49, ET-8 are verified.

Table 1 and Figure 3 present the results of washing on lacquer coatings based on various epoxy resins after the fifth contamination.

From the evolving data it is seen that the sorption-desorption properties of lacquer coatings based on epoxy resins are dependent to a large degree on the

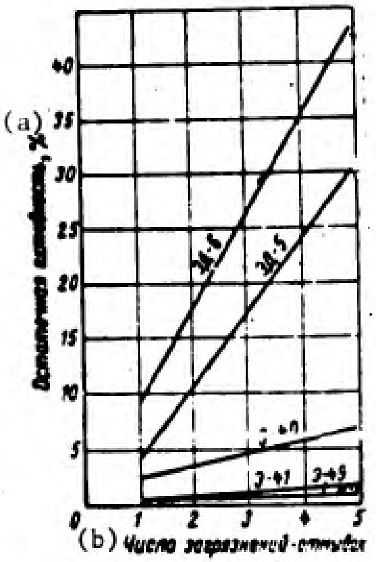

Figure 3. Sorption-desorption characteristic of coating based on various brands of epoxy resins. Key: same as in Figure 1.

TABLE 1. RESIDUAL ACTIVITY AFTER THE FIFTH CONTAMINATION OF COATINGS BASED ON EPOXY RESINS OF VARIOUS MOLECULAR WEIGHTS.

Coating	Resin	Molecular weight	Epoxy number	Hardener at 18-20°C	Residual activity after the fifth contamination, %
ED-5 D-6	ED-5 ED-6	400-500 450-500	22.5 20-22	polyethylene-polyamine	30.0 42.0
lacquer E-4001	E-40	600	18-20	hexamethylendiamine	6.5
lacquer E-55	E-41	1500	9-13	hexamethylendiamine	1.5
lacquer EP-079	E-49	3000	2-4.5	diethylene glycol urethane	0.9
lacquer EP-710	ET-8	-	5-7	toluylene diisocyanate	0.9

molecular weight of the resin. The higher the molecular weight of the epoxy resin, the more easily will radioactive contamination wash off. This is possibly explained by the presence of many reactive epoxy groups in low molecular weight resins which neccessitate a large quantity of hardener for curing. As was indicated above, amines were used as hardeners (polyethylene polyamine, hexamethylene diamine). The higher the molecular weight of the resin, the lower the quantity of epoxy and hardener required for curing. A coating based on such a resin permits better washing off of radioactive contamination. It is established [6] that introduction of amines into polymeric materials (polyvinyl chloride compositions, polyethylene, resin mixtures) to a noticeable degree degrades their sorption-desorption properties.

Radioactive contamination washes off very badly from epoxy resins ED-5 and ED-6 (low molecular weights). They also have a residual activity of 30-40% after the fifth contamination-wash cycle. Because of this, coatings based on them cannot be applied for protective purposes.

The supposition that the cause of difficult decontamination of coatings based on ED-5 and ED-6 is due to incomplete curing under normal temperatures was not verified. Heating the coating at a temperature of 80°C for 10 hours, which guarantees full cure according to experimental data, does not change the sorption-desorption characteristics.

A major improvement of these properties for resins ED-5 and ED-6 can be achieved by the adaptation of acid-type hardeners and by performing the hardening process at a high temperature (150°C) -- hot curing.

Table 2 shows the influence of the hardening temperature on the sorption-desorption properties of coatings containing various epoxy resins.

TABLE 2. INFLUENCE OF HARDENING CONDITIONS ON SORPTION-DESORPTION PROPERTIES OF PROTECTIVE COATINGS

Coating	Hardener	Curing temperature, °C	**Residual activity (%) after the fifth contamination-wash cycle**				
			1	2	3	4	5
resin ED-5	**PEPA - phthalic anhydride**	**18-20**	**3.5**	**9.5**	**17.0**	**25.0**	**30.0**
		150	**1.1**	**1.4**	**1.8**	**2.0**	**2.2**
resin ED-6	**ditto**	**18-20**	**5.0**	**15.0**	**29.0**	**37.0**	**42.0**
		150	**1.2**	**1.6**	**2.0**	**2.5**	**3.0**

TABLE 2. (Continued)

Coating	Hardener	Curing temp-erature, °C	Residual activity (%) after the fifth contamination-wash cycle				
			1	2	3	4	5
lacquer E-4001 on resin E-40	hexamethylenediamine	18-20 100	2.7 0.4	4.2 0.6	5.0 0.8	5.8 1.1	6.5 1.3
lacquer EP-079 on resin E-49	diethylene glycol urethane	18-20 160	0.5 0.4	0.6 0.5	0.7 0.5	0.8 0.6	0.9 0.9
lacquer EP-710 on resin ET-8	product 102T	18-20 100	0.3 0.2	0.4 0.4	0.5 0.5	0.7 0.6	0.9 1.0

From Table 2 it is seen that for the low molecular weight resins ED-5, D-6 and also E-40 the hardening process exerts a great influence on the sorption-desorption properties. Samples of coatings ED-5 and ED-6, prepared using phthalic anhydride as a hardening agent, and hardened at a temperature of 150°C, have, after the fifth contamination-wash cycle, a residual activity of 2-3%, i.e., they clean off significantly better than analogous coatings formed by hardening with amines.

For high molecular weight resins E-49, ET-8, a similar phenomenon is not observed. Lacquer coatings based on E-49 and ET-8 clean off equally well both under cold and hot hardening and have a residual activity of 1% after the fifth contamination.

Cold-cured epoxy lacquers based on high molecular weight resins E-41, E-49, ET-8, give easily deactivatable coatings and seem unquestionably interesting as protection for large surfaces. However, lacquers as such are seldom utilized as protective coatings. In order for coatings to exhibit anticorrosion, thermostability, decorative and other properties, it is essential to introduce various pigments, fillers, plasticizers and other additives into the lacquer, but the introduction of additives, as a rule, degrades the sorption-desorption properties of the coating, as could be seen with polyvinyl chloride and other materials.

Besides coating with pure resins, epoxy enamels and systems of coatings based on ED-5, ED-6 and ED-41 were checked out from the point of view of sorption-desorption properties when used as waterproofing materials for protecting concrete surfaces (Table 3).

