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ITT ELECTRO-OPTICAL PRODUCTS DIV ROANOKE VA
ULTRA LOW LOSS OPTICAL FIBER CABLE ASSEMBLIES. (U)
MAY 79 J C SMITH, R E THOMPSON

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DAAB07-78-C-2922

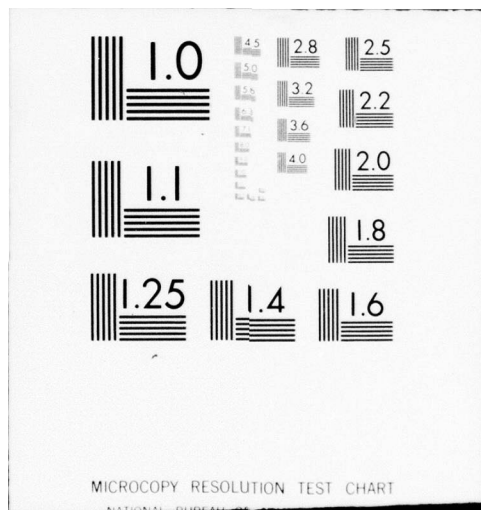
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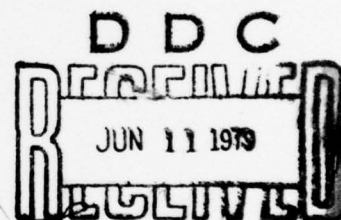
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RESEARCH AND DEVELOPMENT TECHNICAL REPORT
CORADCOM- CONTRACT # DAAB07-78-C-2922
ITT PROJECT # 36027

AD A 069792

ULTRA LOW LOSS OPTICAL FIBER CABLE ASSEMBLIES



J. C. SMITH & R. E. THOMPSON

ITT *Electro-Optical Products Division*

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Roanoke, Virginia 24019*

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APRIL 1978 - NOVEMBER 1978**

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the progress made from April to November, 1978, in the
development of Ultra Low Loss Fiber Optic Cable Assemblies for Time Division
Multiplexed (TDM). This effort includes the fiber optic cable as well as the
connectors needed to terminate them. Optimization of the optical fiber fabri-
cation process is in progress, the objective is to increase the fiber yield
against the cable specification.

Further ruggedization of the cable is needed in order to achieve the 100% fiber survivability in the impact testing per MIL-C-13777. It is also necessary to keep the excess cabling losses at a minimum.

The three sphere connector concept has been selected for full development, and the jeweled ferrule concept as a back up.

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Unannounced	☐
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ULTRA LOW LOSS OPTICAL FIBER
CABLE ASSEMBLIES

B003

Draft Semi-Annual Report
April through November 1978

for

U.S. Army Electronics Command
Fort Monmouth, N.J.

Contract #DAAB07-78-C-2922
ITT Project #36027

Prepared by

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Director of Fiber Optics
Laboratory

Roanoke, Virginia

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1.0 INTRODUCTION

The objective of this contract (#DAAB07-78-C-2922), entitled "Ultra Low Loss Optical Fiber Cable Assemblies", is to develop optical fiber cable assemblies for the Army tactical field data transmission at 20 Mb/sec over eight kilometers without repeaters.

The contract effort includes the development of rugged cable, cable connectors and bulkhead connectors which are jointly optimized for Army tactical field application.

ITT Electro-Optical Products Division has spend considerable time in the search of a suitable sub-contractor who is technically qualified and acceptable to CORADCOM and at the same time willing to work within the financial frame of this contract. The following companies were approached and invited to bid for the connector development phase of the contract:

ITT Cannon

ITT Leeds

ITT Components (Europe)

Hughes Connecting Devices Division

Deutsch

Cablewave

Amphenol

AMP

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Only two companies were interested in bidding: ITT Cannon Electric Division and Hughes Connecting Devices Division.

Personnel from ITT Electro-Optical Products Division met with both Hughes Connecting Devices Division and ITT Cannon Electric Division. It was judged that the three sphere and the jewelled ferruled approaches of ITT Cannon had more merits than the free floating mechanism of the Hughes Connecting Devices six channel hermaphroditic connector. Therefore, ITT Cannon Electric Division was selected as the as the Connector Subcontractor. The connector vendor solicitation and selection effort has taken longer than originally planned and has delayed portions of the program.

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2.0 CABLE DEVELOPMENT

The cable development phase of this contract includes the optimization of the optical fibers as well as the design of a rugged fiber optic cable.

The fiber optimization phase has benefited from progress achieved through the ITT internal R&D program. Table 1 shows the attenuation, dispersion and length of optical fibers recently developed.

Emphasis has been placed upon the improvement of optical properties. The data in Table I is most encouraging in that 73% of fibers exhibit less than 5 dB/km and 60% less than 4.5 dB/km (attenuation measured on spool). Therefore, the intrinsic attenuation of fibers is lower than the reported values. During the first quarter of 1979, considerable effort will be expended under ITT funded programs to further reduce attenuation and dispersion while still maintaining high tensile strength (100,00 psi proof testing).

ITT-EOPD has performed some work toward the development of a 62 μ m optical core fiber. This approach was considered preferable to meet the 1 dB coupling loss specification for the connector. However, this work has not been aggressively pursued because of strong indications that a 50 μ m core fiber

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TABLE 1

<u>CVD#</u>	<u>LENGTH</u> (Kilometers)	<u>ATTENUATION</u> (dB/km @ 0.85 μ m)	<u>DISPERSION</u> (ns/km @ 0.9 μ m)
20449	2.6	4.6	1.2
20450	2.3	3.6	.9
20451	1.2	4.1	1.6
20452	1.6	5.6	.98
20453	1.3	4.0	1.7
20454	1.2	3.9	1.7
20461	3.1	4.2	.65
20462	4.5	4.4	2.3
20463	1.9	4.4	1.3
20467	1.4	5.8	.95
20469	2.5	4.6	.42
20474	2.5	5.4	1.6
20480	2.7	5.3	2.1
20481	2.8	4.0	1.2
20485	4.1	4.9	1.3

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will become the international standard.

All the fibers used in this program are being proof tested at 1% elongation (100,000 psi). This proof testing is an insurance against catastrophic failure when the fiber is strained during manufacturing, installation or service.

2.2 Ultra Low Loss Optical Fiber Cable Design

The cable design plan submitted contains the current approaches which ITT-EOPD believes have the best potential to meet the Technical Guidelines of the Ultra Low Loss Fiber Optic Cable Contract, and at the same time can be mass produced.

Based on the experience acquired in the Low Cost Fiber Optic Cable Assemblies for Local Distribution Systems contract (DAAB07-77-C-2681), an external strength member cable with 1 mm buffered optical fibers not only exhibits low excess cabling losses, but meets almost all the mechanical requirements. The exception of that is that the above contract required 90% survivability while the Ultra Low Loss Fiber Optic Cable Contract requires 100% survivability. This requirement is

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achievable with the proposed cable design, but it still has to be demonstrated.

Table 2 shows the optical attenuation of the external strength member cables using plastic clad silica fibers.

