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Technical Report 591

AIRBORNE FIBER OPTICS MANUFACTURING TECHNOLOGY

Aircraft Installation Processes

G Kosmos
RA Greenwell

19 August 1980

Final Report: May 1978 - June 1980

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Prepared for
Naval Air Systems Command
Washington, DC 20361

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Released by CL Ward, Head Design Engineering Division	Under authority of CD Pierson, Jr, Head Electronics Engineering and Sciences Department

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The following personnel at Boeing Aerospace Corporation were the major contributors to this final report:

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Manufacturing processes were developed for installation of optical fiber harnesses and "stand alone" links on military aircraft. Fabrication and installation plans and procedures were developed and a routing analysis was performed to provide a basis for installation of fiber optics in military aircraft. A life cycle cost analysis of the optical fiber harness indicates economic advantages.

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OBJECTIVE

The objective of this manufacturing technology program was to develop and demonstrate the procedures/documents for fabricating and installing fiber optic harnesses and a fiber optic stand-alone link in a military airframe. The procedures/documents are developed based upon the current state-of-the-art fiber optics technology and then updated by prototyping, production fabrication, and airframe installation (mock-up) of fiber optic harnesses. The output of this program is a complete set of documents for the successful fabrication and installation of a fiber optic interconnect system into a military type aircraft.

RESULTS

1. The two fiber optic harnesses designed and fabricated during the initial two phases of the program were successfully installed in the E-3A Class III mock-up, using the installation procedures documented in Phase I. The harnesses were tested optically before and after installation and evidenced no changes during the installation processes except for one section of the stand-alone link which was damaged (broken fibers) during an observed gross mishandling incident. The cable in this case was pulled 90° to the cable tie in an effort to adjust its position. Precautionary notes have been added to the installation document to emphasize the dangers of violating the minimum bend radius restriction specified. Phases I, II, and III documentation were reviewed and revised as required to incorporate knowledge gained during the production fabrication phases of the twenty bundle-fiber harnesses and the one prototype single-fiber harness.

2. The twenty-one fiber optic harnesses were successfully fabricated during Phase IV. The grinding and polishing of fiber ends was found to be the most time consuming and costly operation in the manufacturing flow. No major problems were experienced during this production activity. Five harnesses were installed aboard the E-3A mock-up, per the developed procedures, with no damage.

3. Full documentation for the successful fabrication and installation of a fiber optic harness/cable has been developed. This documentation has been verified by the fabrication of twenty-one harnesses in a production type environment, using production wire/cable assembly technicians for the actual fabrication. In addition, four of the production harnesses and the single-fiber prototype harness were successfully installed in the E-3A mock-up.

4. A routing analysis was developed to provide a basis for future applications of fiber optics in military aircraft.

5. A life-cycle cost analysis of the optical cable was completed. It is apparent that weight and size reductions of fiber optics offer economic advantages. It is possible to increase the E-3A sortie time by 2.5 percent, which can be equated to a reduction of fleet size by 1.5 aircraft. The reliability of fiber optic interconnect systems appears to be equivalent to wire interconnect systems. It appears easier to install, remove, and/or replace optical fibers. Optical fiber interconnect systems are also simpler to test. Spares, repair parts, materials, and special support/test equipment add to initial costs, as does almost any new technology, but the impact is minor. With simpler equipment and techniques there may be a long-term savings potential. Overall costs and benefits of fiber optics appear to surpass the E-3A wire interconnect configurations.

RECOMMENDATIONS

- Initiate a manufacturing technology program to address the entire spectrum of the termination operation, including automated grind/polish operations, mass polishing techniques, tooling, ultimate producibility, and cost.
- Initiate a program whose objective would be elimination of epoxy in connector designs.
- Initiate a manufacturing technology program on fiber optic transmitter/receiver subsystems so that the entire cost of manufacturing a fiber optic system (transmitter-interconnect-receiver) can be determined.
- Develop and optimize volume production processes for the fabrication of fiber optic harnesses using large core single fiber technology.
- The above program should be a joint effort involving not only the system integrator but both cable and connector suppliers.
- Use the present set of harnesses in a test program to determine the capabilities of the current technology in the area of environmental/mechanical and application stress.
- Expand the technology to include that necessary for the use of fiber optics in shipboard applications.

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ILLUSTRATIONS

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INTRODUCTION

The objective of this work is to establish manufacturing methods in industry to assure the ability to install, on a production basis, fiber optic interconnect systems aboard military aircraft. This report contains the information gained through a four-phase contract (N00123-78-C-0193) with Boeing Aerospace Corporation, Seattle, Washington.

BACKGROUND

It has been demonstrated in the A-7 Airborne Light Optical Fiber Technology (ALOFT) program that fiber optics can be successfully used on military aircraft. The many advantages of a multiplexed, fiber optic data interface – such as immunity to electromagnetic interference (EMI), electromagnetic pulse (EMP), and lightning strikes; reduced systems weight; and reduced complexity in external harnesses and connectors, resulting in improved reliability and maintainability – have also been demonstrated. Before fiber optics can be used on a production aircraft, installation practices and procedures must be established for high volume, low cost, fiber optic interconnects. By the development or improvement of installation processes, techniques, and equipment by the contractor (Boeing Aerospace), this work is intended to develop an industry source for the timely, reliable, and economical assembly of the required fiber optic interconnects.

SCOPE

As fiber optics has progressed from research and development to feasibility demonstrations, it has become apparent that planning for high volume production of fiber optic components is necessary. Questions of production compatibility, applicability, and cost are addressed under this contract in order to identify and correct problems associated with the installation of fiber optics aboard military aircraft. Two major requirements have been undertaken in this contract: (1) the fabrication and installation of fiber optic harnesses; and (2) the fabrication and installation of "stand-alone links." Present electrical harnesses conduct both electrical signal and electrical power. Fiber optic harnesses developed under this contract conduct optical signals and electrical power and are a one-for-one replacement of the electrical harness counterpart. The stand-alone link accounts for retrofit applications for which no fiber optic harness is required – just stand-alone links. Associated with the two major requirements is the development of assembly methods and installation specifications for the incorporation of the harnesses and stand-alone links aboard a Boeing military-type surveillance aircraft. The assembly methods installation specifications, as well as the identification of routing techniques, support test equipment, field repair techniques and procedures, and a detailed cost analysis between the fiber optic cost and the original wire interconnect cost were verified on a full-scale production mock-up.

PROGRAM OVERVIEW

This final report covers a 25-month four-phase program entitled "Fiber Optic Interconnect System: Manufacturing Processes For" (NOSC Contract N00123-78-C-0193). This report covers the activity of all four phases of the contract, with particular emphasis on the final phase. The fourth phase verified all documentation/procedures by the fabrication of

21 production-type harnesses and subsequent mock-up of 5 harnesses aboard an E-3A Class III mock-up. Documentation developed during the fourth phase of this program includes:

Final Installation Process Specification
Final Production/Acceptance Test Procedure
Engineering Drawings
Final Field Repair & Technique Procedure
Final Cost Analysis
Final Description of Harness Assembly and Tooling

The interim procedures developed earlier in the program were updated to generate the above final procedures. These procedures are attached to this report in the appendices and they form, in conjunction with the other reports, procedures, and specifications developed during Phases I, II, and III, a complete set of documentation for the fabrication and installation of complex fiber optic cables and harnesses.

The program plan, as shown in figure 1, was to develop all required documentation for the fabrication and installation of fiber optic harnesses in military aircraft by conducting four distinct phases. The first phase was primarily a design stage where the aircraft type was selected, harnesses for that aircraft were defined or chosen, and the necessary process specifications were developed for fabrication and installation. In this stage, materials were selected and a preliminary cost analysis was then developed based upon the selected materials and processes.

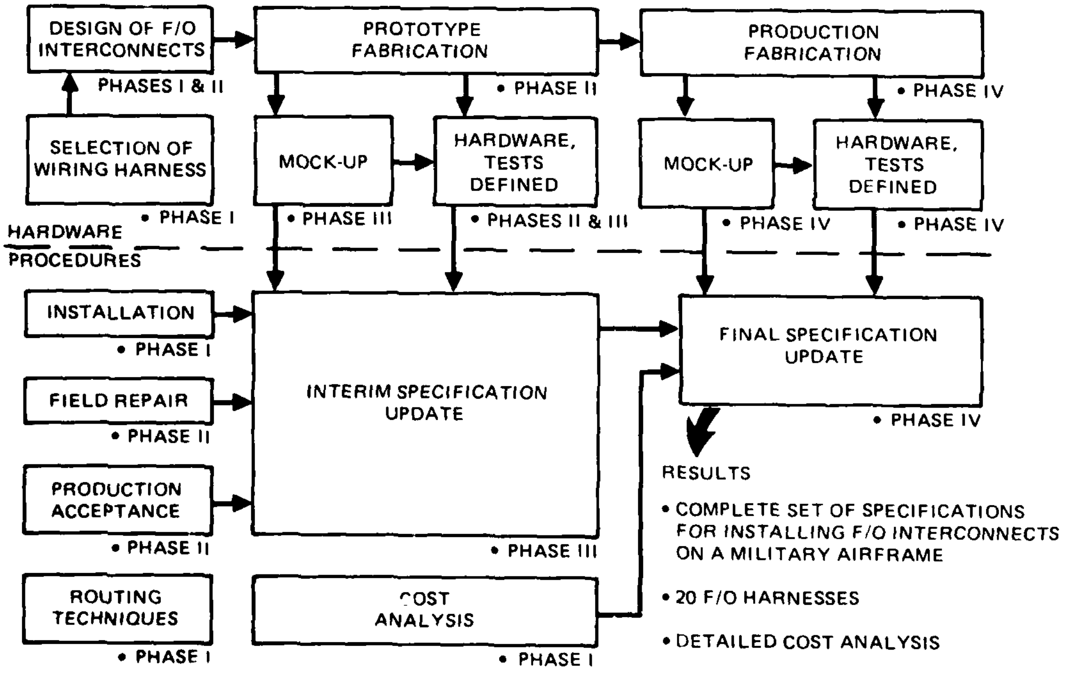

Figure 1. General program flow diagram.

Table 1 lists documents developed for this program. Copies of the documents are appendices to this report.

Appendix	Document Title	Document Number
A	Final Installation Process Specification (General)	D180-24693-20
B	Final Installation Process Specification (Specific)	D180-24693-21
C	Final Production/Acceptance Plan	D180-24693-22
D	Final Field Maintenance and Repair	D180-24693-23
E	Manufacturing Technology Cost Analysis	
F	Final Harness Assembly Description and Tooling	D180-24693-25
	Fiber Optic Rack Integration Harness	D180-59004
G	Fiber Optic Assembly Procedure, General	D180-24693-26
H	Fiber Optic Assembly Procedure, Hughes	D180-24693-26.1
I	Fiber Optic Connector Assembly Procedure, Amphenol	D180-24693-26.2
J	Fiber Optic Termination Procedure, General	D180-24693-27
K	Fiber Optic Termination Procedure, Hughes Connectors	D180-24693-27.1
L	Fiber Optic Termination Procedure, Amphenol, Connectors	D180-24693-27.2
M	Fiber Optic Shop Aids Requirements, General	D180-24693-29
N	Routing Techniques	D180-24693-5

Table 1. Documentation for fiber optic interconnect systems.

The aircraft selected for this program was the E-3A, a military surveillance aircraft. A communication harness within the E-3A was selected for replacement with fiber optics. The basic design of the harness is shown in figure 2. All signal lines were replaced with fiber optic cables; the electrical power requirements were satisfied by conventional twisted-pair wire. The harness design, therefore, was hybrid in nature – consisting of bundle fibers, single fibers and twisted-pair wire. The harness was all point-to-point, with no couplers.

The stand-alone link (SAL) was designed using fiber optic cables only. The purpose of this link is for retrofit applications in which no fiber optic harnesses are required; just stand-alone cables. The configuration of this link is shown in figure 3.

The routing of the harness is shown in figure 4. Figure 5 shows the relationship of both the harness and SAL to the E-3A aircraft. Originally, the SAL was intended to be designed for retrofit to the harness. However, it was decided to design a configuration that would go through a pressurized bulkhead into the wheel-well area. This configuration would provide additional information on routing and handling problems.

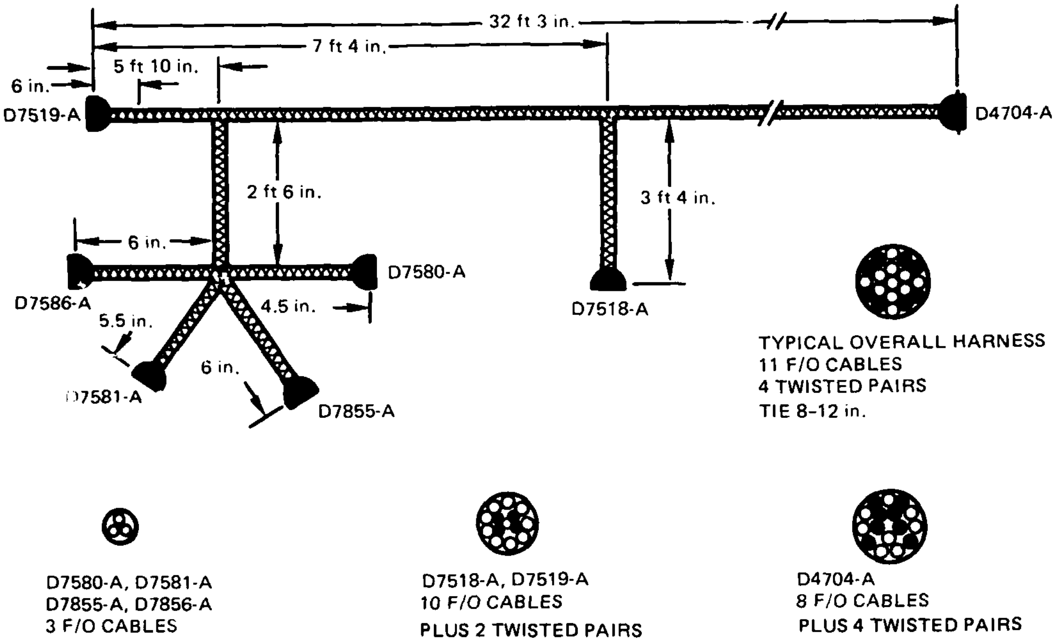

Figure 2. Design of fiber optic communication harness.

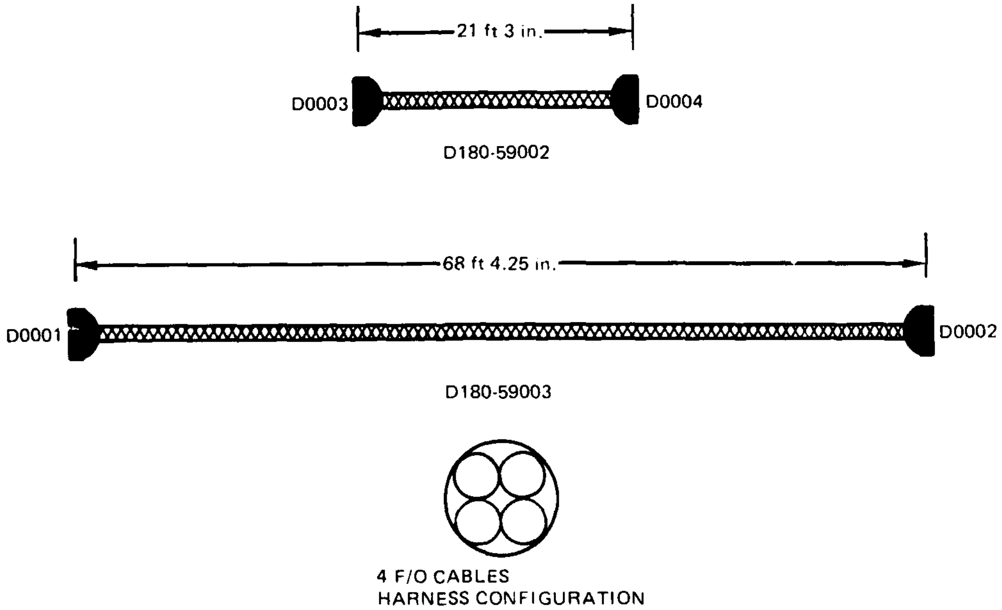

Figure 3. Stand-alone link.

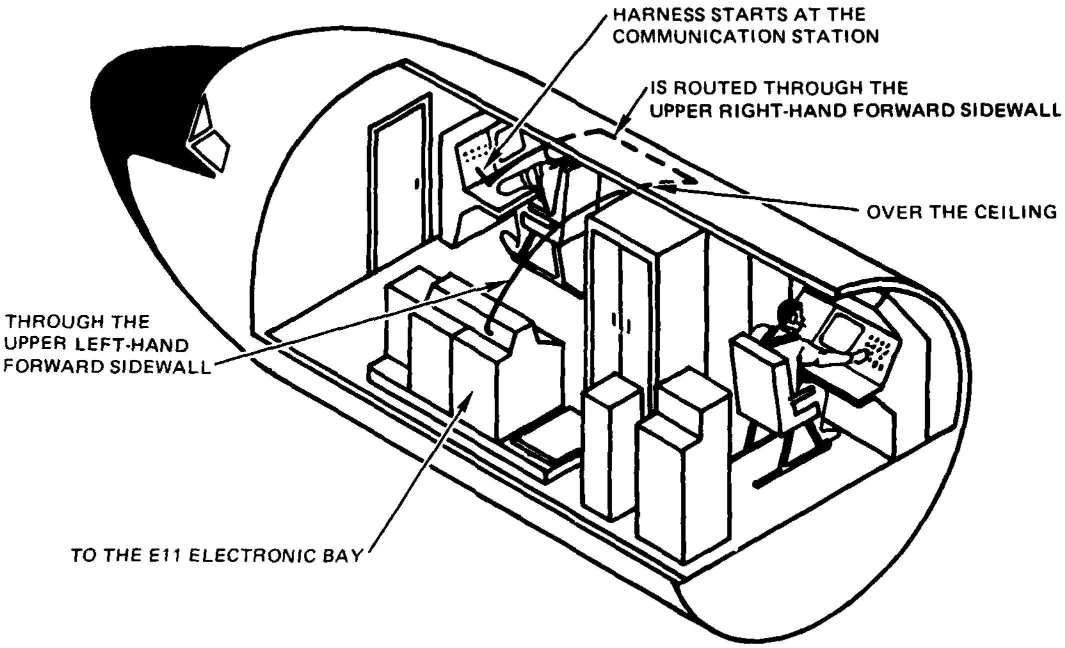

Figure 4. Simplified details of the harness routing.

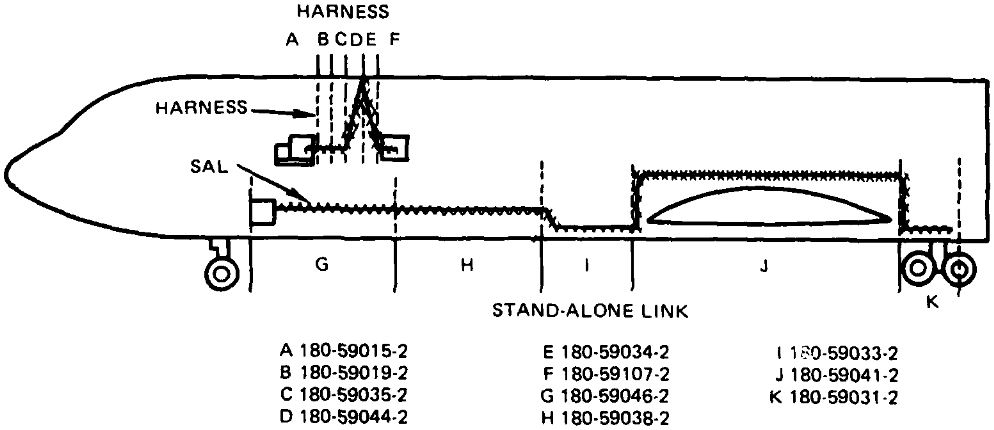

Figure 5. Routing of fiber optic harness and stand-alone link in E-3A aircraft.

SUMMARY OF TECHNICAL WORK

INTRODUCTION

A summary of technical work is presented on a phase-by-phase basis to provide continuity and to present program accomplishments in serial form over the two-year period. Further details of each phase may be found in references 1, 2, and 3.

PHASE I ACTIVITY

The Phase I activity initiated the development of the preliminary procedures/documentation and component selection for the cable configurations. Details of this activity are given below.

CONFIGURATION MANAGEMENT PLAN

A Configuration Management Plan was developed which set down the policies by which all drawings, documents, and deliverable hardware configurations were controlled and modified. The system program contained in D180-24693-7 designates the program manager as chairman and designates representatives from each of the line and staff functions for that board and the change board. The full plan is contained in appendix I of that document.

COMPONENT SELECTION

Major components selected for the Phase I Link Designs (stand-alone link and harness) included four 4-terminal connectors, the fiber optics cable for the link, and seven (three 20-terminal and four 4-terminal) connectors plus fiber bundle cable, single fiber cable, and conventional wire for the harness. Relatively minor items including outer braid, tie materials, clamps, etc, are common shop stock and were selected as required on the program.

Connectors were chosen from three different vendors so that a broad base of connector types could be evaluated as to cost, availability, termination ease, suitability for manufacturing and assembly processes, optical properties, and environmental capability. The connector chosen for the stand-alone link was the Amphenol 4-terminal unit which is compatible with the heavy duty fiber optics 46-mil bundle cable required by the RFQ for this application. The connectors chosen for the harness include three 20-terminal Hughes C-21 rectangular jackscrew units capable of mating single fiber, 46-mil fiber bundle (medium duty) and conventional wire. The four 4-terminal connectors chosen for the harness were the ITT Cannon MIL-C-83723(PV) type, of which three were suitable for fiber bundle use and one was suitable for single fiber applications. All connectors for both links were supplied

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1. OR Mulkey, SP Suave, Final Technical Report – Phase I: Fiber Optic Interconnect System: Manufacturing Processes For (MTP), Boeing Document D180-24693-7, September, 1978.
2. LF Buldhaupt, SP Suave, OR Mulkey, Final Technical Report – Phase II: Fiber Optic Interconnect System: Manufacturing Processes For (MTP), Boeing Document D180-24693-14, February, 1979.
3. LF Buldhaupt, SP Suave, OR Mulkey, Final Technical Report - Phase III: Fiber Optic Interconnect System: Manufacturing Processes For (MTP), Boeing Document D180-24693-15, December, 1979.

with suitable inserts and backshells. All connector assembly was done at Boeing, using standard polishing and terminating equipment plus special crimping and assembly tools peculiar to each of the connectors and cables. All connectors chosen met the contract requirements for aircraft environments.

The cables chosen for the links were of four types: single fiber, heavy duty fiber bundle, medium duty fiber bundle, and standard 22-gage twisted pair. The heavy duty and medium duty 46-mil fiber bundle cable was quoted by three manufacturers and was purchased from Valtec (based upon final pricing) during the next phase of the contract. The single fiber cable chosen (to be used in the harness) was of the large core type (8-10 mil core diameter) and was Galileo Type 3000 LC. This particular cable provided much better optical properties with respect to coupling losses and could be terminated with reasonable ease using any of the connector types chosen for the contract. The conventional wire was drawn from stock.

SELECTION OF MILITARY TYPE AIRCRAFT AND CONVENTIONAL HARNESS

A contractual requirement was the selection of a suitable airframe or mock-up for the fiber optic interconnect installation. The airframe or mock-up was limited to one of the following:

a. High performance fighter type aircraft
b. Military surveillance aircraft
c. Other aircraft which must perform in the military environment.

For this program, the aircraft selected was the E-3A, for which a full-scale, Class III mock-up was available.

A complex communication system cable harness was selected from the E-3A to be the conventional harness replaced by the fiber optic interconnect system. (See figure 4.)

PRELIMINARY INSTALLATION PLAN

The installation plan developed for use on this program was based upon the harness/link designs discussed below, as well as the detailed installation procedure developed to provide the detailed information on each of the process steps involved in the assembly and installation process. (This updated installation plan is included as D180-24693-20, -21 (appendices A and B)). The installation plan details the routing of the cable through each of the sections of the airplane and is supported by production illustration drawings which illustrate all support points for each of the cables plus information on the pressure hull penetration and the conduit necessary for protection from the landing gear environment (for the case of the stand-alone link).

The installation methods were based primarily upon present methods used for conventional cable, utilizing special handling procedures developed for small-diameter coax cable and modified for fiber optics cable.

Particular problems during installation included:

1. Adequate protection of terminations during the pull.
2. Protection against shock.

3. *Protection against strain.*

4. Observance of minimum bend radius criteria.

Problems during the harness assembly operation included:

1. Proper termination and polishing.

2. Second end assembly (should this be done at the form board or back at the primary polishing/termination station?)

3. Protection of terminations during the assembly sequence.

4. Lower cost marking and identification methods compatible with the Tefzel cable covering.

FIBER OPTICS HARNESS/LINK DESIGNS

The two fiber optics designs are the stand-alone link and the seven-connector communications harness. The harness design was based upon the E-3A W1870 communication harness. This harness originally contained 114 terminations of wires, jumpers, shields, and grounds which was reduced to 56 terminations of fiber optics cables, wires, and grounds in the fiber optics/conventional wire hybrid version, while still meeting the EMI and TEMPEST requirements of the original harness. The connectors and cables chosen for this harness and the link are as described in the component selection section and appendix C. The link design was based upon discussions held with the customer and the contractual requirements of a straight point-to-point link for an add-on system containing 4 fiber bundle cables of the heavy duty type. The routing of this cable was intentionally chosen to include passage through a pressure seal, a midpoint disconnect, and exposure to the environmental extremes (such as weather, flying rocks, and hydraulic fluid) found in the landing gear area. This routing demanded that the routing procedures and the cable construction and protection (conduit) include not just the minimum needed to install a cable but also a full measure of procedures designed to provide maximum fiber optics cable utilization. It is believed that this goal has been met.

ROUTING TECHNIQUES

An analysis of the routing techniques for fiber optic interconnects was made using the routing criteria of conventional wire as a starting point. An assessment was made of hazardous/sensitive areas on the aircraft and the ability of fiber optics to be routed through these areas. Coupled with this analysis are the environmental constraints placed on the fiber optic system (per MIL-E-5400P requirements) and the ability of the fiber optic components to withstand this environment.

