PAPERS

Aluminum for Reflectors

By JUNIUS D. EDWARDS

Some of the earlier methods used in meeting the demand for improved reflecting surfaces of aluminum reflectors are reviewed, and data are presented showing reflectivity for radiation of various wave-lengths. A new anodic treatment known as electrolytic brightening is described, and the results attained by the application of this process are discussed.

ALUMINUM is a naturally bright metal and has long been used for reflectors. In some cases, the reflecting surface has been polished to give increased reflecting power or smoothness, or in others it has been used with the bright sheet surface received by finishing on polished rolls. A reflectivity of 65 to 75 per cent is obtainable in this way. With increasing efficiency in the design of lighting fixtures and the study of lighting requirements, came a demand for improved reflecting surfaces—improved as to light-reflecting capacity and permanence.

An obvious means of increasing reflectivity was to produce a better polish upon the surface. This method, however, was found to have very definite limitations. Commercially pure aluminum of the type commonly used for reflector manufacture was too soft to lend itself readily to any marked improvement in reflectivity by commercial polishing methods. However, some of the hard alloys of aluminum take a much better polish than pure aluminum. Composition in the case of alloys has an effect in determining the reflectivity producible by polishing, but hardness is, generally speaking, the controlling factor. With a certain alloy of aluminum, and employing the most careful polishing technique, an aluminum surface having a reflectivity

A Paper presented before a meeting of the Cleveland Section, Illuminating Engineering Society, on January 22, 1934. Aluminum Research Laboratories, Aluminum Company of America, New Kensington, Pa.

as high as 89 per cent has been produced. This, however, can hardly be considered practical for commercial reflectors.

For many uses, a diffuse reflecting surface is not only satisfactory but desirable. Various etching procedures are known to brighten aluminum and at the same time roughen the surface so as to increase its light-diffusing characteristics. Two etching procedures have been found to have outstanding merit for this purpose. One of these employs a solution containing about 5 per cent sodium hydroxide and 4 per cent sodium fluoride, and is used at a temperature of about 90 deg C. A final dip is given in a cold solution of nitric acid (equal parts of concentrated nitric acid and water). Very good results can also be obtained by first etching the aluminum surface with a dilute solution of hydrofluoric acid and then treating with a strong, cold solution of nitric acid. The first named method, however, is more practical for most commercial purposes.

The General Electric Company, in the development of lamps and lighting fixtures for the production and application of ultraviolet radiation, made a detailed study of the use of aluminum for reflectors. It was found in the course of this investigation that aluminum, etched by the methods just outlined, not only showed a high reflection factor for visible light, but also a high reflection factor for ultraviolet. For example, the data published by Taylor and Edwards[1] demonstrate that aluminum, etched by these procedures, had reflection factors for light ranging from 82 to 87 per cent, and reflection factors for ultraviolet radiation, at a wave-length of 2967Å, of 81 to 82 per cent.

Data collected from various sources have been assembled in Fig. 1, to show the reflectivity of aluminum in the ultraviolet, visible, and infra-red portions of the spectrum. The data for the ultraviolet portion of the spectrum are largely taken from the work of Taylor and Edwards. Additional and somewhat higher values are given in Table 1 of this paper. These measurements do not extend below a wave-length of about 2650Å. An observation by Hulburt[2] is recorded for a wave-length of 2000Å, but this value is probably lower than would have been observed had the sample been properly etched to secure maximum ultraviolet reflectivity. The curve is drawn to represent the reflectivity of aluminum surfaces which are reproducible

---

[1] Taylor, A. H. and J. D. Edwards, Ultraviolet and Light Reflecting Properties of Aluminum, *J. Optical Soc.*, *21*, 677 (1931).

[2] Hulburt, E. O., *Astrophys. J.*, *42*, 205 (1915).