Table 2

Attenuation - External Strength Member Cable

Cable Batch #	Fiber #	Attenuation (dB/km)				Cable Length
		.65 μ m	.79 μ m	.82 μ m	1.05 μ m	
110678-CA-II	1	8.02	5.80	9.40	13.54	367m
	2	9.53	6.63	10.56	16.41	
	3	8.81	6.80	10.66	17.11	
	4	8.09	6.76	10.50	14.84	
	5	8.67	6.98	10.84	15.09	
	6	7.62	5.79	9.51	14.52	
	7	7.45	5.84	9.46	14.30	
	Average	8.31	6.37	10.31	15.12	
110778-BA-II	1	7.48	6.04	9.61	13.53	378m
	2	11.16	8.28	11.97	19.97	
	3	8.74	6.82	10.61	16.63	
	4	7.85	6.06	9.89	16.77	
	5	7.54	6.07	9.84	17.20	
	6	8.79	6.94	10.88	18.29	
	7	8.43	6.98	10.62	15.67	
	Average	8.57	6.74	10.48	16.72	

*Note: The fibers of cables 110678-CA-II and 110778-BA-II were made with fibers having Shin Etsu RTV silicone cladding.

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Table 3 shows the number of surviving and broken fibers when the cable was tested over a wide temperature range using three different impact loads (4.07, 4.41, and 4.75 Newton-meters). Note that the poor performance at -55°C was due to the use of a dull polyurethane jacket material (a flame retardant grade). That jacket has been replaced with a non-filled polyurethane compound, which previously had shown good performance at that temperature.

Table 4 shows the number of impacts before the fiber breaks. Note that since there was no light transmission at -55°C , the number of transmitting fibers was found by counting the transmitting fibers after the temperature returned to 25°C .

Flex and Twist Tests were performed, on the Low Cost Fiber Optic Cable, in accordance with MIL-C-13777. All fibers survived these tests at the the extreme temperatures as well as at room temperature.

ITT-EOPD has selected the cable design developed under the Low Cost Fiber Optic Cable Contract as Design I (Figure I) because it meets or nearly meets all the cable mechanical and environmental objectives and can be produced with low excess cabling losses. However, realizing that CORADCOM

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Table 3

IMPACT RESISTANCE

IMPACT LOAD	TESTING TEMP.	# OF SAMPLES	# TRANS/ # FAIL	% SURVIVABILITY
4.07 Newton Meter	R.T. (25°C)	42	39/3	93%
4.41 " "	" "	"	33/9	79
4.75 " "	" "	"	33/9	79
4.07 Newton Meter	40°C	42	42/0	100%
4.41 " "	"	"	42/0	100
4.75 " "	"	"	40/2	95
4.07 Newton Meters	60°C	42	40/2	95%
4.41 " "	"	"	42/0	100
4.75 " "	"	"	38/4	90
4.07 Newton Meters	85°C	42	40/2	95%
4.41 " "	"	"	37/5	88
4.75 " "	"	"	38/4	90
4.07 Newton Meters	-5°C	42	42/0	100%
4.41 " "	"	"	42/0	100
4.75 " "	"	"	42/0	100
4.07 Newton Meters	-30°C	42	42/0	100%
4.41 " "	"	"	42/0	100
4.75 " "	"	"	42/0	100
4.07 Newton Meters	-55°C	42	26/16	62%
4.41 " "	"	"	13/29	31
4.75 " "	"	"	16/26	38