With proper attention to the cladding material, fiber optics can be routed through any hazardous or sensitive area within a military-type airframe. However, some areas exist which will prohibit either the detection or sourcing of fiber optic information. This is due to current limitation on the lifetime of sources/detectors as a function of temperature. Similarly, sources/detectors, and to some degree fibers themselves, are sensitive to radiation effects, although to varying degrees. Technology trends, however, show a gradual improvement in component parameters; it will become feasible (in the mid-1980's) to route fiber optics into, out of, and through all areas of the aircraft. The complete routing technique section is presented in D180-24693-5 (appendix N).

COST ANALYSIS

Acquisition cost estimates by models and by analysis of processes and techniques reflect potential cost savings for fiber optic interconnect systems as compared to wire harnesses. Since most models rely upon historical data and "conventional methods of business," it is implied that savings are realizable with technology maturity and with methods and techniques commonly employed.

Many options exist for production set-up and related costs. The most desirable option will depend on factors such as levels of business forecasts, advancement of the technology, demands on existing harness/cable production equipment and facilities, facility space available for expansion or relocation, economic posture of the company, etc.

The potential for cost improvement in the manufacturing/fabrication process is promising. The development of automated equipment and expedient techniques is needed to exploit this potential, however:

- Cost elements related to operations and support aspects appear to have offsetting effects.
- Cost savings are realized through weight and size advantages, while losses occur through added inventories, training, and special equipment requirements.
- Reliability considerations have a similar neutralizing effect.

The updated cost analysis is given in D180-24693-25 (appendix E).

PHASE II ACTIVITY

PRODUCTION/ACCEPTANCE PROCEDURE

This procedure detailed the inspection steps and equipment required for the fabrication phase of fiber optic cables and harnesses. Test points were detailed as far as the general requirements are concerned, but test limits were left to be included in assembly drawings and documents. This was necessary because limits for parameters such as cable loss are length dependent. The test hardware needed to perform the in-process tests was developed in prototype form. Level II drawings were prepared which detail all information necessary to reproduce the test equipment.

HARNESS ASSEMBLY DESCRIPTION

A description of the harness assembly procedures was developed which used as its basis the manufacturing plan for the particular harness. All cable drawings, form board drawings, cable lists, plug maps, termination procedures, connector assembly procedures, and details of the manufacturing processes are considered part of the manufacturing plan and are referenced by it.

HARNESS AND LINK ASSEMBLY

Based upon the harness and link designs developed in Phase I, a prototype harness and link were fabricated. No unusual problems were uncovered during this manufacturing cycle. The harness/link designs were then finalized in preparation of the actual production run. The final designs are shown in figures 2 and 3.

PRELIMINARY FIELD REPAIR TECHNIQUES

A field repair and maintenance specification was prepared which details the types of damage to cables, harnesses, and connectors. For each type of damage or contamination, the proper procedures for repair, cleaning, etc, are detailed, as well as the material requirements. In addition, before and after test requirements are detailed to assure the quality of the maintenance or repair and the integrity of the assembly.

PHASE III ACTIVITY

HARNESS AND STAND-ALONE LINK INSTALLATION

The prototype harness and the stand-alone link were successfully installed in the E-3A Class III mock-up using production personnel. The hardware was optically tested and photographed at a single contact level before and after installation to assure that no damage occurred. One section of cable was damaged by mishandling, but the optical link remained intact. The damage occurred when the installation personnel pulled on the fiber optic cable to gain more slack. This pulling was done without loosening the cable ties and the pulling motion was 90° to the cable tie.

INTERIM INSTALLATION PROCESS SPECIFICATION

The preliminary installation process specification (D180-24693-2) developed during Phase I of the program was used as the installation procedure for the two harness assemblies. All problems in this documentation were noted, and this information was used to revise the preliminary document to its present form as the interim installation process specification. This document was updated and used in Phase IV for the installation of the five production seven-connector harnesses.

The interim installation process specification was assigned document number D180-24693-16. This document covered the installation of the specific harnesses developed under this program. A general installation specification for all harnesses also developed during Phase I (D180-24693-3) was revised to reflect observations/problems during the mock-up activity. This document was numbered D180-24693-17.

INTERIM TEST REPORT (PRODUCTION/ACCEPTANCE PROCEDURE)

The Phase II production/acceptance procedure (D180-24693-8) was reviewed and modified for use in Phase IV cable fabrication and installation based upon this mock-up activity. No major problems were uncovered in this area. The interim production/acceptance procedure was documented in D180-24693-18.

INTERIM FIELD REPAIR TECHNIQUES

The preliminary field repair techniques document (D180-24693-9) developed and issued during Phase II of the program was reviewed and modified as required to reflect technology and material changes. The interim document was D180-24693-19.

PROBLEM IDENTIFICATION

MATERIALS AND COMPONENTS. The primary problems relating to the materials and components selected for use during this phase of the contract were identification of viable sources and subsequent procurement. The only connector source willing to commit to development of a connector/backshell/terminus combination suitable for use was Hughes. Other vendors either did not have sufficient engineering personnel available or were not structured to provide the support required. Two cable manufacturers had the necessary background and production experience to bid on the bundle cable requirements, and the lower cost type was selected. Only one company bid on the single fiber cable but did not deliver. To provide a suitable cable in time to support connector development, an alternate source (Siecor) was selected.

INSTALLATION EQUIPMENT, PRACTICES, AND PROCEDURES. Installation of the harnesses was a relatively smooth operation marred by the one incident of cable harness damage during positioning of the stand-alone link. In this incident, the harness bend radius restrictions were violated. The installation specification was modified to reiterate in stronger terms the requirements on bend radius and the warnings and instructions on radius limits.

TESTING AND TEST EQUIPMENT. Test methods and equipment documentation were modified to remove optical power measurement tolerance limitations on detectors used for continuity tests, as it was not felt necessary or cost effective to impose an accuracy limit on this test.

HARNESS ASSEMBLY, TESTING, AND DESIGN. No significant problems were encountered in this area.

ENGINEERING DRAWINGS

The engineering drawings developed for installation of the harness during Phase III were revised to reflect the changes in materials and processes required for the cables and connectors used in the revised harness.

PHASE IV ACTIVITY

SUMMARY OF LINK DESIGNS

All design documentation for the 20 fiber bundle/single fiber/wire hybrid harnesses Part No. F0-0004 and the one single fiber/wire hybrid harness is contained in D180-24693-25 (appendix F) and the supporting documentation listed in that document. As described earlier in this report, these 7 connector harnesses were designed as a direct replacement for the W1870 harness used in the E-3A aircraft. The harness configuration, parts list and interconnection list, and assembly method are illustrated in Drawings 180-59004 and 180-59005, part of the -25 document.

COST ANALYSIS

Life cycle cost comparisons for fiber optics and wire interconnect systems are assembled under the three major cost categories of design, development, test, and evaluation (DDT&E), production, and operation and support (O&S). (See appendix E.)

Cost comparisons for a small quantity of interconnect systems typical of a DDT&E portion of a program revealed that fiber optics interconnect systems offer a potential cost savings. Some key considerations in the cost comparison include:

1. The estimated reduction in engineering, primarily through the reduced complexity of the fiber optic system
2. An estimated equality in manufacturing when baselined to a small scale manual assembly process for each type of interconnect system
3. An estimated reduction in fiber optics parts and material costs consistent with present cost projections for large quantity purchases
4. The manufacture of fiber optics systems with pre-established specifications, standards, and processes

Analysis of cost data for production set-up and manufacture of a large quantity of wire and fiber optics interconnect systems revealed that new procedures and processes required for fiber optics systems are dominant cost factors. Consequently, cost effective large scale production depends upon development of tools, equipment, and techniques.

Analysis of cost data for operation and support revealed that advantages of savings in size, weight, and complexity would yield cost benefits in operations and maintenance to offset initial investment costs for special tools, equipment, training, parts, repair materials, and added inventory.

SUMMARY OF FINAL INSTALLATION PLAN

The installation plan is contained in two document sections: D180-24693-20 (appendix A), a general installation procedure for all fiber optic cables and harnesses, and D180-24693-21 (appendix B), an installation procedure specifically for the 180-59004 and 180-59005 (F0-0004 and F0-0005) harnesses. The general procedure covers all phases of the fabrication and installation of harnesses and includes separate appendices which cover harness identification, fabrication, detailed installation procedures, and harness marking.

No revisions other than typographic were required in the "general" document. The "specific" document was revised to include the single fiber cable installation and to delete references to the "stand-alone link" installation which had been completed earlier in the program (Phases II and III). No technical changes to the process were necessary.

SUMMARY OF FINAL PRODUCTION/ACCEPTANCE PROCEDURE

This procedure is contained in D180-24693-22 (appendix C) and lists the procedures for the in-process and final tests of all fiber optic cables and harnesses. Test methods covered include continuity, insertion loss; and visual inspection details of the tests and test limits are included in the Assembly Drawing 180-59004 and -59005. No changes were necessary in the -22 document.

SUMMARY OF FIELD REPAIR AND MAINTENANCE PROCEDURE

This procedure is contained in D180-24693-23 (appendix D) which lists facilities and maintenance methods for all types of fiber optic cables and harnesses. Specific maintenance methods include avoidance of:

Contamination
Abrasion
Cuts/Breakage
Connector Damage

No revisions were required in this document during the fourth phase of this contract.

PROBLEMS ENCOUNTERED DURING THE PROGRAM

CABLE PROCUREMENT. Procurement attempts for the single fiber and fiber bundle cable indicated only one viable source (Galite) for the single fiber cable and several sources for the bundle cable. Galite was chosen as the sole source for the single fiber cable and as lowest bidder for the bundle cable. Orders were placed early in the program (July, 1979) and the bundle cable was received in September, well within schedule. As the single fiber was not received shortly afterwards, checks were made to determine progress. Initial checks indicated delivery, but further investigation revealed that the order had been misplaced and that no cable was available or in process and that no delivery could be promised for 4 months. As this would not support the intended contract schedule, new sources were sought and an order was placed with Siecor for 600 m of their type 155 cable which was in stock. This cable was received and samples were shipped to Hughes, the connector supplier, for their use in designing the connector accessories for the contract. In December, Boeing was informed by Siecor that the furnished cable "had problems" and should not be used. No immediate reasons were given but answers were expected early in January. At this time Hughes was put on hold and another supplier was sought for backup. Galite promised quick delivery and when at the end of January Siecor could not replace the fiber an order was placed to Galite. Delivery of the cable, mid-February, was not per schedule, however, so that connector development was slowed until mid-March when production of the harnesses was started.

CONNECTOR PROCUREMENT. Of the three connector manufacturers identified as being capable of providing connectors of the type required (Amphenol, Cannon, and Hughes), only Hughes responded positively with designs providing adequate strain relief, termination ease, and hermeticity. Hughes was, therefore, selected to provide all connectors for the harness assembly. Two connector types were used, the C21 series 20 contact connector with a larger backshell and a new circular 4-contact connector with integral backshell and positive strain relief. Termination methods for both connectors and both cable types were provided by Hughes and refined by Boeing to meet the production environment to the extent possible. Connector and related hardware deliveries were slower than scheduled but hardware was available to meet production schedule.

PRODUCTION. This phase of the contract was completed using personnel from Boeing Aerospace Company production wire and cable shops. All personnel, including quality assurance, had to be trained in all phases of the production processes different from conventional wire technology. A flow diagram of the manufacturing cycle is shown in figure 6.

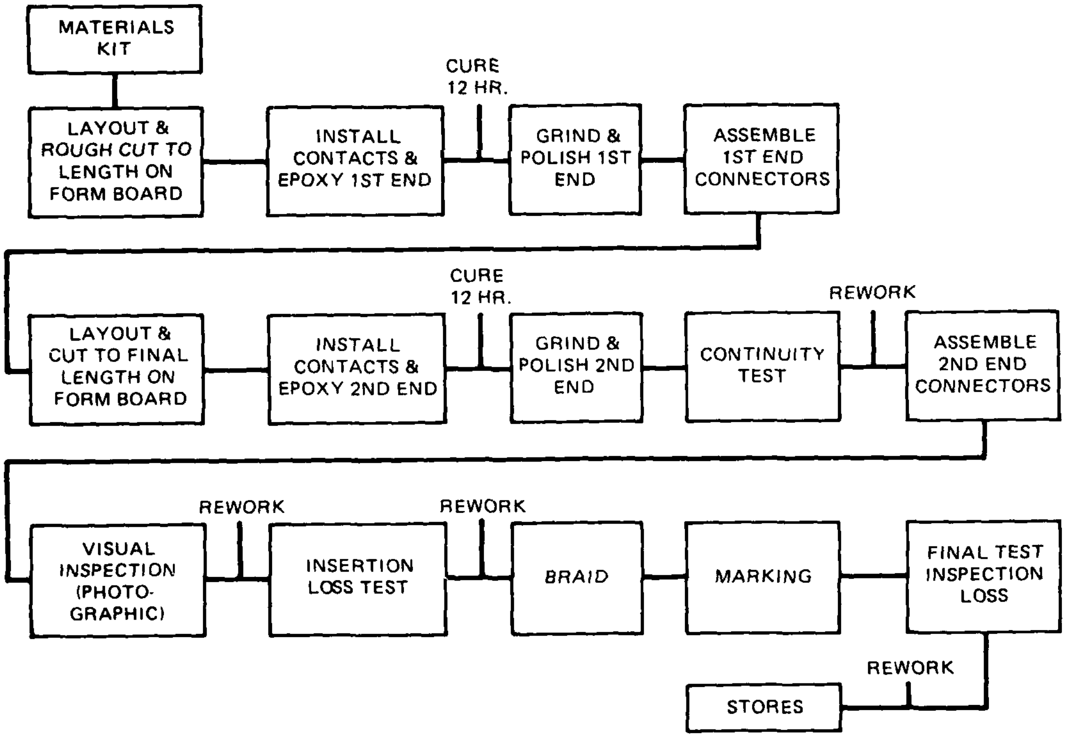

Figure 6. Assembly flowchart, fiber optic harnesses.

All assembly and process steps were optimized and tooling was modified or developed to meet assembly requirements. The grinding and polishing operation was slower than expected and required 3 to 4 minutes for the grind operation and the same for the polish step. The special contact holding fixtures developed by Hughes for these operations tended to clog up and had to be disassembled and cleaned at least once a day, slowing the grind/polish operations.

Wear on some of the inner surfaces of the contact made insertion both difficult and hazardous to the contact. Hughes provided new tooling and repaired the old tools with updated internal parts, which helped the situation later in the program. Hughes in all cases proved to be responsive and helpful in all connector related problems during the program.

The epoxy used in the termination process (BI Pax 2143D) was a viscous material deliberately chosen so to prevent wicking in the termination of the bundle contacts. The high viscosity slowed the application process considerably but the results made it worthwhile. This epoxy also was a room cure (12-hour) type so that the curing type affected flow rates through the production cycle.

The termination of the bundle fiber contacts involves the use of added shrink tubing to protect the fibers at the contact end. Use of the tubing fitted over the end of the contact prevents use of a conventional insertion tool so that special tooling and techniques were required to accomplish the contact insertion and to prevent damage to the cable, fibers, or heat shrink tubing. The single fiber cables, because of the buffer coating and small internal jacket which fit inside the contact barrel, did not require additional sleeving and could be terminated with the standard tooling at a much faster rate.

Harness handling and contact protection during the production sequence was a constant problem throughout the program in that additional time was required to prevent damage to the harness. Use of a multiple contact polishing jig for mass termination finishing would do much to speed the process and to cut down on potential damage.

Inspection of the harness during the production sequence consisted of standard monitoring of strip lengths, crimps, and workmanship items as well as the fiber optic peculiar tests, which were continuity, insertion loss, and visual inspection. The visual inspection operation for terminated bundle cables was the only difficult operation as it required a photograph be taken of each contact. Use of the camera microscope developed by Boeing QC during the second phase of the program speeded the photographic steps, but the time spent in the operation and the counting time was significant in the total cable construction time. Again, as this step is not required with the single fiber cable, the cost advantage of single fiber cable is increased.

ENGINEERING DRAWINGS

All drawings (top, form board, and production illustration) for the seven-connector harness and its installation were revised to reflect process changes and materials changes from the previous stages of the contract. The revised drawings are included as a part of the contract deliverables (CDRL Item D0004).

CONCLUSIONS

Successful completion of the final phase of this program has demonstrated that fiber optic cables and harnesses can be fabricated in a production mode and installed in military aircraft using techniques quite similar to those used in conventional wire harness technology. Fabrication of the harnesses can be accomplished in a production environment using shop personnel trained and skilled primarily in conventional wire technology. Tooling and equipment necessary for the fabrication in a very high production mode have not yet been developed, as no requirement has yet been forthcoming, but these items have been identified and costed. Further development still needs to be accomplished in the tooling and equipment for lower volume production, if fabrication costs are to be minimized.

Hardware (connectors and cables) available today is adequate for military aircraft installation but is not yet optimized. Right-angle connectors are not yet available, but will be required. Strain relief methods are adequate but tend to increase assembly time and are costly, complex, and larger than desired. Terminations are still the most driving cost item. Cabling available today will meet requirements but can still be further optimized for aircraft use. Large core (100μ–200μ dia.) fibers now coming on the market appear to be ideal for this use, and if jacketing materials are chosen properly then high performance cables can be manufactured. The further use of bundle fibers is not recommended as their cost is high, performance is low, and termination/inspection cost is higher in multicontact connectors when compared to state-of-the-art single-fiber cables.

Test equipment now on the market (such as portable power meters and optical time domain reflectometers) can be utilized for harness test and checkout in the shop and in the field. Optical equipment for visual inspection purposes is not yet commercially available. Boeing-designed test equipment (Phase II) will accomplish the task, as proved on this program, but the inspection task would be reduced considerably with the use of single-fiber technology by the elimination of broken fiber count and packing fraction related inspection. Field repair techniques currently available work and are acceptable. Hand termination, using a kit of selected grinding and polishing materials, is not much slower than mechanical finishing. Epoxy cure time can be in the 5-minute range with selected materials, but these materials need to be evaluated for suitability over the expected environmental range of the system.

RECOMMENDATIONS

- Initiate a manufacturing technology program to address the entire spectrum of the termination operation, including automated grind/polish operations, mass polishing techniques, tooling, ultimate producibility, and cost.
- Initiate a program whose objective would be elimination of epoxy in connector designs.
- Initiate a manufacturing technology program on fiber optic transmitter/receiver subsystems so that the entire cost of manufacturing a fiber optic system (transmitter-interconnect-receiver) can be determined.
- Develop and optimize volume production processes for the fabrication of fiber optic harnesses using large core single fiber technology.
- The above program should be a joint effort involving not only the system integrator but both cable and connector suppliers.
- Use the present set of harnesses in a test program to determine the capabilities of the current technology in the area of environmental/mechanical and application stress.
- Expand the technology to include that necessary for the use of fiber optics in shipboard applications.

REFERENCES

1. OR Mulkey, SP Suave, Final Technical Report – Phase I: Fiber Optic Interconnect System: Manufacturing Processes For (MTP), Boeing Document D180-24693-7, September, 1978.

2. LF Buldhaupt, SP Suave, OR Mulkey, Final Technical Report – Phase II: Fiber Optic Interconnect System: Manufacturing Processes For (MTP), Boeing Document D180-24693-14, February, 1979.

3. LF Buldhaupt, SP Suave, OR Mulkey, Final Technical Report – Phase III: Fiber Optic Interconnect System: Manufacturing Processes For (MTP), Boeing Document D180-24693-15, December, 1979.

APPENDIX A

FINAL INSTALLATION PROCESS SPECIFICATION
(General)

D180-24693-20

FINAL INSTALLATION PROCEDURE (GENERAL)

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Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124

4 June 1980

Final Report for Period 16 December 1979 Through 4 June 1980

Phase IV of NOSC Contract N00123-78-C-0193

Prepared For:

NAVAL OCEAN SYSTEMS CENTER
Code 9313
San Diego, California 92152

1.0 SCOPE

1.1 This specification covers the assembly and installation of fiber optic cables and harnesses in military aircraft.

1.2 In case of conflict between this specification and Engineering Assembly and Installation Drawings, the information of the engineering drawings shall have precedence.

2.0 REFERENCES

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-20
SCALE	REV	SHEET 2.

3.0 CONTENTS

4.0 ASSEMBLY OF FIBER OPTIC CABLES AND HARNESSES

4.1 CABLE IDENTIFICATION (Marking)

4.1.1 Physically identify cable as follows:

1. Include in each identification all the information specified by the Bundle Assembly Drawing.

2. Where the Bundle Assembly Drawing specifies identification of the bundle number and cable number, use only the hot embossing on sleeve or tape methods of Appendix A.

4.1.2 Cable Identification Sleeves and Tape

4.1.2.1 a. Identification of cables by means of sleeves or tape is required within 6 inches of the terminating points and within twelve inches of each side of a pressure bulkhead.

b. Identification of unmarkable cables by means of sleeves or tape is required only at terminating points and may be staggered up to twelve inches from termination points to reduce bulk and within twelve inches of each side of a pressure bulkhead.

c. For cable bundles using protective "Expando" sleeving over the cable or harness, the cable identification sleeves or tape may be staggered up to a maximum of twelve inches from termination points to reduce bulk.

4.1.2.2 Include color coding as indicated by the Bundle Assembly Drawing on identification sleeve or tape when these are installed around a multiconductor cable. No color coding is required when the identification sleeve or tape is used on individual cables of a bundle.

4.1.2.3 Add identification sleeves to unidentified cables on vendor furnished components when numbers are required by the Bundle Assembly Drawing.

1. Imprint the cable numbers assigned by the Bundle Assembly Drawing on the identification sleeves.

2. Locate an appropriate sleeve on each cable within three inches of the component.

4.1.2.4 Where heat shrinkable sleeving is used for cable identification, the actual shrinking operation is required only where necessary to prevent the sleeve from sliding out of position on the cable during normal service.

4.1.2.5 When marking RT 876 heat shrinkable sleeving, use a type temperature of 500 ± 25°F. Regulate the machine pressure and dwell time to provide the maximum pigment transfer from foil to sleeve.

4.1.2.6 Quality Control shall determine, on a surveillance basis, that the impressions are clear and legible.

USE FOR TYPEWRITTEN MATERIAL ONLY

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-20
SCALE	REV	SHEET 4

4.2 BUNDLE IDENTIFICATION

4.2.1 Bundle Assembly Part Number

4.2.1.1 Bundles shall be part numbered per 4.2.3.

4.2.1.2 Bundle assembly part numbers shall consist of Bundle Assembly Drawing numbers and dash numbers. Example: 180-50101-1

4.2.1.3 Cable bundle assembly part numbers shall be located as specified on the Bundle Assembly Drawing. Markers shall be located at one end of the bundles if locations are not given by the Bundle Assembly Drawing.

4.2.2 Cable bundle F/0 number.

4.2.2.1 Cable bundle F/0 numbers shall be placed on cable bundles per Appendix A.

4.2.2.2 Bundle F/0 numbers shall consist of the letter F/0 followed by the last four digits of the Bundle Assembly Drawing number with the leading zeros omitted.

EXAMPLE: 180-50001 = F/01
180-51121 = F/01121

4.2.2.3 Bundle F/0 number markers may be placed from six to twelve inches from the bundle terminations and at six foot intervals throughout the length of the cable bundles that contain only cables that cannot be marked by direct imprinting.

4.2.2.4 Bundle F/0 number markers shall not be used on cable bundles that contain any cable that can be marked by direct imprinting.

4.2.2.5 For cable bundles with protective "Expando" sleeving, the F/0 number (yellow wire bundle ID) shall be installed in the overlap area per Figure 4.2.2.5.

NOTE: Mate with and F/0 No. may all be on the same identification marker.

4.2.3 Materials for Cable Bundle Identification Markers.

4.2.3.1 'T&B' 650-51983 nylon perforated tape (or equivalent) imprinted with the information along the length of the tape and centered with respect to the tape perforations shall be optional material. See Fig. 4.2.3A and 4.2.3B.

CAUTION - SLEEVE MATERIAL USAGE IS DETERMINED BY TEMPERATURE TYPE I OR TEMPERATURE TYPE II, AND HYDRAULIC FLUID OR NON-HYDRAULIC FLUID AREAS.

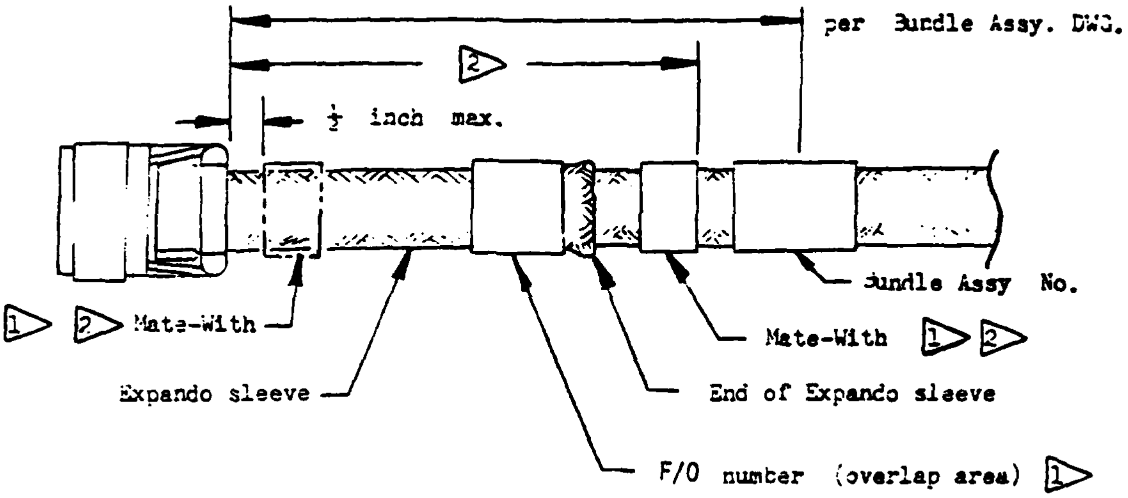


FIGURE 4.2.2.5

1 Mate-With and F/O number may all be on the same identification marker.

2 If Mate-With identification would not be visible after installation, it may be installed loosely around Expando sleeving within $\frac{1}{2}$ inch back of connector hardware.

