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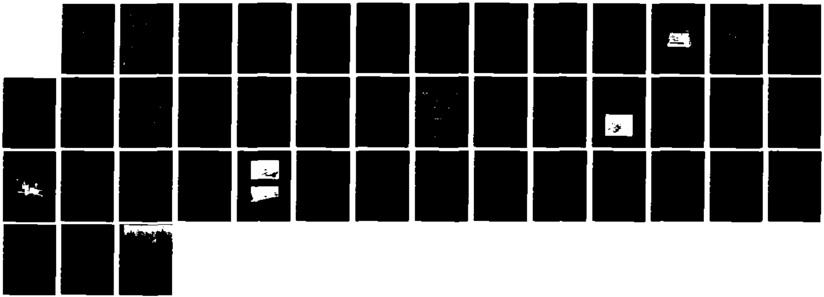

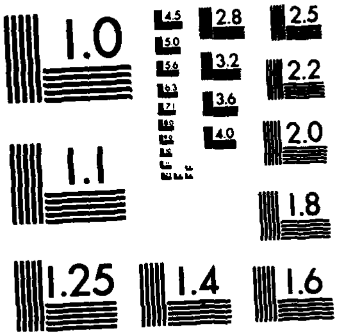

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FIELD EXPEDIENT REPAIR OF FIBER OPTIC CABLES

LAURENCE N. WESSON
TRW INC.
Electronic Components Group
Research and Development Laboratories
Philadelphia, PA. 19108

MAY 1983

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PREPARED BY:

TRW INC.
ELECTRONIC COMPONENTS GROUP
RESEARCH AND DEVELOPMENT LABORATORIES
PHILADELPHIA, PENNSYLVANIA 19108

APPROVED BY:

Kenneth M. Merz
Manager/Fiber Optics Research

APPROVED BY:

David E. McElroy
Director/Research & Development Labs.

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During this semi-annual period the first and second generation of the Field Expedient Splice Kit (FESK) were operated, evaluated, and extensively developed. 10 Interim Splices were assembled with the FESK I, and 5 were delivered to CECOM. The remaining 5 were held for environmental testing. During the splice work a novel method of scribing and breaking fibers was introduced and tested. As a result of these developments the third and final version of the splicing machine was designed and modelled. Evaluation of the model confirmed the validity of its operation principles, and the first deliverable FESK III was ordered.

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PREFACE

This is the third Semi-Annual Report for the work being performed under contract number DAAK80-82-C-0085, "Field Expedient Repair of Fiber Optic Cables". The funding for the development of the repair system is provided by the U.S. Army Communications - Electronics Command (CECOM). Technical direction and coordination is provided by Claire E. Loscoe, the cognizant engineer at CECOM.

The development work performed to date represents the efforts of: Henry D'Amico, Design Engineer; Dr. Malcolm H. Hodge, Manager, Fiber Optic Products Operation; Joseph F. Larkin, Senior Mechanical Engineer; Dr. Kenneth M. Merz, Manager, Fiber Optics Research; Jeffrey Ogilvie, Jr., Designer; Charles T. Smith, Fiber Optics Technician; Laurence N. Wesson, Program Manager; and John G. Woods, Program Manager during the first year of the program. Through December, 1982, all were members of the TRW Electronic Components Group, Research and Development Laboratories, in Philadelphia. On 1 January, 1983, Messrs. Hodge, Ogilvie, and Woods were re-assigned to the Fiber Optic Products Operation of the TRW Connectors Division, and Mr. Wesson assumed management of the program.

1. INTRODUCTION

In the preceding 6 months a brassboard splicing machine, denoted the FESK I, was built and tested with ITT-EOPD tactical fiber optic cable. Splices were assembled in the first splice housing designed. The repair procedure was developed and evaluated for speed, effectiveness, simplicity, and ease of performance. As a result of this study an improved splice machine was designed. This "FESK II" retained many of the advantageous features of the basic splicing method, particularly operations oriented specifically to the use of the TRW 4-rod alignment guide. At the same time it corrected the perceived deficiencies of the FESK I in such areas as the fiber stripping and cleaving action and the overall size and weight. The splice housing was also redesigned to incorporate a novel sled concept for the two prepared cable ends and to insure that the two main housing halves were not separable or susceptible to loss.

During the past 6 months a wooden mock-up of the FESK II was assembled to evaluate the operation of this new design. At the same time a large number of trial fiber cleaves and complete splices was performed with the FESK I. A human factors engineer examined the FESK II for its layout, ease of operation, and general suitability for field use, and he recommended several improvements. As a result of these several developments a further body of changes was designed into the splicing machine. The result, FESK III, was modelled in wood.

This report details these activities in 4 major areas. Under "FESK I" is described the considerable body of single fiber loss and end quality data generated in evaluating the original cleaving method and its successor. The section on the FESK II lays out the design and advantages of the second splicer. The areas identified for improvement, either by experimentation or by expert analysis, are noted. The resulting FESK III is covered in the following section. Its improved features are noted, and the latest splicing procedures are described in detail. Lastly, the splice housings themselves are described. The data derived from the experimental assembly of 10 interim splices are covered, and the various resulting improvements to the splice design are described.

2. TECHNICAL DEVELOPMENT

2.1 FESK I BRASSBOARD

2.1.1 DESIGN AND OPERATION

The FESK I splicing machine is shown in figure 1. This machine has been described in detail elsewhere[1]. No significant changes were made to this splicer except in the fiber cleaving mechanism. Work on this feature of the system will be addressed at length because it is significant to the later development of the FESK III.

