Cracks, which are but one sign of aging in the polyethylene sheath protecting cables, can cause havoc with the telephone system. To find out more about the complex reactions that lead to aging in plastics, scientists are turning to modern analytical tools.

Aging Problems of Plastics

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Plastics are among the most widely used materials in the Bell System. Hundreds of millions of pounds of plastics are built into the telephone system each year and are expected to perform reliably for many decades. In practical applications the evaluation of their aging processes is still largely empirical, and a fuller understanding of the complex chemical and physical reactions that lead to aging is needed. To this end, new analytical approaches and testing methods are being developed at Bell Laboratories. A few examples have been selected to illustrate these methods.

In general, plastics tend to be unstable, reactive materials. Very few types exist in nature. They are mostly synthetic products, made by combining small molecules into large ones, known as polymers (from the Greek ‘many parts’). Continued exposure to many of the common environments of our planet—sunlight, air, oxygen, water, cold, heat, and micro-organisms—can cause polymers to decompose into small molecules similar to those from which they were made. This process is called aging, and it leads to brittleness and eventual failure.

Reliability is a universally accepted design criterion for telephone equipment. The translation of this need into more precise engineering terms depends on the equipment and system. However, few applications allow the luxury of accepting much less than 20 years as an adequate life expectancy. Wire and cable intended for outdoor use must serve reliably for at least 20 years. An ocean telephone cable is expected to operate without attention at a reliability level that allows only two system failures in 20 years. Interior equipment such as that used in switching and transmission offices is designed for a life expectancy of 40 years.

Accelerated aging tests, which intensify the conditions responsible for degradation, have long been useful tools of the materials scientist. The first workable accelerated test procedures for polyethylene were announced by BTL 18 years ago. The report covered results of earlier outdoor and accelerated aging tests on a specific type of polyethylene compound. According to these tests 100 hours of accelerated aging was found to be equivalent to about one year of outdoor exposure. The results of these tests per-

Inside an accelerated aging device, plastic pieces and plastic-coated plates are exposed to ultraviolet radiation. A glass filter over the window of the oven-like structure removes those parts of the radiation spectrum that may harm an observer. The radiation is created by arcing carbon rods and simulates sunlight.
Two identical plastic samples under test are separated by a crystal that guides an infrared light beam and does not absorb its energy. Each time the light beam reflects from a plastic-crystal boundary, it penetrates slightly into the plastic and loses energy at those wavelengths where the material absorbs radiation. The plot of the emerging beam amplitudes at different frequencies yields the absorption spectrum of the plastic.

The detrimental effects of aging through outdoor exposure show up in the absorption spectrum of polyethylene. Increased absorption at 5.85 microns indicates the presence of carbonyl groups.

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Environmental stress-cracking occurs in polyethylene in the presence of certain environmental conditions. This sample was treated with a detergent in the darker area shown. When the sample was stressed, cracks developed in the treated area.

May 1968
temperatures is measured, and the result can be used to predict the useful lifetime of the plastic. As better materials are developed, however, testing times become excessive.

A "differential thermal analysis" technique adopted recently by Bell Laboratories cuts down testing times from hundreds of hours to a few minutes. The procedure involves the measurement of the beginning of oxidation as the temperature is raised. Data resulting from differential thermal analysis agree almost perfectly with those obtained with the slower oxygen-absorption tests.

Besides the chemical reactions of oxidation and thermal degradation, physical reactions can cause failure in plastics.

A phenomenon of great interest to the Bell System is environmental stress-cracking. When some plastics are subjected to stress in the presence of certain environments, failure can occur. Without this environment, the material shows no sign of failure, no matter how long the stress is applied. On polyethylene, such common materials as soaps, wetting agents, detergents, and certain alcohols can cause rapid cracking and failure. In most plastics, the primary factor governing this phenomenon has been found to be molecular weight. Materials with low molecular weight stress-crack easily, while those with high molecular weight may not crack at all, or only after a much longer time. Intuitively, it is easy to understand that stress-cracking must also depend on the applied stress. But the exact nature of this dependence has only been established recently. It has been found that stressing in the region of the yield point of the material is critical. (The yield point is defined as a stress level beyond which the material will not regain completely its original shape when the stress is removed.) Experiments indicated that if the material is stressed below or much above its yield point in the presence of known stress-cracking agents, no failure will occur. It will crack only when the stress is near its yield point (see the photo on this page).

Knowledge of this factor then provides the engineer with an additional parameter when selecting the plastic. The normal use of the material should not induce stresses associated with its yield point, because they can lead to premature failure.

Designing for long life is a complex affair. The nature of the chemical and physical reactions that lead to early failure must be identified before any corrective action can be taken. The results of these tests amply justify the time and expense involved, because they contribute to the fuller scientific understanding of the behavior of materials from which our present and future telephone systems must be constructed.