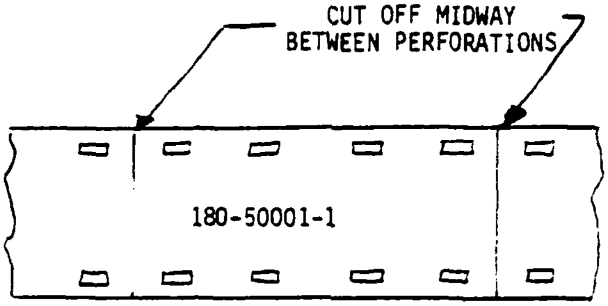


FIGURE 4.2.3A

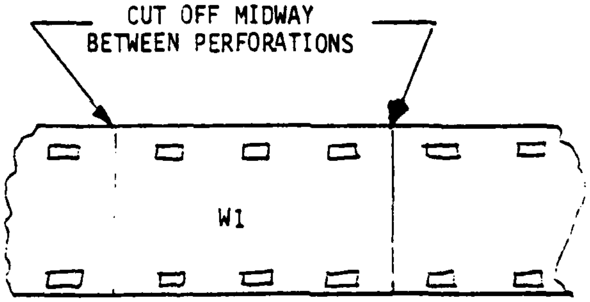


FIGURE 4.2.3B

4.3 REFERENCE POINT INDICATORS (PI Markers)

4.3.1 Production illustration (PI) reference points shall be identified per Appendix A.

4.4 SPECIAL INFORMATION MARKERS

4.4.1 Install special information markers on individual cables or on entire bundles as specified by the Bundle Assembly Drawing.

4.4.2 Locate the markers as near the end of the cable or bundle as possible - unless otherwise noted in the Bundle Assembly Drawing.

4.4.3 Use the materials and installation methods as specified for connector information by Appendix A.

4.4.4 Imprint on the marking media that information which is specified by the Bundle Assembly Drawing.

4.5 CONNECTOR IDENTIFICATION

4.5.1 a) A "Mate With" tape is required for all plugs and receptacles that are not identified with a "P" or "J" suffix. The "Mate With" information on the tape shall match the equipment item numbers shown in the parts list of sheet 1 of the Bundle Assembly Drawing.

b) Mate-With tape is not required on seal fittings.

4.5.2 Identification of equipment mating connectors will be per Appendix A.

4.5.3 In-line connectors will be identified per Appendix A, normally the "Mate-With Dxxxx" notation will be omitted.

4.5.4 Use of nylon tags, per Para. 4.2.3, for connector identification in Type I and Type II temperature areas and in either hydraulic fluid or non-hydraulic fluid area is permitted.

4.5.5 For bundles with protective Expando sleeving, the Mate-With tape or sleeving shall be installed per Figure 4.2.2.5. When the PI markers are located in the Expando area 18 inches back of the connector or on a short cable bundle with Expando on the entire bundle, the PI marker shall be installed tight and secured with a bundle tie, making the flag marker stationary at the location specified by the Bundle Assembly Drawing.

4.5.6 Connector identification markers are not required when connectors are attached permanently to support plate with connector identification marked thereon. "Mate-With" information is not required.

4.6 SPLICE IDENTIFICATION

4.6.1 Where physical identification of a cable splice is specified by bundle assembly or bundle installation drawings, identify the splice as follows:

4.6.1.1 Use RT-876 sleeving with sleeve size such that it fits loosely around the cable of cables to be spliced, yet will not slide over the splice.

4.6.1.2 Mark the splice number (SPXXX) on the sleeve per Appendix A. Do not include leading zeros of the splice number. For example, splice number SP002 as shown on the cable bundle assembly drawing shall appear as SP2 on the identification sleeve.

4.6.1.3 Slide the sleeve over the cable prior to the installation of the splice.

4.6.1.4 Do not shrink the heat shrinkable sleeve.

4.6.1.5 The sleeve must be located within three inches of the splice.

4.6.2 When application of a sleeve is impractical, such as on a completed bundle assembly, pressure sensitive tape may be used. Imprint the splice number and apply the tape within three inches of the splice per Appendix A.

4.7 IDENTIFICATION MARKERS (GENERAL)

4.7.1 Use split or whole sleeves tied or shrunk as applicable. The use of pressure sensitive tape is acceptable.

5.0 INSTALLATION OF FIBER OPTICS CABLES AND HARNESSES

NOTE: Mixed electric and fiber optic cables must be installed using applicable practices for electrical cables plus these extra installation notes applicable to fiber optics.

5.1 ROUTING OF CABLE BUNDLES

5.1.1 Install all cables per Appendix C except as noted.

5.1.2 Install cables with sufficient clearance to prevent chafing of the installed bundles against sharp edges of structures, equipment, etc. (1/8 in. clearance minimum unless secondary protection is provided by engineering drawing). Normal bundle slack may require 3/4 in. separation to account for vibration and bundle movement.

5.1.2.1 When not specifically controlled by engineering drawings, slack portion of bundles may contact smooth flat surfaces and smooth radii 1/8 in. or larger of either metal or plastic. This does not apply to the engine area.

5.1.2.2 Fiber optic cables may be scuffed on the surface without degradation of performance. Scratches deep enough to damage reinforcing braid are rejectable.

5.1.3 Bundles shall not be tied together unless required to provide support for small bundles. When structure for clamping is not available, bundles per above shall be tied to adjacent cable bundles to achieve support.

5.1.4 Reference Point Indicators (PI Markers) for Production Facility.

5.1.4.1 When reference point indicators are specifically called out on the installation drawing, (not all bundle assemblies through a reference location are considered critical at that point) locate the reference point indicators on the side of the support device indicated by the cable bundle installation drawing. The gap between the support device and the near edge of a green indicator will be 1/2 in. ± 1/2 inch. Do not use green indicators in fuel tanks.

5.1.4.2 Allow Reference Point Indicators under the Protective Sleeving.

5.2 CABLE SUPPORTS

5.2.1 Cable bundles shall be supported by channel raceway clamps or loop clamps as specified on the wire provisions installation drawings. Bolt and nut installation shall be per standard practice.

5.2.2 Loop Clamps shall be installed as follows:

1. Cushion-loop clamps (such as ADEL part number 5095__) shall be used for general purpose clamps in nonpressurized areas and for the following special applications in pressurized areas:
   - A. Bundles in high temperature areas (275^{o}F or greater)
   - B. Bundles 1.25 in. in diameter or larger

5.2.2 (Continued)

2. Nylon-loop clamps and plug fillers, when required, shall be used for general purpose clamps in pressurized areas for cable bundles less than 1.25 in. in diameter and with temperatures less than 275°F.

3. Nylon-loop clamps without fillers shall be used inside fuel cells.

   A. Where proper grip of the cable cannot be achieved with standard size clamps, the clamps may be sleeved per the following method:

   B. Select a length of shrinkable tubing such as MIL-I-23053/ (color optional). Slide the tubing onto the clamp so that the tubing will not interfere with the closing of the empty clamp.

   C. The tubing shall not be installed in more than every third clamp on straight runs and shall be installed in each clamp in curved runs. Do not shrink tubing.

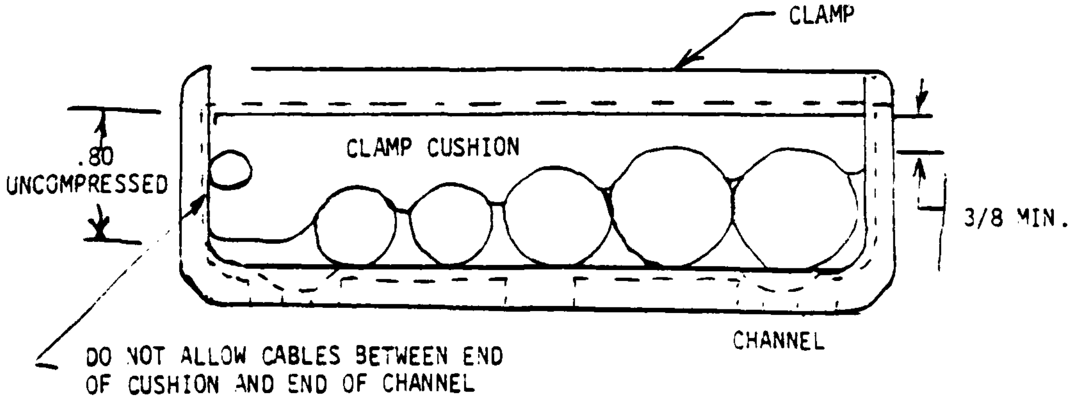
5.2.3 Raceway Clamps

5.2.3.1 Install clamps on channel as follows:

1. With cable bundles distributed in the channel, place the clamp in position with the cushion against the cable bundles and the clamp centered over the channel.

2. With the heel of the hand, press the clamp until the hook on each end has seated in the appropriate slots in the channel.

3. To properly grip the bundles, the sponge cushion must be depressed to a thickness of not less than 1/4 in. The cushion should be depressed to a thickness of not less than 3/8 in. (see Figure 5.2.3.1). Check to determine that the bundle distribution within the channel is such that none of the bundles are free to move.



DO NOT ALLOW CABLES BETWEEN END OF CUSHION AND END OF CHANNEL

FIGURE 5.2.3.1

SIZE A	CODE IDENT. NO. 81205	D180-24693-20
SCALE	REV	SHEET 11

5.2.3.2 Where a short channel is not available, allow trimming of a longer part to the dimensions of the required shorter part. Break sharp edges of reworked area.

5.2.4 Nylon Clamps

5.2.4.1 Where nylon clamps are specified use only Olympic Plastics Co. or Peco Manufacturing Co. clamps as required throughout the airplane.

5.2.4.2 When a nylon clamp is used with a NAS 42 spacer or a metal stand-off, install washers as shown in Figure 5.2.4.2.

CAUTION: Do not use washers within a fuel tank.

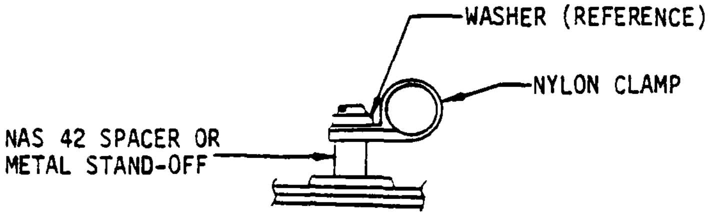


FIGURE 5.2.4.2

5.2.5 Flip Type Grommet (NAS 1368N)

5.2.5.1 Install flip grommets with Western Sky Industries tools WSI-T-3 or WSI-T-32 or WSI-HT-3 through WSI-HT-32 or equivalent.

5.2.5.2 To replace a damaged flip grommet, carefully cut the damaged part out of the hole in structure and install a new grommet with the tool specified in Paragraph 5.2.5.1.

5.2.5.3 If cables are installed through the damaged grommet, cut the grommet as required to remove it from the cables. Install the replacement grommet as follows:

1. Flip the grommet with tool specified in Paragraph 5.2.5.1.
2. Split the grommet as shown in Figure 5.2.5.3 using a sharp knife or razor blade.
3. Apply adhesive to the grommet.
4. Install the grommet around the cable and in the hole of the structure.

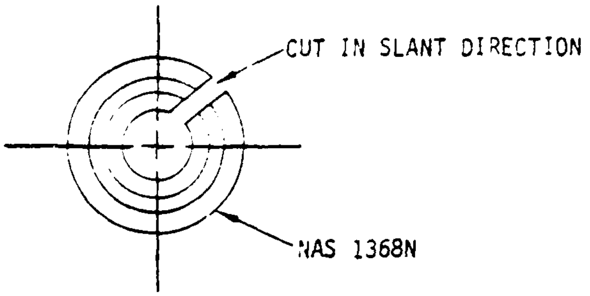


FIGURE 5.2.5.3

5.2.6 Use NAS 603-( ) screws for installation of all single lobe wire bundle support clamps.

5.2.7 Dakota Cab-L-Tite Clamps shall be installed as follows:

1. Select a Cab-L-Tite clamp size which will provide a minimum of one notch above both ends of the keeper when installed.
2. Select countersink screw or hex head bolt as applicable. Insure that the head of the fastener does not protrude above the base of the clamp into the cable gripping area.
3. Mount Cab-L-Tite clamp as specified by installation drawing, lay cable bundle in clamp and install keeper, insuring bundle is securely held.

5.3 REPAIR OF FIBER OPTIC BUNDLE

1. If the outer jacket has minor scuffing such that the inner strength member braid is not exposed, apply a coating of Vyna-Kote No. 6 (Spectra-Strip Wire and Cable Corporation, Garden Grove, California).
2. If the outer jacket is scuffed such that the strength member braid is exposed but is not damaged, apply one coat of Vyna-Kote No. 6 and allow to dry for 3-5 minutes. Wrap area with .003 - .007 fiberglass tape, tie ends with nylon or dacron cord and cover with another coat of Vyna-Kote No. 6.

5.4 RACEWAYS AND CONDUIT

5.4.1 Position cable bundles within raceways as specified in cross-section views on the Wire Bundle Installation Drawings.

5.4.2 Mark and install pull-cord as follows when specified on engineering drawings.

1. Imprint the words "Pull-Cord" on one side of the pull-cord at not more than 15 in. intervals throughout its length using hot embossing machine with D11-51 black foil. Use Bently-Harris Mfg. Co. TG. 40 cord. Optional: Dodge Fibers Corporation TB303.

5.4.2 (Continued)

2. Install the pull-cord in the conduit or raceway with the excess length divided approximately equal and coiled at each end of the inaccessible area. Tie the two coils to the bundle with which it is routed. Do not include the pull-cord under any bundle ties or clamps.

3. Replace the pull-cord per 1 and 2 above if for any reason it is used prior to delivery of the airplane.

5.4.3 Cetyl Alcohol may be used as a lubricant for installations in conduit.

5.5 BEND RADIUS

5.5.1 Use the bend radii specified in Appendix C. Where the stiffness of a cable bundle will not allow bending to the minimum, it is permissible to remove the bundle ties locally. After the bend is formed, retie the bundle per Appendix B. The bundle need not resume a round, cross-section in the bend area.

5.6 FUEL TANK BUNDLES

5.6.1 Do not use cable bundle ties within any fuel tank area.

5.6.2 Do not use tapes or tied-on markers on cable bundles within any fuel tank area.

5.6.3 Wire bundle clamps within fuel tanks shall be procured from the Olympic Plastics Co or the Peco Manufacturing Co.

5.7 CONNECTOR INSTALLATION

5.7.1 Install connectors with the major keyway in the "UP" or "FORWARD" position, unless otherwise noted on drawing.

5.7.2 Torque all firewall connector coupling rings per supplier's specification prior to lockwiring.

5.7.3 Where the drawing specifies application of a "red dot", the coupling nut of threaded coupling connectors shall be safety wired.

NOTE: Safety wiring or otherwise mechanically locking is required to prevent loosening under vibration when installed in engine nacelles, in other areas of severe vibration (excluding those on shock-mounted equipment), and in areas which are normally inaccessible for periodic maintenance inspection of the aircraft.

5.7.3.1 The "red dot" shall be 1/2 inch diameter painted or affixed on the structure adjacent to each connector. The material of the painted "red dot" shall be protective enamel. Color shall be "red" #11136 per federal standard 595, or equivalent.

5.7.3.2 Clean the surface to be painted using an appropriate solvent. Prepare the paint material by mixing the enamel base and catalyst in the proportions specified by the vendor in a clean container. Do not use thinner or reducing agent.

5.7.3.3 Use a modified felt tip applicator. Modify the standard conical felt tip to a flat tip, 1/2 inch in diameter. To use, saturate the tip and press lightly against the prepared aircraft surface. Paint should be dry to touch in 5-15 minutes and will achieve full chemical resistance in approximately 7 days at ambient temperature.

6.0 INSPECTION OF INSTALLED FIBER OPTIC BUNDLES

When the installation of the cable is complete per the Wire Bundle Assembly, the installation procedure and this document, the quality control department shall inspect the finished installation to assure the bundle has been installed in a workmanlike manner. The installation shall be specifically examined for the following:

6.1 SLACK

6.1.1 Sufficient length of individual conductor lengths shall be available for 3 reterminations. This results in additional bundle slack.

6.1.2 The bundle slack shall be evenly distributed between P.I. location markers. The additional slack for retermination should be included in the slack of the first 6 feet at each end of the bundle.

6.1.3 The bundle shall be free about hinge joints with sufficient slack to prevent binding when the hinge is fully opened.

6.1.4 Where equipment may be removed with the bundle installed, sufficient slack should be available to provide operating clearance during rework.

6.1.5 Slack for normal coupling and uncoupling of connectors should be provided.

6.1.6 On shock mounted equipment, the bundle slack should provide for full traverse of the equipment without transmitted strain to the bundle.

6.1.7 Normal expansion and contraction of the airplane should not exert strain on the bundle. This is especially critical in long straight runs where the effect is least obvious to the inspector.

6.1.8 Make sure that there is sufficient separation from adjacent surfaces so that bundles with normal slack will not make contact.

6.2 Drip Loops

a. To prevent fluids or contaminants from entering junction boxes, connectors or other enclosed items, use drip loops unless potting is used in such a way as to accomplish the moisture barrier.

6.2 (Continued)

b. Locate drip loops so that fluid will not drip on electrical equipment.

6.3 Bend Radius

The bend radius shall be no less than 6 times the finished cable diameter or 1.5 inches (3 inch bend diameter), whichever is greater.

6.4 Bundle and Cable Support

Cable clamps must be compatible with the area where the cable is installed, and the smallest which will hold the bundle without crushing or pinching the cable, but will not permit abrasive movement.

6.5 Coupling of Connectors

a. Make certain that the plugs and receptacles are properly mated and fully coupled. Check for tightness by hand and only in the direction of coupling. On bayonet types the locking pin should be visible.

b. Check that safety wiring is installed properly.

c. Make certain that the connector number and mate-with information are per drawing.

6.6 Bundle Identification

Check that cable and bundle marker tapes or sleeves, and marks on cable are per drawing and do not penetrate the cable jacket.

6.7 Optical/Electrical Tests

Prior to closure of the connectors, check continuity and insertion loss of the cables and visually inspect the interface per D180-24693-18. Electrical cables are tested per a separate specification.

APPENDIX A

IDENTIFICATION OF FIBER OPTICS CABLE, CABLE BUNDLES, AND HARNESSES

1.0 SCOPE

This specification contains engineering requirements for the identification of production cabling.

2.0 CONTENTS

3.0 REQUIREMENTS AND VERIFICATION

3.1 REQUIREMENTS

3.1.1 General

a. Identification is not required on cable less than 3 inches long or within concealed runs.

b. Identification is not required on module bundles or connectors when:

   (1) No form board is required.

   (2) The bundle is formed on the module.

   (3) The module is not a panel module.

c. The cable identification information code printed on the cable, tape, or sleeve must resist environmental characteristics to the class and grade levels noted on the engineering drawing or data processing (EDP) paper.

3.1.2 Identification of Cable Covering Suitable for Direct Printing

a. Print identification directly on outer surface. The printed identification shall not puncture or damage the cable. After printing, bending and/or flexing of the cable shall not cause cracks or splits in the cover.

b. A complete identification code shall be legible within 12 inches of the cable termination points, excluding splices, and at 15 inch maximum intervals throughout cable length.

3.1.3 Identification of Cable Covering Not Suitable for Direct Printing

a. Apply a yellow heat shrinkable sleeve or identification tape, printed as indicated below.

b. Use cable number and color code specified by Engineering Drawing. Space the color code characters so they do not appear as an integral part of the wire number.

Example:	IN260H18	GR	L24D18	Y
	IN261H18	R	L24D18	BR

c. Identify spare cable stubs with the connector contact letter or number. When a contact is identified by a lower case letter, the corresponding cable will be identified by an upper case letter followed by a dash.

d. Where two or more unterminated cables, bearing the same identification, are routed together in a single group or bundle, include the code number of the plug in which they terminate on the corresponding cable.

e. If Engineering Drawing requires that the cable(s) or the bundle be protected with sleeving, cable identification may be printed directly on the sleeving.

f. Install printed sleeves or tapes:

(1) Within 3 inches of entrance/exit points of concealed cable runs.

(2) Within 3 inches of connector cable clamps and terminating points, excluding splices, and at 6 foot intervals throughout cable length.

(3) Within 12 inches of each side of bulkhead seal fittings.

(4) So they are outside the connector grommet, potting area, or adapter clamps.

(5) By tieing or shrinking all sleeves unless their movement is restricted to not more than 3 inches by a bundle tie, clamp, shield, etc. Do not shrink the sleeve over a bundle tie. If the sleeve is split and tied in place, it must overlap itself 1/4 inch minimum.

3.1.4 Bundle Identification

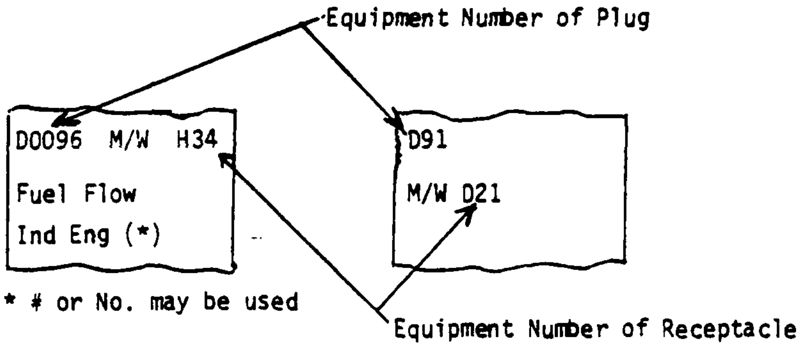
Install a bundle number within 12 inches of each end of the bundle. Use an approved blue tape printed with 1/8 to 1/4 inch high characters. The prefix "ASSY" need not appear in the bundle number but each dash must be included.

3.1.5 Production Illustration Reference Markers

The "PI" markers may be applied to the cable bundle as an installation expedient. Use an approved (Appendix F) colored identification tape marked in accordance with the Engineering Drawing and production installation needs.

3.1.6 Connector Mate-With Markers

Print the connector mate-with information on an approved yellow identification tape and apply the tape to the cable bundle within 6 inches of the connector. The applied tape must not be attached to, or interfere with connector maintenance. Information may be abbreviated in accordance with MIL-STD-12. The equipment reference number, mate-with tape, and the equipment must agree. If no number appears on the equipment, do not print mate-with numbers on the tape. Use sequence depicted in Figure 1.



* # or No. may be used

FIGURE 1. EXAMPLES OF MATE-WITH MARKERS

3.2 VERIFICATION

a. In-process surveillance shall be maintained during production. Random test specimens of specific cable, tape, or sleeve type shall be supplied by Manufacturing when, and as, requested by Quality Control. The test specimens shall have been made using production equipment and material on wire, tape, or sleeve compatible with current design requirements.

b. Specimen shall be tested as indicated in Table I.

TABLE I

Marking Method	Application Class Per Appendix F	Test Required on Specimen		
		Fluid 3.2.1	Abrasion 3.2.2	Longevity 3.2.3
Hot Stamp	1	X	0	
	2		X	
Ink Ribbon	1	X	0	X
	2		X	X

0 = Specimens must be tested consecutively with previous test.
X = Specimens may be tested concurrently.

3.2.1 Fluid Test

Characters printed on cable, tape, or sleeve shall withstand a 24-hour minimum soak in an approved hydraulic fluid at 70 ± 2°C, followed by a 24-hour air dry at room temperature and remain legible after being subjected to conditions of 3.2.2.

3.2.2 Abrasion Test

Characters printed on cable, tape, or sleeve must remain legible to the unaided eye at a minimum distance of 15 inches in minimum daylight of 30 foot candles after 20 rubs with an abrasive felt (Federal Specification C-F-206b, Type III, Class 7A1) using 2 pounds of weight pressure (including the weight of the fixture) and a speed of 30 to 60 rubs per minute. The felt surface shall be 3/16 to 1/4 inch wide and completely contact the printed characters.

3.2.3 Longevity Test

Characters printed on cable, tape, or sleeve shall remain legible after a 24-hour minimum exposure in a weatherometer chamber to alternating cycles of ultra-violet light and typical tap water spray. The cycle periods shall be 102 ± .25 minutes of ultra-violet light and 18 ± .25 minutes of ultra-violet light plus typical tap water spray.

APPENDIX B

FABRICATION OF FIBER OPTIC CABLE BUNDLES/HARNESSES

1.0 SCOPE

This specification describes methods and fabrication materials for assembly of fiber optic bundles/harnesses.

2.0 CONTENTS

3.0 MATERIALS CONTROL

Material "type" classifies materials according to maximum continuous operating temperature listed below. Where drawing specifies a temperature "type" area only materials of that classification shall be used, except, where a specific material is not available, a higher temperature material may be substituted. When the specification or Engineering drawing calls out a specific material, no substitution shall be made. Where temperature "type" or material is not specifically designated, Type I materials shall be generally used.

Type I - to 200°F
Type II - to 275°F
Type III - to 350°F
Type IV - to 500°F

[1] This material is resistant to Skydrol 500.

[2] Except for the adhesive, this material is resistant to Skydrol 500.

3.1 TYPE I MATERIALS

3.1.1 Sleeving, Insulating

a. Sleeving; insulating, flexible, transparent, extruded vinyl, per MIL-I-7444, Type I, standard sizes as required in the following ranges:

Range I (20 AWG to 1/2 I.D. Incl.)
Range II (5/8 inch to 1-1/2 I.D. Incl.)
Range III (1-3/4 inches to 2-1/2 I.D. Incl.)

3.1.1 a. (Continued)

(1) The Borden Co., Chemical Division,
Resinite Department, Santa Barbara, Calif.
"EP-93C" For All Ranges

(2) The Wm. Brand and Co., Inc.;
Williamantic, Conn.
"Turbo 625" For Range I and II

(3) 3M Co.,
Irvington Division,
Freehold, New Jersey
"Irvington 3022" For All Ranges

3.1.2 Strip, Insulating

Strip; plastic, vinyl, transparent, flexible (material same as for sleeving per MIL-I-7444, Type I), .020 or .040 inch ± .0015 thick and .060 inch ± .0025 thick width as required (tolerance ± 5%) in 1/4 inch increments.

The Borden Company, Chemical Division,
Resinite Department, Santa Barbara, California
"CT-93C" for .020 inch
"EP-93C" for .040 and .060 inch

3.1.3 Tape, Insulating

a. Tape; electrical, vinyl, pressure sensitive, black unless otherwise noted, opaque, per MIL-I-7798, .007 ± .001 inch thick, width as required (tolerance ± 1/16) in 1/4 inch increments.

(1) Permacel, New Brunswick, New Jersey
"P-29, Black"

(2) 3M Co., St. Paul, Minn.
"Scotch #33"

(3) Technical Tape Corp., New Rochelle, New York
"Tuck No. 330, Black"

3.1.4 Tape, Cushioning (Cable Clamp)

Tape, pressure sensitive, rubber and cork composition, per MIL-T-6841A, 1/32, or 1/16 inch thick, width as required in 1/4 inch increments.

Armstrong Cork Co.; Lancaster, Pa.
"DK-153"

3.1.5 Tying Material

a. Braid, flat woven, .0125 ± .0030 inch thick and approximately 3/32 inch wide, color white or tan, unwaxed, mildew resistance effectiveness per MIL-T-713, and 48 pound minimum breaking strength.