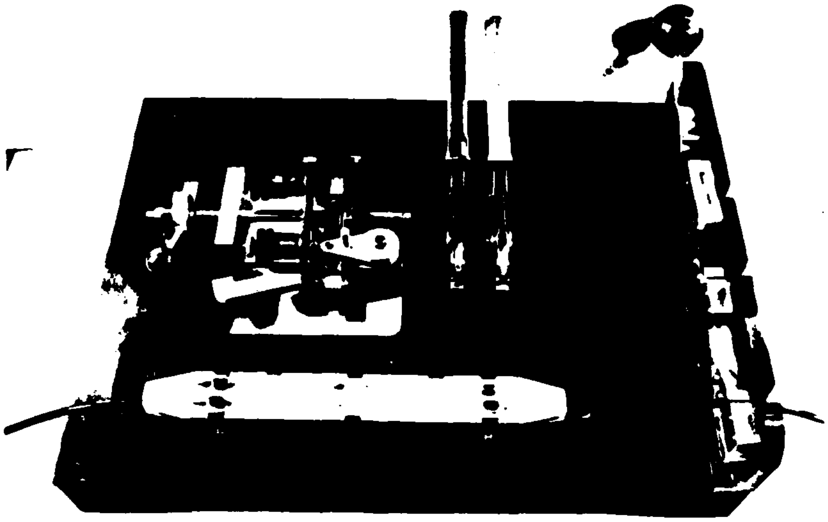
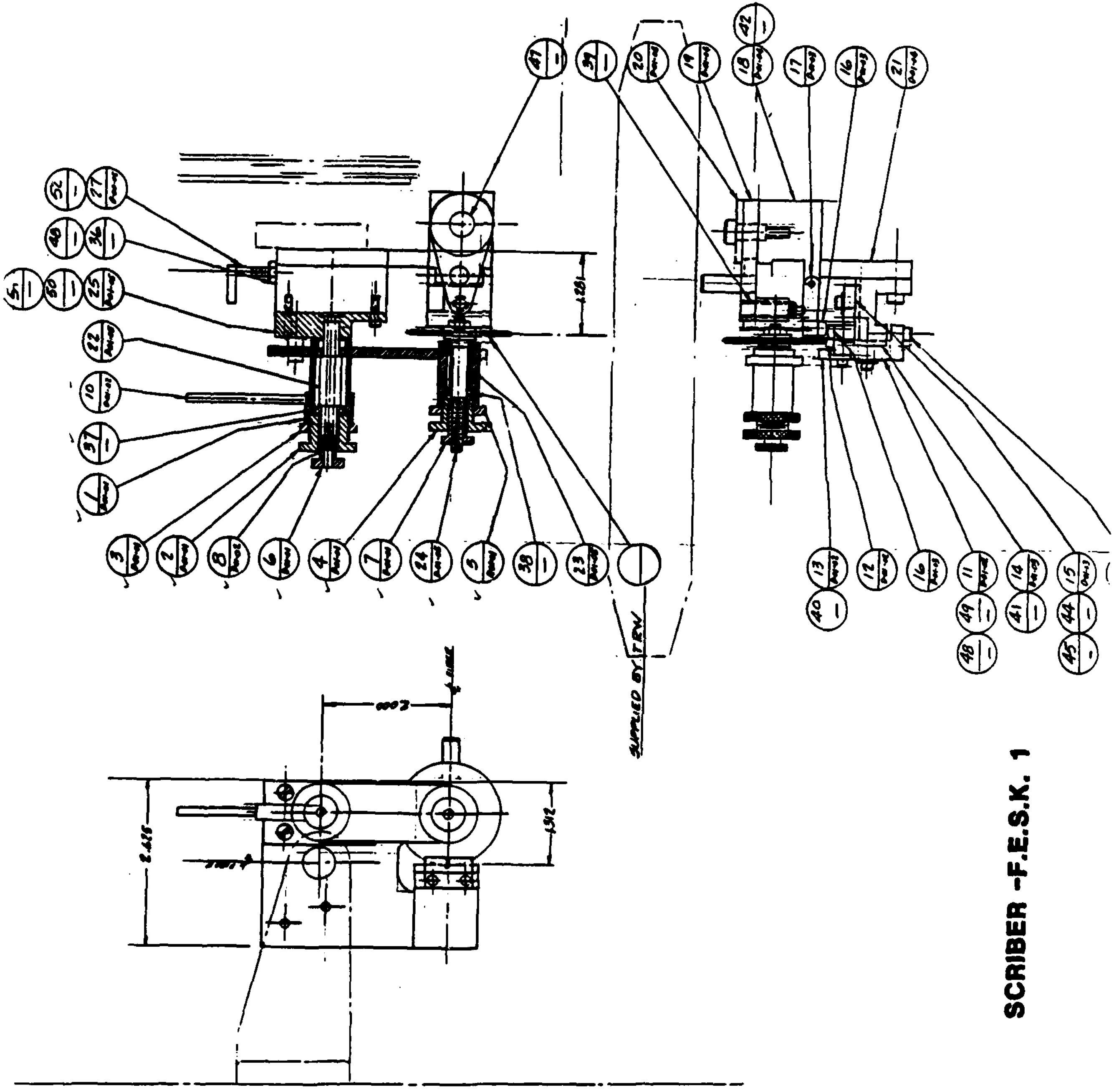


Figure 1. FESK I Splicing Machine

The fiber cleaving mechanism designed for the FESK I is shown sketched in figure 2. In essence it consisted of a carbide wheel for nicking an exposed fiber, a flat platform on which the fiber rested, and a pair of elastomeric pads which clamped the fiber below the nick site and through which the fiber was pulled after nicking.

The fiber platform was constructed of teflon to prevent abrasion of the bare fibers and to allow easy passage of the carbide wheel. At one side of the platform, away from the fiber optic cable and the resilient pads, was provided a notch or



Original Fiber Cleaving Device

Figure 2

groove to locate the fiber and prevent it from slipping sideways.

The carbide wheel was mounted on a counterbalanced freely-pivotting arm. This arm was in turn located on a precision linear ball slide. This arrangement of elements provided that the carbide wheel could roll easily over a fiber with unconstrained vertical freedom and a controllable degree of downward force. Forward/backward motion was accomplished by pushing or pulling the scriber carriage on its ball slide.

The resilient pads were originally flat and parallel. During early experiments at TRW it had been found that good fiber cleaves could be made by pulling a nicked fiber through such plane parallel pads under a certain degree of pressure. During this reporting period, however, it was found that the yield was not as good as desired, and various alterations were made in the shape of the pads to improve the yield. The form settled on consisted of a convex lower pad with a concave (with a larger radius of curvature) pad above it.

The entire clamp pads/fiber platform/carbide wheel carriage assembly was mounted on a work platform on a slide rail.

In operation this cleaving system was used in the following manner:

1) The stripped fiber was threaded between the open clamp pads, across the scribe platform, and into the lateral registration notch. The length of the fiber was controlled by a crimped aluminum ferrule which was retained in the crimp plier jaws during this cleaving operation. During placement of the fiber in the cleaver the clamp pads were held open and the carbide wheel carriage was retained in its rear position. The entire work platform was held at its rightward-most position on the slide rail, where its location was controlled by a set screw.

2) The fiber clamp pads were closed and clamped.

3) The carbide wheel was slid forward on its carriage to cross the fiber once and come to a stop. No pressure was exerted on the wheel or its hinged mounting arm other than that provided by the weight of the wheel itself, offset by the counter weight.

4) The entire work platform was slid to the left away from the fiber optic cable on its slide rail. This action resulted in the nicked fiber being pulled through the resilient pads under pressure. As a result of the bending, the pressure, and the tension on it, the fiber would break at the site of the nick.

