Another method of estimating the life of plastics

Xenon Arc Light Aging

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ne of the tests used to evaluate the usefulness of a plastic is light stability as it relates to the natural aging of the material. Light stability tests apply mainly to the final behavior of the compound and are important since the life of the finished product depends on it. Various devices have been used for this purpose. Probably the most frequently used device has been the Fade-Ometer* or the Weather-Ometer.* The light source of this instrument is the carbon arc. The mercury lamp has also been widely used. However, the light emitted by the carbon arc and the mercury lamp is too rich in ultraviolet light, compared with natural sunlight. A more recent device employs a xenon discharge lamp. The xenon arc shows promise as an accelerated light aging device since it duplicates the spectra of natural sunlight better than most artificial sources. These are accelerated light aging devices whose purpose is to rapidly predict the light stability of a material.

Based on the results of the accelerated aging test and on other factors, the useful life of the material can be predicted without having to wait years for the results from natural aging studies. Unfortunately, the results of accelerated light aging have little or no correlation to natural sunlight aging. This is due to many factors, the most important of which is that sunlight at any one spot is not constant but varies from day to day and year to year. Therefore, the most that can be expected from an accelerated light aging test is that it serves as a guide to the probability of useful life of a compound when compared with that of another compound. A great amount of time has been expended in studying the natural aging of certain materials. When the accumulated information is used together with the accelerated light aging data from a new material or modification of previously studied compounds, the useful life may be estimated.

Accelerated Light Aging Units

There are several accelerated light aging units in use today. Some use carbon arcs or mercury sources such as the S-1 sunlamp, RS sunlamp, or germicidal lamp. However, these light sources vary in their ability to duplicate the spectral distribution of natural sunlight and may not give realistic weathering data.

Carbon Arc

The carbon arc emits an abnormal amount of ultraviolet energy in the cyanogen bands at 360 and 380 millimicrons as compared to natural sunlight (figure 1). If the polymer being exposed is sensitive to light in this range a greatly accelerated exposure may result. On the other hand if the polymer is sensitive to wavelengths above or below this range, the acceleration will be small. Another disadvantage of the carbon arc is its high ambient temperature which can thermally degrade some polymers. Therefore the data would not represent a realistic failure. In addition, the carbon electrodes must be replaced daily.

Mercury Lamps

The mercury lamps have a spectral distribution of narrow band intensity in the low ultraviolet region. Although this high energy short-wavelength radiation effectively accelerates the degradation of most polymers, it is unrealistic since this high-energy radiation is screened out

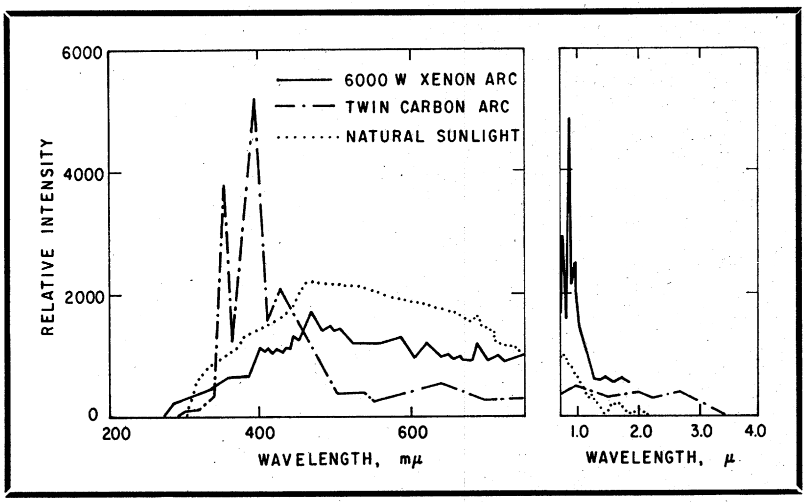

Figure 1, comparison of ultraviolet emission from xenon arc, carbon arc, and natural sunlight.

by clouds and dust before reaching the earth. In addition to not duplicating solar energy, the lamps have a limited useful life of 500 to 700 hours. Also the output of the bulbs decays continually, decreasing the ultraviolet radiation with use.

Carbon and mercury arc devices have been widely used and the results of tests have been well covered in the literature.