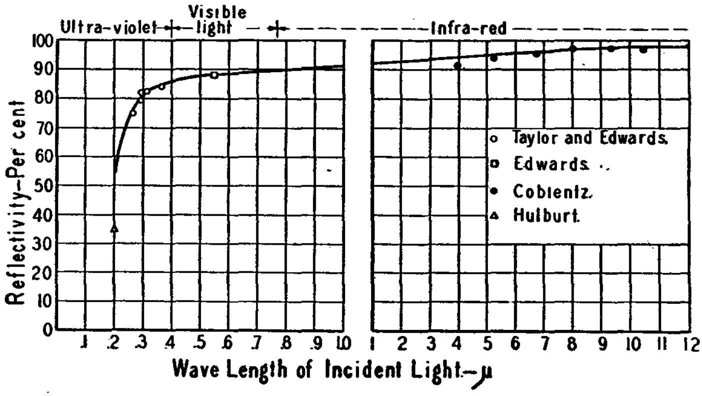

FIG. 1—Reflectivity of aluminum for radiation of various wave-lengths

in practice. The value for visible light is placed at 88 per cent, although it is probable that aluminum surfaces can be produced which have reflectivities close to 90 per cent. This figure is of interest for comparison with the reflectivity of silver, which is generally given as 93 percent. The data for the infra-red range are taken from the work of Coblentz.[3] The sample of metal employed for these infra-red measurements was commercial aluminum, hand polished, and according to Coblentz was somewhat hazy in appearance. He characterized the data for his shorter wave-length measurements as being below normal, and his two lowest values have accordingly been neglected in drawing the curve of Fig. 1. In passing, it may be noted that the high reflectivity (low emissivity) of aluminum for infra-red or heat radiation is effectively made use of in the Alfol type of insulation, which employs bright aluminum foil layers separated by thin air spaces.

The etched aluminum surface has proven highly satisfactory from the standpoint of light-reflecting efficiency when used indoors and under conditions not requiring frequent cleaning. The roughening produced by the etching treatment leaves a surface which marks easily if handled with dirty hands, and is not as readily cleanable as might be desired. Outdoors, both polished and etched aluminum reflectors may show rather rapid depreciation of reflectivity if situated so that they remain moist for extended periods. This moisture

[3] Coblentz, W. W., Bur. Standards, Bull. *2*, 457 (1906).

produces an incipient surface attack which, while not deep, sufficiently roughens the surface so that it readily collects and holds dirt. Resistance against such attack can be added by lacquering the surface, but even the best of lacquers cut the reflectivity by amounts as great as 10 per cent or more, and are not particularly durable under long-continued exposure to light. The use of colorless varnishes and lacquers has therefore found only limited applications on reflectors.

Another process of finishing aluminum is available, namely, electrolytic or anodic oxidation of aluminum, which produces on the metal a hard, abrasion-resistant oxide coating. Aluminum oxide itself is a colorless, transparent material. The process suggested itself as a suitable means of improving the permanence of aluminum reflecting surfaces. It was found, however, that the application of an oxide coating sufficiently thick to give the desired protection to the metal detracted seriously from the reflectivity. The best of the known anodic coating processes decreased the reflectivity about 10 to 20 per cent. Furthermore, the oxide coating left the metal with a rather opaque and milky surface finish which markedly detracted from its value as a reflector.

The loss in reflectivity caused by oxide coating was found to result from the presence of impurities on the surface of the aluminum. These impurities were partly metallic and partly non-metallic in character. For example, the presence of some elements in aluminum does not detract seriously from the appearance or reflectivity after anodic oxidation. Other elements, such as silicon and iron, markedly detract from the reflective qualities. By the selection of special metal compositions, improved results can be obtained after oxide coating. There appear to be, moreover, small amounts of non-metallic impurities on aluminum sheet, picked up from the rolls or from a polishing operation, which affect the appearance after oxide coating. The removal of impurities of both types presents many practical difficulties, particularly in the case of specular reflectors.

In seeking for improved reflecting surfaces, Dr. R. B. Mason, of Aluminum Research Laboratories, found quite unexpectedly a new type of anodic treatment which brightened instead of dulled the aluminum. Most fortunately, also, this anodic treatment, which he characterizes as "electrolytic brightening," does not injure the specular characteristics of the surface. It is now possible, therefore, to take a highly polished aluminum surface and, by application of the electrolytic brightening process, increase its reflectivity, and at the same time leave upon the surface a very thin protecting oxide film. To cite a concrete example, an aluminum reflecting surface having a total reflectivity of 74 per cent was subjected to the electrolytic brightening treatment, which gave to it a reflectivity of 87 per cent, and this without any roughening of the surface.