2.1.2 FIBER END QUALITY

To evaluate the potential quality of the fiber ends prepared by this method, independent of any other factor, a large number of single 50/125μ ITT fibers was cleaved with the FESK I carbide wheel cleaving system. After selection of those with proper lengths and apparently good ends, 20 fiber pairs were tested for insertion loss when mated in 4-rod alignment guides. The guides were pre-filled with alcohol for index matching, and they were not mounted in splice housings.

The loss data are presented in Table 1. Every junction except one showed an insertion loss of less than 1 dB. The mean loss value was 0.38 dB, with a standard deviation of 0.57 dB. If the single high loss value were disregarded, the average and standard deviation would become 0.27 and 0.26 dB, respectively.

These data, while demonstrating the potential quality of the fiber ends prepared with the FESK I cleaver, did not address the question of yield, which is discussed in the following paragraph.

2.1.3 SPLICE YIELD AND INSERTION LOSS - ORIGINAL CLEAVER

Several experimental 2-fiber splices were assembled on ITT-EOPD tactical cable with the FESK I and the length and insertion loss measured. Fiber ends were prepared with the carbide wheel cleaver. The alignment guides were pre-filled with index-matching silicone oil. Loss values were obtained by comparison of the light power received through the two spliced fibers compared to baseline power levels measured before the cable was cut. The test set-up is shown schematically in figure 3.

The data obtained are presented in table 2. It should be noted that all attempts at each operation were recorded; thus an indication of the yields of different steps in preparing a splice was obtained. Most operations yielded a very high success rate; these included the outer and inner jacket strips and the Kevlar and registration ferrule crimps. The percentage of successful fiber strips, at 93%, was judged acceptable.

However, the carbide wheel fiber cleaving system presented a problem. Both the yield of proper lengths and (especially) the insertion loss values were found unacceptable. Several causes were determined for these results:

- Unreliable scribing by the carbide wheel, often too light or too hard.
- The high pressure on the fiber in the curved clamp pads made it very susceptible to particles of dust or glass which could precipitate cleaves at the wrong location.
- Mechanical tolerances in the delicate wheel/counterweighted arm/ ball slide assembly made the cut fiber lengths very difficult to control.

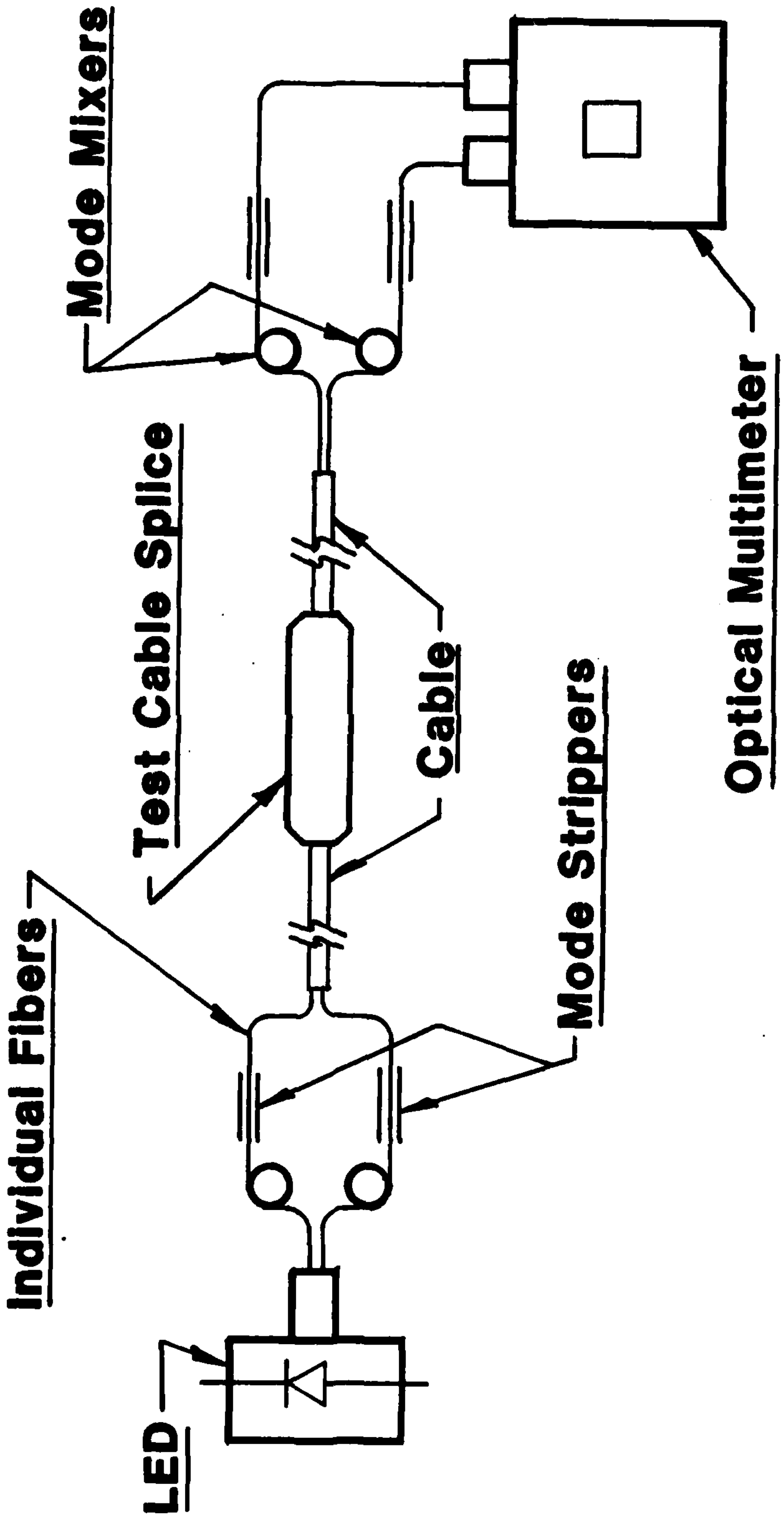


Figure 3. Schematic Diagram of Splice Loss Measurement System

TABLE 1. INSERTION LOSSES OF 20 SELECTED FIBER PAIRS PREPARED WITH THE FESK I CLEAVER

CONNECTION #	ALIGNMENT GUIDE #	RECEIVED POWER (μW)	LOSS (dB)
1	1	0.087	0.15
2	2	0.086	0.20
3	3	0.084	0.30
4	4	0.085	0.25
5	5	0.088	0.10
6	6	0.077	0.68
7	7	0.086	0.20
8	8	0.088	0.10
9	9	0.088	0.10
10	10	0.088	0.10
11	11	0.086	0.20
12	12	0.075	0.79
13	13	0.087	0.15
14	14	0.087	0.15
15	15	0.089	0.05
16	16	0.088	0.10
17	17	0.072	0.97
18	18	0.050	2.55
19	1	0.084	0.30
20	2	0.086	0.20

baseline optical power = 0.090 μW
LED current = 50.5 mA
average insertion loss = 0.38 dB
standard deviation = 0.57 dB
fiber = 50/125μ ITT-EOPD hytrel jacketed
index matching fluid = alcohol

