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Publication Date
1961-08-28

UCRL-9839
Limited distribution

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Contract No. W-7405-eng-48

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ABSTRACT

A diffuse, highly reflecting coating for use with Cerenkov counters is described. This coating can be used to advantage inside inorganic-liquid Cerenkov counters, or can be used externally when bonded to the inside surface of the lighttight radiator cover.

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I. INTRODUCTION

In order to derive maximum photon collection from Cerenkov and scintillation counters, it is frequently desirable to coat the counter faces with some type of low-light absorption medium that will provide a high degree of diffuse reflection. Magnesium oxide powder has long been used as a reflecting agent for counters; however, the formula and method of application described herein is orginal.[1] The mixture developed provides a very high degree of reflectivity, thereby increasing the efficiency of the counter to which it is applied.

II. THE BINDING AGENT

The Acryloid resins were chosen as a binding agent for MgO because of their excellent physical properties (Table I). These resins are polymerized esters derivatives of acrylic acid. They are thermoplastic[2] and dry by solvent evaporation. Of the various resins of this type tested, B-72 was found to be most suitable.[3] It has the additional desirable properties of being extremely stable, highly resistant to alkali, acid, and many types of chemical fumes, highly flexible, very durable, and transparent with good nonyellowing characteristics. However, the plastic is permanently soluble in organic solvents and therefore cannot be used internally in liquid Cerenkov counters that utilize these solvents as the Cerenkov radiator.

The solubility of the dried coating was tested in several types of liquids frequently used in Cerenkov counters. The degree of solubility was checked after 8 hours, 4 days, 7 days, and 3 months and was the same for all periods. The results of the solubility tests are shown in Table II.

III. FABRICATING AND CURING THE REFLECTOR SHEET

Baker and Adamson magnesium oxide powder was used in preparing the mix. This powder is available in reagent grade (designated Code 1917 by the manufacturer) and U.S.P. grade (Code 1920). Each grade has a different grain size, Code 1920 being the finer. Several formulas were prepared from Code-1920 and Code-1917 powder. The Code-1920 mix had the most uniform texture; however, the Code-1917 mix reflected a higher percentage of 3660A light (Table III). In the Code-1917 mix, the coarser MgO particles are not as evenly dispersed because they tend to settle. As a result, the topmost surface (a few thousandths of an inch thick) is predominantly B-72 resin, which on drying tends to form a skin coat. This semidry film slows down the drying of the underlying mix. Inasmuch as the relatively pure plastic skin coat shrinks slightly on drying, the resultant differential drying of the mix causes curling of the drying sheet, giving rise to minute cracks in the dry sheet. These cracks can be prevented by putting weights around the periphery of the sheet while it cures. This procedure is described later in more detail. Many different formulas were made and tried. The best mix formulated (termed Z mix here) was prepared from 30.3% by weight of Code 1917 MgO powder and 69.7% B-72 resin.

These quantities must be accurately measured, or the mix will be too brittle as a result of too much MgO, or reflect less because of excessive resin. In preparing the MgO–B–72 mixture, it is important to get rid of the lumps in the powder before combining it with the resin. This can be accomplished by running the powder through a flour sifter; however, any screen-type device would be suitable. After getting rid of the lumps, one should slowly add the powder to the resin while the resin is being gently agitated with a rotary-blade mixer running at slow speed. After the resin and powder are combined and mixed thoroughly, the resultant mixture should be allowed to stand in a tightly sealed container for 15 to 20 hrs. During this time, some of the MgO grains will settle to the bottom of the container. Therefore, after this "standing time," the mixture should be stirred again. This second stirring should be very slow in order not to introduce air bubbles into the liquid. No solvent was added to this formula to thin the mix, as it was found that the viscosity allowed the mix to be poured from the mixing container so that the liquid tended to spread out, forming a sheet with an "equilibrium" thickness of approximately 0.075 in. This equilibrium thickness appeared quite uniform over small sheets of approximately 60 in.^{2}. Sheets this size were prepared by mixing 35 g of Code 1917 MgO powder with 80.5 g (85 ml) of B-72 resin. These sheets took approximately 55 hr to dry in air. Oven drying at 40°C was tried, but the resultant dry sheet was much more brittle than its air-dried counterpart.

After the sheets of MgO were thoroughly dry, Code-1917 dry MgO powder was hand-rubbed on the surface of the sheet, and the excess loose powder blown away or shaken off. This "dry rub" increased the reflectivity of the sheet by 1.9% (Table III). Two methods of applying the mix were used. The first entailed direct application to cleaned, 0.012-in.-thick aluminum sheets which had been precut to the desired shape to enclose the Cerenkov cell and keep it lighttight. The second method was to "prefabricated" sheets of MgO-B-72 by pouring the mix on 0.003-in.-thick Mylar sheets that were contained in a simple wood frame to prevent the liquid mixture from running off the Mylar. Mylar was found to be the best mold material since it was not affected by the solvents in the resin and was easily peeled away from the dry sheet of MgO, which in turn was cut away from the wooden frame with a razor blade. Mylar is commercially available in 24-by 36-in. sheets, and several sheets can be suitably joined with cellophane tape on the side not in contact with the resin mixture.