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Table 4

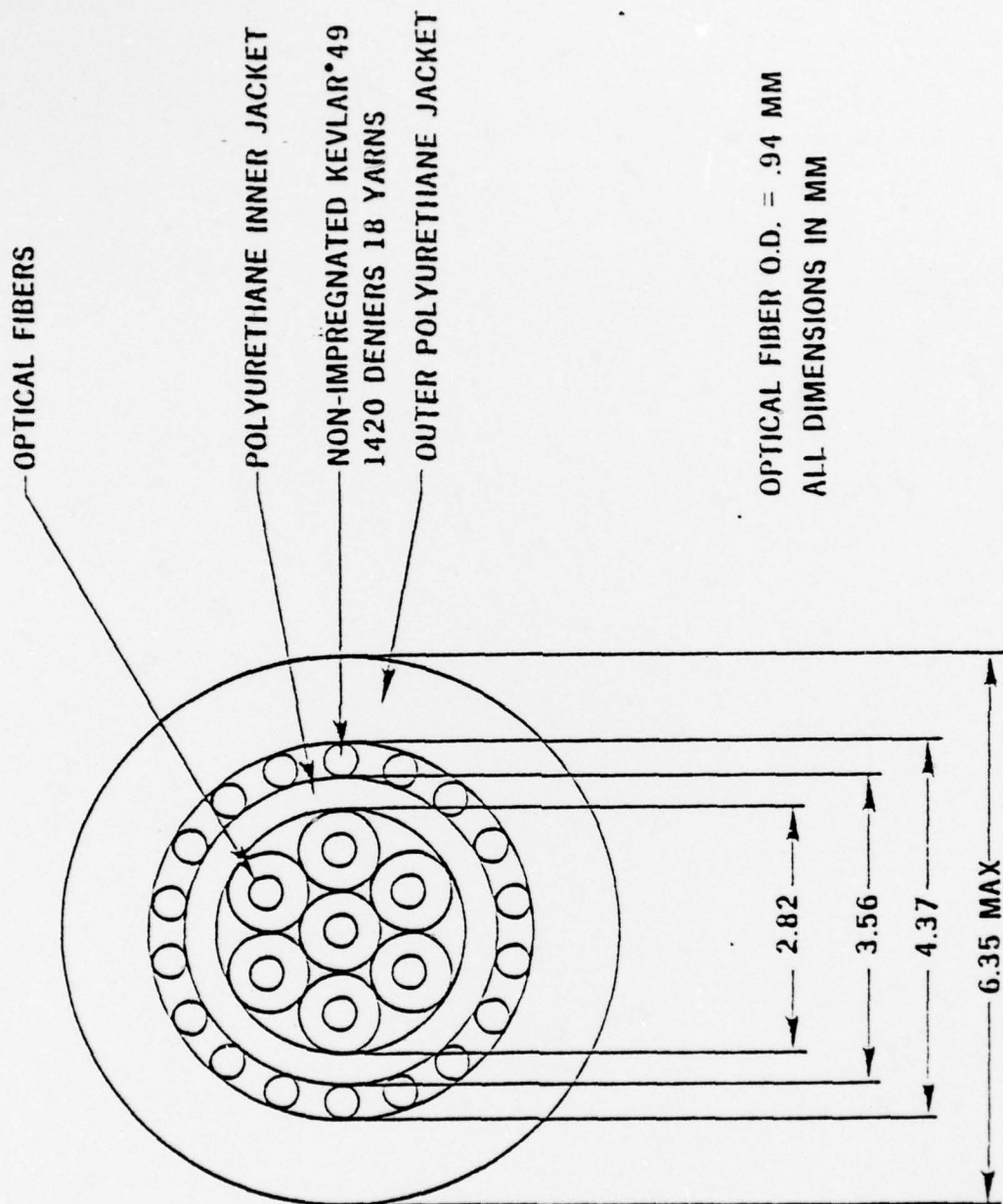
IMPACT RESISTANCE

Energy Level/ Sample #	Room Temperature Break Location/ Fiber Trans	+85°C		+40°C		-5°C & -30°C
		Break Location/ Fiber Trans	Break Location/ Fiber Trans	Break Location/ Fiber Trans	Break Location/ Fiber Trans	
4.07 Newton Meter	S1	--/7	--/7	116/6	--/7	No fiber breakage at these two temp. levels. The outer polyurethane jacket had a slight indent- ation. -30°C seems to be the light trans- mittance transition level, because output oscillated as the temp. changed from -25°C to -35°C.
	S2	--/7	178/6	--/7	--/7	
	S3	149, 192/5	144/6	173/6	--/7	
	S4	--/7	--/7	--/7	--/7	
	S5	--/7	--/7	--/7	--/7	
	S6	*6	--/7	--/7	--/7	
4.41 Newton Meter	S7	--/7	151, 182/5	--/7	--/7	Impact Resistance at -55°C was measured by the number of trans- mitting fibers, after
	S8	127/6	82/6	--/7	--/7	
	S9	108, 135/5	--/7	--/7	--/7	
	S10	49, 69/5	65, 67/5	--/7	--/7	
	S11	49, 69/5	--/7	--/7	--/7	
	S12	116, 132/5	194/6	--/7	--/7	
4.75 Newton Meter	S13	95/6	67, 167/5	127/6	48/6	Impact Resistance at -55°C was measured by the number of trans- mitting fibers, after
	S14	--/7	91/6	--/7	--/7	
	S15	89(2)/5	--/7	82/7	--/7	
	S16	19(2), 89/4	--/7	--/7	--/7	
	S17	68/6	158/6	150/6	--/7	
	S18	57, 62/5	--/7	126/6	--/7	

*Only 6 fibers were transmitting
before testing.