TABLE 3. SORPTION-DESORPTION PROPERTIES OF ENAMELS AND SYSTEMS OF PROTECTIVE COATINGS BASED ON EPOXY RESINS

Coating with cold curing (amines)	Resin	Residual activity (%) after 3 contamination-washes		
		1	2	3
grey enamel EP-711	ET-8	0.4	0.8	1.4
white enamel EP-711	ET-8	0.1	0.6	0.8
white enamel EP-56	E-41	0.8	1.2	1.8
green enamel OEP-4171	E-41	0.7	1.0	1.5
coating system based on ED-5	ED-5	5.5	20.0	56.0
coating system based on ED-6	ED-6	5.5	14.5	55.5
coating system based on E-40 and E-41	E-40 & Ye-41	1.0	2.2	3.2

The evolved data once more verify that coatings based on epoxy resins ED-5 and ED-6 cannot be applied as a protective, since they do not satisfy the necessary cleansability requirements for radioactive contamination. Significantly better cleansability from radioactive contamination is exhibited by coatings of enamels EP-711, OEP-4171, EP-56.

Arising from the presented data, and simultaneously considering good adhesion, high system concentration, and conditions of drying, epoxy coatings based on resins E-41 (enamel OEP-4171, OEP-4173, EP-56) and ET-8 (enamel EP-711) can be recommended when coupled with the overcoating of particularly vulnerable spots with lacquer based on the same resin for protecting concrete.

Organic coating materials based on perchlorvinyl resins and copolymer SVKH-40 are almost equivalent and at the present time are widely available from the organic coating industry. They can be applied to any surface on a corresponding undercoat.

It is practical to apply them to smooth surfaces: to metal, spackling or wood. Organic coating materials based on copolymer SVKH-40 [7] and perchlorvinyl resist exceedingly well the action of dilute solutions of acids, bases, benzines and mineral oils, and excel in low flammability. They are nontoxic, odorless, dense, and elastic. Their drying time at 18-20°C is no more than two hours. Nevertheless, all such products from the industry producing so-called chemically stable enamels based on copolymer SVKH-40 and perchlorvinyl, so far do not satisfy the requirements for deactivation.

A deactivatable enamel, 1-20-61, light rose in color and based on copolymer SVKH-40 has been developed and produced.

The evaluation results of its sorption-desorption properties are shown in Table 4.

TABLE 4. SORPTION-DESORPTION PROPERTIES
OF ENAMEL BASED ON SVKH-40

Brand of enamel	Resin	Basic pigments	Residual activity after 5 contaminations, %
enamel 1-20-61	SVKH-40	titanium dioxide, barite, red oxide	3
white VKHE-4001 grey VKHE-4023	SVKH-40	zinc oxide, lithopone	12-14
lacquer VKHL-4000	SVKH-40	-	2

From the table it follows that enamel 1-20-61 has good desorption characteristics. The residual activity of samples of this enamel after the fifth contamination does not exceed 3%.

The residual activity of coatings from the series of enamels VKHE-4001, VKHE-4023 after the fifth contamination-wash constitutes 12-14%. The unsatisfactory desorption characteristics of these enamels can be explained by the identification of such pigments as zinc oxide in their formulations. Overcoating the enamels with lacquer improves the desorption characteristics of the coating in all cases.

An especially good desorptive coating can be achieved with polyester lacquer KHKL-1. Lacquer KHKL-1 exhibits good adhesion to wood, concrete, ceramic and slate. Coatings based on this lacquer excel in transparency, hardness, gloss, light and temperature stability, mold resistance, stability to humidity, acid and bases of medium concentration, kerosene, benzine and acetone and is distinguished by a red exterior appearance. On a horizontal surface we can achieve a nonshrinkable coating of lacquer KHKL-1 of any thickness with a single application. The drying time is 24 hours at a temperature of 18-20°C. The hardened coated surface can be subjected to abrasion and polishing.

With the aim of finishing up the practical technology of application and verifying the developed systems of organic coatings under working conditions, the following painting was performed: enamel EP-56 based on epoxy resin E-41 on concrete surfaces, enamel 1-20-61 based on copolymer SVKH-40 on spackled walls and ceilings, and also on panels of stainless steel.

CONCLUSIONS

1. The desorption properties of organic coatings to a great extent are dependent on their chemical composition (film-forming substances, pigments, fillers). It is established that organic coatings based on oil and alkyd-oil film formers are practically nondeactivatable; therefore enamels based on them must not be applied as protective coatings on surfaces contaminable by radioactive substances.

2. Enamel 1-20-61 based on copolymer SVKH-40 and also the serially introduced enamels based on perchlorvinyl and SVKH-40 with an overcoat by the corresponding lacquer are recommended as protective coatings from radioactive contamination in place of oil and alkyd-oil enamels.

3. A coating based on high molecular weight epoxy resins E-40, E-41, E-49 and ET-8 is most effective for protecting concrete against radioactive contamination.

4. The investigations carried out provide the opportunity to prepare formulations of organic protective coatings, guaranteeing easy and effective deactivation (washing off the radioactive substances).

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THE APPLICATION OF EPOXY COATINGS FOR PROTECTION OF METALLIC AND CONCRETE SURFACES

V. B. Tikhomirov and Ye. A. Panevkina

At the present time in atomic technology, coatings based on epoxy resins are one of the most widely used forms of corrosion protection in structural installations, communication and instrumentation, in that order. It is well known, for example, that in the U.S.A. epoxy coatings protect steel and concrete surfaces, withstanding radiation doses of 10^9 rads and simultaneous attack with boiling water [1].

The existence in the U.S.S.R. of mass-produced epoxy resins creates the opportunity for application of epoxy coatings for protection of metallic and concrete surfaces.

Several of the known ready-made epoxy materials, produced industrially, can also be used in atomic technology. The investigations we conducted showed that any preference directed at this purpose should be accorded with materials based on high molecular weight epoxy resins. This is related, first of all, to the fact that coatings based on high molecular weight epoxy resins (E-41, E-49, Czechoslovakian resin CHS-epoxy 2000, and others) are outstanding because of their physico-mechanical properties and a relatively high period of utility in adverse environments (Table 1). Data on the life of epoxy coatings in adverse environments are presented in Table 1. We obtained these data by application of the methodology described below [2].

Besides this, it is known that high molecular weight resins, as compared to low molecular weight resins, guarantee the creation of coatings with better sorption-desorption characteristics.

Based on high molecular weight epoxy resins we have developed formulations of epoxy compositions (lacquer and enamel) which permitted the creation of coatings with good protective properties. High molecular weight resins (E-41, E-49, CHS-epoxy 2000), melamine formaldehyde resin, dibutylphthalate, titanium dioxide (in

TABLE 1. COMPARISON OF PROPERTIES OF COATINGS BASED ON VARIOUS BRANDS OF EPOXY RESINS, HARDENED WITH POLYETHYLENE POLYAMINE AT 20°C.

