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An Injection-Molded Plastic Connector for Splicing Optical Cables

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An injection-molded plastic splice connector for splicing optical cables has been fabricated and evaluated. Five optical cables containing 90-μm OD *graded-index fibers with 55-μm core diameters were spliced, yielding an average splice loss of 0.20 dB for the 425 splice joints measured. Fifty percent of the losses measured were less than 0.1 dB and 95 percent of the splice joints had losses less than 0.8 dB.*

Assembly methods for splicing optical cables using this connector and a multiribbon optical-fiber cutting tool capable of cutting 144 fibers simultaneously are also described.

I. INTRODUCTION

The feasibility of splicing groups of optical fibers in a laboratory environment has been demonstrated by a number of investigators.[1–5] The next phase in the development of optical-fiber splicing is to produce splice connectors, based on the concepts that have shown laboratory feasibility that are adaptable to field use. A field-adaptable splicing technique will require that telephone crafts people be able to splice groups of optical fibers in a routine fashion, with relatively simple tools, in a hostile field environment.

In this paper, an injection-molded splice connector fabricated using a mold designed to optimize reproduction of mold dimensions is described and evaluated. Assembly methods for splicing optical cables using this connector and a multiribbon optical-fiber cutting tool capable of cutting 144 fibers simultaneously are also described.

II. DESCRIPTION OF SPLICE CONNECTOR AND PRECISION-MOLDING TECHNIQUES

A precision metal mold was used to fabricate a 12-ribbon, multigroove substrate with prealigning slots. The molded plastic substrate which forms the base for the optical cable splice connector is shown in Fig. 1. It consists of twelve sections. Each section has a prealignment slot and a set of twelve fiber-alignment grooves spaced 90 μm apart.

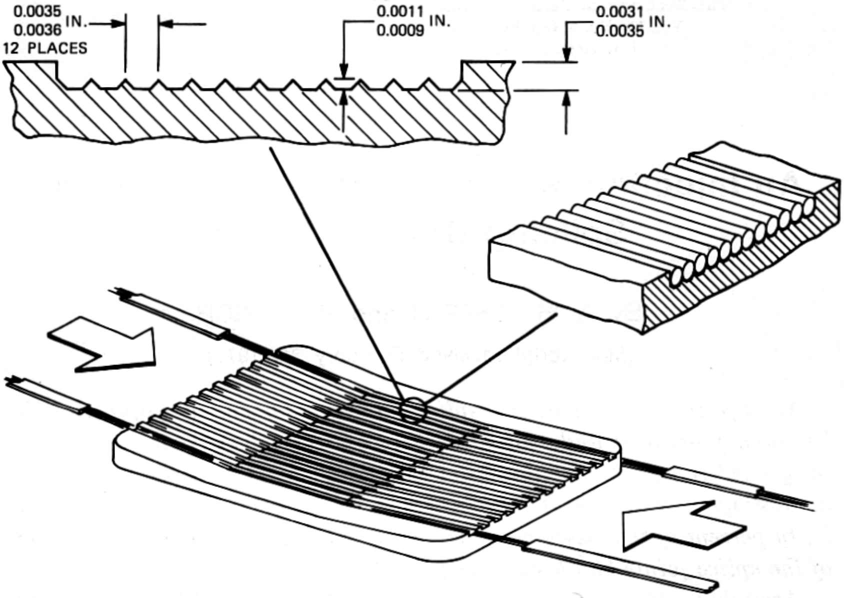


Fig. 1—Precision-molded substrate for 12 × 12 optical-fiber splice connector.