DATA DISTRIBUTION
Optimized Low Cost Fiber Optic Cable

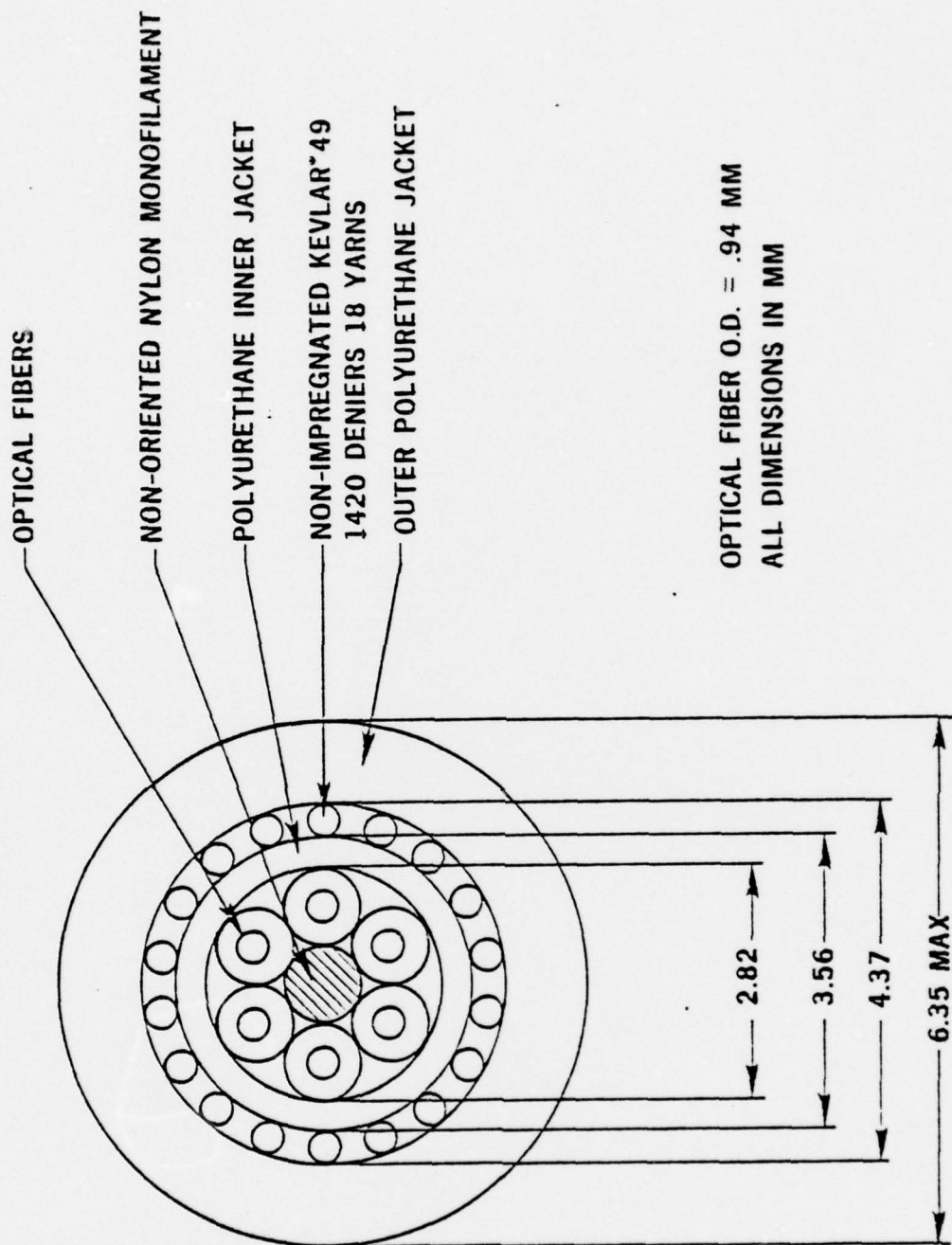
FIGURE 1



DESIGN 1. ULTRA LOW LOSS FIBER OPTIC CABLE

102 10755

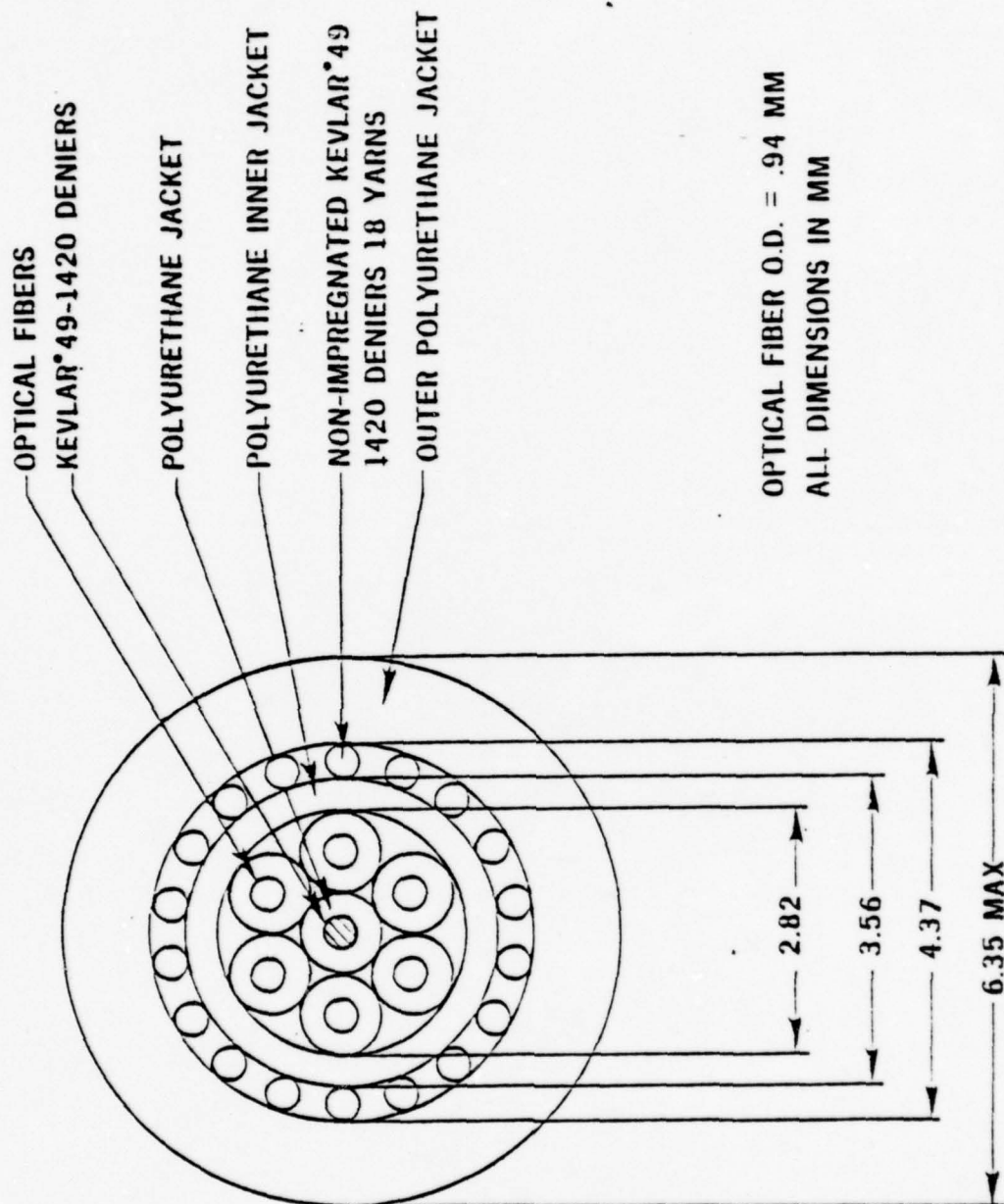
FIGURE 2



DESIGN 2 ULTRA LOW LOSS FIBER OPTIC CABLE

302 10754

FIGURE 3



DESIGN 3 ULTRA LOW LOSS FIBER OPTIC CABLE

302 10757

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intends to procure large amounts of cables, modifications of the design to facilitate its production with conventional cabling equipment is being considered.

Conventional cabling equipment can accomodate larger payoff and take up spools, allowing the production of longer cable lengths thus reducing set up time and increasing the equipment utilization. But heavier spools also mean higher tension, therefore, the cable design must provide portection to the optical core during the fabrication processes.

Cable Design 1 is considered marginally suitable for fabrication in conventional equipment. The next two designs will allow cables to be produced that, in addition to being rugged, are also capable of being produced with higher manufacturing tensions than the first design.

Figure 2 shows cable Design 2. This cable is similar to Design 1 except that a non-oriented nylon monofilament is used instead of the central fiber. The central monofilament is the load member during the fabrication of the optical core. The mechanical and optical properties of Design 1 should remain unaltered.

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Figure 3 shows cable Design 3. The difference between this design and Design 1 is that the central member is a yarn of Kevlar with a polyurethane jacket. This design provides the highest strength during the optical core fabrication, but its impact performance is unknown. This design involves the concept of a flexible center core that yields under impact, absorbing in this manner part of the energy of the impact.

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3.0 CONNECTOR DEVELOPMENT

ITT Cannon has been selected as subcontractor to develop a hermaphroditic connector for the Ultra Low Loss Fiber Optic Cable.

During the reporting period, a study of potential fiber alignment concepts was conducted.

The ability of an alignment concept to provide minimum coupling loss is a function of the design employed and their manufacturing tolerances.

Eleven concepts were critiqued (See Appendix A). These concepts represented the basic techniques currently considered viable within the fiber optic industry. An overall merit rating was given to each approach.

The following parameters were considered while evaluating each concept:

1. Coupling loss potential
2. Physical size - diameter
3. Total number of dimensional tolerances involved
in alignment
4. Potential cost

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5. Termination technique (including time to terminate)
6. Fragility (care in handling)
7. Environmental consideration
8. Required development effort

As a result of the study, ITT's recommendation is to further development effort on the three sphere concept and perform minimal effort on the jewel ferrule concept as a back up.

The choice of the three sphere concept as the number one candidate is based upon the use of precision ball bearings with diameter tolerances of ten millionths of an inch in the alignment components. As can be seen in the conceptual drawing (Appendix A), only the spheres are involved in the lateral and gap alignment. Similarly, the use of an available precision watch jewel makes the jewel ferrule concept a second choice.

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4.0 WORK SCHEDULED FOR NEXT PERIOD

- o Complete fabrication of prototype samples
- o Submit prototype samples
- o Fabricate fibers for exploratory development cable models
- o Fabricate exploratory development of three sphere connector
- o Submit cable plan
- o Submit bi-monthly and cost reports

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APPENDIX A

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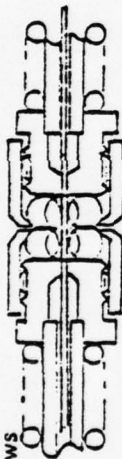
TRADE OFF OF CONNECTOR ALIGNMENT CONCEPTS

<u>Approach</u>	<u>Overall Merit Rating*</u>
Three sphere	1
Jewel Ferrule	2
Double Eccentric	3
Molded Ferrule	4
Resilient Self Centering	5
Multi-Rod	6
Formed Ferrule	7
V-Groove	8
Capillary Tube	9
Viscous Lens	10
Alignment by Fixturing	11

*1 is best rating

11 is worst rating

THREE PRECISION SPHERES (BALL BEARINGS) WHEN NESTED IN A PLANE AT 120° INCREMENTS, PROVIDE AN INTERSTITIAL SPACE AT THEIR GEOMETRIC CENTER EQUAL TO THE FIBER DIAMETER. THE FERRULE CAP CONTAINS AN INTERNAL RAMPED RACE WHICH ALLOWS ADJUSTMENT FOR FIBER DIAMETER VARIATION.



TTC CANNON ELECTRIC TELEPHONE TUBE CO. (INC.) A Division of the Cannon Electric and Manufacturing Company	
DESCRIPTION:	THREE SPHERE
FEASIBILITY: (OVERALL RATING)	1

COUPLING LOSS POTENTIAL	SIZE (DIAMETER)	NUMBER OF TOLERANCES	POTENTIAL COST
0.5 db	APPROXIMATELY 2 mm	ONE - THAT OF THE SPHERE	LOW ☒ MED ☐ HI ☐

TERMINATION TECHNIQUE, (TIME):
 FIELD ☒
 FACTORY ONLY ☐

FIBER IS CLEAVED, POSITIONED IN FERRULE WITHIN THE SPHERES, AND THE CAP IS ADJUSTED TO TIGHTEN SPHERES ON VARYING FIBER DIAMETER. FIBER IS BONDED IN PLACE. TERMINATION TIME IS 10 MINUTES.

FRAGILITY:

FIBER IS PROTECTED BY THE FERRULE.