Xenon Arc

The xenon arc is a relatively new device for accelerated light aging. It shows promise as a good lamp for accelerated aging because it gives a spectral distribution of light emitted which is very similar to natural sunshine in northern latitudes. The spectral emission of the xenon lamp and natural radiation is shown in figure 1. In 1947 a light source called the "gas arc" was introduced. This consisted of a xenon gas discharge lamp in quartz, operated at relatively high current density. The first commercial accelerated light aging unit, based on the xenon arc, was marketed in 1954 by Quarzlampen G. m. b. H., Hanau, Germany. About five years ago the first unit was produced in the United States. The xenon lamps employed in the accelerated aging units* are of the high pressure water-cooled type. Two sizes are used, the 2500 watt in the compact unit and the 6000 watt in the regular size machine.

Each xenon lamp consists of a filter housing and a burner tube. The filter housing assembly contains both an inner and outer glass tube which, in addition to containing water, also filters the radiation. The water circulated through the lamp both cools the lamp and filters out the long infrared wavelengths. These filter housings can easily be dismantled for cleaning and replacement of the filter glasses. For normal testing, two types of outer filters are available. The clear glass outer filter tube has a cut-off at 320 mμ so that the radiation produced is very close to that of natural sunlight under glass. The Pyrex or UV transmissive outer filter with a lower cut-off at 275 mμ produces radiation that is similar to that of natural unfiltered sunlight. Due to solarization it is recommended that the outer filter be replaced after 1500 to 2000 hours of use. Since the inner filter is closer to the burner tube, it should be replaced after 400 to 500 hours of use.

The life of the 6000 watt burner tube is about 1500 to 2000 hours. The 2500 watt burner tube life is about 1000 to 1500 hours. The burner tube shows a progressive drop in intensity with use. This is mainly due to particles from the metallic electrodes being deposited on the inside of the quartz tube. Although the intensity changes, there is apparently no appreciable change in spectral distribution. Burner tubes and filter glasses change their transmission characteristics rapidly during the first few hours of operation. After reaching this point of stabilization, further changes occur at a much slower rate. This can be offset by increasing the wattage of the burner tube. These units can be used for light aging or weathering and are available with temperature, humidity, spray, and cycle control.

Light Aging of Plastics

Unfortunately, as of the present, there is not a great deal of information that has been published relating to the effects of the xenon arc on polymeric substances. This is due in part to the small number of units which are presently in use but also because most specifications are based on the carbon arc.

A comparison of various accelerated light aging devices, including the xenon arc, was made by the C-D-I-C Society of Paint Technology. The various coatings used in the test included acrylics, PVC, PVA, and polyurethanes. In addition the controls used in this study were the standardized yellow poly (methyl methacrylate) molded samples recommended as an ASTM practice. As far as the color change of the acrylic controls, it was found that the change was slower in the xenon machine. The coatings showed no clear cut pattern in that the degradation for the xenon arc in some cases was faster and in other cases, slower than that found for the other aging devices. This varied with the types of coating. However, in most cases the differences were not great.

Effect on PVC

A comprehensive study on the effect of various physical properties of plasticized PVC comparing the xenon arc and the twin carbon arc showed that visually failure occurred after about the same number of hours exposure in either machine. However, when the other physical properties were tested, it was found that the xenon arc produced faster degradation. Spotting was not found to be a significant factor with the xenon arc. This has also been found to be the case with mercury lamps.

In Europe, units based on the xenon arc appear to be more widely used than in this country as noted by the number of articles which show the xenon arc as the light aging device employed. However, the units for the most part use xenon lamps of 150 to 600 watt output. Copolymers of PVC and chlorinated polyethylene evaluated in one of these units were found to take about twice as long to yellow as in the carbon arc Fade-Ometer.

Discoloration of rubber and colored PVC compounds took longer in a xenon arc unit using a 600 watt source than the carbon arc Fade-Ometer. The xenon arc was considered to be a relatively weak light source.

Glass reinforced plastics have been suitably aged out of doors and in a xenon arc device.

The use of the xenon arc is presently covered by a tentative ASTM test method.

Since the xenon arc more nearly approaches the spectra of natural sunlight, it would appear that in the future this should become the standard light for accelerated light aging.