When the second method of applying the mix is used, the wooden frames containing the sheets of Mylar on which the mix is poured should be weighted around the edges to overcome excessive curling caused by differential drying. These prefabricated sheets can then be bonded to an aluminum lighttight Cerenkov cell cover with Epon 828, and the MgO sheet that overlaps can be trimmed with scissors. Obviously this technique is used only in cases where the radiator is Lucite or some other transparent material. In the case most often used, the sheets were prefabricated on Mylar and then bonded to the interior surface of the liquid radiator container with Epon 828. Before bonding, the prefabricated sheet should be allowed to "age" in air for approximately 7 to 10 days. During this time it should preferrably be left attached to the Mylar. The aged sheet will remain flexible for approximately 2 months, during which it is easily bent to conform to curved surfaces and can be easily trimmed to size with scissors. If the surface of the sheet gets dirty, it can be cleaned with a cloth moistened with a water-detergent solution.

IV. REFLECTIVITY MEASUREMENT

Reflectivity was measured in air by means of an RCA 6655 photomultiplier tube. The light source was a 100-w, floodlight-type, mercury-vapor lamp provided with suitable filters so that light of approximately 3660A was emitted. Geometry of all measurements was kept constant. Inasmuch as the phototube was set up to see a 4-in.-diam. area, samples were placed in a 3.860-in.-diam. glass dish, which was placed in a black paper mask to cut down stray reflections from sources other than the sample being measured.

It was found that Code-1917 MgO powder had the largest coefficient of reflection. Therefore, an arbitrary scale based on 100% reflectivity for Code 1917 MgO powder was used. The final results of the experiment are shown in Table III. Mix number 1 in Table III was used for external applications, such as coating the inside of a lighttight radiator-cell cover,[4] while mix number 2 was used internally in liquid counters where the MgO sheet was in contact with the liquid. This latter application has been successfully used several times in the past and was recently used with excellent results in a 4-ft^3 cylindrical water Cerenkov counter at the Bevatron. The addition of small amounts of 2-amino-6, 8-naphthalenedisulfonic acid, disodium salt to the water radiator to shift the wave length of the Cerenkov light produced in the counter does not have a deleterious effect on the MgO coating.

Figure 1 shows the reflectivity of three commonly used reflectors as a function of wave length. One can see from the graph that pure TiO_2 becomes a poor reflector below 4000 A and that in the Cerenkov light region, pure MgO powder is excellent. It is worthwhile to note that the mix described herein has the desirable feature of reflecting only 2% less light of approximately 3660A wavelength than the pure MgO powder.

I would like to thank Dr. T. F. Kycia of Broohaven National Laboratory who suggested the need for this formula and Dr. L. T. Kerth of Lawrence Radiation Laboratory who helped with the reflectivity measurements.

FOOTNOTES

*This work was supported by the U. S. Atomic Energy Commission.

1. Attempts have been made at this laboratory in the past to formulate a mixture of MgO powder and clear acrylic resin. However, the resin was expensive and the resultant coating was extremely brittle and did not adhere well to the surfaces to which it was applied. As a result, the coating readily flaked and chipped off.
2. Thermoplastic materials do not become infusible when subjected to heat and pressure as do thermosetting materials. Therefore, thermoplastic materials may be softened and reshaped under heat and pressure and then become solid again on cooling.
3. The Acryloid B-72 resin used was supplied by Rohm and Haas, Philadelphia, Pa. in 5-gal, 40-lb lots. When ordering, one should specify 40% solids dissolved in toluol.
4. T. F. Kycia, Scattering of K^+ Mesons off Protons (Thesis), Lawrence Radiation Laboratory Report UCRL-8753, May 14, 1959.

Table I. Physical properties of B-72 Acryloid resin.[a]

Percent solid resin (±1%)	40
Solvent	Toluol
Specific gravity	0.97
Pounds per gallon	8.1
Viscosity range at 30°C (cp)	480 to 640
Flash point, closed cup (tag) (°F)	39
Tensile strength (lbs/in.^{2})	2900
Ultimate elongation (%)	44
Toughness[b] (in.-lbs/in.^{3})	1000

[a]From Rohm and Haas's "Acryloid and Rhoplex Acrylic Ester Resins and Emulsions" (1953).

[b]The value shown is the area under the tensile-elongation curve.

Table II. Solubility of dry MgO-resin mix in solvents commonly used in liquid Cerenkov counters.