3.1.5 a. (Continued)

(1) Western Filament Corp.; Glendale, Calif.

1▷ "No. 17-D" (Dacron)

(2) Hemingway & Bartlett Mfg. Co.; New York, N.Y.

1▷ "Dacron Flat Braided Lacing Tape G.E. Finish"

(3) Eon Corporation; Los Angeles, Calif.

(a) 1▷ Airtex #417X (Dacron)

(b) 1▷ Airtex #217 (Dacron)

(4) Gudebrod Bros. Silk Co. Inc.; Philadelphia, Pa.

1▷ Dacron Stur-D-Lace H "18DH"

b. Braid, flat woven, "Dacron", .0125 ± .003 inch thick and approximately 3/32 inch wide, vinyl coated, color black, end-fray resistant; including mildew proofing effectiveness and 50 pound average breaking strength in accordance with MIL-T-713A.

(1) Eon Corporation; Los Angeles, Calif.
"Airtex 217, Class 2, Black"

(2) Gudebrod Bros. Silk Co. Inc.; Philadelphia, Pa.
"Fyr-Lace R, Style 18DR, Black"

3.1.6 Talcum Powder

a. Talcum Powder No. 325

Van Waters & Rogers; Seattle, Washington

3.2 TYPE II MATERIALS

3.2.1 Sleeving, Insulating, Heat-Shrinkable

1▷ a. Sleeving (heat-shrinkable), insulating, irradiated polyolefin, opaque colors as required, sizes per applicable standard (MIL-I-23053).

(1) Material may be obtained from:

Raychem Inc.; Redwood City, California
"Thermofit CRN"

3.3 TYPE IV MATERIALS

3.3.1 Sleeving, Insulating, Heat-Shrinkable

1 Sleeving, heat-shrinkable, Polytetrafluoroethylene, (TFE "Teflon") natural color, sizes as listed below:

Raychem, Inc.; Redwood City, California
"Thermofit TFE"

Size	Max. I.D. as Supplied (In.)	Recovered I.D., (In.)	Size	Max. I.D. as Supplied (In.)	Recovered I.D. (In.)
30	.030	.022	14	.121	.078
28	.035	.025	12	.153	.096
26	.040	.028	10	.191	.116
24	.050	.032	8	.240	.144
22	.055	.037	6	.302	.178
20	.060	.044	4	.370	.224
18	.076	.052	2	.430	.278
16	.093	.063	0	.470	.347

Note: Use on high temperature wire and parts only.

3.3.2 Sleeving, Insulating

a. Sleeving; insulating, fiberglass, silicone rubber covered, fungus resistant treated, white color, per specification MIL-I-18057, (200^{o}C, 8000V minimum average dielectric strength), ASG sizes 24 to 1/0, and 3/8, 7/16, 1/2, and 5/8 inch ID.

(1) Bentley Harris Mfg. Co.; Conshohocken, Pa.
"Ben-Har 1151"

(2) 3M Co., Irvington Division; Freehold, N.J.

Note: This material limited to procurement only when material per a(1) is unavailable.

"Irvington 411"

1 b. Tubing, insulating, Polytetrafluoroethylene (TFE "Teflon"), nonrigid per MIL-I-22129, tubing I.D. sizes AGW 0 thru 30, and additional sizes as follows:

Note: This material may be used only when specified on Engineering drawings.

3.3.2 b. (Continued)

Nominal ID (In.)	Wall Thickness (In.)
3/8	.025 ± .006
7/16	.025 ± .006
1/2	.025 ± .006
9/16	.025 ± .006
5/8	.030 ± .006
3/4	.035 ± .008
7/8	.035 ± .008
1	.035 ± .008

c. Tubing; nonrigid, constructed of spirally welded extruded Polytetrafluoroethylene (TFE "Teflon") tape, per AMS 3653, red, minimum breakdown strength 5000 volts r.m.s., wall thickness .010 ± .002, AWG sizes 8, 4, 2, 0, and 3/8, 1/2 inch ID.

Hitemp Wires, Inc.; Mineola, N.Y.

1 "Nonrigid Temprene Teflon Tubing"

Note: This material may be used only when specified on Engineering drawings.

3.3.3 Strip, Protective

a. Strip (or film); Polytetrafluoroethylene, (TFE "Teflon"), unsupported, skived, virgin or reprocessed, natural or blue color, .005, .010, .015, or .020 thick and width as required in 1/4 inch increments.

(1) Continental Diamond Fiber Co.; Newark, Del.

1 "Unsupported 'Teflon'; Skived Strip"

(2) W. S. Shamban & Co.; Culver City, Calif.

1 "Kelon-T; Skived Strip"

(3) Raybestos-Manhattan, Inc.; Mannheim, Pa.

1 "R/M 829; Skived Strip"

3.3.4 Tape, Insulating

a. Tape, Polytetrafluoroethylene (TFE "Teflon"), pressure sensitive thermosetting adhesive, per MIL-T-23594, width as required in 1/4 inch increments, nominal overall thickness .0065 inch (.005 inch backing).

(1) 3M Co.; St. Paul, Minn.

2 "Scotch #61"

3.3.4 a. (Continued)

(2) Permacel; New Brunswick, New Jersey

2▷ "P-421"

(3) Connecticut Hard Rubber Co.; New Haven, Conn.

2▷ Temp-R-Tape Type "TV"

3.3.5 Tape, Protective

a. Tape, Polytetrafluoroethylene (TFE "Teflon"), glass supported, pressure sensitive thermosetting adhesive, width as required in 1/4 inch increments and nominal overall thickness aslisted.

(1) 3M Co.; St. Paul, Minn.

2▷ "Scotch #64" (.0065 thick)

(2) Permacel; New Brunswick, N.J.

2▷ "ET3758" (.005 thick)

(3) Connecticut Hard Rubber Co.; New Haven, Conn.

2▷ "CHR-A-2005" (.005 thick)

3.3.6 Tying Material

a. Braid; flat woven, fiberglass, "Teflon" coated, approximately 1/8 inch wide x 1/64 inch thick, and minimum breaking strength 90 pounds.

(1) Bentley Harris Mfg. Co.; Conshohocken, Pa.

1▷ "TG40"

(2) Dodge Fibers Corp.; Hoosick Falls, N.Y.

1▷ "E775-303" (Formerly TB-303)

b. Braid, flat woven, fiberglass, "Teflon" coated, approximately 5/64 inch wide x 1/64 inch thick and minimum breaking strength 45 pounds.

(1) Bentley Harris Mfg. Co.; Conshohocken, Pa.

1▷ "TG25"

(2) Dodge Fibers Corp.; Hoosick Falls, N.Y.

1▷ "E775-476" (Formerly TB-476)

3.4 MATERIALS NOT CLASSIFIED BY 'TYPE'

3.4.1 Thinner

Thinner; lacquer, per TT-T-266.

3.4.2 Varnish

a. Varnish, Nylon

(1) Nycote Type 88 with Type 88 accelerator (mix 5.7 parts accelerator with 100 parts base).

(2) Nycote Type 4-30

Nycote Laboratories
15002 Delano Street
Van Nuys, Calif.

4.0 DEFINITIONS

a. Breakout - A "breakout" refers to the point where cables depart from a cable bundle group.

b. Bundle - A cable "bundle" is a number of cables routed together and bound by bundle ties.

c. Group - A cable "group" is a number of cables tied together and routed to a single item or set of equipment.

d. Junction Shell - A cable bundle support fixture used to support bundles entering an electrical junction box. The fixture is similar to a flange mounting connector endbell with a cable clamp. Connector cable clamping requirements generally apply to junction shell clamping.

5.0 MANUFACTURING CONTROL

a. Form cables and bundles so as to minimize stress on cables and connections due to cable bends and clamping during installation. Forming may be accomplished by fabricating cable harnesses on form boards.

b. During fabrication and handling of cable assemblies, care shall be taken to prevent stresses or strains from being placed on terminations or connector contacts. Provide bench clamps or other necessary support when forming wires.

5.1 CABLE GROUPS AND BUNDLES

5.1.1 Binding Cables Into Groups and Bundles

a. Identify cabling in accordance with Appendix A.

5.1.1 (Continued)

b. Untangle cables as much as practicable before tying them into groups. Lay cable groups as parallel as practicable before tying into bundles. Crossed cables under bundle clamps are not acceptable.

c. Tie cable groups and bundles with tying material (3.1.5, 3.3.6) using a clove hitch and square knot as shown in Figure 1. Tying cord may be doubled when cable groups or bundles exceed 1-1/2 inches in diameter.

   (1) Before tying the square knot, cinch the clove hitch firmly in place by pulling the free ends of string in opposite directions while rotating them 90° to 180° about the hitch so they twist beneath it and are held in place. Do not stress or deform wire or cable insulation by overtightening the clove hitch.

   (2) Tie the square knot tightly over the clove hitch and cut off free ends to a length of 1/4 to 1/2 inch.

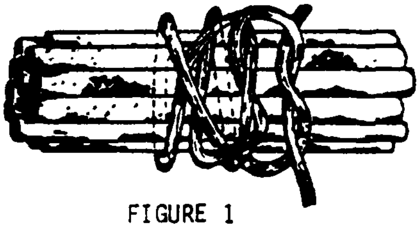


FIGURE 1

   (3) For cabling on which ties tend to slip, an optional tie may be made by passing an initial loop through the bundle prior to making clove hitch as shown in Figure 2. Tighten clove hitch on opposite side of bundle from the initial loop. Tie a square knot over the clove hitch (see Figure 1).

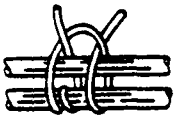


FIGURE 2

d. In restricted areas, the modified clove hitch and square knot shown in Figure 3 may be used as an optional tie for tying cable groups. Follow the procedure in c(1) and (2) above to secure the tie.

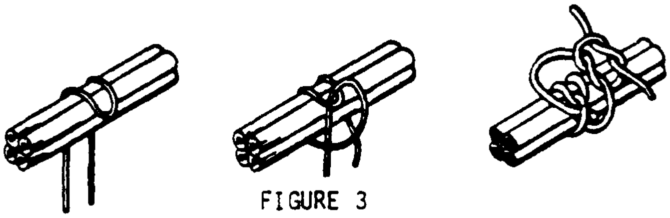


FIGURE 3

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5.1.1 (Continued)

e. Minimize fraying of fiberglass tying braids (3.3.6) by cutting tied ends using very sharp cutting tools. A small amount of nylon varnish (3.4.2) may also be applied on braid ends and knots if necessary to prevent fraying or loosening.

5.1.2 Spacing Ties for Bundle Support

a. Except as provided in 5.1.3, space ties on cable groups and bundles a minimum of 8 inches and a maximum of 12 inches apart except as follows:

(1) Tie as necessary to provide adequate support at bends, breakouts, and locations where cable groups or bundles are adjacent to moving parts.

(2) Tie cables together in junction or terminal boxes only as required for support to facilitate removal of cabling and equipment.

(3) Tie groups and bundles such that support is not derived from terminals.

(4) When cable groups are tied within a bundle, the ties on the individual groups may be spaced a maximum of 30 inches.

(5) Space ties a maximum of 30 inches on groups and bundles installed in raceways.

(6) Use the minimum number of ties necessary to adequately support the groups or bundles as specified herein.

b. Assemble cables in conduit or insulating tubing such that they are untangled and parallel as much as practicable. Cables in conduit or insulating tubing shall not be tied together. Talcum (3.1.7) may be used as a lubricant on cables and tubing.

c. All temporary ties placed on cable bundles to facilitate handling or storage must be removed during or prior to bundle installations.

5.1.3 Tying of Equipment Internal Wiring

a. Stationary groups and bundles contained within ground support equipment consoles, cabinets, and components may be bound together by continuous lacing as an optional method to spot tying per 5.1.1.

(1) Using tying braid (3.1.5b), start the lacing by making a tie per Figure 1. Cut off only the short end after making the knot.

(2) Make a continuous lacing using a series of locking stitches as shown in Figure 4.

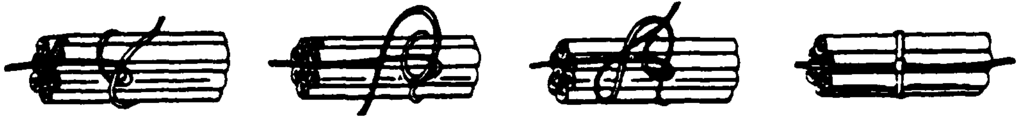

FIGURE 4.

5.1.3 a. (Continued)

(3) Apply continuous lacing with the appropriate interval between stitches per Figure 5, except that a stitch may also be provided adjacent to each side of a cable breakout.

D (Inches)	L (Inches)
Less than 1/2	3/4 ± 3/16
1/2 to 1	1-1/2 ± 3/8
More than 1	2 ± 7/16

Note: Two successive intervals of stitching shall not differ by more than 20% of the larger interval.

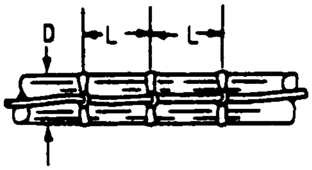

FIGURE 5

b. Where spot ties per 5.1.1 are used on internal wiring of ground support equipment, space ties a minimum of 3 inches and a maximum of 6 inches apart.

5.2 PROTECTION OF BUNDLES

Where contact with adjoining flat or rounded surfaces may be possible but is otherwise unavoidable, protect groups and bundles from chafing or abrasion in accordance with the following:

a. Cover with shrinkable sleeving (3.2.1, 3.3.1) or non-shrinkable sleeving (3.1.1, 3.3.2). Tie non-shrinkable sleeving in place with bundle ties per 5.1.1 over each end of the sleeve.

b. Install shrinkable sleeving as follows:

(1) When practical, remove group or bundle ties prior to installing sleeves.

(2) Use a sleeve size that will fit permanently in place after shrinking. Ties may be omitted on tight fitting sleeves.

(3) Shrink sleeving using good standard practice.

(4) Shrinkable sleeving may be applied by heat-shrinking a minimum of three inches on each end for sleeves exceeding eight inches in length.

5.2 (Continued)

c. Provide drain holes in protective sleeves where more than 12 inches long. A pair of drain holes may be spaced diametrically opposite at 2 inch intervals with alternate pairs rotated 90°, or they may be provided in groups of 4 holes evenly spaced around the sleeve circumference at 4 inch intervals. Make 1/8 inch holes in AWG 4 (nominal ID .208 inch) or larger sleeves and 1/16 inch holes in smaller sleeves.

Note: Drain holes are not required in close fitting shrinkable sleeves.

d. An alternate method to a, above, is to wrap the cable(s) with vinyl or teflon strip (3.1.2, 3.3.3). Completely cover starting end of strip on the first lap, then proceed with a one-half width spiral overlap. Secure wrapping with bundle ties at each end and at intervals of 8 inches maximum.

e. Protect cables and bundles from abrasion in uncushioned metal clamps by wrapping the cables with a minimum of two concentric wraps (.03 inch minimum buildup) of insulating or protective strip or tape (3.1.2, 3.1.3, 3.1.4, 3.3.3, 3.3.4, 3.3.5). Wrap the cables and tighten the clamp in such a manner that the jacket is not crushed or damaged and does not slip. Tightly wrap and hold the strip while tightening the clamp to prevent unwrapping.

f. Protect cables against abrasion at bundle supports and clamps by covering with sleeving or tape (3.1.1, 3.1.3, 3.2.1, 3.3.1, 3.3.2, 3.3.4, 3.3.5). Extend this protection 1 inch ± 1/8 on each side of the support. Install sleeving per a or b, above. Spirally wrap tape with a one-half width overlap, covering the starting end before lapping is begun, and spiral by wrapping the finishing end back under the support clamp or tie.

APPENDIX C
DETAILED INSTALLATION PROCEDURES

1.0 SCOPE

This section covers detailed steps in the installation of fiber optic cables and harnesses.

2.0 CONTENTS

3.0 REQUIREMENTS AND VERIFICATION

3.1 REQUIREMENTS

3.1.1 General

a. Protect unattached ends and connectors. Neatly coil the free ends of the bundles and stow to avoid damage.

b. Assemble cables in conduit or insulating tubing such that they are untangled and parallel to each other. Cables in conduit or insulating tubing must not be tied together.

c. All temporary ties or straps placed on cable bundles to facilitate handling or storage must be removed during or prior to installation.

NOTE: Exercise care to prevent damage to cables when removing ties or straps and to prevent cut straps or ties from dropping into aircraft components or equipment.

3.1.1 (Continued)

d. Smoothing and filling compound may be applied over projecting rivets, bolts, nuts, or other protrusions which present an abrading surface to adjacent cables.

e. Cabling shall not be encased with tape or sleeve unless specified on the bundle assembly or installation drawings. When shrinkable sleeving is specified to be shrunk, shrink from one end heating evenly until the other end of the tube is reached. Move the heat gun evenly without overheating the cable.

f. At shock mounted equipment, all cables from each connector may be tied together, but the cables from one connector shall not be tied to the cables from another connector between the unit and the first clamp.

3.1.2 Cable Slack

a. Distribute slack evenly throughout the length of the bundle. Install cable bundles as shown in Figure 1.

Where installation location markers are used, distribute slack evenly between the markers.

b. In applicable areas make certain that there is adequate slack to meet the following requirements:

(1) Replacement of terminations at least three times.

NOTE: Where space permits, include the excess cable length for retermination of connectors in the form of a drip loop. Otherwise include the length in the first six feet leading to the connector or other terminations.

(2) Movement of hinged joints.

(3) Removal of face-mounted equipment, where other means of access is not provided.

(4) Coupling and uncoupling of connectors.

(5) Special maintenance and service applications specified on the engineering drawing (e.g., to permit ample shifting of equipment while still in the aircraft, for the purpose of realignment, removal of dust covers, servicing, tuning and changing components or assemblies).

(6) Prevention of strain on cables to shock-mounted equipment.

(7) Provision of drip loops.

(8) Adequate cabling movement at bulkheads and on long straight cable runs to compensate for the expansion and contraction of the aircraft structure induced by climate extremes.

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3.1.2 (Continued)

b. (Continued)

(9) Prevent mechanical strain on cables, terminals, junctions, and supports.

c. Make sure that there is at least three inches supported separation between cabling and fluid (except water) lines, oxygen lines, control cables, and their equipment.

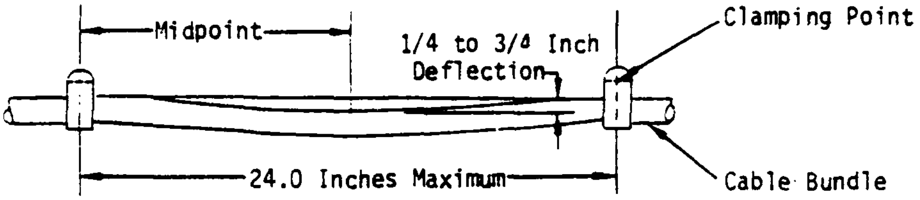


FIGURE 1. SLACK IN CABLING

3.1.3 Drip Loops

a. To prevent fluids from entering junction boxes, connectors, or other enclosed items, provide a drip loop in the cable or bundle just before it enters the item of equipment.

b. Locate drip loops so that fluid will not drip on other equipment.

c. Carefully seal around the cable (except on potted and moisture proof connectors) at the point of entry with a coating compound, required by Engineering drawing.

d. Drip loops are not required on cable or bundles that terminate in a potted connector.

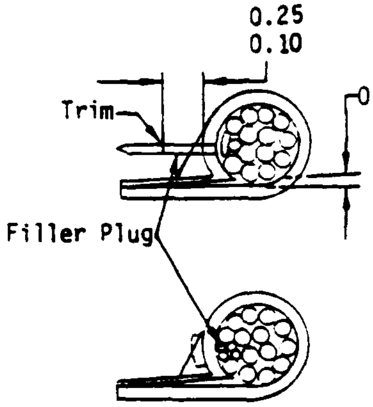
3.1.4 Bend Radius

Use a minimum bend radius of ten times the cable or bundle diameter. In restricted spaces the bend radius may be a minimum of six times the outside diameter or 1-1/2 inches, whichever is greater.

3.1.5 Bundle and Cable Support

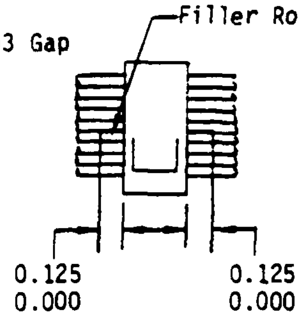
Cable clamps must be compatible with the area where the cable is installed and must be the smallest which will hold the bundle without crushing or pinching the cable. The clamps must conform with the following installation instructions.

a. Clamp wire bundles and cables (including twisted cables) firmly at all supports. Do not allow cables to cross each other under cable bundle clamps.



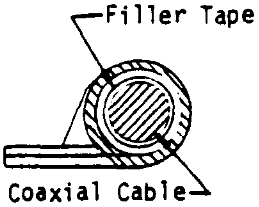
INSTALLATION OF FILLER PLUGS

Figure 2



INSTALLATION OF FILLER ROD

Figure 2A



INSTALLATION OF FILLER TAPE

Figure 2B

3.1.5 *(Continued)*

b. If the bundle diameter is such that none of available clamp sizes will firmly grip the bundle, use one of the following methods to build up the bundle diameter:

(1) For all applications except in fuel cells or with coaxial cable, use filler plugs, installed according to Figure 2, or filler rods, installed according to Figure 2A.

(2) Filler tape shall be installed to Figure 2B, as required.

c. When contact exists, or is possible, between crossing wire groups or bundles, tie the groups or bundles together.

Critical bundles requiring isolation as specified by Engineering drawing diagrams must not be tied to other groups or bundles.

d. Do not install clamps in the bends of the bundle unless the radius of bend exceeds six inches.

e. Use clamp sizes which do not deform the cable.

f. Nylon clamps may be installed with a gap of .03 inches as shown in Figure 2.

g. Install wire groups or bundles on tombstone bundle supports as follows:

(1) Distribute the wires around the cross as evenly as possible.

(2) Double the cord or braid used for tying wire bundles over 3/4 inch in diameter.

3.1.5 g. (Continued)

(3) Tie bundle as shown in Figures 3 and 4. Make the clove hitch snug and the knot tight.

(4) Leave free ends of the knot 3/8 ± 1/8 inch long.

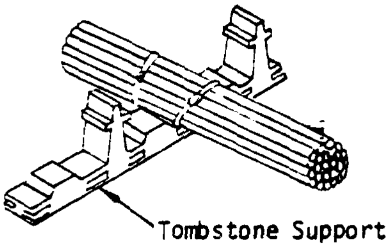
NOTE: Never bind a tie so tightly it cuts or penetrates the insulation.

h. Do not use ties, straps, or tapes for primary supports.

i. When cable groups are bundled and routed together, do not destroy the identity of the individual cable groups, nor remove their ties.

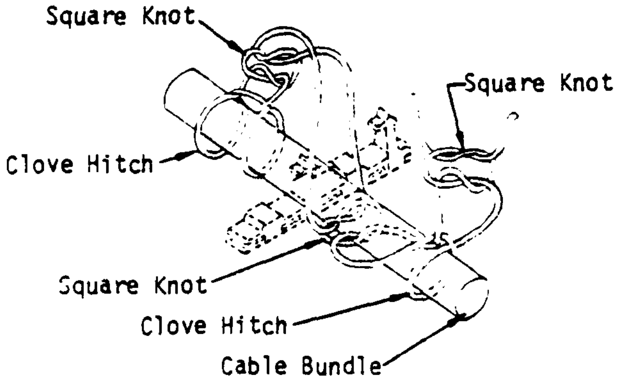
j. Do not use continuous lacing.

k. Do not tie bundles of two or more connectors together until after their first common clamping point.



SECURING WIRE BUNDLES TOMBSTONE SUPPORTS

Figure 3



DETAIL METHOD OF SECURING BUNDLES TO SUPPORTS

Figure 4

3.1.6 Coupling of Connectors

a. Make certain that plugs and receptacles are properly mated and fully coupled.

b. On threaded coupling connectors that do not require safety wiring, tighten coupling nuts by hand, then slightly beyond hand tight (1/8 turn maximum) with tool AT 508K (Aircraft Tools, Inc., Los Angeles, California).

On connectors that do require safety wiring, tighten coupling nuts <u>by hand only</u> before installing lock-wiring.

3.1.6 (Continued)

c. Engage bayonet-type and ball-lock connectors only by hand. Make certain coupling rigs are fully engaged and in the completely locked position.

d. Check for tightness by hand and only in the direction of coupling. On connectors that require safety wiring, check for tightness only prior to safety wiring.

e. Engage connectors with jackscrew-type coupling as follows:

   (1) Before threading the jackscrews into the jacksockets, seat them tightly against each other.

   (2) Use care, turning each screw one-half turn at a time alternately by hand until the pin contacts begin to enter the socket contacts.

   (3) Continue tightening each screw by one or two turns alternately until the connectors are fully mated.

3.1.7 Modification of Harnesses

When a cable or cables must be replaced or added to a completed bundle as a result of a change or a Materials Review Board action, accomplish the modification as follows:

a. Identify cable or cables by appropriate markings.

b. Replacement and added cable(s) may be installed by either threading and pulling the cable(s) through the bundle ties and support clamps or by the procedure outlined below.

   (1) Tie the added cable(s) to the exterior of the bundle with ties in accordance with Appendix B. If the bundle is installed, ties are required between clamps only and at approximately one foot intervals.

   (2) These cables need not be installed under existing ties, tapes, markers, etc. on the parent bundle. However, they must be installed within all support clamps of the parent bundle.

3.1.8 Test of Cabling

Optical power transmission checks are the responsibility of the Manufacturing Department except when otherwise specified on the Engineering drawing.

3.1.9 Protection of Terminations

If cabling is to remain unconnected in the delivered product installation, protect the unconnected ends as follows:

a. Insulate unattached cable ends with tape or shrink sleeving.

b. Protect installed uncoupled connectors with dust caps.

3.1.9 (Continued)

c. Stow the cabling so that contaminants cannot fall or drain into the protective covers.

3.2 VERIFICATION

3.2.1 In-Process Surveillance

a. Assure that only approved materials are used to satisfy the requirements of this specification.

b. Assure that temperature, fluid, and vibration restrictions are observed.

c. Assure that terminals, splices, connectors, and wires are properly installed, supported, and protected.

d. Assure that circuits are properly tested as specified on the Engineering drawing before application of aircraft power.

APPENDIX D

MARKING OF FIBER OPTIC CABLING

1.0 SCOPE

The purpose of this document is to provide the methods and requirements for marking fiber optic cables and bundles.