Resin	Molecular weight	Thickness of coating (microns)	Hardness of coating per M-3	Elasticity on the NIILK scale, mm	Shock resistance per U-1, (kg-cm)	Useful life in 30% HNO_3 at 30°C, hrs
ED-6	500	300	0.89	20	24	170
E-41	900-1000	300	0.84	1	50	540
E-49	3000	300	0.85	3	50	610

enamel) and thinner P-5 go into the make-up of these compounds.

For curing these substances polyethylene polyamine is quite convenient, allowing the achievement of a high quality coating both under air drying and heat drying (polyethylene polyamine is introduced, following contents of epoxy groups in the selected resins).

On the basis of the investigations we conducted, it was decided to introduce about 1% melamine formaldehye resin into the epoxy organic materials since this lowers the surface tension of the epoxy mixture, improving its fluidity on the surface to be covered and removing defects in the film coating.

Examination of the epoxy coatings, developed on the basis of the studied materials, showed that they have relatively good sorption-desorption properties and long working life in adverse environments. Mixing of epoxy materials with a hardener must be carried out independently before applying the coating. After this, the mixture must be used within 2-3 hours, since its viscosity quickly increases (Table 2).

During preparation of epoxy compounds, it is important to take into consideration what method will be subsequently used for their application to the surface -- by brush or by spray -- since in each of these cases a different working viscosity is required. Through the results of the investigations conducted, it is established that at temperatures of 18-20°C the working viscosity of epoxy compounds must

TABLE 2. EFFECT OF THE STORAGE LIFE OF EPOXY COMPOUNDS ON THEIR VISCOSITY (ACCORDING TO VZ-4)

Material	Hardener	Storage life (hrs)	Viscosity (secs)
epoxy lacquer from resin CHS -epoxy 2000	polyethylene polyamine	0	18
		1.0	18
		1.5	19
		2.0	20
		4.0	21
		6.0	23
		8.0	25
		24	40
undercoat E-4021	hardener #1 (50% solution hexymethylene diamine)	0	18
		1.5	24
		3.0	30
		5.0	39
		6.0	51

be at 17-19 secs (according to VZ-4) for application with a spray gun and 40-45 secs for application by brush. On relatively small pieces of work, the coatings can be applied by dipping. In this case, the working viscosity of the compounds must be equal to 18-22 secs.

A reliable protection of surfaces from corrosive effects of adverse environments is guaranteed, as was shown in our investigations, by the application of an epoxy coating consisting of five layers. Nevertheless, depending on the character of the surface to be covered, the coating substance and its thickness can vary (Table 3).

TABLE 3. EPOXY COMPOUNDS FOR PROTECTION OF METALLIC AND CONCRETE SURFACES

Surface to be covered	Thickness of coating (microns)	No. of layers	Identification of layers
metallic	300-350	4-5	1st layer of undercoating E-4021 2nd layer of undercoating E-4021 base layer of epoxy enamel ditto finish layer of epoxy lacquer

TABLE 3. (Continued)

Surface to be covered	Thickness of coating (microns)	No. of layers	Identification of layers
concrete	400-450	5-6	preparatory layer of epoxy resin spackling base layer of epoxy enamel ditto base layer of epoxy lacquer finish layer of epoxy lacquer

In protecting metallic surfaces first an undercoating is applied followed by enamel overcoated with lacquer (a layer is considered to be a coat achieved by applying the material in two mutually perpendicular directions).

In protecting concrete surfaces the first essential is a layer of enamel which, infusing the surface of the concrete layer and hardening there, acts for achievement of a nonporous coating. After application of the first (disclosing) layer of enamel, the application of spackling is recommended, first in those spots where unsound areas, flaws and porosity exists on the concrete surface. After spackling, enamel and two coats of lacquer are applied. The thickness of an epoxy coating on a metallic surface can be less than on concrete, since, in the latter case, there is more danger of getting a porous coating.

In the case of structural assembly works, as a rule the hardening of epoxy resins is performed by air drying. It was established that at 18-20°C, each intermediate layer must be maintained for 1-2 days, and the last layer, no less than 7 days. With an increase in the drying temperature, the drying time can be lowered, since under these conditions it was noted that the time to achieve constant hardness of the coating is shortened.

In applying epoxy coatings on large surfaces, it appeared convenient to use an 0-45 brand spray gun with a slotted tip. The productivity of the spray with this is no less than 70 m^2/hr expelling about 200 g of epoxy compound (diluted) for each layer.

The existence of epoxy organic materials, the technology of their application on various surfaces and the given characteristic properties of epoxy coatings, guarantees widespread application of epoxy coatings in atomic technology.

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METERS AND DOSIMETERS FOR STUDY OF PROTECTION AND THE PROTECTIVE PROPERTIES OF MATERIALS

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At the present time, for the protection of reactors, the most varied materials and their combinations are used; the protective properties of both the materials and their combinations are not always subject to analysis. At the same time, in using a part of the reactor's surroundings for its protection it becomes impossible to accurately calculate the reduction in its radiation. For this reason the protective properties of materials and their combinations must be studied experimentally, while the protective design must be checked out on mock-ups or even in a working installation.

In the process of studying the protective properties of materials and their combinations, the following quantities are generally determined: the decay coefficients of streams of gamma particles and neutrons of various energies; decay coefficients of dose rates of gamma radiation and of fast neutrons; output and spectrum of the captured gamma rays; activity level of the materials in the neutron flow and the deformation of the spectra by gamma radiation of the neutrons during passage through the materials.

These same quantities as a rule are measured during study of an already-completed protective system or its models. The measurement of the indicated quantities is carried out both in conditions of finite geometries and in conditions close to semi-infinite geometries. The instruments produced in factories such as gamma ray dosimeter type SP, radiometer KPN-1 and others cannot always be utilized for such measurements, therefore we have built several special instruments which are described below.

For the study of the spectral composition of gamma ray and neutron currents, scintillation spectrometers are utilized. A description of spectrometers is presented in references [1-4].

Particularly important in significance during design of complex protective shielding becomes the question of passage of the radiation through flaws and voids in the shielding. Similarly for the study of this question special instrumentation is developed, the description of which is presented in reference [5].