The splice is made by properly seating a precut set of ribbons into grooves and sliding them together to form a butt joint. A coverplate is attached to the substrate and matching material is injected through a slot in the coverplate to complete the splice. The completed splice

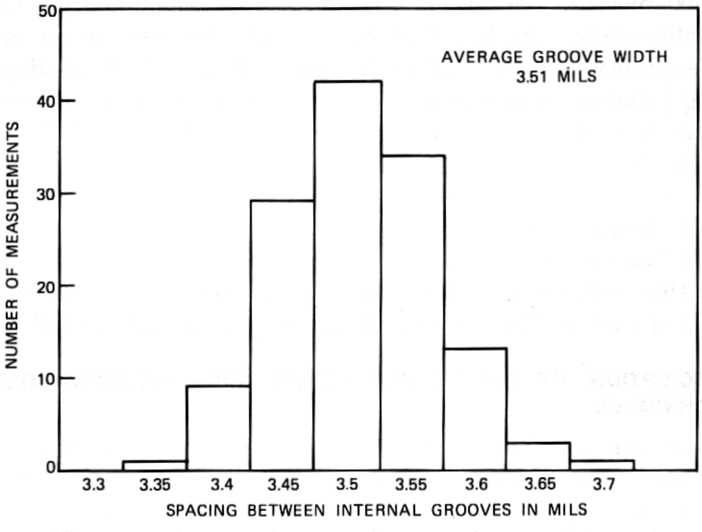


Fig. 2—Histogram of spacing between the internal grooves of metal master.

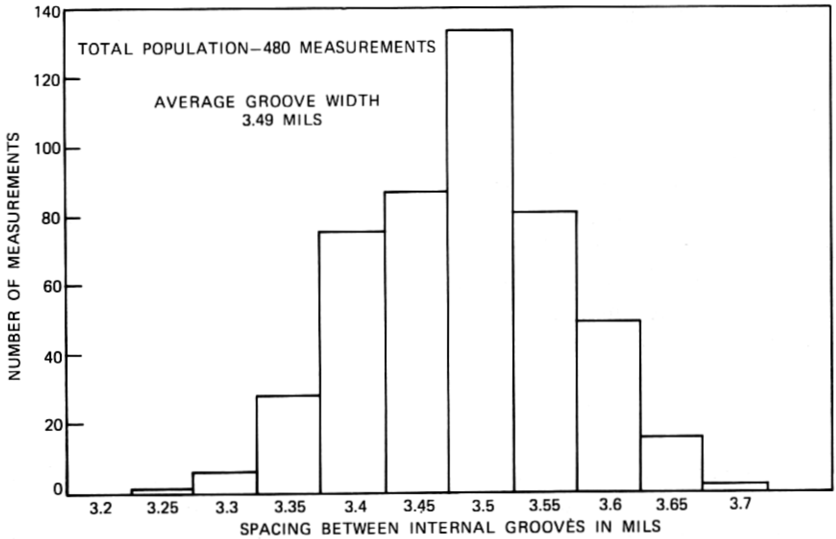


Fig. 3—Histogram of spacing between the internal grooves of molded polycarbonate substrate.

connector can join two optical cables, each consisting of twelve ribbons that house twelve 90-μm OD fibers.

The transverse alignment of the fibers in the grooves of the connector is a critical parameter in attaining low-loss splices. Tight tolerances were placed on the center-to-center spacing between the grooves. The design tolerance for the center-to-center spacing was 3.55 ± 0.05 mils. Less stringent tolerances were placed on the depth of the grooves.

The metal master was measured in an optical toolmakers microscope to determine how well it was machined. Figure 2 is a histogram showing the spacing between the internal grooves. The average groove width was 3.51 mils. Using the metal master in a screw-injection molding machine, a number of polycarbonate substrates were fabricated under different molding conditions. Samples were randomly selected from a batch that was molded to replicate the master as closely as possible. Figure 3 is a histogram showing the spacing between the internal grooves of the molded polycarbonate substrate. The average groove width was 3.49 mils compared with 3.51 mils obtained for the metal master.

Figure 4 is a derived cumulative distribution function of Figs. 2 and 3 showing a comparison of the groove-width dimensions for the master and plastic part. A very small amount of shrinkage, less than 0.1 mil, appears to have occurred in the plastic substrates. Measurement repeatability in obtaining this data with the toolmakers microscope was ±0.05 mil.