A further fortunate circumstance was the discovery that after the electrolytic brightening step, a substantial oxide coating could be produced by anodic processes and without any substantial loss in reflectivity. The Alumilite process, which is well adapted for this purpose, is a means of anodically coating aluminum in electrolytes of patented composition. The electrolytic brightening treatment appears to remove impurities from the surface of the metal, impurities which detract from the appearance after oxide coating with sulfuric acid electrolyte, for example. After this brightening treatment has been applied, the Alumilite process can be employed to electrolytically oxidize the surface. As a final step in producing a finished reflector, the oxide-coated surface is sealed to make it impervious to corrosive influences. The sealing process is a treatment which converts a porous, moisture-absorptive coating into an impervious non-absorptive coating. This prevents staining of the coating and increases its general serviceability. For the best results, sheet of special type and composition is selected for reflectors to be finished by this process.

A particular advantage of this type of reflector, which is called the "Alzak" reflector, is its resistance to marking by handling, and even to ordinarily corrosive conditions such as weather exposure. Alzak reflectors have a smooth, glassy surface which does not collect dirt and which can be readily cleaned by washing with soap and water. If more drastic cleaning methods are necessary, a mild abrasive, such as Bon Ami, can be effectively employed.

In Fig. 2 there is shown a photomicrograph (at 500 diameters) of a section through an Alzak reflector. The transparent oxide film shows in the illustration as a thin dark band on the surface of the aluminum.

Some very interesting results have been obtained in the application of the electrolytic brightening treatment to polished reflectors for ultraviolet radiation. The results from a series of measurements made by Mr. A. H. Taylor on four different types of aluminum surfaces are given in Table 1.

The electrolytic brightening treatment may not increase the reflection factor for ultraviolet radiation on a surface already brightened

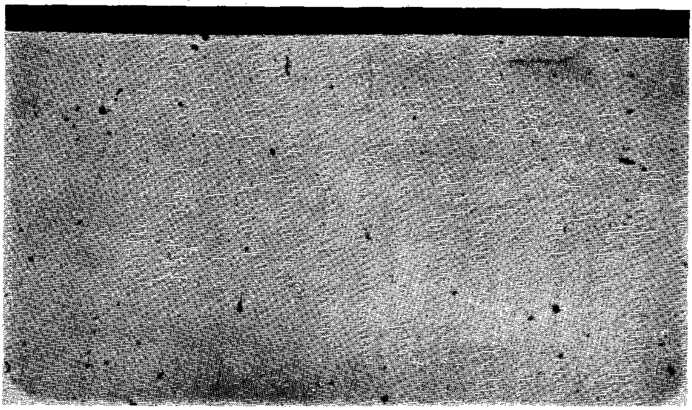

FIG. 2—Photomicrograph of section through Alzak reflecting surface showing the transparent oxide film as a thin band on the surface of the aluminum (500 diameters).

by etching. However, as shown by the data on the fourth column of this table, the surface which was polished and electrolytically brightened showed a very high reflection factor for ultraviolet radiation. Presumably, the filmed surfaces of the microscopic etching pits cause some absorption by inter-reflection of the very short wave-length radiation, and this factor is practically eliminated on the polished surface. The aluminum surface, polished, electrolytically brightened and Alumilited, had a reflection factor of 85 per cent for visible light. Application of the oxide film appears to cause a greater loss of reflection for ultraviolet radiation than for visible light. Values intermediate between those given in the last two columns of the table could undoubtedly be obtained by applying a thinner oxide coating.

TABLE 1—ULTRAVIOLET REFLECTION FACTOR FOR VARIOUS SURFACE FINISHES ON ALUMINUM REFLECTOR SHEET NO. 2

According to measurements by A. H. Taylor

Wave Length	Etched	Etched and Electrolytically Brightened	Polished and Electrolytically Brightened	Polished and Electrolytically Brightened and Alumilited
	per cent	*per cent*	*per cent*	*per cent*
3663Å	81	78	87	79
3130	80	77	85	74
2967	80	77	84	69
2652	76	74	83	62

The ultraviolet reflection data for the polished and electrolytically brightened surface are appreciably higher than those used on the graph of Fig. 1.

The weathering characteristics of the Alzak finish are best illustrated by a test in which an Alzak surface was exposed to the weather for seven months on the roof of the Laboratory. It was taken in and cleaned from time to time and its reflectivity measured. At the end of seven months its reflectivity was still 84 per cent, which is the value it showed when it was originally made. Although there was no loss in reflectivity, there was some slight scratching of the surface when accumulated grit was washed off during the periodic cleanings.

The Alzak finish, with high reflectivity in both specular and diffuse reflectors, combined with the hard, clear, glass-like coating of oxide which protects against deterioration, should have extensive application in many fields.