Scintillation counters are suitable for studying the decay of currents of gamma particles and fast and slow neutrons, and in the majority of cases are prepared in two variations: large and miniature sizes. Miniature counters are prescribed for measurements under conditions of "semi-infinite" geometries.

Scintillation counters for gamma particles are used for studying the decay of gamma ray currents of given energy and essentially are single crystal scintillation gamma spectrometers. Mounted in the pickup of the counter is a photomultiplier, FEU-11B, with a spectrometric crystal, NaJ(Tl), the diameter and height of which is 40 mm. The crystal and photomultiplier are located in a light-tight thin-walled aluminum container. Also mounted in the case is a cathode follower. During measurement the pickup is placed in a lead collimator. The signal from the counter is transmitted through the cathode follower to a linear pip amplifier, and after amplification goes to a single channel differential analyzer of impulse amplitude with a variable width of channel adjustment of wide limits. The number of impulses is recorded with a recounting system.

Prior to measurement with the counter the gamma spectrum of the radiation source is taken and the location of the significant gamma lines in the channel of the analyzer is determined. Further, the corresponding cut-off width of the analyzer channel is established, and the measurement is made without changing these quantities.

Such methodology in essence allows, without special collimation, creation of conditions close to "good geometry" and the study of decay of a narrow energy group of gamma particles.

A scintillation counter for the measurement of flows of fast neutrons comprises a photomultiplier, FEU-11B, on the photocathode of which is mounted a plastic compound scintillator ZnS(Ag) + plexiglass (diameter 30, height 10 mm). The miniature variant of the counter for fast neutrons is comprised of photomultiplier FEU-31 and a plastic compound scintillator of the same composition (diameter 16 and height 10 mm). The signals from the counters are transmitted to the registration mechanism through a cathode follower, during which, in the miniature version of the counter, the cathode follower is put together with a 6J1B tube. The suitability of the miniature photomultiplier and tube made it possible to make a pickup of very small dimensions: diameter 27 and length 275 mm (Figure 1), which permits its use in "semi-infinite" geometries.

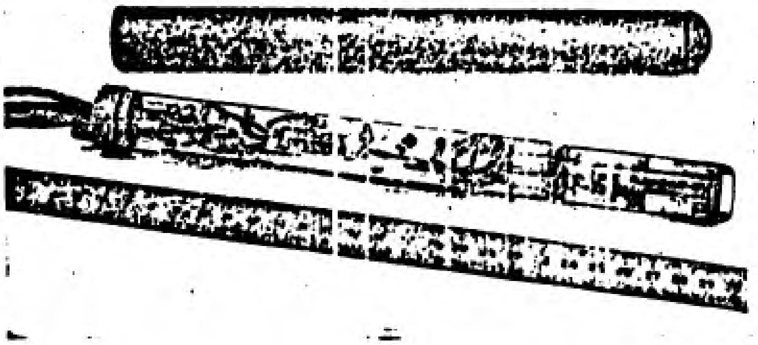

Figure 1. External view of a miniature scintillation counter (cover removed).

The pickup with the plastic compound scintillator is relegated for the study of decay of neutron flows with energies below 2 Mev[1] and during recording of the neutron flow on a background of gamma radiation the impulses from the latter cut off by matching the corresponding threshhold of the integral analyzer, connected into the recording circuit of the counter. For selection of the essential threshhold of the analyzer, the pickup is placed in a gamma field of a dose intensity of 200 microrads/sec and a threshhold is picked such that the gamma particles do not record. Customarily, the gamma field is created with the help of a cobalt^{60} source.

A scintillation counter for fast neutrons of correspondingly large size can be contained within a collimator of paraffin with boron carbide during measurement. During measurement in finite geometries a miniature pickup is used with a collimator,

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[1] See page 18

while during measurement in an "infinite field" geometry the pickup is fitted in special openings in the shielding, besides which, depending on the size of the shielding, up to 10 pickups are used simultaneously.

A scintillation counter for fast neutrons (Figure 2), similar to the one de-

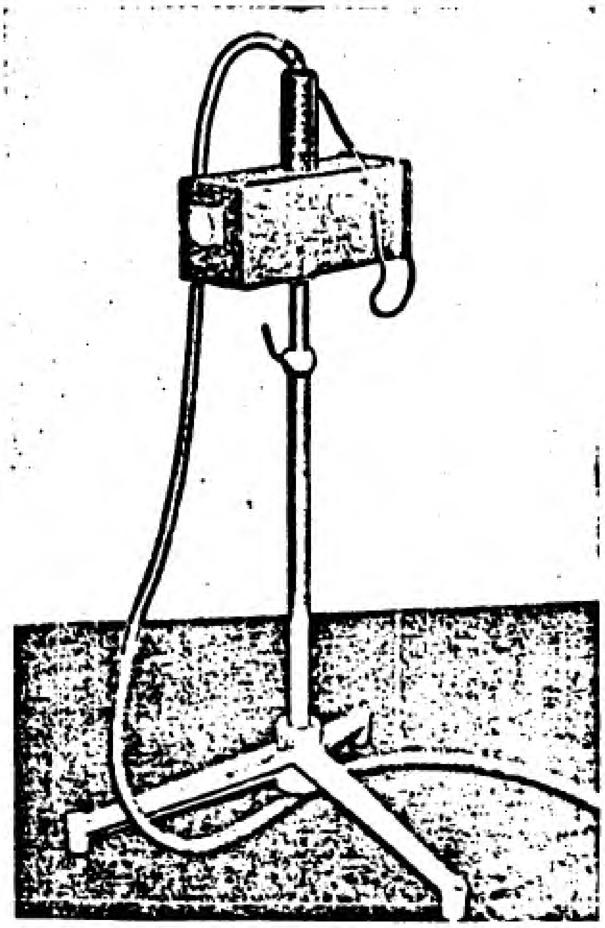

Figure 2. External view of a counter for fast neutrons -- monitor.

scribed, is used as a monitor during measurements on a reactor. The scintillator is fastened to a photomultiplier, FEU-29, which is installed in a standard case from a series of high voltage rectifiers of the VSF type. The pickup is installed on a tripod whose height can be adjusted. During measurement pickups are used without a collimator.