2.0 CONTENTS

3.0 MATERIALS CONTROL

NOTE: These are suggested sources. Where competing equal suppliers are available, use is permissible.

a. Agent, Parting, Silicone Grease, 400°F minimum decomposition temperature

Dow Corning "High Vacuum Grease"
Dow Corning Corporation

b. Adhesive

(1) Gaco N-29 Cold Bond and N-39 Accelerator (BAC 5010, Type 53)
Gates Engineering Company

(2) PR1527M with PR1523M, Primer (BMS 8-81) Products Research Corporation

c. Braid, flat woven, synthetic fiber, 0.0125 ± 0.0030 inch thick and 0.070 to 0.100 inch wide, color white or tan, unwaxed. Mildew resistance effectiveness in accordance with MIL-T-43435 and 48 pounds minimum breaking strength.

(1) Airtex 417X (Dacron), Associated Suppliers Co.

(2) No. 17D (Dacron), Western Fishing Line Company

(3) Dacron Flat Braided Lacing Tape, G.E. Finish
Heminway and Bartlett Manufacturing Company

d. Braid, flat woven, fiberglass, Teflon coated, approximately 5/64 inch wide by 1/64 inch thick, minimum breaking strength 45 pounds.

(1) #TG-30, Bentley Harris Manufacturing Co.

(2) #TG-476, Dodge Fibers Corporation

e. Coating, Spray, Protective, Removable, Spraylat #SC1071, Spraylat Corporation

f. Coating, Spray, Protective, Nonremoveable

(1) Acrylic Aerosol Spray

Tartan #91-1, Rudd Paint and Varnish Company
Krylon #1303, Krylon Incorporated

(2) Varnish, Moisture, and Fungus Proof, IAW MIL-V-173
Sprayon #608, Sprayon Products, Incorporated

3.0 (Continued)

g. Foil, Printing 1-1/2 and 3 inch widths

(1) Kingsley Stamping Machine Co.

(a)	K-36	General Purpose
(b)	K-46	Nylon
(c)	KFP-16 Black	Surface Treated Teflon
(d)	K-289 White	Polyethylene

(2) M. Swift and Sons, Incorporated

(a)	C20114 Black	Surface Treated Teflon & General Purpose
(b)	C20118 Black	Surface Treated Teflon & General Purpose
(c)	C20206 White	General Purpose
(d)	C20110 Black	Nylon

(3) Howmet Corporation, Roll Leaf Division

(a)	5821 Black	General Purpose
(b)	WW99 Black	Surface Treated Teflon

h. Ink, Marking

(1) #73X-NW, Black, Independent Ink, Incorporated

(2) W. E. 42 Paste Ink, White, General Printing Ink, Incorporated

i. Paper, Liner, Creped-Kraft, width as required

(1) No. RP360, 3M Company

(2) Permacel E13734, Permacel Division, Johnson and Johnson, Inc.

j. Ribbon, Printing

(1) IBM 143341 (for IBM 407 Printer)

(2) IBM 1403-OCR No. 424325 Black (for IBM 1403 Printer)

(3) IBM Cartridge #1136108 (for IBM Selectric typewriter)

(4) H&M Gold Star #37 (heavy black) (for IBM Selectric Typewriter)

(5) Singer (Friden) #4003030 (for Singer (Friden) Flexowriter typewriter

3.0 (Continued)

k. Sleeving, insulating, fiberglass, silicone rubber covered, fungus resistant treated, color white, Class H-B-1 meeting performance requirements of MIL-I-3190, in standard sizes as required.

(1) Turbo 117, Brand-Rex Division, American Enka Corp.

(2) Class H-B-1 Type SR-9, Varflex Corp.

m. Sleeving, identification, fiberglass, Kel-F suspensoid treated, in standard sizes as required, Gencote 125C, General Plastics Corp.

n. Sleeving, insulation, electrical, flexible in accordance with MIL-I-7444, Type III, Class 2, color yellow

o. Strip, polyvinyl alcohol film, perforated, 17/64 or 3/4 inch spacing on diagonal, 3 mil thick x 3/4 or 1 inch width.
Reynolds Metals, Plastic Division

p. Strip, plastic vinyl (PVC), transparent, flexible (material same as for sleeving in accordance with MIL-I-7444), 0.020 ± 0.0015 inch thick, 3/4 or 1 inch widths.
Strip-Plastic No. CT93, Borden Co., Chemical Division, Resinita Department

q. Strip, plastic, polyvinyl chloride, black opaque, nonrigid, Type F, form Ts, Class, Category I, in accordance with MIL-I-631, 0.020 ± 0.0015 inch thick, width as required (tolerance ± 5 percent) in 1/4 inch increments.
Plymouth Rubber Company

r. Strip, silicone rubber, self bonding, 0.020 inch thick x 1 inch width.
Permacel 2650
Permacel Division, Johnson & Johnson, Incorporated

s. Tape, Electrical Polyvinylchloride, pressure sensitive, yellow or black, opaque, 0.007 ± 0.001 inch thick, width as required (tolerance 0.06 inch) in 1/4 inch increments.

(1) Permacel No. 29 (specify yellow or black)
Permacel Division, Johnson & Johnson, Incorporated

(2) X-1235, Prebacked (specify yellow - not available in black)- 3M Co.

t. Tape electrical, glass cloth-backed, white, pressure sensitive, according to MIL-I-19166 widths as required in 1/4 inch increments.
Mystic Brand #7000, Mystic Tape, Inc.

u. Tape Masking, creped, various widths - Purchased from any available source.

v. Tape, paper backed cloth, vinyl impregnated
B-500 + specify color, width, and type of backing, W. H. Brady Company

3.0 (Continued)

w. Tape, polyvinylchloride, pressure sensitive, red, opaque, width as required in 1/4 inch increments, Parmacel No. P-32, Permacel Division, Johnson & Johnson, Inc.

x. Tubing, shrinkable, heat reactive plastic

y. Tubing, shrinkable, heat reactive plastic according to BMS 1-41, Type 5, sizes according to BACT63B

4.0 FACILITIES CONTROL

The printing devices listed below are suggested. Equivalent models or devices may be used provided all marking requirements are met.

a. Embossing Machines

(1) Kingsley Wire Marking Machine Model KW-7 for sleeve and tube marking.

(2) Kingsley Wire Marking Machine Model AW3.

(3) Kingsley Wire Marking Machine Model AWIV.

(4) Kingsley Wire Marking Machine Model AWIVC.

(5) TAB Wire Marking Machine Model MA-200.

b. Cold Imprinting Machines

(1) Singer (Friden) Automatic Typewriter, Model 2201 Flexowriter

(2) IBM Selectric

(3) IBM 407 and 1403

5.0 MANUFACTURING CONTROL

5.1 GENERAL REQUIREMENTS

a. All marking shall be of sufficient size and definition to be legible and of a permanent nature.

b. The characterisitcs of the wire or cable shall not be impaired by the use of any marking device or by the removal of marking when required.

c. Metallic markers or bands shall not be used for identification.

d. The information for identification, mate-with, and P.I. markers shall be obtained from the Engineering drawings.

e. Identification of wiring in furnished equipment shall not be altered unless authorized by the procuring activity.

5.1 (Continued)

f. Required marking on cables and bundles attached to connector plugs and receptacles shall be applied outside potting material or adapter clamps. The marking shall be outside any sealant or wrapping under the cable adapter clamp.

g. Wires in permanently concealed runs shall be identified at the entrance and exit points of the run and at any additional points specified by the drawing.

h. Where space permits, markings on cables and harnesses shall not conceal other markers.

i. All ordnance markings shall be red, and marked in white with the work "ORDNANCE".

j. Make every effort to locate terminating point identification so that ties, clamps, supporting devices, shielding, and terminals do not have to be removed, or the cable twisted in order to read the identification. Terminating point identification which falls on the underside of the wire or beneath a tie are acceptable if they can be easily read by the use of an inspection mirror or by moving the tie.

k. Heat shrinkable tubing installation and size selection shall be performed in accordance with good standard procedure.

5.2 INDIVIDUAL CABLE MARKING

5.2.1 Selection of Marking Method

5.2.1.1 Identification Markers (Direct Imprinting)

a. Use a hot embossing machine to mark cable surfaces which provide good contrast with the most suitable marking foil from the materials list, or, if ink jet marker is available, the most suitable ink identified in the materials list or by the supplier.

5.2.1.2 Identification Markers (Imprinted Tubing or Sleeves)

a. Cables that provide poor contrast when imprinted with marking foil, and cables which will not accept or retain a clear machine imprinted identification shall be identified as follows:

   (1) Use yellow heat-shrinkable tubing (3.0x) to identify wiring contained in areas with temperatures below 200°F which is not directly imprinted.

   (2) Sleeving may be used as an option in place of heat-shrinkable tubing for wire identification. The sleeve shall have the smallest practicable diameter which will fit over the wire.

5.2.1.2 a. (Continued)

(3) When specified on the Engineering drawing, for use in high temperature areas (above 200°F), markers shall be made from sleeving.

b. Identification (number and color code) for individual cables contained in jacketed bundles shall be installed on the cable outer covering using heat-shrinkable tubing or imprinted sleeves. The color coding as shown below shall be spaced so that it does not appear as an integral part of the cable number.

Blu - Blue
Brn - Brown
Blk - Black
Gra - Gray
Yel - Yellow
Red - Red
Whi - White
Vio - Violet
Grn - Green
Orn - Orange

When a multiconductor cable is broken out into individual branches which are 12 inches or shorter the cable marking shall be sufficient. Individual branches longer than 12 inches shall be marked in addition to the normal cable marking.

c. Split identification sleeves may be used to replace defective sleeves. Split sleeves may also be used to identify wires at terminating points.

5.2.1.3 Identification Markers (Imprinted Adhesive Tape)

When specified on the Engineering drawing, paper-backed vinyl impregnated cloth tape shall be used to identify cabling.

5.2.1.4 Ordnance Markers

Ordnance markers shall be made from red heat-shrinkable tubing marked in white with the word "ORDNANCE".

5.2.2 Location of Marking

5.2.2.1 Identification Markers

a. These markings shall be located at intervals not greater than three inches except as noted in b. and c. below.

b. When specified on the Engineering drawing, for electronic equipment and interconnects in aircraft or missiles, the markings shall be within three inches of each end and at intervals not greater than 15 inches between end marks.

c. Lengths less than three inches long shall not require marking.

5.2.2.2 Ordnance Markers

Ordnance markers shall be located as near as possible to the wire ends and at intervals no greater than 15 inches throughout the cable length.

5.2.3 Marking Application

5.2.3.1 Direct Imprinting

a. Select the size of type which is appropriate for the cable to be marked. The curvature of the type face should approximate the surface curvature (See Figure 1).

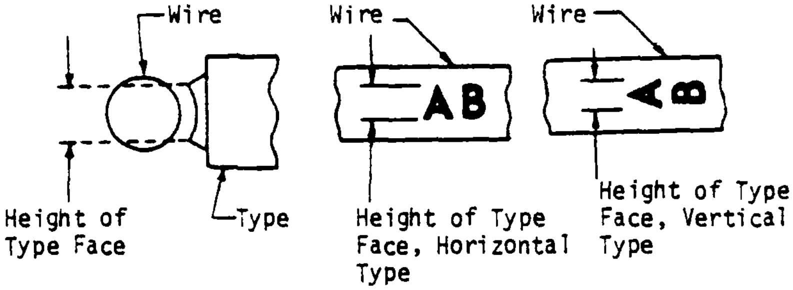


FIGURE 1

b. Table I gives the ranges of type face heights for corresponding diameters which will produce the optimum mark with the least penetration of the type into the outer surface.

TABLE I

WIRE SIZE AND TYPE FACE HEIGHT

Kingsley Type		Wire O.D.		Trojan Type	
Type Height	Identification Number	Minimum	Maximum	Type Height	Identification Number
0.025	VC-24	0.035	0.025	0.025	Vertical Type AP204 [1]
0.025	VC-24	0.040	0.061	0.040	AP104
0.050	DS	0.052	0.076	0.050	AP105
1/16	RS	0.068	0.096	0.050	AP105
1/16	RS	0.075	0.106	0.070	AP106 [2]
5/64	S	0.095	0.165	0.080	AP108 [3]
7/64	L	0.162	And Larger	0.109	AP110 [4]

[1] AP104 (Optional)
[2] AP105 (Optional)
[3] AP105 or AP106 (Optional)
[4] AP105, AP106, or AP108 (Optional)

5.2.3.1 (Continued)

c. To prevent uneven depth marking, make sure that type faces are clean and that all characters are set in the same plane. Plated and unplated type may be of different lengths and should not be used together.

d. Select a marking foil as specified in the materials list for the jacket type being marked.

e. Adjust machine pressure, temperature, and dwell time to provide markings for best legibility. Markings shall be considered permanent if legible after being subjected to the test specified in the test methods.

5.2.3.2 Imprinting Tubing and Sleeving

a. Printing on heat shrinkable tubing and sleeving shall be accomplished by hot embossing as on wire insulation. Printing shall be along the length of the tubing or sleeving. Heat shrinkable tubing on bandolier or with similar type backing in tubing may also be printed with a Friden automatic typewriter, modified as necessary, and using printing ribbon.

CAUTION: Exercise care not to smear markings on tubing immediately after printing with Friden typewriter. Printing is not permanent for up to 1/2 hour after typing.

b. In most cases flat-faced type will be used with a flat anvil. Very small size tubing or sleeving may be marked with curved face type and a wire guide if the marking requirement can be met.

c. For hot embossing, the imprinting type temperature shall be 400°F minimum (indicated temperature). Use printing foil specified in Table II.

TABLE II

HOT EMBOSSING FOIL

Tubing or Sleeving Type	Foil Type
3.0x.	3.0g.
3.0n.	3.0g.
3.0m.	3.0g.(1)(a) 3.0g.(2)(a) 3.0g.(2)(b)
3.0y.	3.0g.
3.0x. (Ordnance)	3.0g.(1)(d) 3.0g.(2)(c)

5.2.3.3 Imprinting Adhesive Tape

Print identification on the tape in accordance with 5.3.3.2.

5.3 HARNESS MARKING

5.3.1 Selection of Harness Marking Method

5.3.1.1 Identification Markers

Identification (part number) markers shall be as follows:

a. Use tape (3.0s., yellow) or heat-shrinkable tubing (3.0x., yellow).

b. When specified on Engineering drawing, for use in high temperature areas (above 200°F), markers shall be made from tape (3.0t.) or sleeving (3.0k. or 3.0m.).

5.3.1.2 Mate-With Markers

Connector mate-with markers shall be as follows:

a. Use tape (3.0s., yellow), sleeves (3.0n.), or heat-shrinkable tubing (3.0x., yellow).

b. When specified on Engineering drawing, for use in high temperature areas (above 200°F), markers shall be made of tape (3.0t.) or sleeving (3.0m.)

5.3.1.3 Production Illustration (P.I.) Markers

P.I. markers shall be made of tape (3.s., yellow) unless otherwise specified

5.3.1.4 Ordnance Markers

Ordnance markers shall be made from tape (3.0w., red), or heat-shrinkable tubing (3.0x., red) marked in white with the word "ORDNANCE".

5.3.2 Location of Harness Marking

5.3.2.1 Identification Markers

These markers shall be located as near as possible to each end of the wire harness, and at intervals no greater than 6 feet, throughout the length of the harness.

5.3.2.2 Mate-With Markers

These markers shall be placed on the connector or on the wire harness within 3 inches of the rear face of the connector grommet, but not close enough to cause misalignment of contacts due to pressure on wires.

5.3.2.3 Production Illustration (P.I. Markers)

These markers shall be located in accordance with Engineering drawings.

5.3.2.4 Ordnance Markers

These markers shall be located as near as possible to the ends of the harness and at intervals no greater than 15 inches throughout the length of the harness.

5.3.3 Marking Application

5.3.3.1 Imprinting Heat-Shrinkable Tubing and Sleeves

Imprinting heat-shrinkable tubing and sleeving shall be accomplished as specified in 5.2.3.2.

5.3.3.2 Imprinting Adhesive Tape

a. Tape which is not prebacked shall have the adhesive protected with backing paper (3.0i.) during this operation. Tape shall be marked by direct embossing or printed with an automatic typewriter (4.0b.) as follows:

(1) Direct Embossing - Apply marking using a hot stamping machine (4.0b.) with 1/8 inch high printing type and with type regulator set at approximately 450°F. Use printing foil in accordance with Table III.

TABLE III

HOT EMBOSSING TAPE & FOIL

Tape	Ribbor
3.0s. (Yellow)	3.0g.(1)(a) 3.0g.(2)(b) 3.0g.(3)(a)
3.0s. (Black)	3.0g.(1)(d) 3.0g.(2)(c)
3.0w. (Red)	3.0g.(1)(d) 3.0g.(2)(c)

(2) Automatic Typewriter - Apply marking with an automatic typewriter using tape and ribbon in accordance with Table IV.

TABLE IV

AUTOMATIC TYPEWRITER TAPE & RIBBON

Tape	Ribbon
3.0t.	3.0j.(3) 3.0j.(4)
3.0s. (Yellow)	3.0j.(3) 3.0j.(1) 3.0j.(5)

5.3.3.2 (Continued)

b. Print across the width of the tape. The printing shall be wholly contained on the tape.

c. The P.I. mark and the lettering on the marker must be printed symmetrically to the centerline of the tape in accordance with Figure 2.

d. Print the marking repetitively (except according to 5.3.3.2e.) on a continuous tape. Space between each marking shall be at least twice the line spacing but not to exceed 1-1/2 inches, however tape length shall be such as to accommodate at least two complete markings. See Figure 2 for typical Marking Bands.

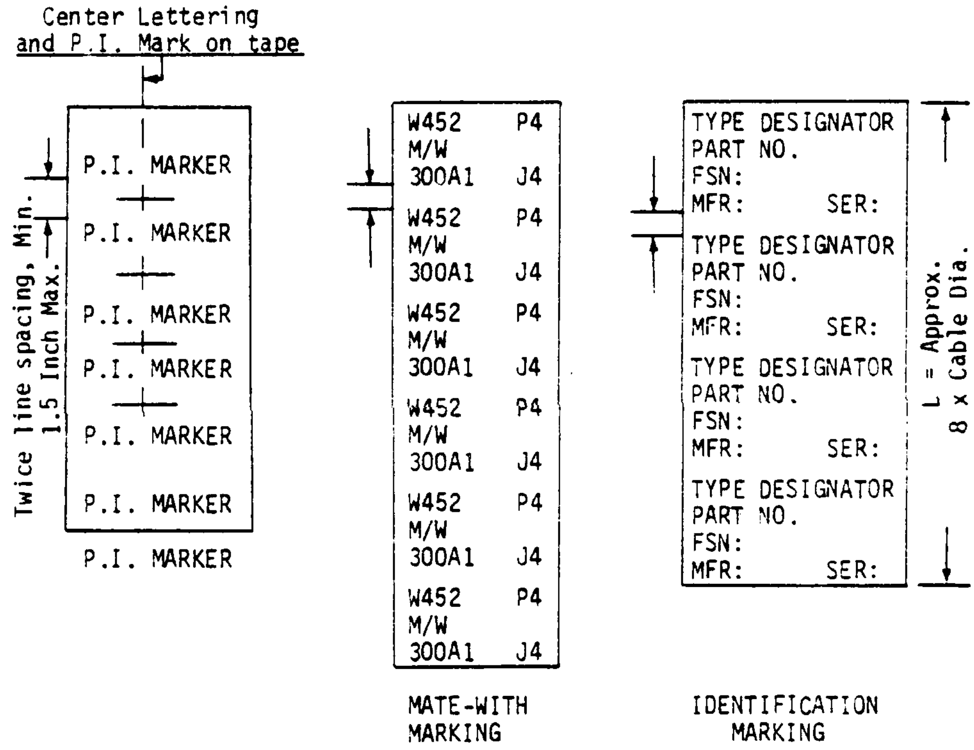
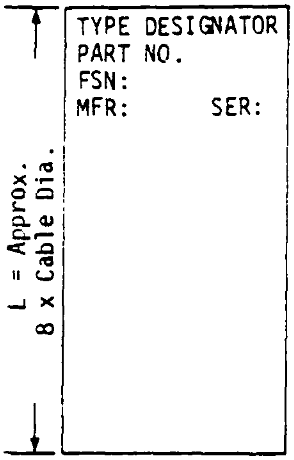


FIGURE 2. TAPE MARKING BAND, REPETITIVELY PRINTED

5.3.3.2 (Continued)

e. On identification bands repetitive printing on the same band is not necessary if the cable or harness is long enough to require at least two identical identification bands, in accordance with 5.3.2.1 or 5.4.2.1. See Figure 3.



IDENTIFICATION BAND
WITH SINGLE PRINTING

FIGURE 3

f. Marking bands of tape must have the information printed repetitively, even if only one complete nomenclature can be read without unwrapping the tape. This assures at least two sources from which to reconstruct information from worn, one-of-a-kind cable bands. Mate-With Marking bands and P.I. Marker bands appear once only on each cable or wire harness regardless of length. Therefore, they must always be printed repetitively if marking tape is used, because the printing on tape is less permanent than hot stamped printing.

g. Cure markings on tapes printed with an automatic typewriter by one of the following methods.

  (1) Process marked tape through an infrared heating unit.

  (2) Apply heat from a 500^{O}F rated air gun. Exposure shall be from one minute to five minutes maximum. Distance from the tape shall be 6 to 7 inches.

  (3) Apply a light coating of Acrylic Aerosol Spray (3.0f.(1)).

5.3.3.2 g. (3) (Continued)

CAUTION: Follow manufacturer's instructions printed on the container. The spray may not be used in electric wiring or part assembly areas.

h. Marking shall be considered permanent if it is legible after being subjected to the test specified in 5.6.1.

5.4 CABLE MARKING

5.4.1 Selection of Cable Marking

5.4.1.1 Jacketed Cables

Cables shall be marked using the applicable method indicated in Table V.

TABLE V

CABLE JACKET MARKING GUIDE

Marking Method / Jacket Material	Shrinkable Sleeve (3.0x.)	Tied-On Sleeve (3.0k.)	Adhesive Tape	Direct Embossing
Neoprene	2	Do Not Use	4	Do Not Use
Polyurethane	2	Do Not Use	4	Do Not Use
Polyvinylchloride (PVC)	2	1	3	Do Not Use
Polyethylene	1	2	3	2
Teflon	1	2	3	Do Not Use
Nylon	1	2	3	Do Not Use

1 Use this method unless otherwise specified on Engineering drawings.

2 Use this method only if specified on Engineering drawings.

3 Use this method (tape 3.0s., yellow) for rework on cables with damaged marking sleeves.

4 Use this method (tape 3.0s., black) only when specified on the Engineering drawings.

5.4.1.3 Polyurethane Connector Moldings

a. When specified on the Engineering drawing, polyurethane connector moldings shall be marked with white ink stamping with a clear acrylic overcoat.

b. When specified by Engineering drawing, adhesive patches per 5.4.3 may be applied to connector moldings.

5.4.1.4 Polyolefin Heat-Shrinkable Boots

When specified on the Engineering drawing, marking shall be applied to polyolefin heat-shrinkable boots by white ink stamping with overcoats of clear acrylic and abrasion resistant varnish.

5.4.1.5 Cadmium-Plated Connector Backshells and Fittings

When specified on the Engineering drawing, marking shall be applied to cadmium-plated connector rear hardware by black ink stamping with an acrylic overcoat.

5.4.2 Location of Bundle Marking

5.4.2.1 Identification Markers

a. On cables over six feet long, these markers shall be located as near as possible to each end of the cable jacket.

b. Cables six feet long, or shorter, shall be identified at the approximate center.

c. Breakouts of individual cables shall be marked as required in 5.2.1.2b.

5.4.2.2 Mate-With Markers

Mate-with markers shall be located on the connector or on the cable adjacent to the connector. When specified on the Engineering drawing, they shall be placed on the molding, boot, or backshell.

5.4.2.3 Production Illustration (P.I.) Markers

P.I. markers shall be located in accordance with Engineering drawings.

5.4.2.4 Ordnance Markers

Ordnance markers shall be located as near as possible to each end of the cable jacket and at intervals no greater than 15 inches throughout the length of the cable.

5.4.3 Marking Application

5.4.3.1 Printing on Adhesive Patches

This procedure describes the color transition marking of the green surface Hypalon laminate. Heated areas of the patch change from green to yellow producing a contrasting legible marking which is inherently permanent.

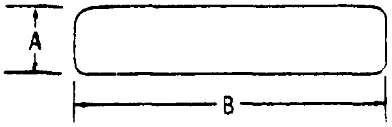
Preparation of Patch for Printing:

a. Spray or brush a thin layer of "spraylat" (3.0e.) on the rear (black side) of the laminate stock. Allow a minimum of 90 minutes drying time at normal room temperature before trimming the patch to size.

CAUTION: Do not spray in electric wiring or part assembly area.

b. Cut the patch, after drying, to the dimensions shown in Figure 4, taking care not to delaminate the patch nor separate the "spraylat" coating from the patch. For patches requiring more than three lines of type or more than 20 characters and spaces per line, dimensions A and B may be increased proportionately. Minimum edge margin requirements of 5.4.3.1c must be maintained. Patch size tolerance is ± 1/4 inch.

Patch Type	Dim. "A" (Inches)	Dim. "B" (Inches)
Identification	3/4	3
Mate-With	3/4	3/4
	1/2	1 1/4
	3/4	1 1/4 or 3
P.I. Marker	3/4	1 1/4
Reference Designator	1/2	1/2



3/32 ± 1/32 Radius
(Typical)

FIGURE 4. PATCH SIZES

5.4.3.2 Printing on Polyurethane Connector Moldings

Mark polyurethane connector moldings using method specified on Engineering drawing (adhesive patches or ink stamping).

a. Adhesive Patches

Apply marking to adhesive patches as specified in 5.4.3.1.

b. Ink Stamping

(1) Use rubber stamps with a character height of 1/8 to 1/2 inch. On small components, where size is a limiting factor, 1/16 inch character height may be used.

(2) Abrade the area to be marked with an aluminum oxide grit drum, disk, or rotary file.

(3) Clean surface to be printed with aliphatic naphtha. Wipe dry with clean material and then allow surface to air dry for ten minutes.

(4) Use white paste ink (3.0h.(2)) without thinning. Apply a small amount to a clean sheet of glass or metal and roll out to a smooth layer. Apply ink to the prepared area using rubber stamp.

(5) Air dry until tack-free and for an additional ten minutes.

