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RADIATION SHIELD

Raymond E. Zirkle, Olympia Fields, Ill., and Howard J. Curtis, Shoreham, N. Y., assignors to the United States of America as represented by the United States Atomic Energy Commission

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This invention concerns a composition matter and process for shielding against radiation. More particularly, this invention concerns a plastic type shield which is useful for shielding against the radiations encountered in an environment such as a pile type neutronic reactor, and which is effective against both slow and fast neutrons but especially effective against slow neutrons.

In the prior art, the problem of shielding against radiations has been primarily with respect to shielding against X-rays and the like. This has been accomplished usually by various lead containing materials. There have also been shielding problems in connection with cyclotrons which have been handled by the use of large tanks of water.

In relatively recent years, however, there have been developed devices described as neutron reactors, specifically illustrated by piles, wherein fission of certain heavy isotopes such as U^{235} and Pu^{239} is accomplished. As a result of this atomic disintegration not only are great amounts of heat and other forms of energy produced, but there are evolved radiations comprising slow and fast neutrons in addition to beta and gamma rays. Not only are these radiations of an intensity and energy many times greater than radiations heretofore encountered in the prior art, but in the instance of fast and slow neutrons, the character of the radiation is considerably different than X-rays and similar radiations heretofore encountered industrially on a large scale.

It is therefore apparent that because of the different and high energy factors involved that the development of shielding of the class indicated, particularly shielding effective against neutrons, constitutes a problem of considerable magnitude and one in which prior work is not of great help.

After extensive investigation we have found that there are certain plastic materials in which there may be incorporated certain inorganic compounds to give a composition of matter that is an effective and durable shield against fast and slow neutrons. There are a number of methods of employing this shielding, particularly in connection with carrrying out biological work involving studies of the effects of irradiation or particle bombardment of living tissue.

This invention has for one object to provide shielding material.

Another object is to provide shielding material effective against fast and slow neutrons.

Still another object is to provide a shielding material that is substantially free of elements which become dangerously radioactive as a result of neutron bombardment.

A still further object is to provide a shielding material for use in environments of high neutron flux, in connection with biological studies.

A still further object is to provide a shielding material that may be fabricated into sheets, boxes, and other forms having high mechanical strength, durability, and radiation resistance.

Another object is to provide methods for manufacturing shielding of the class described.

Other objects will appear hereinafter.

We have found that a very satisfactory shielding composition of matter may be prepared by incorporating boron compounds in plastic material, the atomic composition of the plastic material being essentially composed of hydrogen, carbon, and oxygen. More specifically, we have found that the various commercially obtainable polymeric plastic materials exemplified by the various acrylate type resins may be suitably impregnated or admixed with borax, boric acid, boric anhydride, or similar boron compounds which have the property of capturing neutrons efficiently, to obtain a shielding material of considerable utility. The resulting compositions of matter possess suitable physical characteristics to permit their fabrication into sheets, boxes, or various other structures as may be desired. We have further found that because such plastic compositions are principally comprised of the elements carbon, hydrogen, and oxygen, shielding of this character is particularly useful in connection with biological research. For example, such shielding does not contain components which would become objectionably radioactive with respect to induced beta or gamma activity when subjected to high intensity neutron irradiation.

The preferred plastics for use in our shielding compositions comprise the methyl methacrylate resins. The boron-methyl methacrylate compositions of the present invention have been found to be surprisingly stable in intense radiation fields in spite of indications to the contrary in the prior art literature, cf. Nature (London), vol. 143, page 640 (1939), and Proceedings of the Physical Society (London), vol. 50, page 438 (1938). Any methyl methacrylate resin having the desired mechanical properties may be employed in our compositions, and the commercially available resins of this type such as "Lucite," "Plexiglas," and "Crystallite" have been found to be fully satisfactory.

Any boron compound may be employed in shielding prepared in accordance with the present invention, but we prefer to use solid compounds having the mechanical characteristics of the pigments and fillers employed generally in molded plastics. We also prefer to employ boron compounds which have a high weight percentage of boron and are free from elements in which objectionable beta or gamma radioactivity can be induced by neutron irradiation. Borax, boric acid, and boric anhydride meet the above requirements satisfactorily, but boron carbide has been found to be outstanding in all of these respects.

The concentration of boron compound to be employed in the shielding may vary over a considerable range, depending on the neutron flux to be encountered and the neutron energies desired to be shielded out. Boron preferentially absorbs slow neutrons, its absorption cross section bearing an approximately linear relationship to the reciprocal of the square root of the energy of the neutrons. Thus, the absorption cross section of boron of natural isotopic constitution is about 1×10^{-24} sq. cm. for neutrons of about 20,000 e. v. and about 700×10^{-24} sq. cm. for thermal neutrons of about 0.03 e. v. It is therefore possible to estimate the optimum quantity of boron to be employed in the shielding of the present invention for any particular application requiring neutron absorption.