III. SPLICE CONNECTOR ASSEMBLY TECHNIQUE

The splicing of optical cables requires the integration of a number of operations including stripping of the cable sheath, ribbon preparation, removal of the plastic coatings from the fibers, fiber-end preparation, and, finally, the assembly and protection of the splice connector itself. Approximately 1 hour and 45 minutes is required to splice two optical cables consisting of 12 ribbons (each containing 12 fibers) together with the molded connector. Using current techniques, the majority of this time (about 1 hour) is spent stripping the ribbons and assembling them in the fiber organizers. Fiber-end preparation using the multiribbon cutting tool described in the Appendix requires about 15 minutes to prepare both ends of the cable. After the 144 fibers have been cut, the organizer is removed from the cutting tool and clamped to a micropositioner stage in preparation for insertion into the substrate of the splice connector. As shown in Fig. 5, tapered prealignment combs allow the ribbons to be lowered into the prealignment slots and grooves of the substrate. A mechanical wiper is attached to each organizer and is used to massage the fibers to assure that they are seated properly in their grooves. After the wiping process is completed, epoxy is used to permanently fix the wipers in place. The splice is closed by means of an assembly that enables the coverplate to be tacked in place with extra-fast-setting epoxy. An epoxy index-matching material is then injected through the slot in the coverplate to complete the splice. To assemble the connector itself requires only 30

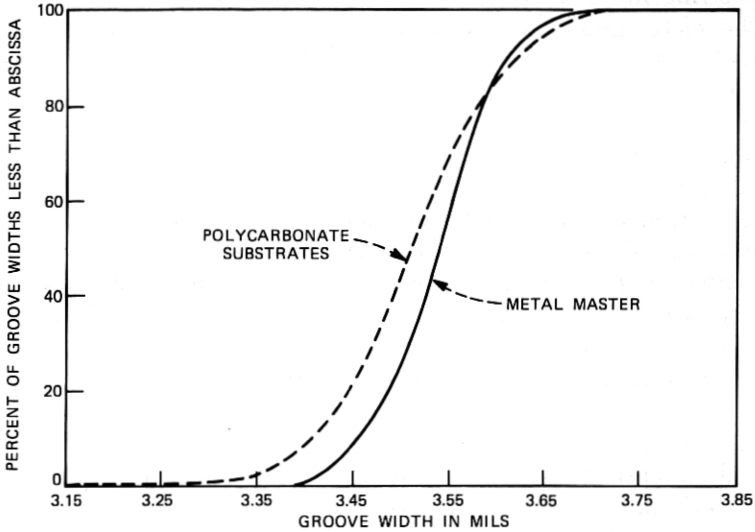


Fig. 4—Cumulative distribution function of groove widths.

