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by

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INTRODUCTION

The purpose of this paper is to review the present status of electrical wiring that is applicable to lower-cost housing and to forecast some changes for the future. The material for this paper was obtained from current literature, interviews with people who are involved in housing construction and personal observations. The 1968 report of the Urban Study Committee of the American Society for Engineering Education (1) made several astute statements regarding housing that can be applied to the electrical portion of construction.

First, home-building technology has not advanced commensurate with housing needs. A good example of this is aluminum wire which will be discussed in detail later in the paper. It was introduced right after World War II but it still has many unknown qualities that limit its full use today. Other innovations that need more development are the substitutes for metal in all types of electrical materials.

Second, the amount of basic and applied research that is concerned with electrical wiring is too small. It is encouraging to note that research and development expenditures in the United States are expected to be at a record $30-billion in 1972. (2) This is a mild 7% increase compared to the large increases that were seen in the mid-fifties to mid-sixties. However, it is much better than the 3.7% increase in R&D expenditures in 1971. Expected R&D in 1972 for the electrical and communications industry is $4.4-billion. These figures are from a survey by the magazine Industrial Research. Also noted in the survey was a concern over the problems plaguing technology and the current hostility toward technology by the public and Congress in the United States. Progress in the development of innovations in the electrical field are directly related to these figures.

Third, those innovations that have evolved have not been accepted well by industry and its allied portion of society. In conducting the investigation for this paper, it was noticed that the rural areas in the Midwest had not readily adopted such new materials as aluminum wire whereas the urban areas were more inclined to take advantage of new ideas. However, in one large metropolitan area, the association of electrical contractors will have nothing to do with low-cost housing. One low-cost housing project was bombed while being constructed.

Fourth, a complete lack of uniformity in electrical codes hampers the application of innovative ideas. Codes in some localities are nonexistent, others are too restrictive. Such variances cause modular or mobile home builders to design and build for the ultimate code (3) and precludes the use of new and lower-cost material. This is true because these units must meet inspection requirements wherever they are shipped.

Any significant improvement in the present status of the above items could lower the costs at no decrease in quality.

REDUCING COSTS OF ELECTRICAL WIRING

Aluminum Wire

The substitution of aluminum wire for copper is one of the principal means of reducing electrical material costs. On large contracts this procedure may cut the cost of wire in half. Electrical contractors who are wiring many units of low-cost housing in metropolitan areas have used aluminum wire as extensively as possible. (4) The National Electric Code allows the use of Aluminum wire but some local codes exclude its use. The reasons for this disparity are explained in the following paragraphs.

The problems that have resulted from the use of aluminum wire are caused by its properties of rapid oxidation, larger coefficient of expansion and tendencies to flow under pressure and break more easily than copper. All of these characteristics combine to cause installation difficulties at the terminations and the splices in the aluminum wire. Because of these problems, more expertise is required to install aluminum wire.

This author was fortunate in being concerned with some of the first applications of aluminum wire after World War II. The first instance involved the electrical wiring system for aircraft. Aluminum wire was tried because of the saving in weight. Stake-on or crimp-type terminals that were filled with anti-oxidation compound failed under lab and operational testing and its use was abandoned. This particular type of termination is no longer used for aluminum wire. Large-size aluminum wire for overhead, underground and feeder cables using a special compression-type terminal has proved to be highly successful for electric utilities and contractors. (5)

One of the primary reasons for the use of aluminum wire, in addition to its advantages of reduced weight and cost, was that copper was in short supply due to wars or world economic conditions. This was especially true after World War II, the Korean conflict and lately, during the peak of the Vietnam War. Such conditions have subsided somewhat for the present; however, they could return due to such things as Chilean strikes, Rhodesian politics and a booming, free-world economy. So it remains for the contractor and those in the construction industry to be well informed about the capabilities of aluminum wire. Complaints about aluminum must be examined with care because some of them may be old wives' tales.

Since it is a recognized fact that large aluminum wire can readily be used for distribution and large feeder circuits, this paper will concentrate on its employment in branch circuits. For those who desire to investigate all of the possibilities of aluminum wire, it is suggested that the references that are being used in this paper be consulted.