ENVIRONMENTAL CONSIDERATIONS:

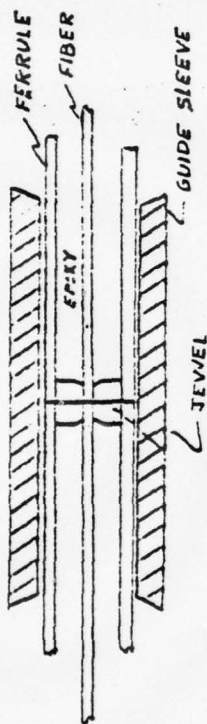
CONCEPT HAS BEEN EVALUATED UNDER SEVERAL ENVIRONMENTAL CONDITIONS; AFFECT OF SAND AND DUST MUST BE FURTHER CONSIDERED.

DEVELOPMENT EFFORT:

THE ALIGNMENT CONCEPT HAS BEEN THOROUGHLY EVALUATED UNDER LAB CONDITIONS. COUPLING LOSS DATA ON SEVERAL HUNDRED TERMINATIONS IS LESS THAN ONE (1) db. FURTHER EFFORT IS REQUIRED TO PERFECT THE CONCEPT UNDER ENVIRONMENTAL CONDITIONS AND FULFILL THE DESIGN TO A PRODUCTION STATUS. THE MAJOR EFFORTS WOULD ADDRESS: 1) LIFTING OF THE SPHERES TO THE FERRULE; 2) BALL RETENTION DURING FIBER ASSEMBLY; 3) MANUFACTURING TECHNIQUE; 4) COST REDUCTION (PRESS FIT INSTEAD OF THREADED FASTENERS AND/OR CLIP ON CAP); 5) FIBER ANTI-CORROSION SPRING BACK; 6) ELIMINATION OF LEAKAGE; 7) SELF-CLEANING OF FIBER DURING TERMINATION.

NOTES:

CONCENTRIC FERRULES CONTAIN A CONCENTRIC, PRECISION WATCH JEWEL TO ALIGN THE FIBER. THE INTENT IS TO USE A SINGLE SIZE JEWEL I.D. WITH A FIBER WHERE DIAMETER VARIATION IS CLOSELY CONTROLLED.



JOHN CANNON ELECTRIC INCORPORATED 1000 N. 10TH ST. SUITE 100 MINNEAPOLIS, MINN. 55412 A Division of International Telephone and Telegraph Corporation	
DESCRIPTION:	JEWEL FERRULE
FEASIBILITY: (OVERALL RATING)	2

COUPLING LOSS POTENTIAL	SIZE (DIAMETER)	NUMBER OF TOLERANCES - LIGHT MAY BE POSSIBLE TO REDUCE TO SIX BY USING A SPRING MEMBER IN THE GUIDE SLEEVE.	POTENTIAL COST
< 1 dB	< 2 mm		LOW ☒ MED ☐ HI ☐

TERMINATION TECHNIQUE, (TIME):

FIBER IS BONDED INTO FERRULE, SUBSEQUENTLY GROUND AND POLISHED. MAY BE ABLE TO DEVELOP TECHNIQUE TO USE CLEAVED FIBER THEREBY REDUCING TERMINATION TIME. CURRENT DATA IS APPROXIMATELY 10 TO 15 MINUTES.

FIELD ☒
FACTORY ONLY ☐

FRAGILITY:

METALLIC FERRULE PROTECTS THE JEWEL AND FIBER, THEREFORE BETTER THAN AVERAGE.

ENVIRONMENTAL CONSIDERATIONS:

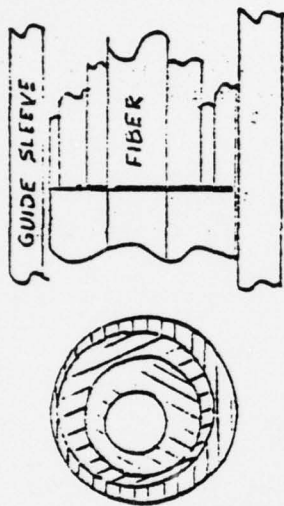
CONCEPT HAS BEEN USED EXTENSIVELY IN VARIOUS ENVIRONMENTS.

DEVELOPMENT EFFORT:

THE FOLLOWING PARAMETERS WOULD BE THOSE NECESSARY TO CONCENTRATE UPON: 1) COST REDUCTION; 2) FERRULE CYLINDRICAL TUBE ID/OD CONCENTRICITY OPTIMIZATION; 3) JEWEL CONCENTRICITY TO 1 MICRON; 4) A MEANS TO IMPLEMENT FIBER CLEAVING TO REDUCE TERMINATION TIME; 5) A SPRING MEMBER GUIDE SLEEVE TO IMPROVE FERRULE ANGULARITY CONTROL; 6) ATTENTION OF FIBER BY A LEADS OTHER THAN EPOXY (CERAMIC OR LOW TEMP MELTING GLASS).

NOTES:

THE FIBER IS MOUNTED IN AN X-Y ADJUSTABLE FERRULE AND TERMINATED UNDER A MICROSCOPE FOR PERFECT CONCENTRICITY. OPPOSING FERRULES MATE IN A PRECISION BORE GUIDE SLEEVE.



TIT CANNON ELECTRIC
UNIT
 1-1/2" DIA. 1-1/2" HIGH
 A Series of Standard
 and Special

DESCRIPTION:

DOUBLET. ECCENTRIC

FEASIBILITY: (OVERALL RATINGS)

3

POTENTIAL COST
 LOW ☒ - PARTS COULD BE MOLDED
 MED ☒ - PLASTIC - BUT ASSEMBLY
 HI ☐ ARE REQUIRED (ALSO TO COSTS)

NUMBER OF TOLERANCES - TWO
 FERRULE O.D. AND GUIDE SLEEVE I.D.

SIZE (DIAMETER)
 APPROXIMATELY 4 mm

TERMINATION TECHNIQUE, (TIME):

FIELD ☐

FACTORY ONLY ☒

FIBER MUST BE SECURED IN INNER SLEEVE, THEN GROUND AND POLISHED. MAY BE POSSIBLE TO USE CLEAVED FIBER AND POSTHOLD FACE PRECISELY. THE SLEEVES VARY IN WALL THICKNESS; RELATIVE ROTATION PROVIDES AN X-Y MECHANISM TO ADJUST THE FIBER CORE CONCENTRIC WITH THE OUTER DIAMETER. THIS MUST BE DONE UNDER AT LEAST 200X MAGNIFICATION AND INTRODUCES A HUMAN ELEMENT IN THE ALIGNMENT ACCURACY. TERMINATION TIME: 30 MINUTES.

FRAGILITY:

SOMEWHAT LESS FRAGILE THAN OTHER TYPES OF FERRULES.

ENVIRONMENTAL CONSIDERATIONS:

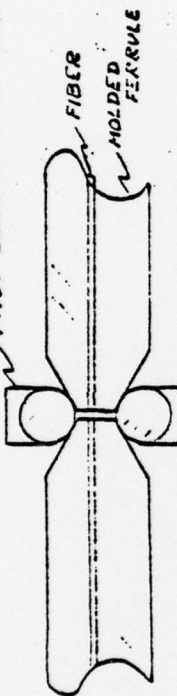
VIBRATION & TEMPERATURE CYCLING MAY CAUSE MECHANICAL SHIFT OF CORE SINCE THREE LAYERS OF MATERIAL MUST FIT TIGHTLY UPON EACH OTHER.