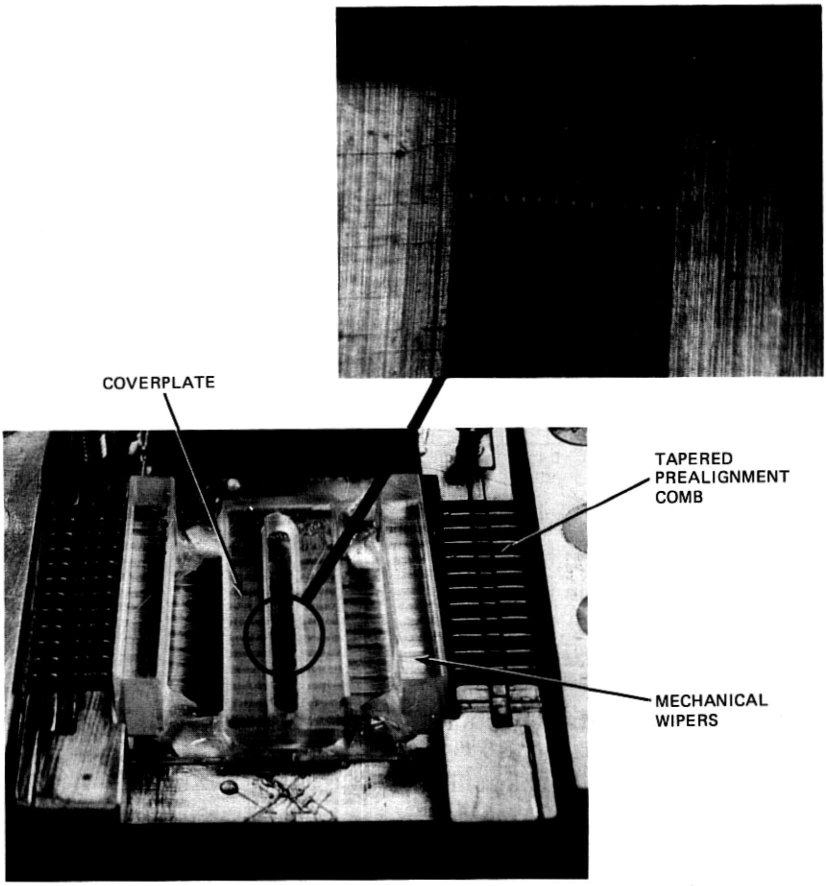


Fig. 5—Splice with coverplate epoxied in place showing expanded view of one ribbon joint.

minutes. Since splicing is a parallel operation, all twelve ribbons are spliced simultaneously.

IV. EVALUATION OF SPLICE CONNECTOR

Using Corning Glass Works graded-profile 90-μm OD fibers with 55-μm core diameters, adhesive sandwich ribbons[6] were made and formed into short prototype cables for the splicing studies. Following the procedures outlined in the previous section, five different cable splices were assembled and measured. Included in the statistics quoted were all ribbon-to-ribbon splices with twelve fibers present at the splice joint. When fiber breakage occurred, ribbon-to-ribbon splices with less than twelve fibers present were included in the statistics if proper alignment was maintained. Figures 6 and 7 show, for the 425

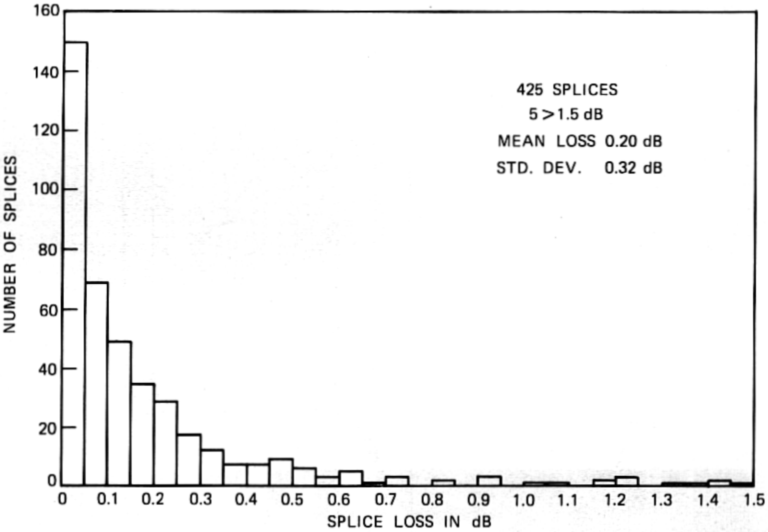


Fig. 6—Histogram of total splice loss data.

splice joints measured, the histogram and derived cumulative distribution function of the total splice loss data taken. The average splice loss was 0.20 dB with a standard deviation of 0.32 dB. Fifty percent of the total losses measured were less than 0.1 dB and 95 percent of the splice joints had losses less than 0.8 dB. Five additional outliers, not shown in the histogram but included in the statistics, had losses of 1.60, 1.64, 1.79, 2.03, and 2.66 dB. Four of these high-loss splices occurred in one of the cable splices.