In the same situation, when the dimensions of the shielding to be investigated, or any other reasons, do not even allow placing the miniature pickup within the shielding, a pickup is used in which a light guide of organic glass is installed between the scintillator and the photomultiplier (Figure 3). The length of the light guide can be as high as 60 cm. A great lengthening of the light guide seriously complicates the measurement, since the light stream on the photocathode is strongly attenuated [6]. The light guide has a diameter of 10 mm and on its end, pointing toward the scintillator, a light accumulator is provided [7]. The diameter of the plastic composition scintillator coincided with the diameter of the light guide. The light guide and scintillator are contained in a thin-walled aluminum tube. As an example, with the help of the pickup with its light guide the distribution of fast neutrons behind a steel furnace were measured.

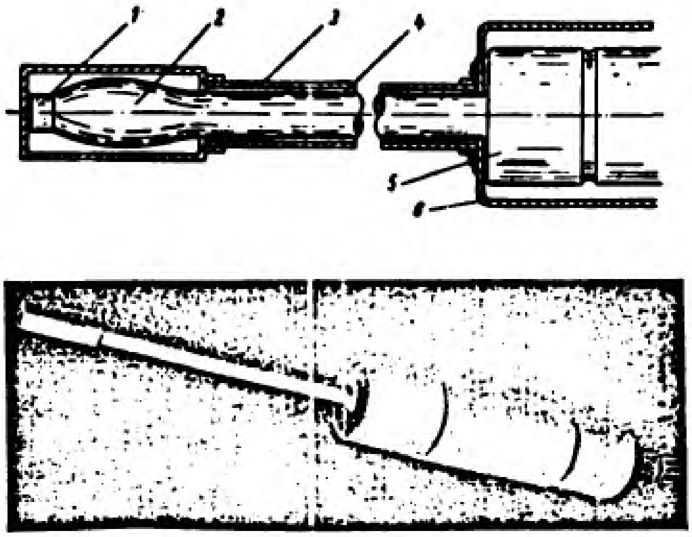

Figure 3. Schematic cross-section (top) and external view (bottom) of a counter for fast neutrons with a light guide. Key: 1 = scintillator; 2 = light guide; 3 = tube of light guide; 4 = reflector; 5 = photomultiplier; and 6 = photomultiplier case.

For measuring currents of fast neutrons in the energy region from 1 to 10 Mev a scintillation counter with a stilbene crystal (diameter 30, height 20 mm) is used. The discrimination of gamma background is realized by the scheme proposed in reference [8] by using the difference in time of scintillation of the stilbene crystal during irradiation with protons and electrons [9].

A block schematic for the counter for fast neutrons is shown in Figure 4. The effectivity of recording neutrons in the energy range of 1-10 Mev equals 10-2%

respectively; the effectivity of recording gamma particles, for example, is 10^4 times lower. The general maximal loading of the counter must not exceed 10^5 impulses/sec. The counter for fast neutrons with a stilbene crystal is used for measurements on a nuclear reactor.

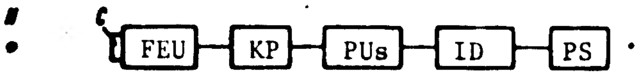

Figure 4. Block diagram of a counter for fast neutrons with a stilbene crystal. Key: N = radiation source; C = crystal; FEU = photomultiplier with a discrimination circuit for gamma background; KP = cathode follower; PUs = linear amplifier; ID = integral discriminator; PS = decoding circuit.

A scintillation counter for slow neutrons is also built in two variants: with a pickup of relatively large dimensions and with a miniature one. In the first variation, a photomultiplier FEU-29 is adapted, while in the second -- FEU-31, As a scintillator in counters for slow neutrons, glass of composition $Li_2O \cdot 3SiO_2$ is used [10], through which the recording of slow neutrons is accomplished by the reaction $Li^6 + n \rightarrow \alpha + H^3$. In our pickups, glasses with 100%-ile enrichment with Li^6 are utilized. The dimensions of scintillator glasses are as follows: thickness (in both cases) 3 mm, diameters 25 and 20 mm, respectively. The dimensions of the miniature pickup are identical to the dimensions of the pickup of the counter for fast neutrons with photomultiplier FEU-31 (see Figure 1).

Similarly, for measurements under conditions of "semi-infinite" geometries, a counter for slow neutrons was constructed based on photomultiplier FEU-35. The outside diameter of the case of this counter is 40, and the length 140 mm. With the help of such a pickup we measured, for example, the distribution of hot neutrons in polyethylene [11].

During measurement, the counter for small neutrons is plugged into a circuit with a single channel analyzer which has broad channel width adjustment. We use a standard single channel analyzer AADO-1 in this circuit. Before measurement, the amplitude distribution of the counter pulses is recorded and a threshhold and channel width of the analyzer is selected so that at least those impulses whose amplitudes correspond to the peak of the distribution will be recorded.

For measurement in finite geometries, the counter for small neutrons is placed in a cadmium and boron carbide collimator. The body of the collimator is also made of cadmium 1.5-2 mm thick, and boron carbide is sprinkled inside between the cadmium walls. A layer of boron carbide, for example, is 5 cm thick. Use of a collimator in a substance containing an effective inhibitor is not permissible since this leads to a distortion of the active results. Over the collimation aperture a cadmium shutter is attached which can be used to open and close the opening in the collimator by use of a flexible cable. Carrying out the measurement with an opened and closed shutter allows determination of the effect of the cadmium on the neutron stream behind the shielding.

A collimator with a pickup mounted on a portable elevatable arrangement with a rack (Figure 5), allows relocating the counter vertically, which is often necessary during measurement of distribution of slow neutrons behind a nonuniform (vertically)

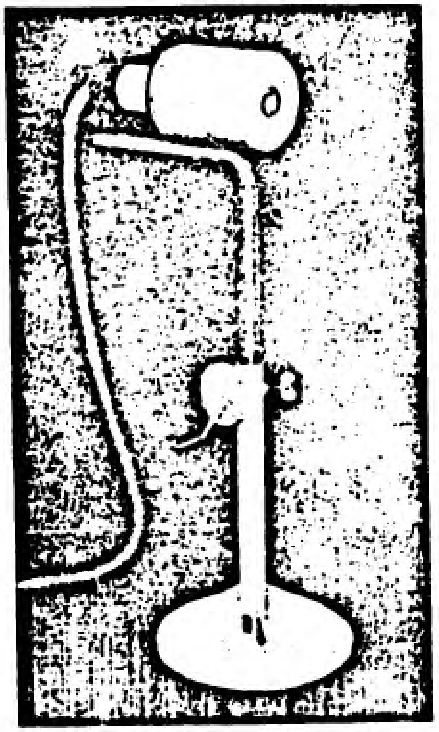

Figure 5. External view of the counter for hot neutrons in a collimator on a height adjustable support.

shielding of a plane source. The height of elevation of the collimator is noted on the scale which is attached to the rack.