DEVELOPMENT EFFORT:

METHOD OF LOCKING SLEEVES TOGETHER AFTER MICROSCOPIC ALIGNMENT OF CORE WITHOUT SHIFTING CORE. MECHANICAL ASSEMBLY OF SLEEVES. DEVELOP FABRICATION PROCESS TO HOLD DIALECTRIC TOLERANCES (CONCENTRICITY IS NOT IMPORTANT). REDUCTION OF SLEEVE WALL THICKNESS TO MEET FERRULE O.D. REQUIREMENTS. DEVELOPMENT COSTS WILL BE HIGH DUE TO REQUIRED HOLD TOOLS. A MEANS TO REMOVE FIBER IN HOLDER SLIDE. PRESERVE RESISTION PROPERTIES WITH PLASTIC COMPONENTS MAY CAUSE DIMENSIONAL CHANGE AND INCREASED LOSSES.

NOTES:

PIVOT BEARING GUIDE SLEEVE



THE CANNON ELECTRIC
INC. 1215 WEST
LAWRENCE ST., CHICAGO, ILL.
A Division of International Telephone and Telegraph Corporation

DESCRIPTION:

MODIFIED FERRULE

FEASIBILITY: (OVERALL RATING)

1

COUPLING LOSS POTENTIAL	SIZE (DIAMETER)	NUMBER OF TOLERANCES - THREE LATERAL AND GAP ALIGNMENT DEPEND ON FERRULE CONCENTRICITY, TAPER AND SPHERE DIAMETER.	POTENTIAL COST LOW ☒ - FERRULE COST COULD BE MED ☐ LOW BUT TOOLING COST HI ☐ WILL BE VERY HIGH.
< 1 dB	AS SMALL AS 1 mm		

TERMINATION TECHNIQUE, (TIME):

FIELD ☐

FACTORY ONLY ☒

CAN BE EITHER GRIND/POLISH OR CLEAVE. IF CLEAVED FIBER IS USED, IT MUST BE PROTECTED DURING MOLDING CYCLE. DETERMINATION TIME INCLUDES FABRICATION OF PRODUCT; COULD APPROACH 2 MINUTES.

FRAGILITY:

SINCE THE FIBER IS INSERT MOLDED INTO A FERRULE, IT IS SUSCEPTIBLE TO DAMAGE (END FACE CHIPPING) DURING THE INSERTION INTO THE TOOL. THIS MAY REQUIRE SUBSEQUENT GRIND/POLISH WHICH WILL SHORTEN THE FERRULE AND INCREASE GAP LOSSES.

ENVIRONMENTAL CONSIDERATIONS:

1) TEMPERATURE CYCLING MAY CAUSE DIFFERENTIAL EXPANSION OF GLASS AND PLASTIC RESULTING IN LOSSES OF FIBER RETENTION AND/OR ALIGNMENT.

2) FIBER END FACES MUST BE INITIALLY SEPARATED (INTENTIONAL GAP) SINCE PLASTIC MATERIAL WILL COMPRESS UNDER AND/OR ALIGNMENT.

2) MOISTURE ABSORPTION MAY CAUSE DIMENSIONAL CHANGE IN PLASTIC PARTS.

DEVELOPMENT EFFORT:

THE MAJOR EFFORT WILL BE TO FABRICATE A MOLD TOOL WHICH WILL ALLOW THE FIBER TO BE INSERT MOLDED CONCOMITANTLY WITHIN THE OPHERENT EFFORT: EACH NEW TOOL NEEDED WILL REQUIRE THE SAME EFFORT SINCE IT WILL BE AN ITERATIVE PROCESS TO ACHIEVE THE REQUIRED ACCURACY. THE TAPER ANGLE AND WILL BE AS CRITICAL AN EFFORT. A MEANS TO CONTROL THEIR ANGULARITY WITHIN THE FIBER MUST BE DEVELOPED AS WELL AS CONTROL OF FIBER ANGULARITY WITHIN THE COLLECTOR. FALS TO CONSIDER ARE: 1) FLASH OR LEAKAGE FROM THE FIBER GUID./

POLISH DUE TO CLEARANCE IN MOLD PILOT HOLE; 2) MOLDING PRESSURE AFFECTS ON GLASS FIBER; 3) RESIDUAL COMPRESSION STRESSES DUE TO PLASTIC CURING WILL CAUSE FIBER STRESSES AND DIFFICULTY IN GRINDING/POLISHING; 4) FIBER CLEANLINESS FOR ADEQUATE BONDING.

531CN

THE CANNON ELECTRIC
114 EAST 12TH STREET
CHICAGO, ILL. 60604
A Division of International Telephone and Telegraph Corporation

DESCRIPTION:

RESILIENT SELF-CENTERING

FEASIBILITY: (OVERALL RATING)

5



COUPLING LOSS POTENTIAL
UNKNOWN - MUST DETERMINE
EXPERIMENTALLY

SIZE (DIAMETER)

**APPROXIMATELY AS SMALL AS THE
FIBER**

NUMBER OF TOLERANCES
"ABSORBED BY THE ELASTOMER"

POTENTIAL COST

☒ Low ☒

MED ☐

□

TERMINATION TECHNIQUE, (TIME):

01313 ☒

FACTORY ONLY ☐

MUST BE CLEAVED AND POSITIONED; POTENTIAL OF MINIMUM TIME TO TERMINATE.

FRAGILITY:

MAY INVOLVE EXPOSED, CANTILEVERED FIBER; ALSO A MAJOR DRAWBACK IS THE ALIGNMENT REQUIRES THE CONTINUOUS APPLICATION OF COMPRESSIVE FORCES ON THE FIBER.

ENVIRONMENTAL CONSIDERATIONS:

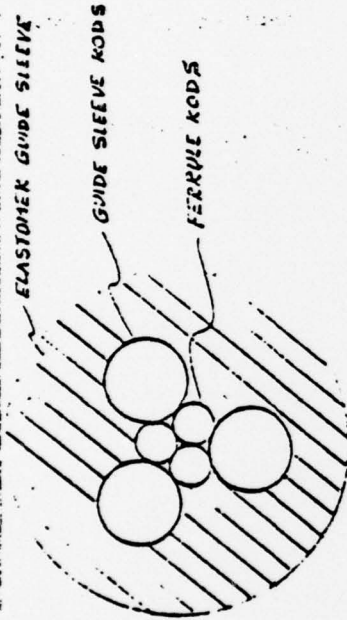
TEMPERATURE ENVIRONMENT MAY CAUSE COMPRESSION SET OF ELASTOMER AND RESULT IN MODULATION OF PULSE DURING SUBSEQUENT VIBRATION; AFFECTS OF ENVIRONMENT ON ELASTOMER MATERIAL I.E., OZONE MUST BE CONSIDERED.

DEVELOPMENT EFFORT:

1) MATERIAL DEVELOPMENT TO OVERCOME COMPRESSION SET AND TO INSURE HOMOGENEITY; 2) A MEANS TO APPLY THE DEVELOPMENT EFFORT; 3) A MEANS TO PROTECT THE FIBER; 4) OPPOSING FIBER GAP CONTROL MUST BE MECHANICALLY PROVIDED; 5) INVESTIGATE DIFFERENTIAL EXPANSION RATES OF GLASS AND ELASTOMER; 6) DEVELOP PRECISION TOOLING TO LOAD OR MACHINE THE ELASTOMER ACCURATELY.

NOTES:

THREE RODS PROVIDE A SPACE AT THEIR GEOMETRIC CENTER FOR THE FIBER. OPPOSING FERRULES MATE WITHIN A GUIDE SLEEVE CONTAINING THREE RESILIENTLY MOUNTED RODS WHICH OVERLAP THE OPPOSING FERRULES.