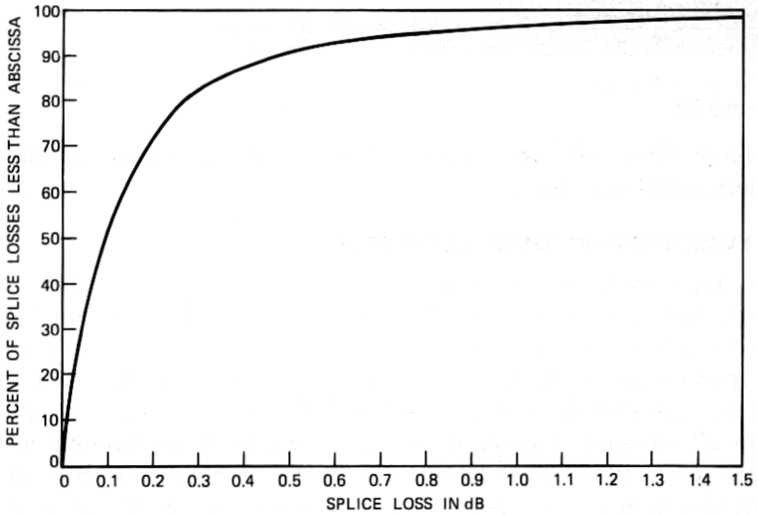
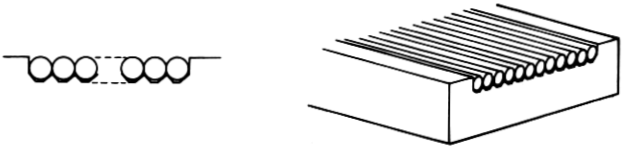


Fig. 7—Derived cumulative distribution of total splice loss data.

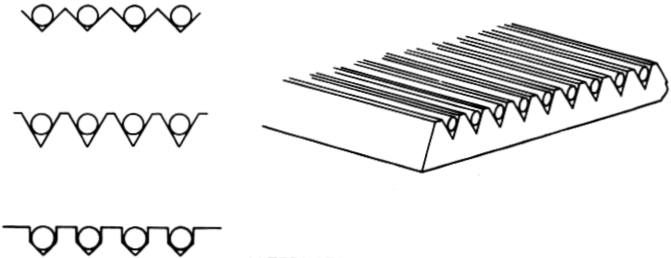
To determine the loss in a splice joint, an input beam with a numerical aperture approximately equal to that of the fiber was used and the input and output power to the splice joint was measured. This technique for measuring the loss in a splice joint has been described in detail in a previous paper.[1] The detector used in this study consisted of a United Detector Technology PIN long-line photodiode housed in a special glycerin-immersed fixture built to accommodate a ribbon organizer. To maintain accuracy in the splice loss measurements when measuring large groups of fibers (144 fibers in a linear array), it is necessary to establish accurate positioning of individual fibers on the surface of the detector. Variations in the sensitivity, as a function of position on the active surface of a large area detector, can cause errors in the measurements which are greater than 0.1 dB.

V. REQUIRED IMPROVEMENTS AND DISCUSSION

To maintain a high splice yield with this method of parallel splicing of large groups of optical fibers, 12 contiguous fibers must be present. If fibers are broken in the ribbons during ribbon stripping, fiber organizing, or end-preparation processes, gross misalignment (>10-μm transverse misalignment) can occur at the splice joint. The small alignment grooves shown in Fig. 8 do not provide adequate guidance unless the 12 contiguous fibers are present to force partial alignment of the fibers in the connector.



CURRENT DESIGN



ALTERNATE DESIGNS

Fig. 8—Alternate groove depths.

Typically, two fibers per cable end are broken in the ribbon stripping, cleaning, and organizing processes. The fiber-end preparation process yields about 99.7 percent efficiency. Thus, three to five ribbons within the group of twenty-four ribbons being spliced in a connector have less than twelve surviving fibers and have the potential for being badly misaligned.