The National Electric Code 1971 (6) sets forth the correct wire sizes for desired current capacities as it has in the past. Typically the size of aluminum will be one size larger than its current equivalent in copper. This may necessitate the use of larger conduit or outlet boxes but presents no physical problems or increased costs that are not offset by the lower cost of the aluminum wire.

The real trouble may occur with terminal or splicing connections. Walter R. Stone, Editorial Coordinator for the National Electrical Code, has stated (7) that most difficulties with connections result from poor workmanship or the use of unsuitable connection devices. The use of a device that has connectors designed for copper in aluminum wiring installations causes much of the trouble. Aluminum expands and contracts almost 40% more than copper. This causes the connection to become loose as load is applied and removed which makes a progressively higher resistance joint every time that it is cycled and eventually causes the connection to fail. Since copper and aluminum are dissimilar metals, electrolysis is also a problem, especially in damp locations. A unique type of corrosion can occur. Mr. Stone discusses several other aspects of this problem in his writings in the Fire Journal.

W.A. Farquhar, Chief Engineer of Electrical Underwriters' Laboratories, Inc., reported (8) that failures of aluminum conductors were not duplicated in controlled testing in the laboratories, so engineers went into the field. Their field reviews demonstrated conclusively that connections were not being made properly or tightened adequately. Wires were either wrapped too far around the connector or not far enough. Failures could be attributed to poor workmanship or the use of the wrong termination. Several remedial measures have been taken.

Since May 17, 1971, all manufacturers of Nos. 8, 10, and 12 AWG solid aluminum wire have been required to provide instructions with each package of wire that was sold (See Figure 1). The

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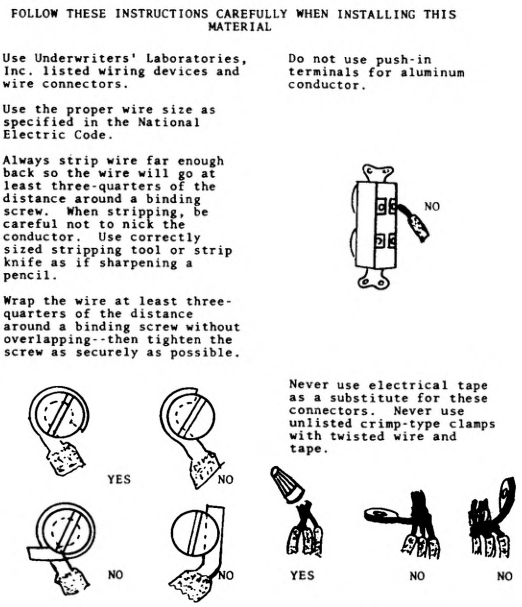

Fig. 1. Sample of instructions issued with each package of Nos. 8, 10, and 12 aluminum wire.

instructions explicitly describe the proper method to connect aluminum wire to terminals.

On June 1, 1971, the Electrical Underwriters' Laboratories upgraded their required specifications for wire. This step was taken because relatively wide variations had been permitted in the mechanical characteristics of aluminum conductors.

Since September 1, 1971, UL required that only devices which have been investigated and found suitable for use with aluminum wire be marked "AL" and used with aluminum.

In addition, UL is conducting other investigations and obtaining knowledge which will be used to further improve the use of aluminum wire.

Other Innovations

Aluminum wire is probably the means of achieving the largest cost reduction but there are others, many of which are untried due to the reasons that were set forth in the introduction.

A good example is a recent low-voltage switching device (9) for which its proponents claim a considerable saving for each switching circuit. It uses a NASA-type flat conductor which is only 7 mils thick for the low-voltage control of the high-voltage fixture or outlet. It is particularly suitable for renovation of old construction where it might be necessary to tear into walls and partitions to install switching circuits. Its adhesive-backed conductor can easily be adhered to the wall.

Many other innovations exist that have seen little use. Plastic outlet boxes and conduit are used some. More popular is the fiber glass outlet box which is more resilient than plastic.

CONCLUSION

It is apparent that the cost of the electrical portion of construction may be reduced by using innovative materials and methods such as aluminum wire. It will be necessary to follow specifications closely and properly indoctrinate personnel when such material is used. Designers and builders should look for innovative ideas for reducing the cost of the electrical contract.

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