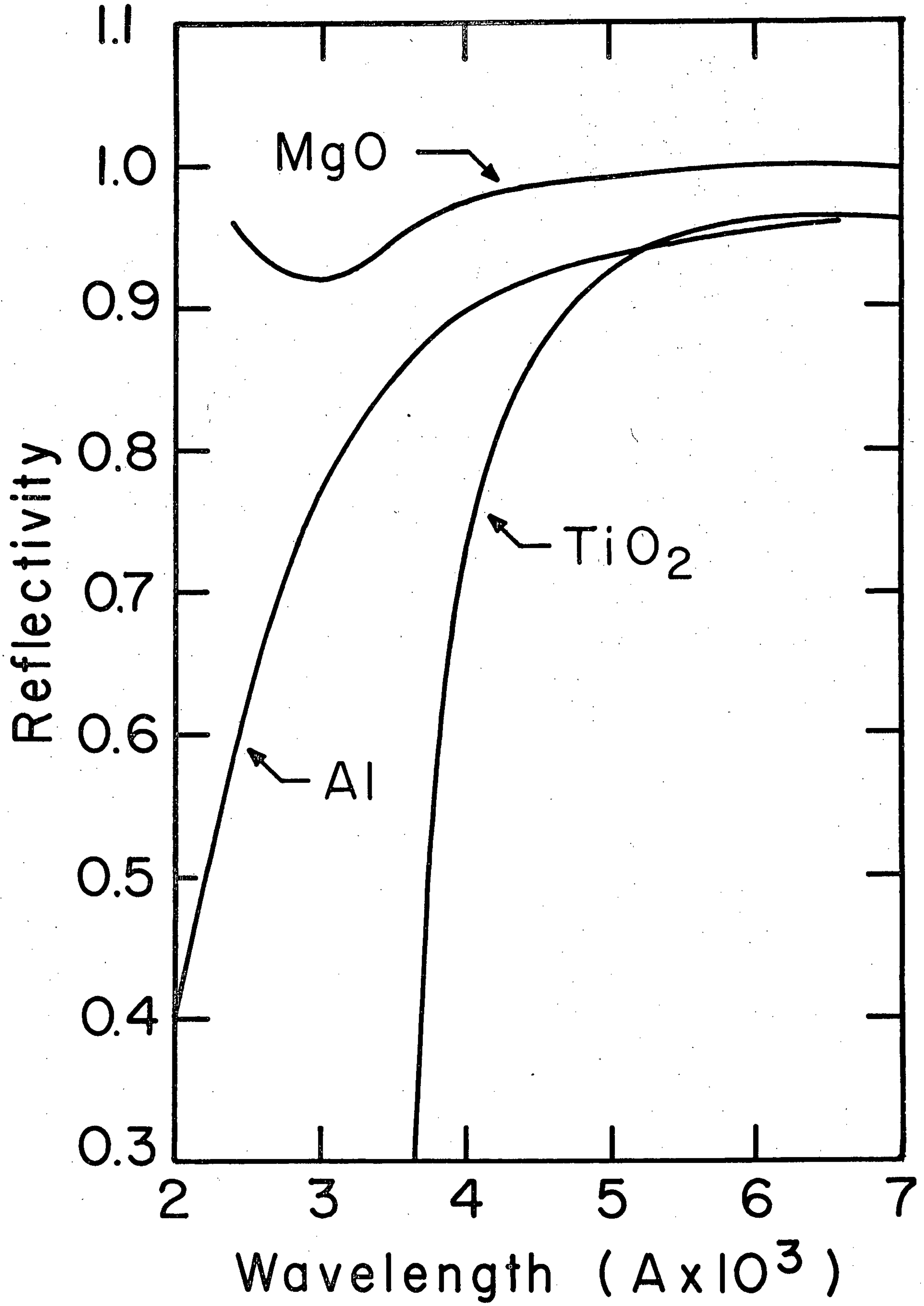
Type of liquid	Degree of solubility	Retention of whiteness
Immersion oil	Insoluble	Excellent
Styrene monomere	Completely soluble	Excellent for powder residue
Glycerin	Insoluble	Excellent
Carbon disulfide	Completely soluble	Powder residue has yellowish tinge
Water	Insoluble	Excellent
O-75	Insoluble	Excellent

Table III. Arbitrary reflectivity scale based on 100% reflectivity for Code 1917 MgO powder.

Mix No.	Reflector	Reflectivity (%)
	Code 1917 powder (pure and dry)	100
	Code 1920 powder (pure and dry)	99.4
1	Z mix Code 1917, rubbed with 1917 (external use)	99.8
2	Z mix Code 1917, no rub (internal use in liquid cells)	97.9
3	Z mix Code 1920, rubbed with 1917	97.4
4	Z mix Code 1920, no rub	93.0
	Black paper	6.2

FIGURE LEGEND

Fig. 1. Reflectivity of MgO, Al, and TiO_2 as a function of wavelength [from W. E. Mott and R. B. Sutton, "Scintillation and Cerenkov Counters," in Handbuch der Physik, S. Flügge, Editor (Springer Verlag, Berlin, 1958), Vol. XLV, Nuclear Instrumentation II, p. 96].


1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Reflectivity
MgO
Al
TiO_2
2
3
4
5
6
7
Wavelength (A x 10^3)

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