The sensitivity of the counter for slow neutrons to gamma radiation is customarily controlled through knowledge of the amplitude distribution of the impulses from gamma radiation from Zn^{65} or Co^{60}, i.e., from gamma particles of 1-1.25 Mev in energy. Regardless of the fact that during measurement, for example with a source of Po + Be or on a reactor, gamma particles are present with energies of 4.46 Mev in the first case and gamma particles with energies up to 7-10 Mev in the second, such control is quite sufficient.

This is confirmed by the following considerations. The density of the scintillator glass is about 2.5 g/cm^3, i.e., according to its gamma ray absorptive properties the glass is close to aluminum, the density of which is 2.7 g/cm^3. The values of the decay coefficients for gamma rays of aluminum for the designated energies are less (see table) than for gamma rays with energies of 1-1.25 Mev [12]. That is, with all other conditions equal (which can be achieved under controlled conditions) the quantity of gamma particles recorded with energies of 4.5 to 10 Mev will, in the extreme, be two times less than the magnitude of recorded gamma particles with energies of 1-1.25 Mev. Besides this, the path length equals 2.02 mm. Consequently, the scintillation as a result of the decay of gamma particles of relatively higher energy on the average is lower in amplitude than scintillation during decay of gamma particles with energies of 1.25 Mev since a large part of the secondary electrons in the scintillator are not fully retarded. Such an effect can be observed even during measurement with gamma radiation Na^{24} (E_γ = 2.76 Mev), though the decay

COEFFICIENTS OF DECAY μ AND PATH LENGTH R OF ELECTRONS IN ALUMINUM FOR VARIOUS ENERGIES

E_γ, Mev	μ, cm^{-1}	R, mm	E_γ, Mev	μ, cm^{-1}	R, mm
1.25	0.149	2.02	7.5	0.069	14.3
4.5	0.079	8.44	10	0.062	19.2

coefficient of gamma rays Na^{24} (μ = 0.1 cm^{-1}) and the path length of the secondary electrons of corresponding energy (R = 4.75 mm) are much closer to the analogous magnitudes for gamma particles Zn^{65} or Co^{60}.

Nevertheless, in a series of cases, when the flow of gamma particles significantly exceeds the flow of slow neutrons, the magnitude of recorded gamma particles turns out to be comparable with the number of slow neutrons recorded. During measurement under these conditions for elimination of gamma background in the path of the current, a bismuth screen approximately 100 mm thick is installed in the counter. During treatment of the measurement results, a correction is introduced for the weakening of the neutron flow by the bismuth [1].

An all-wave neutron counter is used for the determination of a rule for the decay of neutron current with energies from zero to the maximum of the radiation source. In the all-wave neutron counter a gas-discharge counter SNM-5 is used, filled with gaseous BF_3. Counter SNM-5 is mounted in a paraffin cylinder whose wall thickness is 80 mm. From the end window the counter is covered with a cadmium cover 1.2 mm thick. Along the end of the paraffin cylinder pointing toward the source, eight grooves are made (diameter 20 and depth 80 mm) for compensation of the dependency of the counter effectivity on the energy of neutrons in the region of small energies. Let us note that the dependence of effectivity of an all-wave counter on neutron energy was not explored by us, but since the construction of our counter is close to the construction described in reference [13], it can be assumed that the dependence of effectivity on energy is also analogous.

The paraffin cylinder is wrapped on the outside with a cadmium layer 2.5 mm thick, and is located in a protective cylindrical screen of paraffin and boron carbide. The signal from counter SNM-5 is amplified through a preamplifier, installed in the immediate vicinity of the counter, and is transmitted through a coaxial cable to an amplifier and integral discriminator. The gamma background is eliminated by means of selection of the corresponding cutoff of the count of the discriminator during placement near the all-wave counter of the gamma ray source (usually Co^{60})

giving a dose power of 200 microrads/sec at counter SNM-5.

The all-wave counter together with the preamplifier is installed on a light hand car. The height of the counter relative to the floor can be changed with the help of an arm.

A dosimeter for fast neutrons is adapted for measurement of decay of the dose power of fast neutrons in developmental materials and for measurement of dose power of fast neutrons behind a shield. Basing ourselves on the results of references [14, 15], in which it is shown that fluid and plastic organic scintillators can be used as dosimeters for fast neutrons, we made a scintillator dosimeter with a plastic scintillator (polystyrene + terphenyl + POPOP), mounted on the photomultiplier FEU-25. The scintillator is in the form of a sphere 38 mm in diameter on which a cut is made along the diameter of photocathode FEU-25. The optical contact between the scintillator and the photocathode is accomplished with the help of petroleum jelly. The photomultiplier and the scintillator are contained in a thin-walled aluminum sheath.

The current of the photomultiplier is integrated at the input of the circuit and is amplified by a constant current amplifier. The sensitivity of the constant current amplifier is controlled by the change in resistance of its input circuit. The amplified current of the photomultiplier, proportional to the power of the dosage of fast neutrons, is measured by microammeter M-24, connected to the anode input of the constant current amplifier. With a photomultiplier supply voltage of 1350 V, the maximum sensitivity of the dosimeter is 0.5 mcfer/sec per division of the apparatus. The feed of the photomultiplier comes from a cascade voltage multiplier, comprised of selenium stack AVS-5-1a; the voltage is stabilized with the help of voltage regulators. Before measurements with the dosimeter, it is calibrated in a current of a fast neutron from a Po + Be source.

Fast neutron scintillation counters of the described type are characterized by one specific disadvantage, namely, the dosimeter is equally sensitive to both fast neutrons and gamma particles. For this reason, measurement in the presence of gamma background must be simultaneously carried out by two dosimeters, a fast neutron scintillation dosimeter and a gamma dosimeter insensitive to fast neutrons, besides which the gamma dosimeter must be damped to exactly the same degree as the neutron dosimeter. A gamma dosimeter of the SP type with a uniliter ionization chamber with thin aluminum walls [15] satisfies the essential requirements. The result of the measurement, i.e., the dose power of fast neutrons, is presented as the difference in the readings of the neutron dosimeter and the gamma dosimeter, adjusted to one current value.

The effects of gamma background on the readings of the dosimeter can also be excluded through carrying out supplementary measurements with a bismuth screen [7].