(6) Overcoat marking with a light coat of acrylic spray, 3.0f.(1). When tack-free, apply an additional coat to achieve a glossy, continuous coating. Air dry for ten minutes.

CAUTION: Do not spray in electric wiring or part assembly area.

5.4.3.3 Printing on Polyolefin Heat-Shrinkable Boots

Mark polyolefin heat-shrinkable boots by ink stamping as follows when specified on Engineering drawings.

a. Use rubber stamps with a character height of 1/8 to 1/2 inch. On small components, where size is a limiting factor, 1/16 inch character height may be used.

b. Abrade the area to be marked with 400 grit abrasive paper.

c. Clean surface, apply markings, air dry, and overcoat with clean acrylic as specified in 5.4.3.3b.(3) through b.(6).

d. Overcoat clear acrylic with abrasion resistant varnish (3.0f.(2)).

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5.4.3.4 Printing on Cadmium Plated Connectors Backshells and Fittings

Mark cadmium plated connector hardware by ink stamping as follows when specified on Engineering drawings.

a. Use rubber stamps with a character height of 1/8 to 1/2 inch. On small components, where size is a limiting factor, 1/16 inch character height may be used.

b. Clean surface to be printed with aliphatic naphtha. Wipe dry with clean material and then allow surface to air dry for ten minutes.

c. Apply black ink (3.0h.(1)) to the prepared area using rubber stamp.

d. Air dry and overcoat with clear acrylic as specified in 5.4.3.3b.(6).

e. Overcoat clear acrylic with abrasion resistant varnish (3.0f.(2)).

5.5 INSTALLATION OF MARKERS

5.5.1 Attachment to Polyurethane Molded Parts

Bond patches to molded parts using procedure specified, except roughening of the molded part prior to cleaning is not required.

5.5.2 Heat-Shrinkable Tubing

Shrink in place in accordance with good standard practice.

5.5.3 Tied-On Sleeving

a. Tie all sleeves at both ends with braid (3.0c. or 3.0d.) using square knots unless the axial movement is restricted to one inch or less by obstructions such as bundle ties, clamps, or shielding.

b. On teflon insulated wire, two wraps of 1/2 inch tape (3.0t.) shall be applied, centered under the sleeve, before tying.

5.5.4 Adhesive Tape

a. After printing, wrap 2-1/2 ± 1/2 turns of the tape around the cable, cable harness, or cable jacket, so that at least one complete nomenclature appears on the outermost layer.

b. Where a complete nomenclature would not appear on the outermost wrap, apply tape around the circumference for one turn and pinch excess end lengths together to form flag. Fold flag back around and tie at both ends of tape with braid (3.0c.), using a square knot, as necessary to preclude flag damage during handling and installation.

c. P.I. marker tape flags, and flags inside equipment, are not required to be folded back and tied with braid unless the cables or wire bundles are to be pulled through conduit or other restricted openings which may result in damage to the flag.

5.5.4 (Continued)

d. When printed adhesive markers are to be installed over <u>vinyl sleeving</u>, do not use pressure sensitive tape directly applied. The use of adhesive tape is acceptable provided the adhesive does not come in contact with the vinyl sleeving. This may be accomplished by folding the tape back on itself and wrapping around the sleeving. If there is a possibility of the tape sliding on the cable, fasten securely by tying both ends of the tape with braid (3.0c.) using a square knot.

5.6 TEST METHODS

5.6.1 Permanent Marking Test

Marking shall be considered permanent if it is legible after being subjected to 20 strokes from a wire mark abrasion tester using a 1/16 inch gray felt abrasive in accordance with Federal Specification C-F-206, Type I, Class 9R4 Operate the tester either manually or under power on 3 or more imprints no sooner than 2 minutes after the coding operation if the mark is applied with a hot stamping machine, or no sooner than 4 hours after marking and curing if the mark is applied with a cold stamping machine (automatic typewriter).

6.0 QUALITY CONTROL

a. Quality Control shall perform surveillance of marked cables and harnesses to ensure conformance with the requirements of this specification. Particular attention should be paid to the following:

(1) Correct markings placed on cables and harnesses.

(2) Correct placement of markings on cables and harnesses.

(3) Legibility of markings.

(4) Use of proper type marking for cable jacket material and wires.

(5) Verification of tests specified in 5.6.

b. Quality Control shall ensure that the operation of any device used for the marking processes mentioned in this specification conforms to the requirements.

APPENDIX B

FINAL INSTALLATION PROCESS SPECIFICATION
(Specific)

D180-24693-21

FINAL REPORT
FABRICATION AND INSTALLATION PROCEDURES, *FIBER OPTICS RACK INTEGRATION HARNESS,* AND STAND-ALONE LINK

O. R. Mulkey

Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124

4 June 1980

Final Report for Period 16 December 1979 Through 4 June 1980

Phase IV of NOSC Contract N00123-78-C-0193

Prepared For:

NAVAL OCEAN SYSTEMS CENTER
Code 9313
San Diego, California 92152

TABLE OF CONTENTS

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1.0 INTRODUCTION

1.1 SCOPE

This document will cover the physical installation of harnesses 180-59004 and 180-59005. Also included are the installation sequence and cautions to be observed during installation, inspection standards, and remove and replace notes. The purpose of the installation is to demonstrate production installation methods for F/O cables.

1.2 KEY WORDS

Fiber Optic Cables
E-3A
AWACS
Flight Instrumentation
Aircraft Installation

1.3 FOREWORD

The installation of the fiber optics harnesses into the AWACS (E-3A) airplane will use standard cabling procedures as a baseline. The intention of this effort is to demonstrate that fiber optics harnesses can be installed and tested in a production environment as opposed to special lab conditions. Except as noted, standard tools and normal handling procedures may be used in installing fiber optics cables. Fiber optics cables are a different technology from standard electrical cables and a few precautions must be taken initially, especially to protect ends and connectors during installation. Sharp impacts could be disastrous to fiber optic cables. This is a result of the fracture properties exhibited by glasses under impulse shear stresses. Copper is malleable under the same conditions, even when the critical yield point is exceeded. Stress concentrations occur at connector joints, at clamps and accessory hardware fastening points, and at the point of impact.

This document will describe the steps taken in installing the fiber optics cables into the airplane, including site preparation, installation sequence, and procedures and quality control inspection, and general removal and reinstallation procedures.

2.0 AIRPLANE ROUTING AREAS

The airplane routing areas where the harnesses are installed are shown in production illustration drawings 180-59000 and on. The environmental extremes in these areas are described in MIL-E-5400.

3.0 HARNESS DESCRIPTIONS

3.1 Each of the harnesses is clearly identified with a tape imprinted with the following information:

3.1.1 Harness identification is contained on blue tapes within 12 inches of each end of the bundle with the harness and dash numbers printed in characters 1/8 - 1/4 inch high.

3.1.2 First end - Where conduit or restricted area space does not permit a connector to be threaded through on the cable, the first end shall have the connector installed and installation shall commence from its mate-with location. The unterminated end shall be taped or otherwise protected so that the individual finished fiber optic surfaces are protected and the entire cable is taped to both protect and prevent separation of the individual fiber optics cables. If this is not accomplished in cable prep, the protection should be applied before leaving the shipping container.

3.1.3 PI flags - The bundles have green tags without markings. These correspond with location marker arrows shown in the PI drawings. When the bundle is properly installed, the green tags will be installed under the clamps.

3.1.4 Mate-with marker - Within 6 inches of each connector is a yellow identification tape which lists the connector equipment number and the equipment number of the receptacle with which the connector is mated.

4.0 IDENTIFICATION OF FIBER OPTICS CABLES AND HARNESSES

4.0.1 Identify all cable and cable harnesses per Appendix A as noted.

4.0.2 Unless otherwise noted all harness identifications shall be located per Figure 4.0.2 and dimension tolerances shall be ±¼ inch. For overall shielded wire bundles with Expando sleeving, see Figure 4.2.2.5 of D180-24693.

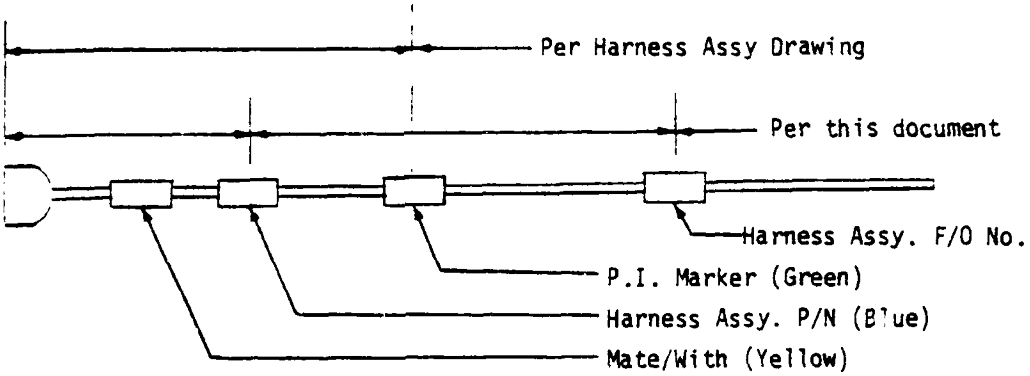
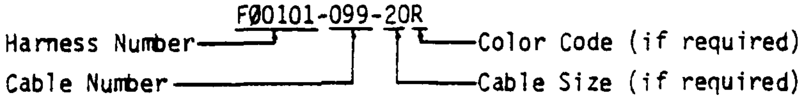


FIGURE 4.0.2

Harness Part No., F/O No., and Short Title may all be on the same Identification Marker.

4.1 CABLE IDENTIFICATION

4.1.1 Use the following wire identification system: (see sample callout)



4.1.2 Harness Number

The harness number as it appears in the cable identification is the equipment number assigned to a specific harness by the cable harness Assembly Index Drawing (D180-59004-(xx) or 180-59005-(xx)).

4.1.3 Cable Number

The cable number as it appears in the cable identification consists of sequencially assigned numbers. Jumpers and pigtails which are not assigned cable numbers by the Harness Assembly Drawing do not require identification.

4.1.4 Color Code

Color code as indicated on the Cable Harness Assembly.

5.0 INSTALLATION

5.1 SPECIAL HANDLING CAUTIONS

5.1.1 Glass has low impact and compressive strength. Never drop or hit the cable.

5.1.2 Glass has high tensile strength but low tolerance to elongation and shear. Microfractures otherwise unnoticeable may cause stress risers. Whipping, jerking, or flexing which exceed the installation limits, even momentarily, should be avoided.

5.1.3 The contact surfaces are precision finished and can be damaged by dust, oil from your fingers, or by scratching.

Leave the protective covers in place until closing the connector.

Check alignment of the connector shells when closing so that they're as straight as possible.

5.1.4 Shocks over 100 g's can occur inside a connector by seemingly minor roughness to the bundle near the connector. Be careful handling connectors.

5.2 SEQUENCE PLANNING

The sequence planning for the two harnesses is:

180-59004: Interrack Harness
180-59005: Interrack Harness (single fiber)

5.2.1 Bundle tie table with excess length allowed at both ends.

5.2.2. Form board fabrication with excess length trimmed to with sufficient slack allowed for 3 subsequent reterminations at each end allowed. At this step, the ends must be capped off with tape or shrink sleeving and the end taped so no subsequent damage may occur.

5.2.3 Solder one 1st end termination where both ends have terminations, connector halves, and backshell hardware installed.

NOTE: Protective end caps are necessary for subsequent shipping.

NOTE: Check continuity and proper pins.

5.2.4 Final assembly for installation of cable but not end closure.

5.3 INSTALLATION STEPS

Harness 180-59004: Rack Integration Bundle
Harness 180-59005

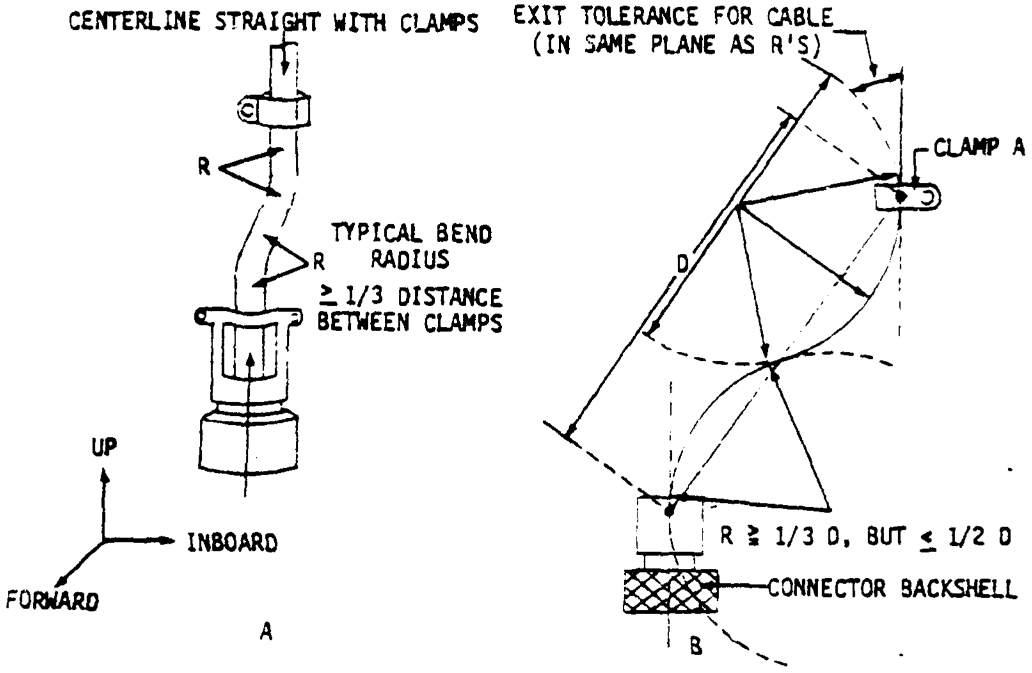
5.3.1 The 180-59004 and -59005 harnesses will be installed in the same routing clamps as the 204-51870-5 harness which they replace. The first end is installed at the floor joint shown in the production illustration.

5.3.1 (Continued)

Leave the connector protective caps in place until inspection is conducted. Measure, without connecting, the distance between the mate-with connector and the first run clamp and allow sufficient length so that, when the cable connector is mated, the cable directly behind the connector backshell is not stressed. The harness must not be installed with a flex point at the backshell; any flex distribution must run evenly from the backshell to the first cable clamp. See Figure 5.3.1.

6.0 FIBER OPTIC HARNESS CONFIGURATION

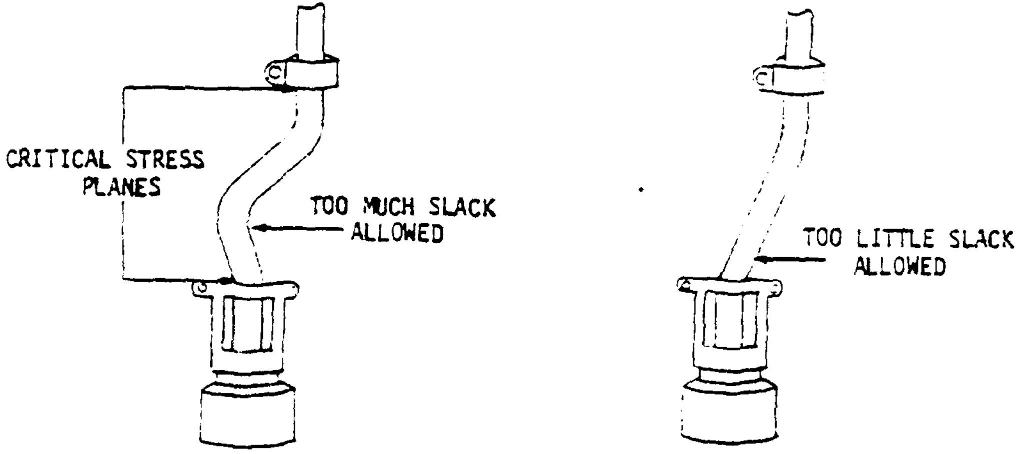
6.0.1 Harness configurations consist of fiber optic lines and pairs of standard wire that are twisted together. Various configurations are shown in Figure 6.0.1.



A

B

ILLUSTRATION 1: ACCEPTABLE INSTALLATION



A

B

ILLUSTRATION 2: UNACCEPTABLE INSTALLATION

FIGURE 5.3.1: EXAMPLE INSTALLATIONS

The second phase of the contract was a "proof" stage for the Phase I design and consisted of the fabrication of a harness and "stand-alone link" to the designs and documents developed during Phase I. In addition, all processes were reviewed and additional ones were written to provide complete documentation.

Phase III of the program consisted of the installation of the prototype harness and stand-alone link in the Class III (Full Scale) E-3A mock-up and then the complete review and modification of all program documentation to upgrade it based upon knowledge gained thru the prototype fabrication and installation. Design of a production cable to be built in Phase IV was initiated so that materials could be ordered to meet schedule requirements.

Phase IV of the program consisted of the fabrication of 21 harness (20 hybrid fiber bundle, single fiber, and conventional wire types and 1 single fiber, conventional wire type). All harnesses were built in a production mode using the revised documentation to test validity of the design and the process specifications. After the fabrication sequence, four of the twenty harnesses and the one single fiber harness were installed in the mock-up and checked for installation damage. Process specifications were again reviewed to verify correctness and utility. This final installation was part of the contract demonstration.

AD-A093 304 BOEING AEROSPACE CO SEATTLE WA F/G 20/6
AIRBORNE-FIBER OPTICS MANUFACTURING TECHNOLOGY, AIRCRAFT INSTAL--ETC(U)
AUG 80 G KOSMOS, R A GREENWELL N00123-78-C-0193
UNCLASSIFIED NOSC-TR-591 NL

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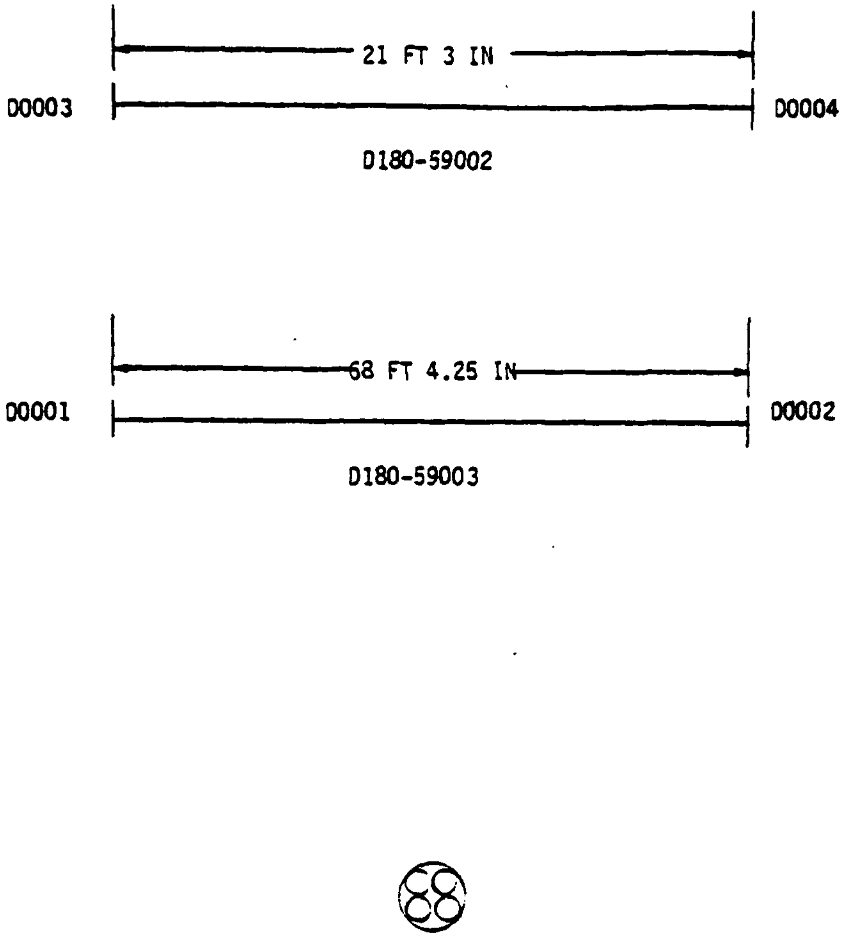

4 F/O CABLES

HARNESS CONFIGURATION

FIGURE 6.0.1B

180-59002 and 180-59003 STAND-ALONE LINK

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APPENDIX C

FINAL PRODUCTION/ACCEPTANCE PLAN

D180-24693-22

FINAL REPORT

IN-PROCESS TESTING OF FIBER OPTIC CABLES AND HARNESSES

O. R. Mulkey

Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124

4 JUNE 1980

FINAL REPORT FOR PERIOD 16 DECEMBER 1979 THROUGH 4 JUNE 1980

Phase IV of NOSC Contract N00123-78-C-0193

Prepared For:

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2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Final In-Process Testing of Fiber Optic Cables and Harnesses

5. TYPE OF REPORT & PERIOD COVERED
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Dec. 16, 1979, to 4 June 80

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fiber optic interconnects
Fiber optic installation procedures
Fiber optic test methods
Fiber optic test equipment
Test equipment

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

This report covers the in-process testing requirements for fabrication of fiber optic cables and harnesses. Test equipment requirements are described and required testing after rework is listed.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

USE FOR TYPEWRITTEN MATERIAL ONLY

In-Process Testing of Fiber Optic Cables and Harnesses

1.0 SCOPE

This specification covers the requirements and procedures for in-process tests on all fiber optic cabling assembled and installed in accordance with Released Process Specifications. For cabling containing both fiber optic cables and conventional wire, this specification and the specification for wire should both be used in their respective areas of interest.

2.0 REFERENCES

a. Government

DoD-STD-1678, Military Standard, Fiber Optics Test Methods and Instrumentation

b. Industry

EIA Standard RS440, Fiber Optic Connector Terminology

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3.0 CONTENTS

4.0 FACILITIES CONTROL

a. Only the instruments meeting the requirements of this specification shall be used for testing.

b. The accuracy of the test instruments shall be as follows:

Measurement	Accuracy
Continuity	No Limit
Optical power loss	± 0.1 db

5.0 DEFINITIONS

For definitions of terms used in this specification see DoD STD 1678 and EIA RS440.

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6.0 MANUFACTURING CONTROL

All personnel involved in the testing of fiber optic cabling shall be properly instructed to operate the test equipment and adequately trained to carry out the test procedure.

WARNING: The tests in this specification shall be not made in explosion hazardous areas which either contained, or have contained, explosive material of the ordinance, dust, or flammable vapor type, except when the test can be performed with an explosion-safe type tester.

CAUTION: Uncoupled plugs and receptacles of production cables, and test cables which mate with production cables, are to be protected with dust caps.

6.1 Testing to Basic Requirements

This level of testing shall be used unless otherwise specified on Engineering drawing.

6.1.1 Terminated Cabling Without Connectors (Assembled cabling terminating in any hardware except connectors).

The following tests shall be performed on all assembled cabling not having connectors.

6.1.1.1 Continuity

Test for the continuity of each cable. The test optical power may be any convenient source. Measurement of quantitative values not required.

6.1.2 Cabling With Connectors

The following tests shall be performed on all assembled cabling having connectors.

6.1.2.1 Continuity

a. Test for the continuity of all cables.

b. For cabling having potted connectors, the continuity of all cables may be tested before potting and must be tested after potting.

6.1.2.2 Insertion Loss

Cables shall be tested to the insertion loss limits detailed on the assembly drawing.

6.1.2.3 Visual Inspection

a. Surface finish shall be inspected to the limits detailed in the assembly drawing. Microscope power to be used shall be such that, for fiber bundles, the bundle end shall fill from ½ to all of the field of view. For a 45 mil bundle, the range will generally be from 50X to 100X. Single fiber ends shall be examined at no less than 100X. Oblique reflected light shall be used.

b. Active fiber count shall be determined photographically for all bundles containing greater than 19 fibers. The quantity or percentage of unlit fibers shall be detailed in the assembly drawing.

6.1.3 Installed Cabling

The following tests shall be performed on all installed cabling.

6.1.3.1 Continuity

a. Test for the continuity of all cables.

b. For cabling having potted connectors, the continuity of all cables may be tested before potting and must be tested after potting.

6.1.3.2 Insertion Loss

Cables shall be tested to the insertion loss limits detailed on the assembly drawing.

6.1.3.3 Visual Inspection

a. Surface finish shall be inspected to the limits detailed in the assembly drawing. Microscope power to be used shall be such that, for fiber bundles, the bundle end shall fill from ½ to all of the field of view. For a 45 mil bundle, the range will generally be from 50X to 100X. Single fiber ends shall be examined at no less than 100X. Oblique reflected light shall be used.

b. Active fiber count shall be determined photographically for all bundles containing greater than 19 fibers. The quantity or percentage of unlit fibers and the allowable area of voids shall be detailed in the assembly drawing.

7.0 QUALITY CONTROL

a. Quality Control shall verify the successful completion of in-process testing in accordance with the requirements of this specification.

b. Quality Control shall ensure that both test connectors and terminated connectors and their contacts are clean and have contacts straight, smooth, and aligned before and after tests.

c. Quality Control shall ensure that test leads are not placed so that they can be jarred or stumbled over, thus exerting damaging forces on contacts.

d. Quality Control shall ensure that uncoupled ends of plugs and receptacles of production cables and test cables which mate with production cables are protected with dust caps except when necessary to work directly upon them.

e. Quality Control shall ensure proper selection and utilization of equipment to meet the requirements of this specification.

f. Quality Control shall ensure that test equipment is certified in accordance with the applicable test equipment certification requirements.

APPENDIX D

FINAL FIELD MAINTENANCE AND REPAIR

106-Blank

D180-24693-23

FINAL REPORT

FIELD MAINTENANCE AND REPAIR OF FIBER OPTIC CABLES AND HARNESSES

O. R. Mulkey

Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124

4 June 1980

Interim Report for Period 16 December 1979 Through 4 June 1980

Phase IV of NOSC Contract N00123-78-C-0193

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Field Maintenance and Repair of Fiber Optic Cables and Harnesses - Final Procedures

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Fiber optics
Fiber optics harness
Fiber optics cables
Field Repair
Field Maintenance

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

This document describes the field maintenance procedures which are allowed for fiber optic cables, harnesses, and connectors. In addition, repair techniques and materials are prescribed and post-repair testing requirements are detailed.

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1.0 SCOPE

This specification covers the methods, materials and equipment required for maintenance of fiber optic cables and harnesses outside the original manufacturing facility.

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2.0 REFERENCES

EIA Standard RS 440, Fiber Optic Connector Terminology

Installation Drawing for Assembly being maintained.