TABLE 2 **PRELIMINARY SPLICE YIELD AND INSERTION LOSS DATA - ORIGINAL CLEAVER**

					Channel 1				Channel 2			
Splice #	Side	Outer Jacket Strip	Inner Jacket Strip	Kevlar Crimp	Aluminum Crimp	Jacket Strip	Cleave	Insertion Loss (dB)	Aluminum Crimp	Jacket Strip	Cleave	Insertion Loss (dB)
(1) - 1	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	-	-	-	-	✓	break	-	-
	"	✓	✓	✓	✓	✓	✓	1.0	✓	✓	✓	14.5 (broken fiber)
(2) - 1	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	2 tries	too long	-	✓	✓	too long	-
	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	-	-	-	-	✓	✓	broke	-
	"	✓	✓	✓	✓	✓	✓	11.7	✓	✓	✓	-0.75
(1) - 2	A	✓	✓	✓	✓	✓	broke	-	-	-	-	-
	"	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	✓	-	✓	✓	broke	-
	"	✓	✓	✓	✓	✓	✓	8.8	✓	✓	✓	5.2
(3) - 1	A	✓	✓	✓	✓	broke	-	-	✓	✓	✓	-
	"	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	too short	16.6	✓	✓	too short	16.2

Average insertion loss (8 completed channels) = 9.16 dB
standard deviation = 6.33 dB
Yields: Outer jacket strip = 100%
Inner jacket strip = 100%
Kevlar crimp = 100%
Aluminum (registration) crimp = 100%
Fiber jacket strip = 93%
Cleaves to length = 72%
Insertion loss of 1 dB or less = 25%

- The motion of the work platform during the sliding operation along the slide rail was unavoidably uneven and jerky due to binding. This made it practically impossible to achieve a smooth even pull on the fiber during cleaving, with the result that the fiber was much more likely to succumb to any imperfections in the scribing or the clamps.

To avoid or mitigate these problems a novel fiber cleaving system was substituted for the original method on the FESK 1. The binding problem of the work platform on its slide rail was addressed by an innovative swinging arm mechanism for the fiber strippers and cleaver, introduced on the FESK II.

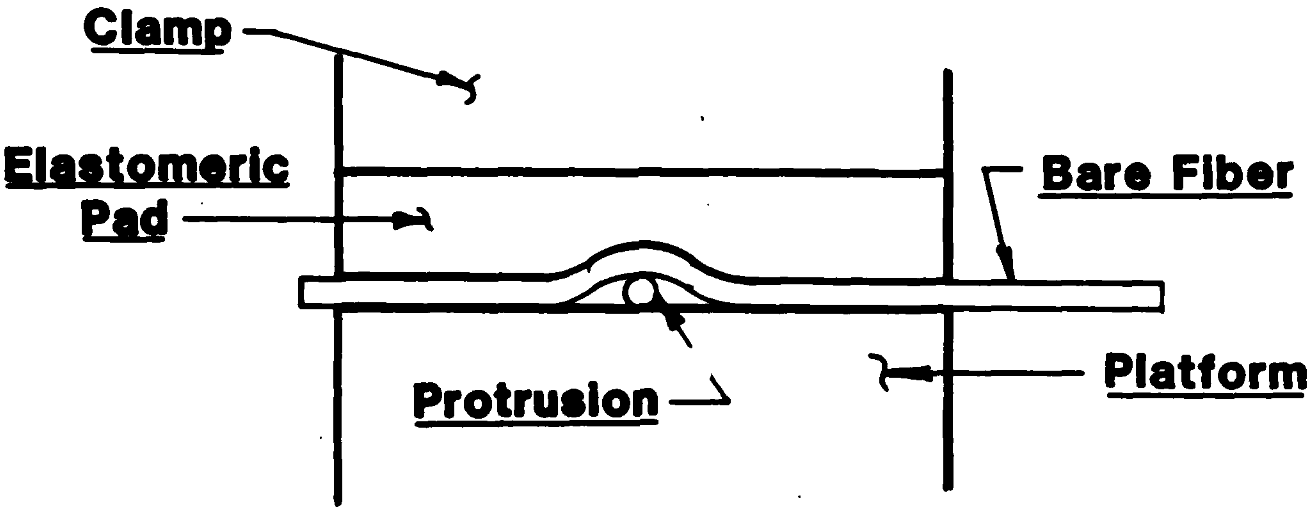
2.1.4 FIBER END PREPARATION - NEW CLEAVER

Figure 4 shows a schematic diagram of the "crossed fiber" cleaving method. As installed on the FESK I this method employed a flat wooden surface on which a fiber to be cleaved was placed. Attached to the platform, and crossing it perpendicular to the fiber (and under it) was a second short length of optical fiber of the same size as the ITT-EOPD 125μ fiber used in this program. The fiber to be cleaved was clamped against the platform and the crossed fiber with a large flat rubber pad mounted on the same clamp device used in the original cleaver.

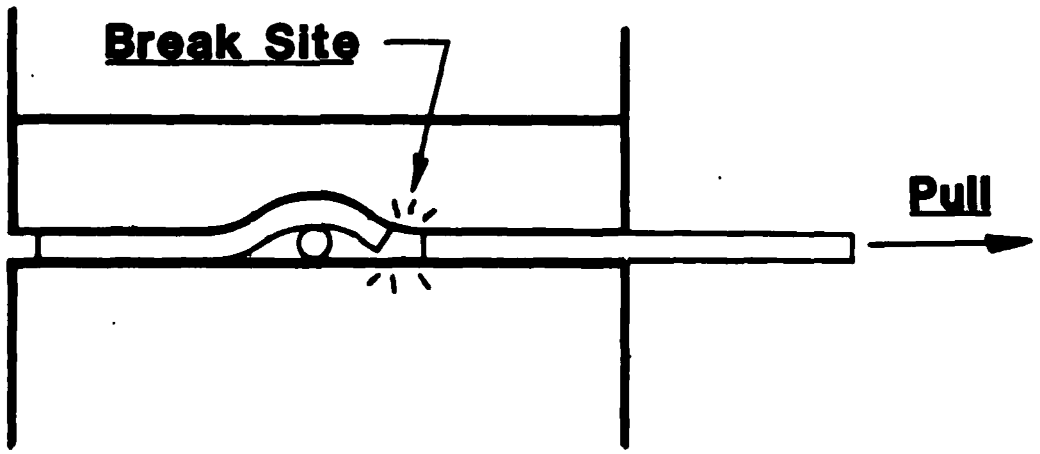
The operational sequence for the new cleaver on the FESK I was as follows:

1) Lay the stripped fiber on the wooden platform, across the crossed (fixed) fiber. The work platform is at its rightwardmost position on the slide rail.
2) Clamp the flat rubber pad on the fibers, compressing them against the work surface.
3) Slide the entire work platform to the left along the rail. This action has the effect of pulling the fiber to be cleaved out through the clamps under combined longitudinal tension and lateral compression against a precisely-located flaw-inducing element (the crossed fiber). As the original flawed point of contact moves away from the crossed fiber it develops, under tension, into a complete high quality cleave.