A scintillation gamma dosimeter without damping is used for measuring the dose power of gamma rays instead of ionization gamma dosimeters, since, first, the dosimeter does not have damping and, second, during significantly lower sensitive volumes it has a significantly higher sensitivity. As was shown in reference [16], for elimination of the influence of gamma particle energy on the sensitivity, the scintillation dosimeter finally is adapted to the combined scintillator, comprised of organic and ionorganic scintillators. For this purpose an organic scintillator of plastic composition is used based on polystyrene with added terphenyl and POPOP and an inorganic scintillator, a crystal CsJ(Tl).

The plastic compound scintillator is prepared in the form of a cylinder whose diameter and length are 50 mm. Along the axis of the cylinder to its center a hole 10 mm in diameter is drilled, into which a crystal, CsJ(Tl), of 1.5 cm^3 is mounted. The top of the hole is plugged with a plastic compound scintillator material. Everything coming in contact with the surface of the scintillator is coated with petroleum jelly to improve optical contact. The outside of the scintillator is surrounded by a reflector. Such a scintillator is mounted on photomultiplier FEU-29, the current of which is measured by passing it through a constant current amplifier. The constant current amplifier has seven sensitivity levels [17]: 0.3; 1.5; 9.5; 30; 150; 750 and 3×10^3 microrads/sec over the full scale of instrument M-24 plugged into the anode input of the constant current amplifier. The minimum measurement power of the dose of gamma rays is equal to 2 x 10^{-3} microrads/sec, i.e., the sensitivity of the dosimeter changes more than 10^{6} times solely through simple change of scale selection.

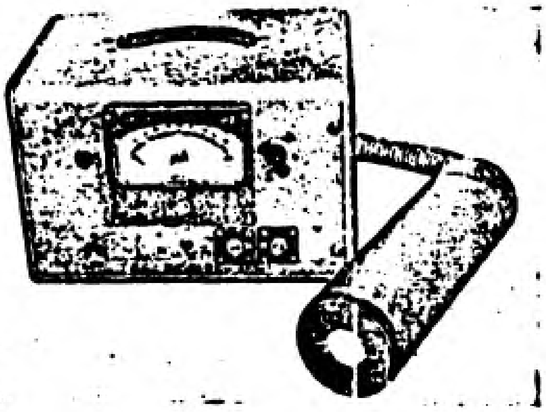

Figure 6. External view of a gamma dosimeter without any damping mechanism.

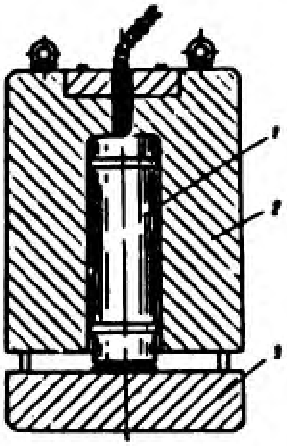

Figure 7. Schematic cross-section of arrangement for measuring gamma ray power dosage in a half-cylinder source. Key: 1 = dosimeter pickup; 2 = side shielding; 3 = lower shielding.

For elimination of zero drift, the feed of the constant current amplifier is stabilized. During use of the dosimeter, it is noticed that the shift of zero during 2 hours of use does not exceed one scale division during use at the first level. An external view of the dosimeter is shown in Figure 6.

The feed of photomultiplier FEU-29 comes from a cascade amplifier, stabilized by voltage regulator SG-fB. The dosimeter pickup is direction sensitive, therefore during measurement the dosimeter is normally used without a collimator. If, however, because of the conditions of the experiment collimation is required, the pickup is installed in a special collimator with an input opening diameter of 50 mm; this dimension cannot be decreased, since the dosimeter works without a damping mechanism lest, in this case, the current flood the scintillator.

For measurement of the strength of the gamma ray dosage inside a semi-cylindrical gamma ray source, a second variant of the scintillator gamma dosimeter without internal damping is adapted. The second variant of the dosimeter differs from the first in the dimensions of the scintillator and during measurement it is installed in a special collimator. The diameter of the plastic compound scintillator is 30, and the height 25 mm. The volume of crystal CsJ(Tl) is 0.85 cm^3. The collimator consists of a steel cylinder (Figure 7), inside of which the pickup of the dosimeter is fitted; the lower edge of the collimator coincides with the surface of the photocathode of the photomultiplier. Underneath, attached by steel tie rods to the cylinder, a cast iron plate is mounted. The distance between the plate and the cylinder is equal to the height of the scintillator. Such a collimator construction allows the measurement of the dose strength from a thin annular layer of a cylindrical source.

During measurement, the collimator and pickup are hung on steel trusses and lowered along the axis of the gamma ray source. The scintillator gamma dosimeter is sensitive to fast neutrons and, as is shown in work [15], can be adapted for measurement of gamma ray dose strength in the presence of fast neutrons only in the case where the gamma particle current increases the flow of fast neutrons by approximately 8-10 times.

A universal pedestal is allocated for work with several of the described apparatus (for example, for scintillation counters for gamma particles, with fast or hot neutrons), and similarly for determination of the induced activity of radioactive indicators. Using instruments combined on a universal stand, with the help of switches several combinations can be put together allowing the carrying out of one or another measurement.

Figure 8 shows a block diagram of a universal rack. The signals from the pick-

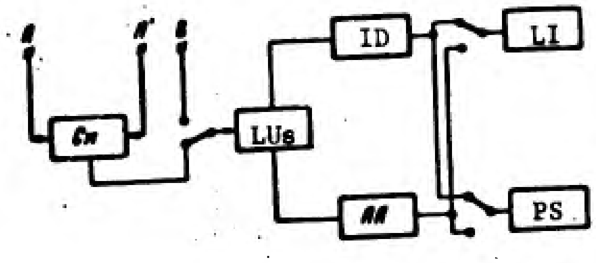

Figure 8. Block diagram of a universal rack. Key: Cm = mixer; LUs = linear pip amplifier; ID = integral discriminator; AA = single channel amplitude analyzer; PS = scaler; LI = logarithmic intensifier.

ups are fed to connectors A and A' or B, during which the signals from the pickups, arriving at the connectors A and A' are transmitted to the mixer Cm. The signals from the mixer, or from input B go to a linear pip amplifier LUs. The amplifier has two outputs, one of which is plugged into an integral pip discriminator ID, and the other to a single channel impulse analyzer AA. The outputs of the discriminator and analyzer can be switched either to a scaler PS, or to a logarithmic intensifier LI. Besides the illustrated circuits, into the make-up of the universal racks go stabilized rectifiers for feeding these circuits, a cathode follower in the pickups and a stabilized high voltage rectifier for feeding the photomultipliers.