3.0 CONTENTS

4.0 FACILITIES CONTROL

a. Only the instruments meeting the requirements of this specification shall be used for testing.

b. The accuracy of the test instruments shall be as follows:

Measurement	Accuracy
Continuity	No Limit
Optical power loss	± 0.1 db

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-23
SCALE	REV	SHEET 4

USE FOR TYPEWRITTEN MATERIAL ONLY

5.0 DEFINITIONS

For definitions of terms used in this specification see DoD STD 1678 and EIA RS440.

6.0 MAINTENANCE METHODS

6.1 Contamination

6.1.1 Optical Contamination

6.1.1.1 Indications

Indications of optical contamination include loss of signal, variation in signal strength and visual evidence.

6.1.1.2 Maintenance Procedures

Gently clean surface of termination using as a solvent isopropyl alcohol. A "Q tip" or similar cotton tipped applicator may be used. In some cases removal of the termination from the connector may be necessary. If removal is required use only the removal and insertion tools recommended for the connector type. Inspection of the cleaned termination should be made for complete removal of residue and for absence of scratching or pitting. The optical power loss should be retested using test equipment detailed on the installation drawing or maintenance procedure.

If repeated cleaning of the surface does not remove contamination or if excessive surface damage is evident (see Installation drawing for acceptable limits) the connector may be resurfaced using the polishing tools and materials called out on the drawing. Acceptance limits will be as noted.

If the resurfacing procedure is not satisfactory, replace or reterminate per Assembly drawing.

6.1.2 Cable/Connector Exterior Contamination

Protect optical surfaces of the connector during any cleaning operation near the connector.

Remove any soft contaminant by wiping with an absorbant material. Final residue may be removed by rewiping with a solvent recommended on the assembly drawing.

6.2 Abrasion

6.2.1 Optical Surface Abrasion

Check for surface contamination and/or abrasion on the mating contact. If either is present follow the procedures of Paragraph 6.1.1.2.

6.2.2 Cable Exterior

Superficial damage may be repaired on individual cables by taping with applicable pressure sensitive tape using a spiral wrap with 1/2 lap overlap. The wrap should extend one inch on each side of the damaged area. An alternate method is covering the affected area with a heat shrinkable tubing extending one inch on each side of the damaged area.

6.3 Cuts/Breakage

6.3.1 Optical Fiber

6.3.1.1 Fiber Bundles Cables

A limited number of individual fibers may be broken in a fiber bundle cable. The quantity is listed on the assembly drawing for that cable. A count may be made either visually or photographically. An excessive number of broken fibers in a cable is cause for rejection and replacement unless spare cables are included in a harness. Removal and replacement of cable terminations from the connector must be accomplished using tooling described on the assembly drawing or in an established maintenance procedure.

6.3.1.2 Single Fiber Cables

A broken fiber in a single fiber cable which is part of a harness may be replaced with a new fiber if sufficient sheath material is left to provide an area for termination. The broken fiber should be removed and the new one fished through the sheath using a length of "piano wire" as a tool.

A spare cable of course may be used if available. Terminations should be removed and replaced from the connector per the instructions of the assembly drawing or maintenance procedure.

6.3.2 Sheath/Jacket

Cuts or breakage of the sheath or jacket which penetrate to the optical fiber or fibers may not be repaired.

Cuts or breakage which penetrate only to a strength member with no damage to that member may be repaired using the method of 6.2.2.

6.4 Connector Damage

Superficial damage to connector shells or backshells, i.e., nicks, gouges, scrapes, are not cause for replacement. Any rough edges should be dressed with a file or deburing tool to prevent damage to personnel or other equipment.

Damage that affects connector alignment, engagement removal, retention or hermeticity is cause for replacement. On connectors with replaceable parts, i.e. shells, backshells, terminations, etc., the damaged portion may be replaced only. This must be done only with tooling and methods detailed on the assembly drawing or maintenance procedure.

7.0 QUALITY ASSURANCE

7.1 General

Any cable repair involving the removal of the cable or disconnection of the connectors will require that protective end caps be placed on all matings surfaces of affected connectors.

Care should be taken in handling cables and harness so as not to exceed minimum bend radius limits detailed in the cable assembly drawing or maintenance procedure.

Cables should not be subjected to severe shock, i.e., dropping, etc., If in doubt as to the handling history of the cable/harness during repair a full visual examination and optical power loss test should be performed.

7.2 Optical Surfaces

Any repair technique to the optical surfaces of a cable or termination/contact other than "gentle" cleaning with an approved solvent will require the visual examination of the repaired resurface and retest for optical power loss which is detailed in the cable assembly drawing or maintenance procedure.

7.3 Cable

Repairs to the cable should be examined for neatness and workmanship. Materials used should be those detailed on the assembly drawing or maintenance procedure.

7.4 Connector

Repairs involving disassembly of the connector terminations will require visual examination and optical power loss test per cable assembly drawing or maintenance procedure.

Superficial damage repair requires examination for workmanship and proper operation of the connector only.

APPENDIX E

MANUFACTURING TECHNOLOGY COST ANALYSIS

APPENDIX E
MANUFACTURING TECHNOLOGY COST ANALYSIS

In a contract awarded to the Boeing Aerospace Corporation, Seattle, Washington, the objective of the task was to develop installation processes and procedures for the incorporation of fiber optic interconnect systems aboard military aircraft. As a portion of this task, a life-cycle cost analysis of the optical cable was performed. It was apparent that weight and size reductions of fiber optics offered economic advantages. With the E-3A as the baseline military aircraft, it was possible to increase the E-3A sortie time by 2.5 percent, which can be equated to a reduction of fleet squadron size by 1.5 aircraft.

The reliability of fiber optic interconnect systems appears to be equivalent to wire interconnect systems. It appears easier to install, remove and/or replace optical fibers. Optical fiber interconnect systems are also simpler to test. Spares, repair parts, materials, and special support/test equipment add to initial costs, as does almost any new technology, but the impact is minor. With simpler equipment and techniques there may be a long-term savings potential. Overall costs and benefits of fiber optics appear to surpass the E-3A wire interconnect configurations.

An important assumption has been made that must be recognized as a basis for the results of this life-cycle cost analysis. Material costs are based on current vendor estimates but production set-up cost and other engineering/manufacturing costs are based on a futuristic analysis and prediction of a large production of fiber optic harnesses fabricated at a rate typical of wire harnesses. This report will not attempt to predict with accuracy the cost variations of the current fiber optic technology nor the inflationary impacts of the future of fiber optics versus wire materials.

The overall results from Boeing's parametric cost model (PCM) indicate a per system cost for this project's twenty-one systems at $7893 for technology developments. Projecting these initial costs and manufacturing technology concepts to a planning production cost base, the fiber optic harness cost will be about $3620, which is a reduction of more than half of the initial technology development costs. Wire harness costs per system are about $4900, which is a nine-percent increase over the optical fiber harness. Engineering costs are reduced by 38 percent for the fiber optic harness and manufacturing costs are reduced by 16 percent. Initially, because of the high cost of the connectors, fiber optic material costs had increased above wire material costs by nearly 300 percent. After one year, the increased use of fiber optic materials has driven costs down, while the cost of metals was rising. Thus, this results in a cost savings in using fiber optics.

This cost analysis includes acquisition cost elements involved in producing fiber optic harnesses in a modern production and manufacturing facility. It also includes ownership cost elements derived from applicable historical data and from reliability and maintainability analysis.

Production set-up costs, the nonrecurring costs, are based on the concept of a production facility which is of minimal scale for yielding economical benefits from advanced automated equipment and methods. Equipment costs are based on quotes or estimates of purchase prices or upon engineering estimates.

Manufacturing costs, the recurring costs, relate primarily to the flow of tasks and processes which generally dictate the greatest share of the cost of a harness assembly.

Production and manufacturing cost estimates are based on a survey and analysis of company experience in producing various quantities of wire harness assemblies for both military and commercial programs. Three separate and distinctly different company production/manufacturing facilities provide the primary base of experience. The approach used was to correlate this experience with similar tasks related to production/manufacture of a fiber optic harness assembly and then to provide engineering estimates of unique equipment, tasks or processes. These results are supported by harness assembly cost model estimates and by generic level cost factors established from direct experience on past and ongoing company programs.

In manufacturing, process flow manhours is the dominant factor related to manufacturing costs. The tasks, steps, and related timelines for the baseline wire harness assembly have been estimated by financial and by mechanical and industrial engineering specialists. Similar estimates have then been applied to a planned fiber optics harness assembly process, with the addition of unique steps and processes. The epoxy/dry/cure/grind/polish task is the dominant cost factor. Cost effectiveness therefore hinges to a large degree upon development of automated equipment and improved techniques.

Wire harness and cable production costs incurred on past programs, SRAM, Minuteman, E-3A, etc., have been factored into a manhour-per-wire ratio. This factor has also been tracked along improvement curves as program and production experience is accrued. This history applied to the baseline wire cable yields a first unit DDT&E cost of approximately 24 manhours. The historical data for the Short Range Attack Missile, SRAM, reflects an approximate 28% higher cost for carrier aircraft harnesses than the average harness on the program. With this adjustment, costs of 47 and 31 manhours are obtained for the DDT&E and production units, respectively. Using this history along with a range of improvement curve histories, the following high and low estimates are obtained for the average cost of 20 production units:

1. High estimate, assuming a 90% improvement curve slope and 47 manhours for the first unit, is 35 manhours.

2. Low estimate, assuming a 90% improvement curve slope and 24 manhours for the first unit, is 16.5 manhours.

These estimates frame the range of costs for typical DDT&E and production units.

Estimates of fabrication costs of the fiber optic harnesses utilized in the YC-14 were made based on the assumption of a cost breakdown similar to this contract. This assumes that the company which fabricated the eight YC-14 optic harnesses/cables did so as part of a DDT&E effort which allocated 12 percent of the total cable cost to fabrication. In this case $167 of the 1393.00 purchase price would be allocated to fabrication. Further, assuming that technology advancements and labor rates act to balance cost effects of fabrication, then this would equate to approximately 5 manhours at a $34 per manhour manufacturing WRAP rate.

The DTLCC cable assembly computer model estimated an average cost of approximately 8 manhours for each of eight equivalent wire harnesses produced on an improvement curve with a 90% slope.

The above results suggest that fiber optics manufacturing and fabrication experience of the past offers economies at least comparable to wire harness assemblies. It should be observed that three assemblies were utilized on two YC-14 aircraft (six harnesses) with no failures in over 600 flight hours. Each of the harnesses included four fiber cables and two connectors.

Operation and support costs analyses are based on historical data on the E-3A aircraft along with an extensive history on four Navy aircraft, the S-3A, E-2C, P-3C and EC130G and Q.

A reliability analysis of both the baseline wire harness assembly and the fiber optics assembly provides the added information base appropriate for prediction of fiber optic harness field reliability maintenance factors. Policies of the using agency relative to inventory, spares, and repair parts appear to be the dominant factor affecting the supply and support costs. Since the baseline harness assembly is for an E-3A aircraft, the policy for this aircraft was selected as a baseline in conjunction with policies formulated in the A-7 ALOFT Project Technical Reports NELC TR 2024, 1998, 1982 and 1968. Some cost elements are also derived based on operational efficiencies that could be realized for a fiber optic harness configured E-3A.

A historical base for estimating installation, operation, and support costs and data for MTBF and MTTR estimates for fiber optics harnesses is extremely limited. The experience record of six fiber optic harnesses (four fiber bundles per harness) utilized in the YC-14 aircraft avionics system reflects zero failures in over 600 flight hours. A history base for wire harnesses in military and commercial aircraft is also relatively limited. Wire harness failures and maintenance actions are most generally recorded in a category associated with the system or subsystem of which they are a part. A search of service history records on military aircraft uncovered some data on five aircraft which are included in Appendix H. The lack of data indicates a proper area to be investigated by the services in the interest of minimizing life-cycle costs. This conclusion is based on costs attributed to failure and maintenance of harnesses and cables as compared to costs of maintaining detailed records.

For comparison and estimation purposes assume that fiber optics harnesses/ cables are used for all applications except power distribution. Further, assume that a weight savings of 50% is achieved by replacing baseline wire harness with the fiber optics harness. This results in a total weight savings of 1,378 pounds per aircraft. When this weight savings is replaced by jet fuel it increases the sortie length by a factor of 1.167×10^{-4} hours/lb. The sortie length increases by 0.16 hours (9.65 minutes) or a 2.5% increase. Under the assumption that this increased sortie length can be utilized effectively over the fleet of E-3As (a reasonable assumption) then an increase in effectiveness equivalent to 1.5 aircraft is achieved. This equates to an acquisition cost savings for at least one aircraft at a cost in excess of $100,000,000.

An institute for defense analysis paper (IDA paper P-1244 May 1977) concluded that a decrease of one pound in avionics weight will result in a decrease of six to eight pounds in 'dry' weight due to system overhead effects within the total aircraft system. It concluded that since fly away cost per pound of a modern fighter is approximately $500 per pound the savings in cost per pound would average in the range of $3500 per pound of avionics weight reduction in 1975 dollars.

Applying this factor to the E-3A example yields an acquisition cost savings of $4,823,000.

Estimate for the installation of a group of harness assemblies which include the baseline wire harness assembly during aircraft production is approximately six hours. Since, during cable installation a group of cables are installed at one time, the exact time line for a single cable is not traced. However, installation of the baseline harness by itself would approach one half to one hour.

Installation or removal and replacement estimates are dependent upon the size and weight of the harness assembly. Hence, if the fiber optics harness is smaller and lighter, then a potential savings exists but it is judged to be of minimal significance.

Appendices A through H provide the necessary cost elements, cost data, and cost equations to support the findings reported in this analysis.

In summary, acquisition cost estimates by models and by analysis of processes and techniques reflect potential cost savings for fiber optic interconnect systems as compared to wire harnesses. Since most models rely upon historical data and "conventional methods of business," it is implied that savings are realizable with technology maturity and with methods and techniques commonly employed.

Many options exist for production set-up and related costs. The most desirable option will depend on many factors such as level of business forecasts, advancement of the technology, demands on existing harness/cable production equipment and facilities, facility space available for expansion or relocation, economic posture of the company, etc.

The potential for cost improvement in the manufacturing/fabrication process is promising. The development of automated equipment and expedient techniques is needed to exploit this potential; however,

a. cost elements related to operations and support aspects appear to have offsetting effects.

b. cost savings are realized through weight and size advantages, while losses occur through added inventories, training, and special equipment requirements.

c. reliability considerations have a similar neutralizing effect.

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APPENDIX A
COST BREAKDOWN STRUCTURE

A. Research and Development Cost Elements

1. Program Management

    Contracts

    Cost/Schedules

    Logistics Support

    Configuration Baselines, Changes and Records

2. Engineering

    Design Engineering and Design Support

    Direct Labor

    Materials

    Overhead

3. Fabrication

    Full scale model development

    Direct labor

    Materials and overhead for material procurement

    Tooling and test equipment for manufacture, fabrication, assembly and test

4. Development Tests

    Demonstrate that design specifications are met.

        Performance

        Maintenance/Reliability

    Direct labor, materials, overhead

5. Test Support

    Support of government tests.

6. Producibility Engineering and Planning
    - Technical data packages
    - Special purpose equipment/tool design
    - Computer modeling/simulation
    - Engineering drawings/diagrams
    - Material, inspection, test, etc. information
7. Engineering Data
    - Drawings or lists
    - Specifications
    - Plans and procedures
    - Reports and documents
    - Technical orders and manuals
8. Peculiar Support and Test Equipment
    - Equipment
    - Tools
9. General and Administration
    - General Officers and staff
    - Fringe benefits
10. Fee or Profit

B. *Production (Non-Recurring)*

1. Program Management
    - Configuration
    - Cost/schedules
2. Production Facilities
    - Engineering
    - Tooling and tooling modifications
    - Property acquisition/modification
    - Manufacture support equipment

3. Technical Support

   Acceptance tests or operational acceptance/evaluation test

4. Spares and Repair Parts

5. Training

   Instructor and maintenance training of Navy personnel.

6. Engineering Data

   Drawings, lists, specifications

   Plans, procedures, reports, documents

7. Support Data

   Maintenance data

   Provisioning data and lists

   Logistics support plans and progress reports

8. Management Data

   Configuration management

   Cost, schedule, contract data

9. Peculiar Support and Test Equipment

   Equipment, tools } develop under other cost element

   Labor, materials and overhead } develop under other cost element

   (PMS checks and routine maintenance)

10. General Administrative

    General and executive offices

    Staff services, etc.

11. Production Acceptance Test and Evaluation

12. Profit/Fee

C. Production (Recurring)

1. Manufacturing

   Fabrication, assembly, processing, etc.

   Labor, overhead and direct charges

2. Production Material

   Off-the-shelf hardware

   Subcontract items

   Raw material/semi-fabricated material

3. Sustaining Engineering

   Redesign and evaluation

   Maintainability/reliability

   Manufacture/production

4. Quality Control and Inspection

5. Packaging and Transportation

   Packing for shipment

   Transportation to point of contract

6. Assembly, Installation and Checkout

7. General and Administrative

8. Fee or Profit

D. Operations and Support

1. Operations

   Cost of readiness

   Im proved efficiencies

2. Maintenance Personnel

3. Maintenance Facilities

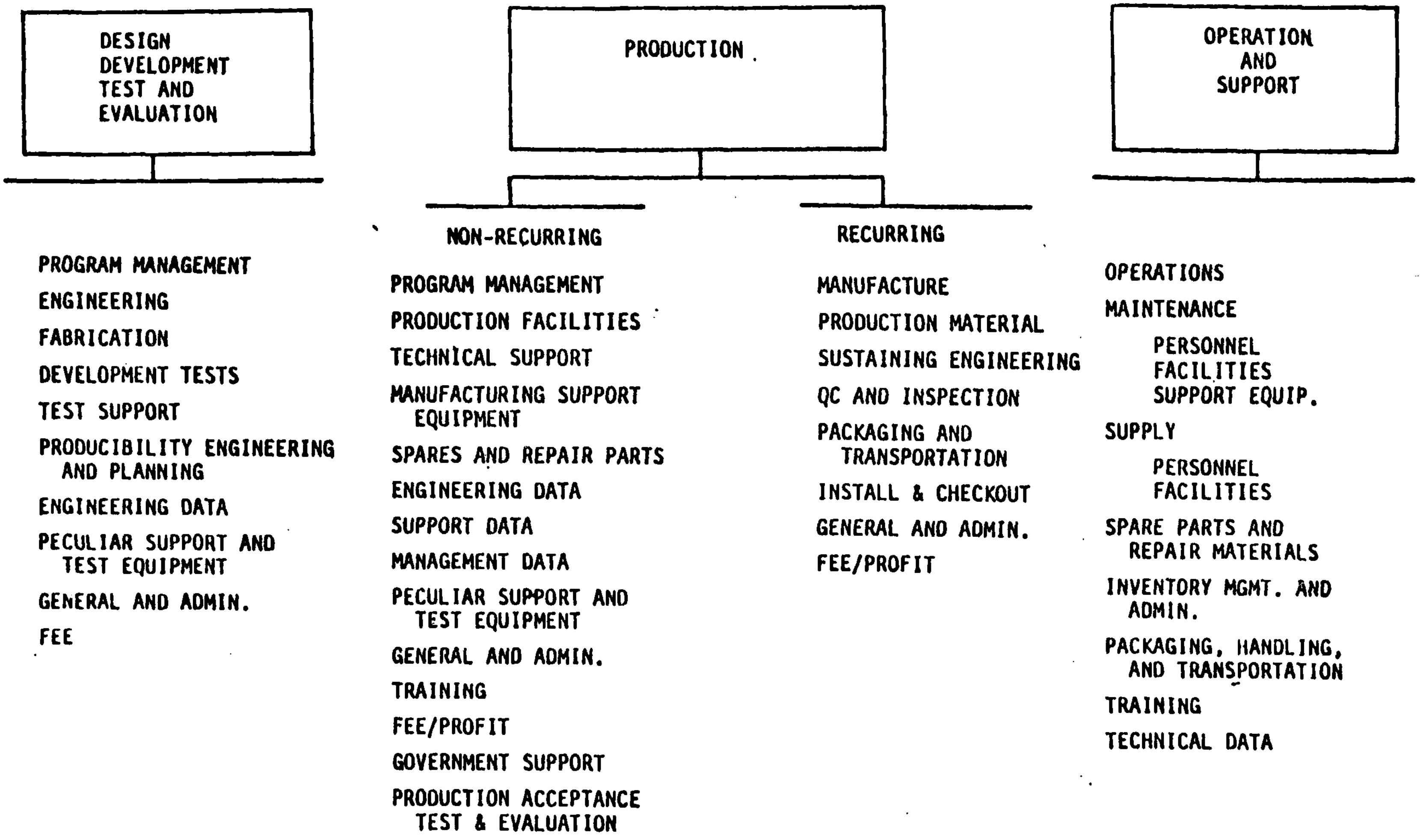
4. Support Equipment Maintenance

5. Supply Personnel

6. Supply Facilities
7. Spare Parts and Repair Materials
8. Inventory Management/Administration
9. Packaging, Handling and Transportation

APP ' A

FIBER OPTICS IN -RCONNECT SYSTEM
LIFE-CYCLE-COST CONSIDERATIONS



DESIGN DEVELOPMENT TEST AND EVALUATION

- PROGRAM MANAGEMENT
- ENGINEERING
- FABRICATION
- DEVELOPMENT TESTS
- TEST SUPPORT
- PRODUCIBILITY ENGINEERING AND PLANNING
- ENGINEERING DATA
- PECULIAR SUPPORT AND TEST EQUIPMENT
- GENERAL AND ADMIN.
- FEE

PRODUCTION

NON-RECURRING

- PROGRAM MANAGEMENT
- PRODUCTION FACILITIES
- TECHNICAL SUPPORT
- MANUFACTURING SUPPORT EQUIPMENT
- SPARES AND REPAIR PARTS
- ENGINEERING DATA
- SUPPORT DATA
- MANAGEMENT DATA
- PECULIAR SUPPORT AND TEST EQUIPMENT
- GENERAL AND ADMIN.
- TRAINING
- FEE/PROFIT
- GOVERNMENT SUPPORT
- PRODUCTION ACCEPTANCE TEST & EVALUATION

RECURRING

- MANUFACTURE
- PRODUCTION MATERIAL
- SUSTAINING ENGINEERING
- QC AND INSPECTION
- PACKAGING AND TRANSPORTATION
- INSTALL & CHECKOUT
- GENERAL AND ADMIN.
- FEE/PROFIT

OPERATION AND SUPPORT

- OPERATIONS
- MAINTENANCE
  - PERSONNEL
  - FACILITIES
  - SUPPORT EQUIP.
- SUPPLY
  - PERSONNEL
  - FACILITIES
- SPARE PARTS AND REPAIR MATERIALS
- INVENTORY MGMT. AND ADMIN.
- PACKAGING, HANDLING, AND TRANSPORTATION
- TRAINING
- TECHNICAL DATA

APPENDIX B

Interconnect Harness Cost Breakdown
Table B-1
Interconnect Harness Cost Comparisons for DDT&E

Function	Fiber Optics (Current Contract)		Wire (Baseline Harness)		Fiber Optics (Projected Design and Build with Established Processes and Standards)	
	Hours	Dollars	Hours	Dollars	Hours	Dollars
Engineering (1)	130	4,335	21.8	1,199	20(4)	1,100
Manufacturing (2)	63	2,153	43.1(5)	1,490	41.9(5)	1,449
Production Material		1,356	-	552	-	520(3)
Other		49	-	-	-	-
Totals(6)		$7,893		$3,241		$3,069

Notes: (1) The engineering WRAP rate for the current contract is $33.30 as compared to a WRAP rate of $55 used for the baseline harness and the fiber optics projection. The $55 WRAP rate is typical for large programs.

(2) The manufacturing WRAP rate is approximately $34 for all comparisons.

(3) Material costs are adjusted based on projected quantity purchases.

(4) Engineering is projected to be less than wire due to reduced size, weight and complexity of design. Refer to pages 24 and 25 for a summary of engineering tasks and considerations.

(5) Manufacturing estimates are based on experience data for small quantity design and build. Refer to 5.0.A and Appendix G for manhour estimates based on experience data.

(6) Values are expressed in 1978 Dollars.

A few important and vital factors relative to the above comparisons must be recognized. First, fiber optics is a new technology while wire harness production is a matured industry. Second, for the current contract effort some fiber optic components are comparatively expensive and additional parts and materials are required for developmental contingencies. Production costs of fiber optic components in quantity lots can decrease costs considerably. Thirdly, even establish technologies offer opportunity for dramatic cost improvement. Initial harness assemblies have experienced improvement along an improvement curve with 70% slope. Follow-on production quantities also commonly experience improvement along improvement curves with slopes in the average range of 90%. A greater rate of improvement is anticipated for fiber optics harnesses.

Included below are program financial estimates broken down to a single harness assembly for both fiber optic and baseline wire harness assemblies. The fiber optic estimate is based on the revised firm price fixed proposal dated 24 April 1978. The wire harness estimate is based on financial accounting and cost estimates.

Table B-2

Fiber Optic Interconnect System Cost Estimates

Cost Element	Cost Goal
Direct Labor	
Engineering	$ 1,465
Developmental Elec. Mil.	508
Quality Assurance	34
Program Finance Controls	210
Total Direct Labor	$ 2,217
Labor Overhead	
Engineering	453
Manufacturing Elec. Mil.	441
Quality Assurance	25
Program Contracts	567
Total Labor Overhead	$ 1,486
Travel	36
Other Direct Costs	
Fringe Benefits	995
Freight-In	28
Product Liability Insurance	2
Sub Total (All of above)	$ 4,728
General and Admin. Expense	
Products New Business	811
Puget Sound	136
Total G&A	$ 947
Direct Materials	
Production Materials	$ 1,217
Washington State Taxes	$ 89
BCS	$ 6
Total Estimated Cost	$ 6,987
Profit	849
Total Price	7,836
CAS 414 Cost	57
Total Grand Price	$ 7,893

Note: The above estimates were derived from proposal estimates by extracting the stand-alone link engineering costs and then by factoring other costs by 22 (the total number of harnesses to be produced under the current contract).