The concentration of any particular boron compound in a shield of the present type may generally be considered in terms of units of weight of the boron content of the compound, per square unit of area of the shield, irrespective of the thickness of the shield. Concentrations of boron ranging from 0.1 g. to 0.5 g. per sq. cm. of shield surface are generally satisfactory. Our preferred shielding contains approximately 0.25 g. of boron per sq. cm.,

which is sufficient to reduce the intensity of slow neutrons by a factor of about 10^4.

Since the concentration of boron compound per unit area controls the neutron absorption characteristics of the shield, the ratio of methyl methacrylate to boron compound may be chosen in accordance with the shield thickness and mechanical characteristics desired. When employing boron carbide in concentrations of 0.30–0.32 g. per sq. cm., shields as thin as 3/16 inch have adequate mechanical strength for most purposes. Somewhat thicker shields may be required when employing other compounds of lower boron content at the same boron concentration per unit of area. In any case, the proportions may be varied over a wide range without affecting the shielding properties of the composition as long as the concentration of boron per unit area is maintained at the desired value.

The boron compound may be incorporated in the methyl methacrylate resin in accordance with previous practices for the incorporation of pigments, fillers, and the like into plastic compositions. A very hard boron compound such as boron carbide may be imbedded in the surface of a relatively hard plastic by pressure rolls or similar means. Most conveniently, however, the boron compound is incorporated in partially polymerized methyl methacrylate and the mixture is then formed into the desired shapes by casting, molding, or extruding. During or after the forming operation the material is subjected to further polymerization, for example by heating at a temperature of 70–90° C., to obtain the desired hardness.

Our invention will be further illustrated by the following specific examples:

Example I

Boron carbide powder was suspended in a viscous partially polymerized commercial methyl methacrylate resin. The resulting suspension was cast between glass plates to form 3/16 inch sheet and was then hardened at 70–90° C. The resulting sheet had a boron carbide concentration of approximately 0.31 g. per sq. cm. and was effective in reducing the intensity of a beam of thermal neutrons by a factor of about 10^4.

Example II

Commercially molded "Plexiglas" sheet of 3/16 inch thickness, containing #400 grain boron carbide abrasive powder in a ratio of 10 lbs. per 15 sq. ft. of sheet, was employed for the construction of a biological exposure tunnel and other biological shields for use in a neutronic reactor. This shielding material showed no deterioration or objectionably high induced radioactivity after more than 1000 experimental exposures in a pile operating at power levels of the order of 4000 kw.

It is to be understood that the above examples are merely illustrative and do not limit the scope of our invention. Other equivalent resins and boron compounds, or mixtures thereof, may be substituted for the specific materials employed in these examples, and other shapes and thicknesses of shielding may be prepared in accordance with the foregoing description. In general, it may be said that the use of any equivalents or modifications of procedure which would naturally occur to those skilled in the art is included in the scope of our invention. Only such limitations should be imposed on the scope of this invention as are indicated in the appended claims.

We claim:

1. The new and improved method for protecting an environment against neutron radiation which comprises interposing between the source of said radiation and said environment, as a shield, a mass of polymerized acrylate plastic, having incorporated therein a sufficient quantity of a boron compound to provide at least 0.1 gram of boron per sq. cm. of shield area.

2. The new and improved method for protecting environment against neutron radiation which comprises interposing between the source of said radiation and said environment, as a shield, a mass of methyl methacrylate plastic containing a sufficient quantity of a solid boron compound to provide from 0.1 to 0.5 gram of boron per sq. cm. of shield area.

3. The method of claim 2 in which the boron compound is boron carbide.

4. The method of claim 2 in which the boron compound is boric acid.

5. The method of claim 2 in which the boron compound is boric anhydride.

6. The new and improved method for protecting an environment against neutron radiation which comprises interposing between the source of said radiation and said environment, as a shield, a mass of methyl methacrylate plastic sheet, containing sufficient quantity of a boron compound to provide approximately 0.25 gram of boron per sq. cm. of sheet area.

7. The method of claim 6 in which the boron compound is boron carbide.

8. In a method for reducing the neutron intensity in a protected area within a neutronic radiation field the improvement which comprises interposing, between the neutron source and said protected area, a shield comprising essentially a methyl methacrylate plastic having incorporated therein a sufficient quantity of a boron compound to provide at least 0.1 gram of boron per square centimeter of shield area.

9. The method of claim 2 wherein the boron compound is borax.

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