The individual circuits of the universal rack have the following characteristics.

The linear pip amplifier LUs is comprised of a preamplifier with an amplification of 3, and an amplifier. The adjustable resistance of the feedback circuit of the amplifier allows adjustment of the amplification from a level of 75 to 250. Plugged into the output of the amplifier is a cathode follower based on a dual triode 6N6P. On the cathodes of 6N6P we get two identical and independent signals. The upper limit of the transmission band of the amplifier is approximately 5 Mc; the amplifier linearly amplifies the signals with an output amplitude up to 100 volts.

The mixing cascade Cm is based on dual triode 6N15P with common cathode loading. The amplitude characteristic of the mixing cascade is linear to 5.5 volts at the output.

The integral discriminator ID is based on a series limiter circuit on diode D2J. The signal, going through the limiter, triggers a flip-flop oscillator. The standard amplitude (~25 V) and duration (~1.2 microsecs) signal from the output of the integral discriminator can be fed to the scaler circuit or to the logarithmic intensifier.

From the second output of the amplifier the signal goes to a single channel impulse analyzer. The analyzer is put together with a circuit of two series-connected diode limiters with different cutoff potentials. The channel width of the analyzer is adjustable and can be set at 1, 2, 3, 5, 7, 10 and 24 volts. The cutoff potential (threshhold of the analyzer) is fed to the limiters from an adjustable voltage divider. All the resistors in the voltage divider are wire-wound and are selected to an accuracy of 0.2%.

The amplitude characteristic of a single channel analyzer is linear up to 100 volts at the input. The magnitude of the impulse at the output of the analyzer is approximately 30 volts. The resolution time of the analyzer is equal to approximately 3×10^{-6} sec. The scalar circuit is similar to the circuit of instrument PS-10,000. The scalar coefficient is 10^4.

The logarithmic intensifier LI is built with a circuit of graduated diodes [18]. The output voltage of the intensifier, proportional to the logarithm of the admission frequency of the input signals, is measured by a microammeter M-24 or is written on a chart with the help of an electronic autopotentiometer PSR1. The statistical error during recording shown by the autopotentiometer does not exceed 10%.

The zero point of the logarithmic intensifier corresponds to an input signal of 6 imp/sec; for setting the zero of the intensifier, a potentiometer regulated voltage is fed to the input of the constant current amplifier. The range of admission frequency signals at the input of the logarithmic intensifier, is measureable for instance, without any switching in the range of 10-80,000 imp/sec.

The logarithmic intensifier is provided with two auxiliary devices: a level indicator and a differentiator. The differentiator allows measurement of the rate of change of the signal frequency, arriving at the input of the intensifier. The level indicator permits receiving a signal when the admission frequency of the input signals to the intensifier reaches a predetermined level.

The feed of all the instruments of the universal rack, other than the scaler circuit, comes from regulated rectifiers. For the feed of the photomultiplier, a standard stabilized rectifier VSF is adapted.

All the described circuits and feed blocks are assembled in one rack, an external view of which is shown in Figure 9. The overall dimensions of the rack are 185 x 50 x 60 cm. Assembly of the basic units of the universal rack is carried out so that during use it is still possible to easily get at any circuit.

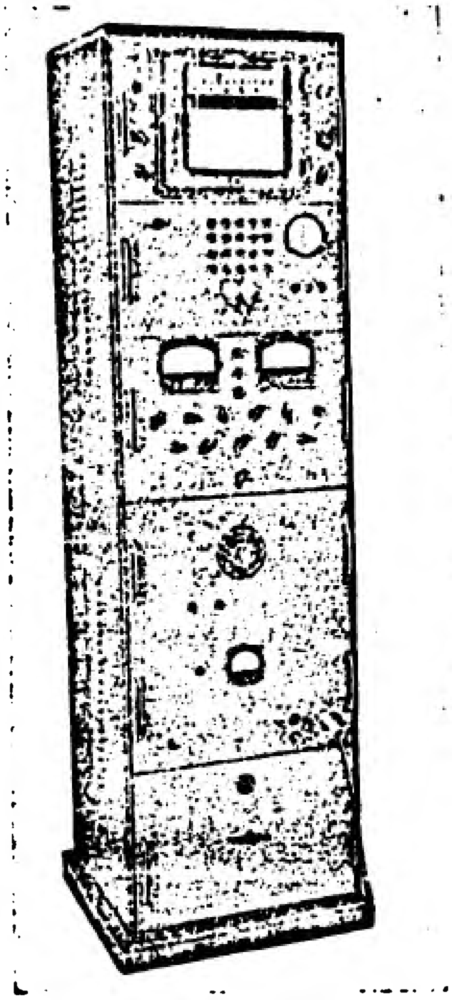

Figure 9. External view of a universal rack.

From the presented write-up of the universal rack, it is clear that with its help we can find the following quantities:

1) activity indicators by way of measuring the number of gamma particles with energies above a given level;

2) activity indicators by way of measuring the number of gamma particles of given energy (i.e., along a single gamma line);

3) activity indicators by way of measuring the quantity of gamma particles with energies higher than a given level;

4) the period of half-life of a given activity indicator by way of the same measurements as in the measurement of activity, during which we can simultaneously measure the activity indicator and its half-life;

5) the nature of the induced activity, i.e., to apportion the identification of the induced activity in accordance with the gamma and beta spectra and the half-life period;

6) decay of flow of gamma particles of given energy with the help of a scintillation counter;

7) decay of neutron currents with the help of corresponding counters.

In view of the relatively large number of problems solvable with the help of the described instrumentation, it is called a universal instrument. Nevertheless, basically a universal rack is allocated for work with radioactive counters [19].

With the help of the instruments described above we can determine most of the quantities characterizing the shielding properties of materials, and determine the qualities of specific shieldings.

V. M. Isakov, D. I. Chupyrin, A. I. Vasil'yev, V. N. Kozyrev and Yu. G. Anisimov took part in the building and debugging of the apparatus; the authors take this opportunity to express their gratitude to them.

Footnote

1. to p. 3. Numerous experiments on reactors showed that the effective threshhold of a pickup with a scintillator of ZnS(Ag) + plexiglass is identical with the effective threshhold of the reaction $P^{31}(n, p)Si^{31}$.

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