After assembling the new cleaving device on the FESK I machine a series of test splices was assembled and measured for insertion loss while the crossed fiber position, length adjustment, pad pressure, and stripper position were continuously adjusted. This tuning process used splices #(3)-2 through (3)-13.



STEP 1: Pressure Applied



STEP 2: Pull and Break

Figure 4. Schematic Diagram of "Crossed Fiber" Cleaving Method

Following the adjustment and development process a series of single fiber cleaves was made to determine the intrinsic success rate. The following data were noted: number of failures to break at all, number of incorrect lengths, and number of poor ends (irregular faces or face angles more than 2^o from the fiber axis). The results are presented in Table 3.

As can be seen from these somewhat remarkable results, the method was capable of exceptionally high yields of good quality fiber cleaves to the proper length. The cautionary consideration was that the preliminary test was performed by pulling the fiber from the cleaver, rather than the cleaver from the fiber. On the FESK I machine, as discussed above, the cleaver on the slide rail had an unavoidable tendency to bind and jerk to some degree during a supposedly smooth slide. Further, introducing the complications of cable and fiber crimps on a fully terminated cable would be expected to affect the yield. Nevertheless, the early results with the new cleaving method led us to employ it for the assembly of the interim splices on the FESK I brassboard splicer (see section 2.4).

Table 3. PRELIMINARY TEST OF NEW FIBER CLEAVER

Trial	Break	Length	End Condition
1	yes	correct	square and flat
2	"	"	" " "
3	"	"	" " "
4	"	"	" " "
5	"	"	" " "
6	"	"	" " "
7	"	"	" " "
8	"	"	" " "
9	"	"	" " "
10	"	"	" " "

2.2 FESK II

2.2.1 DESIGN

This version of the splice kit was designed during the preceding period and is described in some detail in reference 1. Briefly, it incorporated a number of changes deemed necessary in initial handling of the FESK I machine. Among these improvements were:

- Positive - action toggle clamps for the cable jacket stripper blades. In the FESK I the stripper blade slide employed a spring action return, which was found to be unreliable.
- Butt-closing stripping blades in place of overlapping blades. This allowed simpler design as well as a reduced possibility of jacket shreds clogging the mechanism.
- Placement of the two (inner and outer) jacket strip functions in separate blade/clamp assemblies.
- Re-arrangement of the crimping pliers for easier access with gloved hands.
- Considerably reduced tool platform area.
- considerably reduced weight.
- A combination rotating/swinging arm assembly for the crucial fiber stripping and cleaving tools. This assembly replaced the work platform on a slide rail, which was easily susceptible to binding. This novel arm assembly, by substituting a rotating action, vastly reduced the risk of binding and consequent bumpy movement which appeared to contribute significantly to the fiber strip and cleave failures on the FESK I.
- Enlarged two-station jaws for the aluminum registration crimp pliers. This allowed the pliers to crimp both fibers simultaneously. An enlarged fiber guide assembly with a spring-loaded lid was provided around the pliers to allow easy insertion of the two fibers into their respective registration ferrules and later easy removal after crimping, stripping, and cleaving.
- Parallel mounting of two Utica fiber strippers to strip both fiber jackets at once.

- Enlargement of the fiber cleaving assembly to cleave both fibers at the same time.

2.2.2 MODEL

A wooden mock-up of the FESK II (shown in Figure 5) was built during these 6 months to verify the proper functioning of the new design ideas. In almost all regards it fulfilled expectations.

Several minor shortcomings were noted and corrected in the FESK III. Among these were the susceptibility of the cantilevered swinging fiber stripper/cleaver assembly to shock or vibration in transit. Other areas for improvement were noted by the human engineering specialist or developed during the experimental work with the FESK I. These will be discussed at length in the following sections.

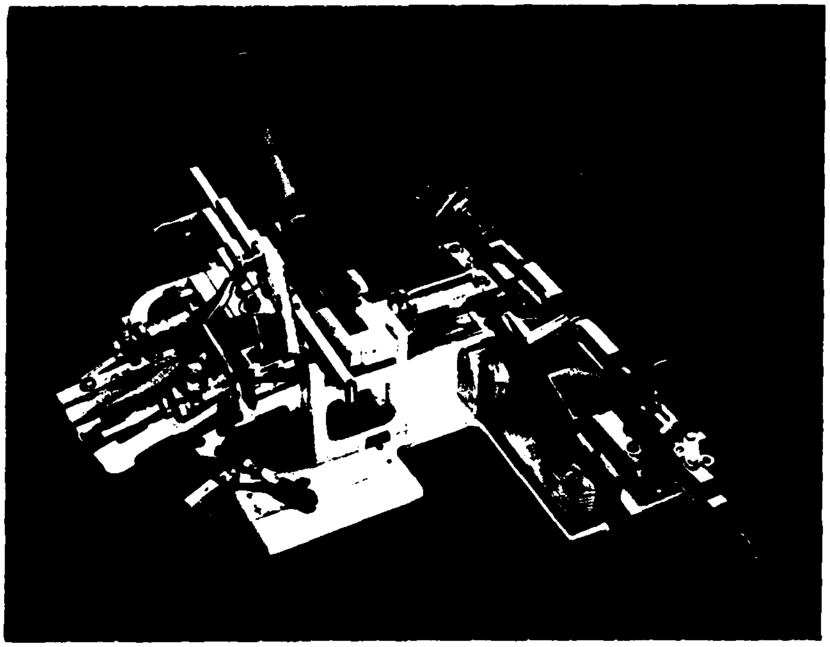


FIGURE 5. WOODEN MOCK-UP OF THE FESK II SPLICING MACHINE

2.2.3 HUMAN FACTORS ENGINEERING IMPROVEMENTS

The FESK II mock-up was examined by a human factors engineer from Armament Systems, Inc., acting as consultant to CECOM. On the basis of his recommendations the following changes were made to the FESK II or planned for incorporation in the final deliverable (FESK III) kits:

- A shield was planned to cover the carbide fiber-scribing wheel to prevent the operator from handling the wheel or its mounting arm directly and thus affecting the force of its contact with the fiber. This change was rendered moot by the implementation of the new cleaving system on the FESK III.
- Improve the fiber guide slots on the splice sleds to hold the projecting fibers more straight and ease their insertion in the plastic funnels and the alignment guides.
- Numbers will be printed on the various stations of the FESK III to remind the operator of the sequence of splice assembly operations.
- Tape dust covers will be provided over the dirt-sensitive parts of the splice prior to use.
- Enlarged serrated shears will be provided for cutting the Kevlar strength members. The shears chosen have proven both unusual facility for cutting the tough Kevlar and ease of operation by a person wearing gloves.
- Eliminate the splice "nest" on the machine. This is a major weight-saving change.
- Eliminate the toggle clamp operation of the two parallel fiber coating strippers. Operation of the strippers is more direct and obvious with a simple hand grip.