UNIT CANNON ELECTRIC INCORPORATED 10000 W. 10th Ave. Denver, Colorado 80202 A Division of Cannon Electric and Equipment Corporation	
DESCRIPTION:	
MULTI-ROD	
FLEXIBILITY: (OVERALL RATING)	
6	

COUPLING LOSS POTENTIAL	SIZE (DIAMETER)	NUMBER OF TOLERANCES - THREE	POTENTIAL COST
< 1 dB	FERRULE DIAMETER WILL BE APPROXIMATELY 5 mm BUT GUIDE WILL BE EXCESSIVE IN DIAMETER; THEREFORE, CONNECTOR WILL BE LARGE.	LATERAL ALIGNMENT IS DEPENDENT UPON DIAMETER TOLERANCES OF FERRULE RODS AND GUIDE RODS. GAP CONTROL TO BE DETERMINED.	LOW ☒ - MAY BE ROD BEARINGS AND MOLDED ELASTOMER GUIDE SLEEVE OR SPRING GUIDE SLEEVE. MED ☐ HI ☐

TERMINATION TECHNIQUE, (TIME):

FIELD ☒

FACTORY ONLY ☐

FRAGILITY:

SIMILAR TO MOST OTHER CONCEPTS.

ENVIRONMENTAL CONSIDERATIONS:

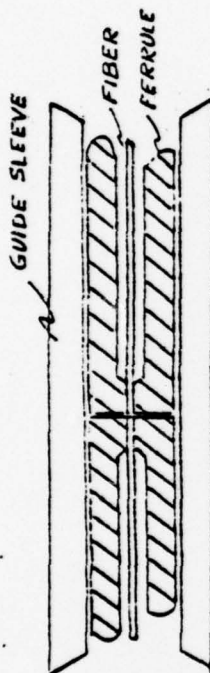
TEMPERATURE CYCLING MAY CAUSE LONGITUDINAL SHIFT OF FIBER DUE TO DIFFERENTIAL EXPANSION (RODS VERSUS GLASS), THIS SHIFT WILL CAUSE A VARIABLE END FACE SEPARATION.

DEVELOPMENT EFFORT:

- 1) MEANS TO CONTROL FIBER GAP; 2) PREVENT RODS FROM CRUSHING FIBER; 3) MEANS TO CLOSE RODS ON FIBER AND RETAIN THE A
- 4) MEANS TO RETAIN GUIDE RODS IN PARALLEL IN ELASTIC GROMMET; 5) MEANS TO LOCATE CLEAVED END FACE WITHIN RODS; 6) MEANS TO ASSEMBLE ROD ENDS IN A PLANE; 7) GUIDE RODS TEND TO PRY FERRULE RODS OPEN. DESIGN MUST CONSIDER GEOMETRY TO PRECLUDE THIS; 8) CONSIDER GUIDE SLEEVE AS OPPOSED TO GUIDE RODS
- 9) MUST CONSIDER FIBER DIAMETER VARIATION WITHIN ROD LENGTH.

NOTES:

THE CONCEPT INVOLVES FABRICATING A PRECISE, CONCENTRIC FERRULE.



TOPP CANNON ELECTRIC INCORPORATED 1000 N. 10TH AVE. SUITE 100 MINNEAPOLIS, MINN. 55412	
DESCRIPTION:	FORMED FERRULE
FEASIBILITY: (OVERALL RATING)	7

COUPLING LOSS POTENTIAL	SIZE (DIAMETER)	NUMBER OF TOLERANCES	POTENTIAL COST
< 2 dB	< 3 mm	SIX	LOW ☐ MED ☐ HI ☐

TO BE DETERMINED

TERMINATION TECHNIQUE, (TIME):

FIELD ☒

FACTORY ONLY ☐

EITHER GRINDING AND POLISHING OR CLEAVING MAY BE USED. FIBER MUST BE BONDED INTO THE FERRULE. TIME COULD APPROACH 15 MINUTES.

FRAGILITY:

SIMILAR TO OTHER CONCEPTS, I.E., THE JEWELLED FERRULE; THE FIBER IS PROTECTED BY THE FERRULE.

ENVIRONMENTAL CONSIDERATIONS:

PERFORMANCE WOULD NEED TO BE EVALUATED UNDER VIBRATION AND TEMPERATURE CYCLING.

DEVELOPMENT EFFORT:

THE MAJOR EFFORT WOULD BE TO DEVELOP A FABRICATION PROCESS TO PROVIDE A HOLE (APPROXIMATELY 127 MICRONS) IN THE FERRULE FACE CONCENTRIC TO THE FERRULE O.D. WITHIN FIVE (5) MICRONS. POTENTIAL METHODS ARE: 1) LASER DRILLING; 2) CHEMICAL MILLING (USING PHOTO REDUCTION); 3) SPINNING; 4) COLD HEADING; 5) MOLDING. EACH PROCESS WOULD NEED TO BE REDUCED TO PRAGMATIC TO DECREASE LEASIBILITY THEREBY REQUIRING CONSIDERABLE TIME AND EXPENSE.

NOTES:

DESCRIPTION:

V-CHECKWE ALIGNMENT

FEASIBILITY: (OVERALL RATING)

2

COUPLING LOSS POTENTIAL	SIZE (DIAMETER)	NUMBER OF TOLERANCES	POTENTIAL COST
< 1 db	TO BE DETERMINED; POTENTIALLY QUITE SMALL RELATIVE TO OTHER CONCEPTS.	DEPENDENT ON FIBER DIAMETER TOLERANCE ONLY.	LOW ☐
			MED ☒
			HIGH ☐

FIBER MUST BE CLEAVED IN ORDER TO USE THIS CONCEPT; IT WOULD BE SUPPORTED IN A FERRULE MOST LIKELY BY BONDING. TIME COULD APPROACH 15 MINUTES.

FRAGILITY:

FIBERS ARE EXPOSED IN ORDER TO POSITION IN THE GROOVE DURING CONNECTOR MATING.

ENVIRONMENTAL CONSIDERATIONS:

CONTINUOUS COMPRESSIVE LOAD IS APPLIED TO THE FIBER; POTENTIALLY LESS AFFECTED BY ENVIRONMENTAL CONDITIONS. SUSCEPTIBLE TO VIBRATION DAMAGE AT EXT OF V.

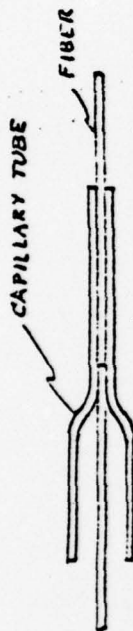
DEVELOPMENT EFFORT:

THE CONCEPT HAS BEEN PROVEN AS A LAB SET UP; CONSIDERABLE EFFORT WOULD BE NECESSARY TO IMPLEMENT THE CONCEPT
OPMENT EFFORT:

INTO FERRULE HAND-MADE USABLE IN A HERMAPHRODITE CONNECTOR. DEVELOPMENT EFFORTS MUST ADDRESS: 1) CARTRIDGE EXPOSED FIBER; 2) CAP CONTROL;
3) FIBER OUTSIDE CAP AFTER CLEANLINESS AFTER STIFFING BUFFER JACKET; 4) FIBER RETENTION IN FERRULE; 5) A MECHANISM TO CLAMP FIBERS AFTER EATING.