The development of automated ribbon-stripping techniques and better fiber-handling methods will improve the yield of this process. It is very probable, however, that some fibers will break. To prevent high splice losses in an entire ribbon, if breakage occurs, requires a redesign of the molded connector. Increasing the alignment groove depth as shown in the connector designs of Fig. 8 will tend to provide guidance for individual fibers independent of the ribbon structure. When guidance of this type is achieved, the breaking of an individual fiber will not affect the alignment of the remaining fibers in a ribbon, and splicing performance will be greatly improved.

APPENDIX

A Multiribbon Optical-Fiber Cutting Tool

The production of low-loss splices between optical fibers or the splicing of groups of optical fibers in the form of fiber ribbons and cables requires a reliable and convenient method of fiber-end preparation. Two basic techniques of end preparation have been developed and are described in the literature. The first, a conventional grinding and polishing technique, has been used by Miller[3] and Cherin[1] in the splicing of optical-fiber cables and ribbons. This technique of end preparation could be utilized in a controlled environment to prepare the ends of factory-installed cable connectors.[3] The second method of fiber-end preparation requires the controlled fracturing or breaking of fibers as developed by Gloge et al.[7] A simple cutting tool for preparing the ends of individual fiber ribbons has been used by Chinnock et al.[4] and Cherin and Rich[1,2] with excellent results. A properly engineered tool of this type seems well-adapted for use under field conditions.

In this Appendix, we briefly describe the design of a cutting tool that, operating on the principle described by Gloge et al.,[7] is capable of cutting 12 fiber ribbons (144 fibers) simultaneously. The cutting tool has been designed to be compatible with the injection-molded splice connector described in this paper.

A.1 Cutting tool and ribbon organizer

The fiber-cutting tool, shown in Fig. 9, consists of four basic parts.

(*i*) A precision diamond-tip-stylus scoring assembly used to create a crack or origin of fracture on the outer surface of the fibers.

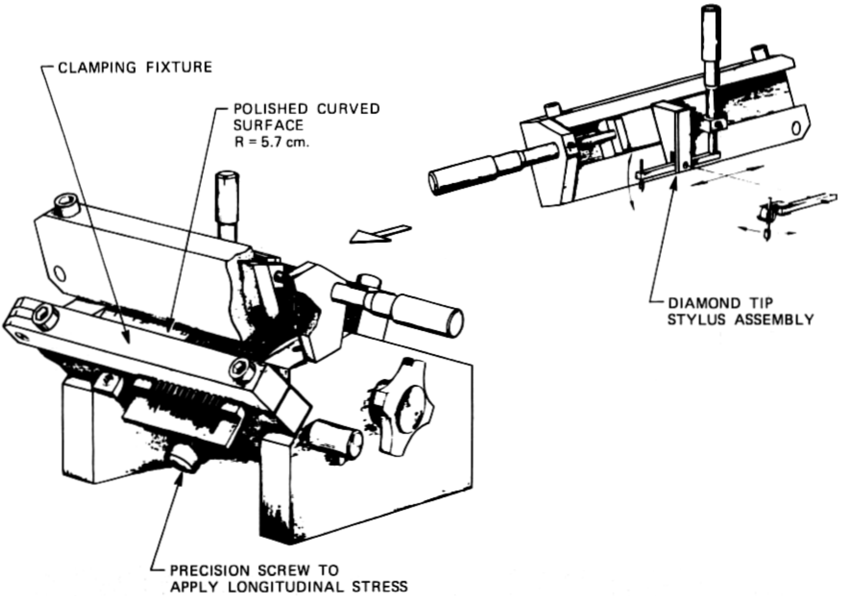


Fig. 9—Fiber ribbon cutting tool.