2.3 FESK III

2.3.1 DESIGN

The third and final version of the Fiber Optic Splice Kit was designed during this period based on the considerable experience gained with the first two models. An assembly drawing of the FESK III machine is shown in Figure 6.

The principle improvements over the FESK II are as follows:

- The two cable jacket strippers are combined in a single blade with a single toggle clamp. This eliminates both the size and weight of the second stripper, and avoids leaving a redundant element in cases where the cable to be spliced has only a single jacket.
- Improved strength member retention ferrule crimper jaws. The new design both guarantees properly tight crimps and provides pull strengths in excess of 400 lb.
- Crimp plier oriented sideways to save board space and reduce kit weight.
- Refined bell-mouth fiber guide channels around the registration crimp pliers to more smoothly orient the fibers in position for crimping, stripping, and cleaving.
- Considerable reinforcement was added to the swinging fiber stripper/cleaver assembly to improve shock and vibration tolerance. This consisted of gussets and an extended bar on the end of the assembly for engagement by a latch for shipping.
- Implementation of the new cleaving system in the form of a flat work surface with a slightly protruding carbide blade and a rubber pad on a toggle clamp. Bell-mouth guides were provided to direct the two stripped fiber ends in position on the cleaving station.

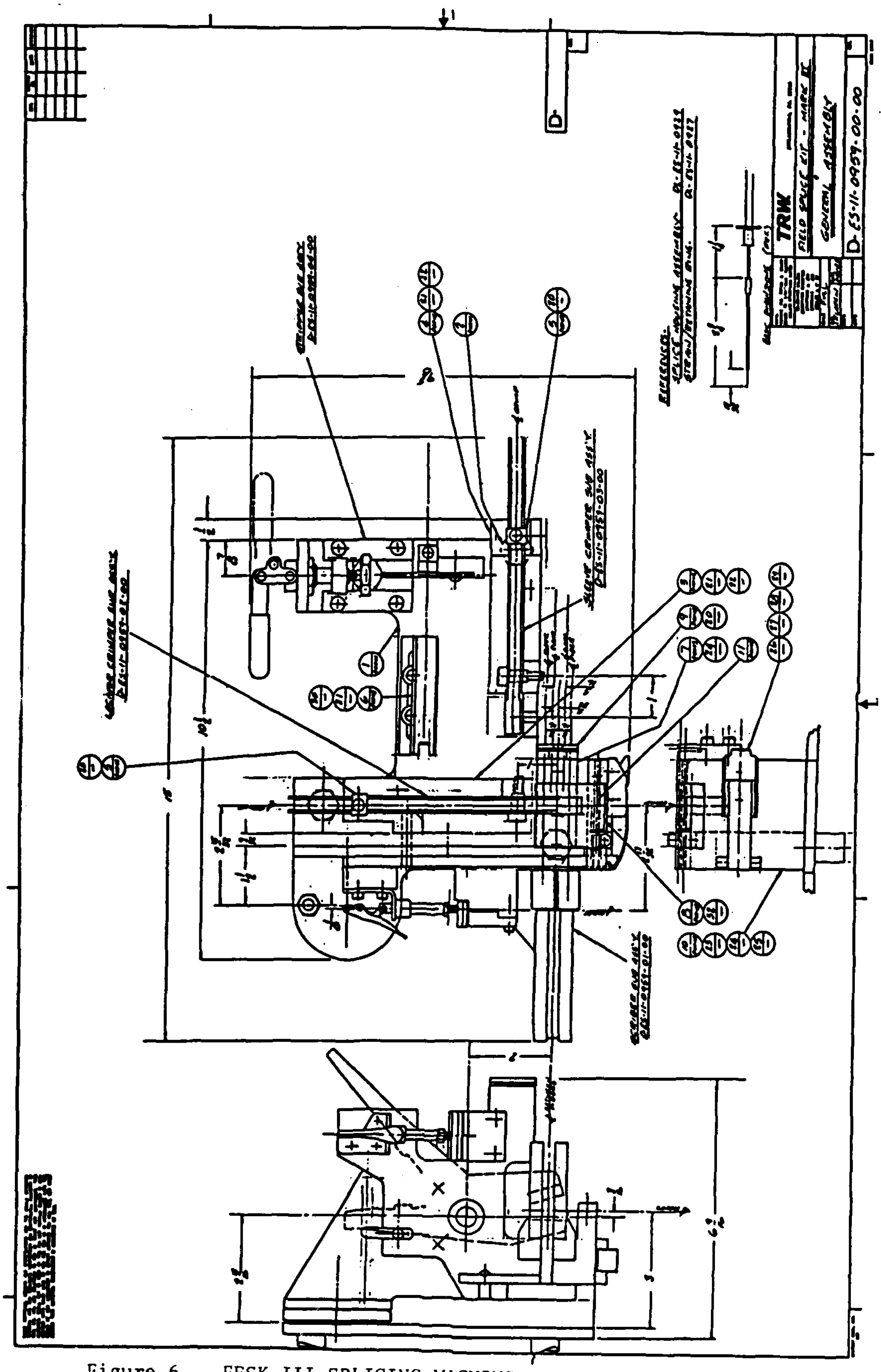


Figure 6 FESK III SPLICING MACHINE

2.3.2 MODEL

A wooden mock-up of the FESK III splicing machine was constructed to verify the latest design changes in advance of ordering the first deliverable "brassboard" splicer. This model is shown in Figure 7, with major features identified.