NOTES:

A LOW TEMPERATURE GLASS TUBE IS COLLAPSED ON THE LARGER OF TWO FIBERS. THE SMALLER DIAMETER FIBER IS PLUGGABLE INTO THE TUBE OPENING.



THE CANNON ELECTRIC
INCORPORATED
 10000 WILSON AVENUE
 A Division of General Electric Company

DESCRIPTION:

CAPILLARY TUBE

FEASIBILITY: (OVERALL RATING)

9

COUPLING LOSS POTENTIAL	SIZE (DIAMETER)	NUMBER OF TOLERANCES	POTENTIAL COST
< 1 db	< 1 mm	ONE	LOW ☐ FERRULE COST MAY BE SMALL, BUT TIGHTING CLOUT BE EXPENSIVE.
			MED ☒
			HI ☐

TERMINATION TECHNIQUE, (TIME):

FIELD ☐

FACTORY ONLY ☒

GLEAVED FIBERS WOULD BE USED; TERMINATION TIME INVOLVES CLEAVING, MEASURING FIBER DIAMETER, BONDING IN FERRULE AND TUBE COLLAPSE.

FRAGILITY:

FIBERS MUST BE CANTILEVERED FROM THE FERRULES AND REQUIRE MORE HANDLING THAN OTHER CONCEPTS.

ENVIRONMENTAL CONSIDERATIONS:

SINCE THE OPPOSING FIBERS ARE RIGIDLY MOUNTED, EVALUATION UNDER VIBRATION CONDITIONS WOULD BE REQUIRED.

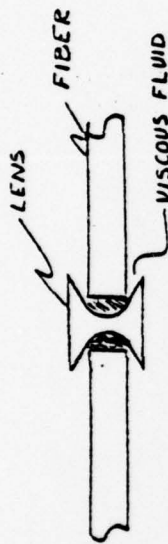
DEVELOPMENT EFFORT:

INVESTIGATION OF GLASS TECHNOLOGY IS REQUIRED; FIBER RESIDUAL STRESSES VERSUS LIFE EXPECTATION MUST BE EVALUATED. CONTAMINATION PARTICLES ON THE FIBER SURFACE MUST BE ELIMINATED TO PRECLUDE BUCKLEBEND LOSSES AND FIBER BREAKAGE DURING TUBE COLLAPSE. A MEANS TO PREVENT END FACES CHIPPING EACH OTHER MUST BE DEVELOPED; TELESCOPING SLEEVE TYPE FERRULES MAY BE NECESSARY. THE COLLAPSING TECHNIQUE MUST BE DEVELOPED TO PRECLUDE TOO SMALL A DIAMETER HOLE TO RECEIVE THE PLUG FIBER. DUE TO THE TEMPERATURE REQUIRED IN THE PROCESS, THE HEAT MUST BE REMOVED.

NOTES:

CONCEPT IS NOT APPLICABLE TO HERMAPHRODITE CONNECTORS SINCE PREDICTION OF WHICH CABLE CONTAINS THE LARGER FIBER IS NOT POSSIBLE & not fully interchangeable.

FIBER ALIGNMENT IS ACHIEVED THROUGH THE USE OF A DOUBLE CONCAVE LENS AND A VISCOUS INDEX MATCHED FLUID.



TTC CANNON ELECTRIC INCORPORATED A Division of Cannon Engineering and Industrial Services	
DESCRIPTION:	VISCOUS LENS ALIGNMENT
FEASIBILITY: (OVERALL RATING)	10

COUPLING LOSS POTENTIAL	SIZE (DIAMETER)	NUMBER OF TOLERANCES OPTICAL EFFECTS COMPENSATE FOR MECHANICAL TOLERANCES.	POTENTIAL COST
< 1 db	1.5 mm		LOW ☐ MED ☐ HI ☒

DUE TO NUMEROUS MATER AND COMPONENTS

TERMINATION TECHNIQUE, (TIME):

FIBER CLEAVING IS APPROPRIATE FOR THIS CONCEPT.

10-15 min.

FIELD ☒

FACTORY ONLY ☐

FRAGILITY:

FIBER MAY BE EXPOSED AND/OR A MECHANISM REQUIRED TO PROTECT THE FIBER AND AUTOMATICALLY RETRACT UPON ASSEMBLY. CAREFUL HANDLING SO AS TO NOT LOSE VISCOUS FLUID MAY BE REQUIRED.

ENVIRONMENTAL CONSIDERATIONS:

NUMEROUS QUESTIONS MUST BE ANSWERED IN REGARDS TO AFFECT OF ENVIRONMENT. FOR EXAMPLE: 1) TEMPERATURE LIMIT ON MOULDED PLASTIC LENS, RETENTION OF VERY VISCOUS FLUID UNDER SHOCK, TEMPERATURE, VIBRATION, ETC., 2) CONTAMINATION OF VISCOUS FLUID CAUSING OPTICAL LOSS; 3) DURABILITY.

DEVELOPMENT EFFORT:

1) A MEANS TO SUPPORT THE FIBER IN A FERRULE, PROTECT IT UNTIL MATING AND ALLOW IT TO SEEK ITS OWN CENTERED POSITION IN THE LENS; 2) INVESTIGATE POTENTIAL OF FIBER CLEAVED LONG SCRAPING THE LENS AND PRECLUDING REPEATED USAGE; 3) LENS MOLDING TECHNIQUE; 4) LENS MATERIAL; 5) MEANS TO MOUNT LENS IN SIX CHANNEL CONNECTOR; 6) MEANS TO ASSEMBLE FLUID INTO LENS. DEVELOPMENT COSTS APPEAR TO BE CONSIDERABLE.

NOTES:

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DESCRIPTION:

COMING TO A THEATRE NEAR YOU

FEASIBILITY: (OVERALL RATING)

11

COUPLING LOSS POTENTIAL

0.4 dB

SIZE (DIAMETER)

TO BE DETERMINED

NUMBER OF TOLERANCES

NONE

POTENTIAL COST

☒ Low ☐ High

MED ☐



TERMINATION TECHNIQUE, (TIME):

FIELD ☒

FACTORY ONLY ☐

FIBERS WOULD BE CLEAVED AND ALIGNED IN A PRECISION FIXTURE. CONNECTOR COMPONENTS WOULD BE ASSEMBLED AS THE FIBERS WERE CLEAVED AND ALIGNED. TERMINATION TIME WOULD APPROACH 30 MINUTES.

FRAGILITY:

MORE FRAGILE THAN OTHER CONCEPTS SINCE FIBERS ARE COMPLETELY EXPOSED DURING CONNECTOR ASSEMBLY.

ENVIRONMENTAL CONSIDERATIONS:

TO BE DETERMINED; SEPARABLE CONNECTOR WOULD REQUIRE USE OF ASSEMBLY FIXTURE FOR EVERY MATING.

DEVELOPMENT EFFORT:

CONSIDERABLE EFFORT IS NECESSARY TO CONCEIVE THE ARRANGEMENT OF FIXTURE AND CONNECTOR COMPONENTS TO ACHIEVE THE CONCEPT GOAL. THE PRECISION FIXTURE COULD BE A V BLOCK OR EQUIVALENT; IT WOULD BE ALLOCABLE AS A TERRAZINATION TOOL.

NOTES:

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