(*ii*) A polished curved surface over which sets of fiber ribbons are securely clamped. When the fiber ribbons are stressed over this surface, the stress distribution necessary to form flat hackle-free ends on the fibers is created.

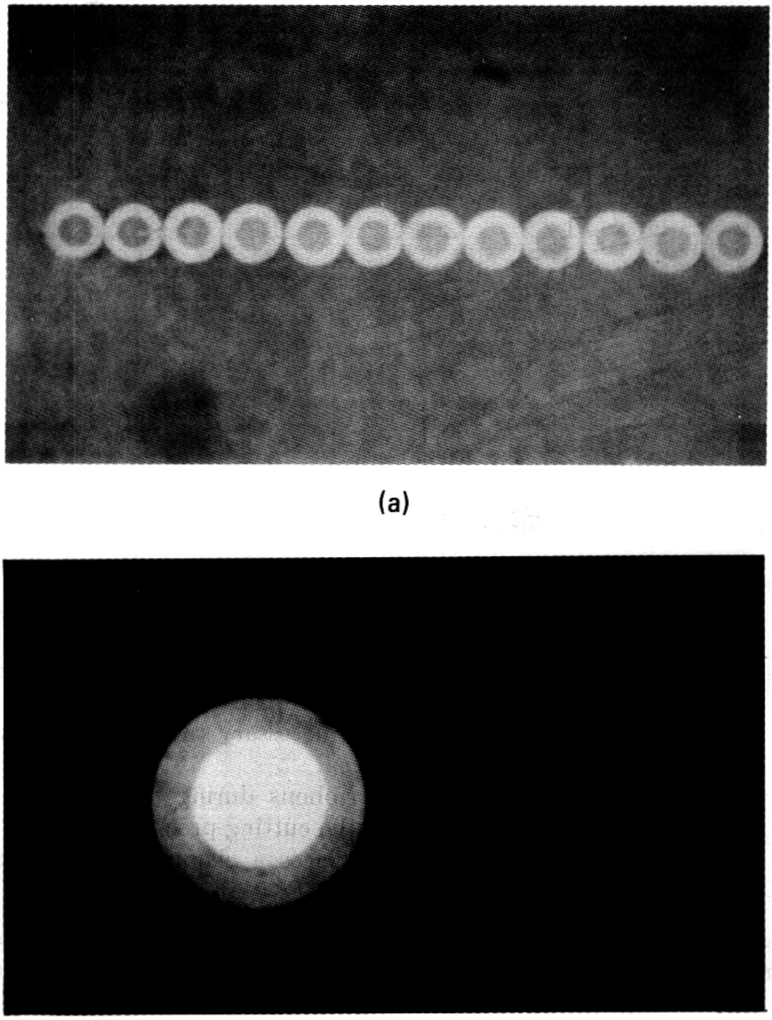
(*iii*) Clamps to secure the fiber ribbons during the scoring and stress-application portions of the cutting process.

(*iv*) A precision screw, which displaces a clamp and causes the application of a longitudinal stress within the fibers.

A ribbon organizer is used to hold 12 ribbons in the form of a linear array. The organizer is clamped to the cutting tool and holds the fibers securely in place during the cutting process. After the 144 fibers have been cut, the organizer is removed from the cutting tool and is ready for insertion into the cable-repair splicing fixture.

A.2 Cutting experience

To date 52 cable ends have been prepared using the cutting tool. The nominal cable consisted of 12 ribbons each containing 12 fibers. Planar ends have been made on 99.67 percent of all the fibers that have been cut, 7328 out of 7352 (a few of the ribbons had less than 12 fibers within them). Typical fiber ends that were prepared using the tool are shown in Fig. 10. The total cutting efficiency of the tool was determined by the number of fibers surviving the entire process



(a)

(b)

Fig. 10(a)—Optical ribbon with prepared fiber ends. (b) Typical fiber end.

of clamping, scoring, and tensioning. A total of 7283 fibers successfully survived the entire process, yielding a cutting efficiency of 99.06 percent.

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