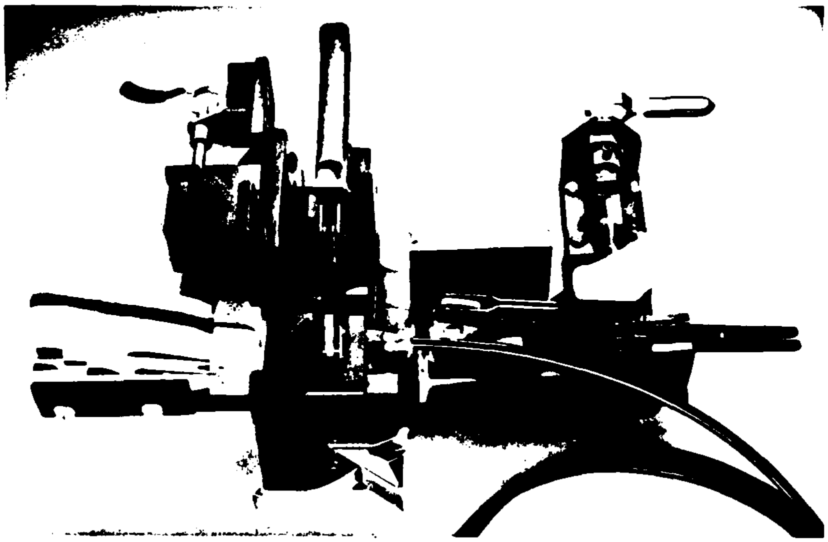


FIGURE 7. WOODEN MOCK-UP OF FESK III SPLICER

As a result of work with the model, all new design features were verified and the first brassboard FESK III was ordered. Delivery is expected early in the next 6-month period.

2.3.3 SPLICING PROCEDURE

Using the FESK III the assembly process for a field splice may be summarized as follows:

1. The damaged section of the cable is cut away cleanly with the shears.
2. A stainless steel ferrule is slipped over one cable end and slid down a few inches.
3. The cable end is inserted in the outer-jacket strip station until it reaches the stop in the length gauge. The stripper blades are closed with the toggle clamp and the cable pulled through by hand to expose the inner jacket and Kevlar strength members.
4. The Kevlar is folded back over the stainless ferrule on the uncut portion of the cable, and a brass crimp sleeve is passed over the inner jacket to cover the folded-back Kevlar and stainless ferrule.
5. The exposed inner jacket is inserted in the second station of the re-opened jacket stripper blades. The stripper is again closed and the cable pulled through once more to expose the plastic-jacketed individual fibers.
6. The end of the jacketed portion of the cable, with the aligned stainless ferrule, folded-back Kevlar, and brass sleeve, is laid in the jaws of the first crimper. Closing the crimper handles until they release automatically completes the strength-retention crimp.
7. A pair of aluminum fiber registration crimp tubes, with plastic liners, is placed in the jaws of the second crimper. These tubes will be pre-packaged in an easily-handled tape.

8. The two jacketed fibers are fed into the bell-mouthed channels of the second crimp station until they pass through and into the two fiber strippers. The Kevlar crimp is laid into the slot provided.

9. The second crimper is compressed until it releases, simultaneously completing both fiber registration crimps.

10. The latch on the fiber strip/cleave assembly is released. Fiber stripping is accomplished by closing both strippers with one hand and pulling the swinging arm back in a single smooth motion.

11. The strip/cleave assembly is rotated 90°, while in the open position, to align the cleaving mechanism with the protruding fibers. A pin prevents the arm from closing until and unless the assembly has been fully rotated to its new position to prevent possible damage to the fibers. The arm is then closed again. The bell mouths on the cleaver guide the fibers into their proper positions on the cleave platform.

12. The toggle clamp of the cleaver is closed, clamping both fibers in place. The assembly is then pulled open once more in a single smooth motion, automatically cleaving both fibers to the proper length.

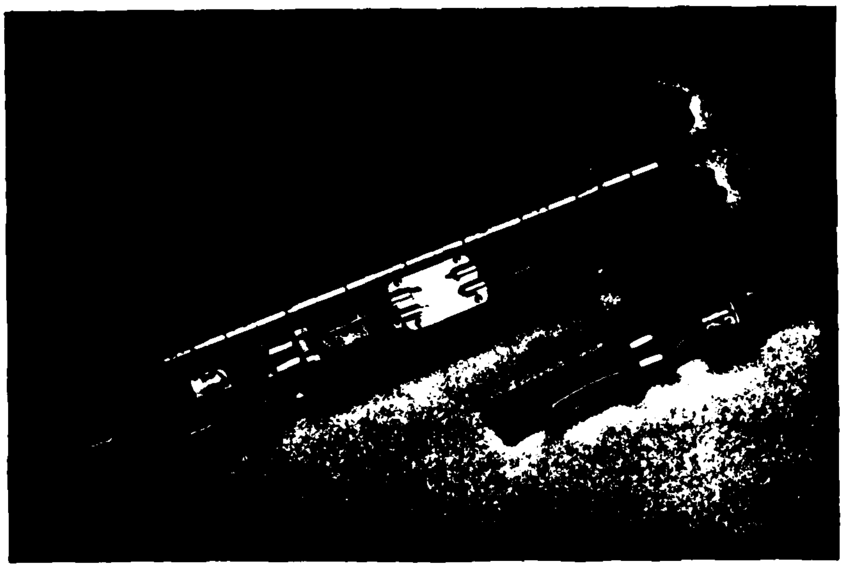
13. The spring-loaded cover of the registration crimp station is opened, and the terminated cable is lifted out of the machine ready for insertion in the splice.

14. One of the two sleds is removed from the splice housing, and the terminated cable end is pressed down into the appropriate slots of the sled. This includes placing the stainless/brass Kevlar crimp into the end slot, the two prepared fibers into their respective slots, and the aluminum registration crimps into the appropriate cavity. At this point the exposed fibers protrude approximately 0.1 inch beyond the end of the sled.

15. The dust seal tape is now removed from the alignment guide assembly in the center of the splice, and the sled with the prepared cable is slid into its channel in the splice housing (see Figure 8). By this action the optical fibers automatically enter the plastic guide funnels straight and parallel. As insertion is completed and the sled is dropped down into place the fibers enter the flared ends of the oil-filled 4-rod guides and penetrate precisely to the centers.

16. The preceding sequence is then repeated for the other end of the cable to be spliced. When the second sled is completed and slid into place the respective ends of the two mating fibers have been brought to an accurate alignment, in contact, at the centers of the two 4-rod guides.

17. The housing lid is then closed and latched, completing the splice. By virtue of the latching action the foam gasket and the ridges in the cable entry holes are compressed to seal out dust and moisture.



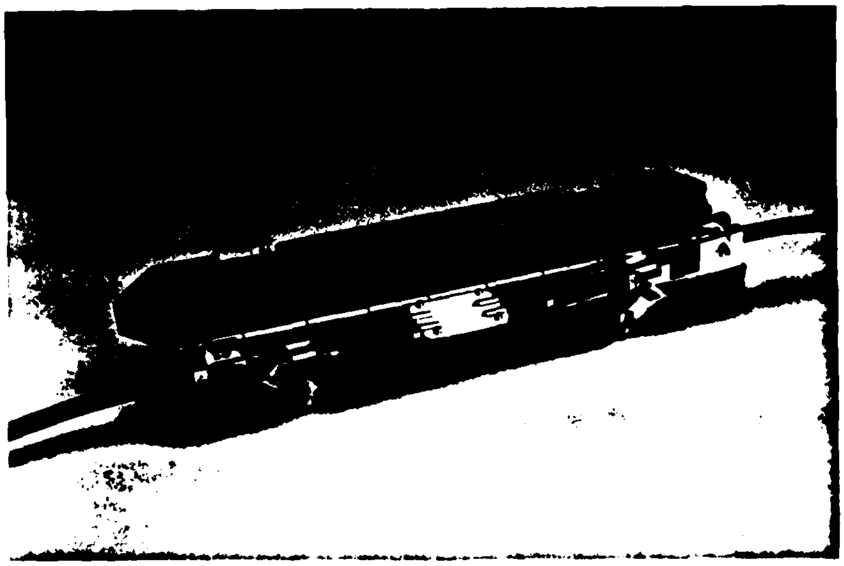


Figure 8. Tactical Field Splice With Prepared Cable In Sled Ready For Insertion.

2.4 TACTICAL FIELD SPLICES

Using the newly adjusted "crossed-fiber" cleaver on the FESK I, a series of complete tactical splices was assembled and tested for yield and insertion loss. The results are given in Table 4. As in the earlier test series with the original cleaver (Table 2), the cable jacket strip and crimping operations had a 100% yield. The fiber jacket strip yield, at 95%,was statistically close to the 93% value obtained in the first test series.

The fiber cleave operation and the insertion loss yields both showed great improvement, from 72% to 98% and 25% to 85%, respectively. The few insertion loss values above 1 dB were judged due to insufficient durability in the makeshift cleaving device, which allowed the crossed fiber to shift laterally or crack under the stress of the test fiber being pulled across it. These shifts and cracks were apparent during the test sequence and were taken into account during the design of the FESK III splicer. Nevertheless, at an average loss of 0.58 dB and a yield of at least 85%, the new cleaving system became accepted as the method of choice for the final deliverable splice kits.

Completed splices (3)-16, (2)-3, (1)-3, (4)-1, and (5)-1 were forwarded to CECOM in fulfilment of CLIN 0001 of the contract. The remaining 5 (#'s (6)-1, (7)-1, (8)-3, (9)-1, and (10)-1) were retained for environmental testing during the coming 6-month period.

As a result of our experience with the splices, a few minor design changes were made for the "final repairs", to be delivered at the end of the contract. These include changes in the stainless Kevlar crimp ferrules for greater pull strength (consistent with the new crimp plier jaw design), a slightly different size for the brass crimp tube to allow its being cut from stock diameter tubing, rounded ends on the sleds to ease their insertion into the splice housing, narrower

TABLE 4.

SPLICE YIELD AND INSERTION LOSS DATA - NEW CLEAVER

					Channel 1				Channel 2			
Splice #	Side	Outer Jacket Strip	Inner Jacket Strip	Kevlar Crimp	Aluminum Crimp	Jacket Strip	Cleave	Insertion Loss (dB)	Aluminum Crimp	Jacket Strip	Cleave	Insertion Loss (dB)
(3)-14	A	✓	✓	✓	✓	✓	short?	-	✓	✓	short?	-
	B	✓	✓	✓	✓	✓	-	-	✓	broke	-	-
	"	✓	✓	✓	✓	✓	✓	11.2	✓	✓	✓	-0.1
(3)-15	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	✓	0.2	✓	✓	✓	1.5
(3)-16	A	(same as (3)-15)										
	B	✓	✓	✓	✓	✓	✓	2.1	✓	✓	✓	0.1
(2)-2	A	✓	✓	✓	✓	broke	-	-	-	-	-	-
	"	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	✓	1.0	✓	✓	✓	broke on insertion
(2)-3	A	(same as (2)-2)										
	B	✓	✓	✓	✓	✓	✓	0.7	✓	✓	✓	0
(1)-3	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	✓	0.5	✓	✓	✓	0.6
(4)-1	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	✓	0.9	✓	✓	✓	-0.2
(5)-1	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	✓	0	✓	✓	✓	-0.2
(6)-1	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	✓	0.3	✓	✓	✓	-0.1
(7)-1	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	broke	-	-	broke	-	-
	"	✓	✓	✓	✓	✓	✓	0	✓	✓	✓	-0.3
(8)-1	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	short?	2.7	✓	✓	✓	0.6
(8)-2		replaced crossed fiber, tested loss, then re-adjusted length						(3.5)				(3.4)
(8)-3	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	✓	0	✓	✓	✓	1.3
(9)-1	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	✓	0.5	✓	✓	✓	0.4
(10)-1	A	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-
	B	✓	✓	✓	✓	✓	✓	0.3	✓	✓	✓	0.5

Average insertion loss (26 completed channels) (omitting(3)-14 channel 1 and (8)-2 and treating negative loss values (power greater than baseline) as zero) = 0.54 dB

Standard deviation = 0.68 dB

Yields: Outer jacket strip = 100%
Inner jacket strip = 100%
Kevlar crimp = 100%
Aluminum (registration) crimp = 100%
Fiber jacket strip = 95%
Cleaves to length = 98%
Insertion loss of 1 dB or less = 85%

fiber guide slots on the sleds, and ridges in the cable entry slots to enhance the moisture seal.

Further changes were made in the splice design to make the parts readily amenable to fabrication by die casting (aluminum) or molding (Lexan). These changes essentially consisted of making wall thicknesses more uniform. It was anticipated that early in the next period the 50 final splice housings would be ordered fully tooled in one of the two materials of choice.

3. CONCLUSIONS: PROJECT STATUS AND FUTURE WORK

The design iterations of both the splicing machine and the splice housing itself have now been completed. After extensive experimentation and evaluation, every possible shortcoming has been addressed and every desirable change implemented. The final splicing machine has been modelled in wood and its operation concepts verified. The interim splices have been completed and delivered. During these tasks a novel method of scribing and breaking fibers has been implemented, tested, and verified.

During the coming final phase of this program the first machined "brassboard" FESK III, now on order, will be received. Its operation will be checked, any necessary corrections will be made, and the final 5 machines fabricated. The 5 interim splices will be fully tested under the specified environmental conditions and any shortcomings analyzed and corrected in the final splice design. 50 fully-tooled final splice housings will then be ordered for delivery to CECOM with the kits at the end of the program.

Based on the encouraging results to date and the simplicity and effectiveness of the latest Field Expedient Splice Kit, it is anticipated that the final results of this program will fulfill every expectation.

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