Table B-3
Baseline Wire Harness Assembly Cost Estimates

Cost Element	Cost Estimate	
	Dollars	Mannours
Engineering (3 manmonths)	$1,198	21.7
Fabrication		
Production Labor	254	32.7
Tool and Planning	22	2.55
Tool Labor	22	2.55
Inspection Labor	45	5.3
Finge @ 43%	147	-
Manufacture Overhead	777	-
Production Material	493	-
Distributed Material	19	-
Tool Material	4	-
Direct Charges	15	-
State and Local Taxes	5	-
CAS 414 Costs	21	-
Total Cost (excluding Engineering)	$1,824	-
Profit/Fee (excluding Engineering) @ 12%	$ 219	-
Grand Total (including Engineering)	$3,241	

APPENDIX C

PRODUCTION SET-UP EQUIPMENT COST OPTIONS

	Qty.	Cost Goal	Fixed or Tradable*	
			Wire	F/o
1. Cut and code equipment options				
a. Ink jet marker	1	100,000	A	A(1)
b. Conrac	1	150,000	A	-
C. Trojamatic	1	20,000	0(2)	A(1)
2. Stripper equipment options				
a. Ewbanks (or equivalent) automatic	2	8,000	R	R
b. Ideal (or equivalent) manual	100	5,000	R	R
c. Carpenter (or equivalent) manual, power	2	1,200	0	0
d. Work station - tables, lighting, storage	3	4,200	R	R
3. Crimper equipment options				
a. Amp (or equivalent) automatic/power	3	60/mo. ea.	R	0(4)
b. Vip (automatic/power)	1	4,550	0(3)	0(4)
c. Manual, hand operated @ 250 ea.	250	62,500	R	0(4)
4. Tie tables and form boards				
a. Tie tables @ $1000 ea.	3	3,000	R	R
b. Form board support tables @ $500 ea.	50	25,000	R	R
c. Form boards @ $25 ea.	100	2,500	R	R
5. Processor/Printer equipment				
a. Word processor Xerox, 850 or equiv.	1	18,000	0(5)	0(5)
b. Convertor or communicator	1	3,600	0(5)	0(5)
c. Frieden	1	12,000	0(5)	0(5)
6. Braiding equipment				
a. Braid machine	1	18,000	R	R
b. Braided shield termination equipment	1	8,000	R	0
c. Wire wrap (Wraps tape)	1	4,000	R	R
d. Braid spool machine	1	3,000	R	R
7. Tie wrap equipment				
a. Panduit (or equivalent) plastic tie, power	2	1,800	R	R
b. Thomas & Betz (or equivalent) manual	4	250	R	R
c. Ultrasonic (or equivalent) cloth tie	2	3,000	R	R

*R-required, A-alternates, 0-optional

		Qty.	Cost Goal	Fixed or Tradable*	
				Wire	F/O
8.	Testing Equipment				
a.	DITMACO (or equivalent)	1	110,000	R	R
b.	Cable, scan (or equivalent) continuity tester	2	20,000	-	A
c.	Test cables	100	50,000	R	R
d.	Cable management system	1	200,000	O	O
9.	Miscellaneous equipment				
a.	Heat guns @ $80.00	20	1,600	R	R
b.	Hand cutters @ $25.00	50	1,250	R	R
c.	Solder irons @ $80.00	15	1,200	R	R
d.	Burn tools @ $100.00	10	1,000	R	R
e.	Exhaust fans @ $190.00	15	2,850	R	R
f.	Pin insertion/removal tools	20	1,000	R	R
10.	Potting and Epoxy Equipment (silicon and non-silicon)				
a.	Oven (hot air)	1	8,000	R	R
b.	Vacuum table (mixing, etc.)	2	4,000	R	R
c.	Vacuum impregnator	2	40,000	R	R
d.	Electronic balance (scales)	2		R	R
e.	Mechanical balance (scales)	2		R	R
f.	Marble tables	2		R	R
g.	Deep freeze (80^0 below zero)	1		R	R
h.	Refrigerators	2	2,500	R	R
i.	Ovens	4	8,000	R	R
j.	Paint shakers	2	1,500	R	R
k.	Test benches	2	1,400	R	R
l.	Eye bath	2	500	R	R
11.	Materials and Parts Handling and Storage				
a.	Conveyor 200 ft. @ $50/ft.		10,000	R	R
b.	Shelving		10,000	R	R
c.	Bulk parts	3	6,000	R	R
d.	Small carts $360.00	10	3,600	R	R
12.	Epoxy/dry/cure equipment				
a.	Oven (hot air)	2	16,000	-	R
b.	Tables and fixtures	2	2,000	-	R
13.	Grind and polish equipment				
a.	First end connector machine	2	9,000	-	R
b.	Holding fixtures and supplies, i.e., abrasion wheels, solverts, swabs		2,000	-	R

	Qty.	Cost Goal	Fixed or Tradable Wire	F/O
14. Optical test and inspection				
a. Microscope	2	2,000	-	R
b. Attenuation test set	2	1,000	-	R
15. Cut and splice equipment				
a. Cleaving	2	3,000	-	R
b. Splicing	2	2,400	-	R

Notes:

(1) The Ink Jet Marker is required for fiber optics cables if marking is required. If marking is not required the Trojamatic or equivalent may be used.

(2) A Trojamatic or similar machine is needed if a Conrac is used.

(3) This unit is efficient for small wires.

(4) These are required with fiber optics harness production due to possible mix of wire and fiber in a harness.

(5) This equipment produces tapes, patches, work orders, etc. Computer services can be purchased as an alternate.

APPENDIX D

EQUIPMENT DDT&E COST OPTIONS

Equipment Description	QUANTITY	COST GOAL
1. Ewbanks (or equivalent) automatic stripper evaluation and modification	1	50,000
2. Epoxy application and dry/cure equipment		
a. Fixtures, tools, etc.	1	2,000
b. Oven (modified)	2	3,000
3. Grind and Polish Equipment engineering, factory and materials	2	175,000
4. Optional automatic cut, strip, epoxy, grind, polish		500,000

APPENDIX E

Production Set-up Facilities Options

1. Expansion of an existing production facility into adjacent unused areas of 3000 sq. ft.
    - a. Refurbish cost with air conditioning = $180,000
    - b. Special electrical = 9,000
    - c. Air Hook-ups = 36,000
    - d. Exhaust Hook-up = 4,000
    - e. Equipment Installation =
    - f. Miscellaneous =

    Approx. Total = 230,000

2. Build on to existing facilities to expand by 3000 sq. ft.
    - a. New expansion (90 + 15) = 315,000
    - b. Special electrical = 9,000
    - c. Air Hook-ups = 36,000
    - d. Exhaust Hook-up = 4,000
    - e. Equipment Installation =
    - f. Miscellaneous =

    Approx. Total = 365,000

3. Locate complete production set-up into a refurbished facility, assume 30,000 sq. ft. and assume that parts and materials and tool storage is available in separate support area.
    - a. Refurbishment costs
        - 27,000 without air conditioning = 1,215,000
        - 3,000 with air conditioning = 180,000
    - b. Special electrical = 9,000
    - c. Air Hook-ups = 36,000
    - d. Exhaust Hook-ups = 4,000
    - e. Equipment Installation =
    - f. Miscellaneous =

    Approx. Total = 1,450,000

4. Construct new facility, assume 30,000 sq. ft. plus required support area of approximately 20,000 sq. ft.

a. New facility cost = 5,000,000
b. Special Electrical = 9,000
c. Air Hook-ups = 36,000
d. Exhaust Hook-ups = 4,000
e. Equipment Installation =
f. Miscellaneous =
Approx. Total = 5,050,000

APPENDIX F

TRAINING COSTS AND OPTIONS

A. Contractor Training

A projection of training requirements for the size of production facility and for the two proposed courses is tabulated below:

Personnel	Courses 24 Hour	 16 Hour
Manufacturing (hourly)	100	10
Quality Control	10	10
Engineering	-	25
Supervision	12	15
	122	60

The above personnel and course requirements yield the following:

1. Approximate number of 24 hour classes - 12 classes
2. Approximate number of 16 hour classes - 6 classes
3. Total classroom hours - 384 hours
4. Total student hours - 3888 hours
5. Course development hours
    a. Eight hours per course hour for 16 hour course 8x16 - 128 hours
    b. Four hours per course hour for 24 hour course 4x24 - 96 hours
    c. Instructor preparation 8x16 - 128 hours
    d. Illustrations 26x6 - 156 hours
6. Course maintenance

    Course length x 2 24x2 - 48 hours
    16x2 - 32 hours

Course development manhour cost goal 588 hours

Course development dollar cost goal $24,431

APPENDIX G

MANUFACTURING PROCESS FLOW

A. Baseline Wire Harness Assembly

	COST ESTIMATES (MANHOURS)			
	Method #1	Method #2	Method #3	Method #4
1. Wire Cut and Code	1.0	0.53		1.8
2. Wire Shields - Strip and terminate	6.9	2.54	12 wires at .20 is 2.40	1.1
3. Wire Ends - Strip and Crimp	2.8	1.33		
4. First End Connectors - Install pins	1.0		44 wires at .50 is 22.00	.8
5. Form Board - Layout and tie	3.0	6.46		6.0
6. Wire Shield - Braid or install	3.5			2.1
7. Jacket - braid or install	2.5	2.15	17 Shields at .20 is 3.40	2.1
8. Wire Ends - strip and crimp	2.8	1.33		---
9. Second End Connectors - Install pins	1.0	1.69		1.1
10. Labels/Patches/Tape	.8	.32		.8
11. Test	.5	.5		.5
12. Pack and Ship	.3	.3	0.3	.3
TOTALS	26.1	17.15* to 41**	28.1	16.6*

* Estimate based on high rate/large quantity production/manufacturing set-up and 100% production efficiency.

**Estimate based on reduced rate of production and a lower level of production efficiency. Production efficiency levels based on past experience May vary over a 2.5 to 1 range.

APPENDIX G
(Continued)

B. FIBER OPTICS HARNESS ASSEMBLY

		Manhour Estimate	
		Single Fiber	Multi-Fiber
1.	Cut and Code	1.0	-
2.	Fiber Ends		
	Termination (20x.5)	10.0*	15.0*
	Grind and Polish (20x.25)	5.0*	6.7*
3.	Wire Ends - Strip and Crimp (12x.06)	0.7	-
4.	First End Connector - Install Pins	0.7	-
5.	Form Board Layout and Tie	2.2	-
6.	Fiber Ends		
	Termination (20x.5)	10.0*	15.0*
	Grind and Polish (20x.25)	5.0*	6.7*
7.	Wire Ends - Strip and Crimp	0.7	-
8.	Second End Connect - Install Pins	0.7	-
9.	Test - Photographic and Insertion Loss	2.3	-
10.	Jacket - Braid or Install	2.5	-
11.	Labels/Patches/Tape	0.8	-
12.	Pack and Ship	0.3	-
	TOTALS	41.9	55.3

*The manhour cost driver is associated with new processes. A potential exists for significant improvements.

APPENDIX H

1.0 MAINTENANCE AND RELIABILITY DATA ON AIRCRAFT WIRING

The following data base (Table H.1) was used as source for aircraft wiring maintenance and reliability history. The data is formatted in Table H.2.

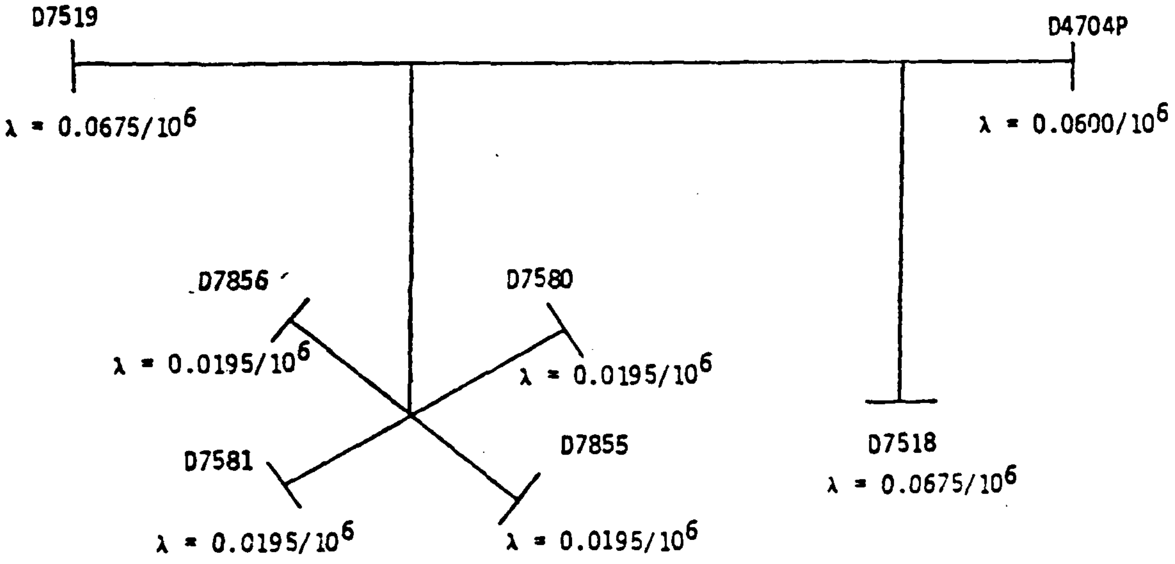
TABLE H.1 HISTORY DATA BASE

Aircraft	Data Time Period	Flight Hours	Average Inventory	Average Sortie Length	Utilization/ Month/ Aircraft
E-2C	Jul '76 - Jun '77	13,181	23	2.79	47.76
S-3A	Mar '76 - Jun '77	56,831	81	2.75	53.97
EC-130G,Q	Mar '75 - Nov '77	38,514	10	6.78	128.4
P-3C	Jan '74 - Dec '74	71,321	93	4.85	63.9
E-3A	May '77 - Mar '78	1,635	3	6.36	49.54

2.0 BASELINE WIRE HARNESS ASSEMBLY RELIABILITY CALCULATIONS

Failure Rate of 204-51870-5 Wire Harness Assembly

$\lambda = 0.273$ failures/10^6 hours, distributed as shown.



Back-up information and calculations attached.

TABLE H.2

AIRCRAFT WIRING MAINTENANCE AND RELIABILITY

AIRCRAFT	WORK UNIT CODE AND (NUMBER OF WIRE HARNESS TYPES)	FLIGHT LINE REMOVE AND REPLACE	FLIGHT LINE FAILURES	SHOP FAILURES	REMOVE AND REPLACE PER 1000 FLIGHT HOURS	MANHOURS/ REMOVE AND REPLACE TASK	FAILURES PER 1000 FLIGHT HOURS	MMH/1000 FLIGHT HOURS
E-3A	(101)	0	5	0	0	2.2	----	------
E-2C	428 (172)	12	562	2	.910	4.90	42.789	.190
S-3A	428	38	1006	16	.669	12.974	17.983	.185
EC-130G,Q	428 (206)	39	896	22	1.013	6.651	23.835	.162
P-3C	428 (203)	72	1017	64	1.009	5.004	15.157	.081
	TOTALS	161	3481	104	Average .9003	Average 7.276	Average 24.941	Average .1545

2.0 (Continued)

Basic Information and Calculations for Failure Rate of 204-51870-5 Wire Harness Assembly

1. Cable Construction - cable is made of AWG #20 and #22 wire, with seven (7) MS27467 type connectors.

2. Connectors used -

   1 ea. MS27467T23B53P. 24 active pins, including 4 shields
   2 ea. MS27467T15B35SA. 27 active pins, including 3 shields
   4 ea. MS27467T11B35S. 6 active pins, including 1 shield
   Insert Material - diallyl phthalate

3. Operating Conditions -

   Temperature - 25°C ambient with no appreciable rise due to current
   Environmental Service Condition - airborne, inhabited transport (A_{IT})
   Connector Mating/Unmating - assume 1-5 cycles (both connect and disconnect) per 1000 hours

4. Connections - crimp, manual, standard quality factor

Calculation of failure rate due to connectors:

From MIL-HDBK-217C, Table 2.11.1-1, "Prediction Procedure for Connectors", the failure rate model for a mated pair of connectors is:

$\lambda_p = \lambda_b(\pi_E x \pi_p x \pi_K)$ failures/10^6 hours, where

λ_b = base failure rate for the part
π_E = factor for environmental service condition
π_p = factor for the number of active pins
π_K = factor for connector mating/unmating cycles

From MIL-HDBK-217C, Table 2.11.1-5, the value for λ_b at 25°C is (by extrapolation) 0.00050 failures per million hours. The π factors in the model have the following values in this instance:

π_E = 5.0 for airborne, inhabited, transport (A_{IT})
π_{p1}= 4.62 for 24 active pins
π_{p2}= 5.11 for 27 active pins from Table 2.11.1-7
π_{p3}= 2.02 for 6 active pins
π_K = 2.0, from Table 2.11.1-8

Then, λ_{p1} = 0.0005(5x4.62x2)x1 for the first connector type listed.
λ_{p1} = 0.023/10^6 hours

λ_{p2} = 0.0005(5x5.11x2)x2 for the two connectors of the second type.
λ_{p2} = 0.051/10^6 hours

λ_{p3} = 0.0005(5x2.02x2)x4 for the four connectors of the third type.
λ_{p3} = 0.040/10^6 hours

$\lambda_p = \lambda_{p1} + \lambda_{p2} + \lambda_{p3}$ = 0.114 failures/10^6 hours

2.0 (Continued)

Calculation of failure rate due to lead connections:

From MIL-HDBK-217C, Page 2.13-1, the failure rate model for an individual connection is:

$\lambda_p = \pi_b(\pi_E \times \pi_T \times \pi_Q)$ failures/10^6 hours, where

λ_b = base failure rate for type of connection
π_E = factor for environmental service condition
π_T = factor for tool type (manual or automated)
π_Q = factor for quality grade employed

From Table 2.13-1, λ_b for the crimp connector is 0.00026 failures/10^6 hours. Values for the π factors are:

π_E = 3.0 (Table 2.13-2, for A_{IT})
π_T = 2.0 (Table 2.13-3, for manual)
π_Q = 1.0 (Table 2.13-4, for manual tools, standard)

Substituting, $\lambda_p = 0.00026(3.0 \times 2.0 \times 1.0) = 0.00156/10^6$

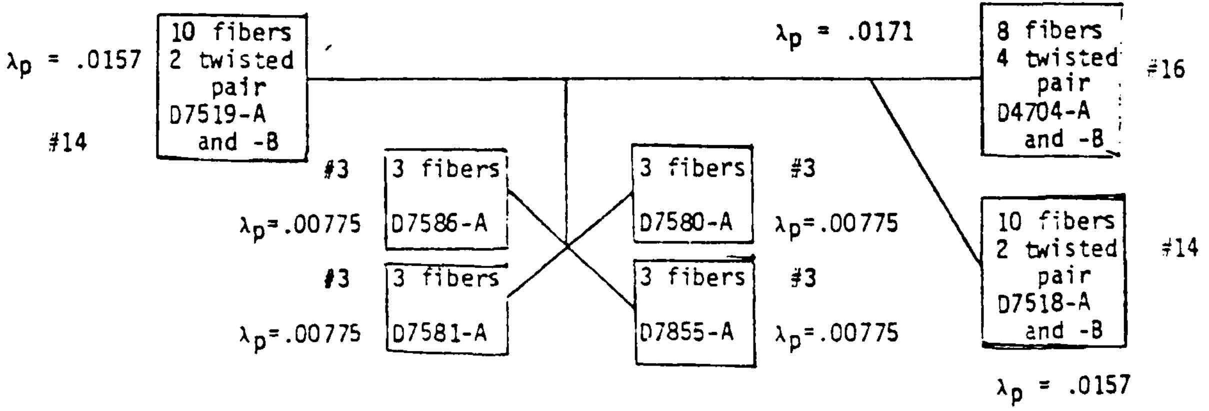
In this cable, there are 102 active pins, so 102 x 0.00156 = 0.159 failures/10^6 hours is the rate due to lead connections. Added to the failure rate due to the seven connectors, the predicted failure rate of the cable is:

$$\lambda_{P(\text{connectors})} + \lambda_{P(\text{crimps})} = (0.114 + 0.159)/10^6 \text{ hours}$$
$$= 0.273 \text{ failures}/10^6 \text{ hours}$$

Failure rate of the lead wires (approximately 0.003/10^9 hours) is considered negligible.

3.0 FIBER OPTICS INTERCONNECT SYSTEM RELIABILITY CALCULATIONS

a. Connectors - λ_p = failures/10^6 hours
Failure Rate = λ_p = 0.0795 failures/10^6 hours



3.0 a. (Continued)

$\lambda_p = \lambda_b (\pi_E \times \pi_p \times \pi_K)$ failures/10^6 hours

$\lambda_b = A_e^{x}$

where $x = \frac{N_T}{T+273} + \left(\frac{T+273}{T_o}\right)^p$

T = operating temperature

= ambient + temperature rise

Insert material B is chosen, which fixes λ_b as a function of operating temperature. In this case with milliamp current, operating temperature equals ambient (temp rise = 0).

Assuming ambient temperature = 25°C

$\lambda_b = .00050$

π_E (environmental service condition)

Assuming A_{IT} (airborne inhabited transport) π_E (Mil-Spec) = 5.0

π_p = multiplier for number of active pins in a connector

Calculations here are based on the assumption that fiber optic connections behave like regular connections.

Number of Contacts	π_p	# of Times
3	1.55	4
14	3.14	2
16	3.42	1

(from Table 2.11.1-7.)

π_K = mating/unmating factor

= 2.0 from Table 2.11.1-8.

$$\lambda_p = .00050[5.0(2.0\ (4x1.55)+(2x3.14)+3.42\ )]$$

4 connectors	2 connectors	1 connector
D7580-A	D7519-A and -B	D4704-A and -B
D7581-A		
D7585-A		
D7586-A		

λ_p = .0795 total failures/10^6 hours

3.0 (Continued)

b. Opto-Electronic Devices

$\lambda_p = \lambda_b \pi_C \pi_E \pi_Q$ failures/10^6 hours

λ_b = base failure rate in failures/10^6 hours
π_C = complexity factor (from tables)
π_E = environmental factor (from table)
π_Q = quality factor (from table)

π_E = selected environment = 2.8

π_Q = 1 (JANTXV Quality)

π_C = 1.5 for a simple single isolator

λ_b = .0028 for hermetic

Assuming S = .5, T_s = 25°C
T_{max} = 125°C hermetic

$\lambda_p = (0.0028)(1.5)(2.8)(1) = .01176$ failures/10^6 hours

c. Lead Connections

$\lambda_p = \lambda_b(\pi_E \times \pi_T \times \pi_Q)$ failures/10^6 hours

λ_b = .00026 for crimped wires
= .0013 for fiber optic welds

π_E = environmental factor = 3.0 Table 2.13-2

π_T = tool type factor = 1 for fibers
= 2 for wires

π_Q = quality factor = 1 for fibers
= 1 for wires

Total fiber ends = 40
Total wire terminations = 16

$$\lambda_p = \underset{\text{wires}}{16(.00026)(3)(2)(1)} + \underset{\text{fibers}}{40(.0013)(3)(1)(1)}$$

$$= .02496 + .15600$$

$$= .18096 \text{ failures}/10^6$$

d. System Failures = (Lead)+(Connector)+(Opto-Electronic) Failures

= .18096 + .0795 + .01176

= .26046 + .01176

= 0.27222 failures/10^6 hours

APPENDIX F

FINAL HARNESS ASSEMBLY DESCRIPTION AND TOOLING

D180-24693-25

HARNESS ASSEMBLY DESCRIPTION & TOOLING

O. R. Mulkey

Boeing Aerospace Company
P.O. Box 3999
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4 June 1980

Final Report for the Period of 16 December 1979 Through 4 June 1980

Phase IV of NOSC Contract N00123-78-C-0193

Prepared For:

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

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3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
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5. TYPE OF REPORT & PERIOD COVERED
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Fiber optics
Fiber optic harness
Fiber optic stand-alone link
Installation procedures
Assembly of fiber optic cables

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

This report describes the materials, processes, tooling, and assembly plan used to fabricate the FO-0004 and FO-0005 fiber optics harness. Particular process steps are referenced to the document series D180-24693-20 through -29 and drawing numbers 180-59000, 180-59004 and 180-59005 which to the extent referenced are considered part of this report.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

1.0 SCOPE

This report covers the details of the assembly procedures, parts, and tooling used in the fabrication of the FO-0004 fiber optics harness as well as those used for the FO-0005 "Single Fiber Harness". The technology for both single fiber and fiber bundle harness is covered for all phases of the assembly. Because the termination and fabrication of conventional wire harnesses is well documented by both the military and industry, details of the processes used in the fabrication of that part of the harnesses not covered.

2.0 REFERENCES

2.1 Introduction

To provide the most flexibility in the use and extraction of the information contained in this report, the technical information and instructions for the various processes are formatted as stand-alone specifications, engineering drawings, and production illustrations. This documentation is then referenced by the "Harness Manufacturing Plan" which details the harness assembly and test. The following documentation therefore forms a part of this report as referenced by the "Harness Manufacturing Plan".

2.2 Data List

Document No.	"Title"/(Information Contained)
1) 180-59000	(The top drawing)
2) 180-59004	(Harness drawing, form board drawing, also includes shop aids package)
3) 180-59004	(Single fiber harness drawing and form board drawing)
4) D180-24693-20	"Preliminary Installation Procedure, Harness General"
Appendix A	(Cable/harness identification)
Appendix B	(Cable/harness fabrication)
Appendix C	(Installation procedures)
Appendix D	(Marking of F.O. cabling)
5) D180-24693-21	"Fabrication and Installation Procedures, Fiber Optics Rack Integration Harness" (Fabrication and installation procedures)
6) D180-24693-22	"In-Process Testing of Fiber Optic Cables and Harnesses"
7) D180-24693-23	(Maintenance procedures)
8) D180-24693-26	(Connector assembly specification)
9) D180-24693-27	(Fiber optic cable termination specification)

3.0 CONTENTS

4.0 FABRICATION PROCEDURES

4.1 Introduction

This section details the specific steps required in the fabrication of the harness and is intended to be extracted as a planning order to the production shop as a basis for drawing major materials.

4.2 Manufacturing Plan

(See Attached Sheets)

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-25
SCALE	REV	SHEET 2

TR/ S | PART NUMBER 180-59004-1

CH | PROJ F-0 | JOB NUMBER | RV A | FOI AC | PAGE 1-49

DI 4002 9820 ORIG. 3/71

BOEING
INTEGRATED RECORD SYSTEM
DRAWING INDEX
FIRST PAGE

LN | FT

I | IN J | M 9 | SERIAL 001-020 | UNIT | SCHED CODE | ST | COM | A | I | REL DT

END ROUT EP3 3 | MATL CODE | PROC NO

ISSR 53490 | CC 5 | WO 7E4?? | SUB 3622 | CA SER | EJN | ERN | EWA

BUDGET AP | SHOP | BUDG | SHOP | BUDG | SHOP | BUDG | SHOP | BUDG

LOT/OR	EFFECTIVITY	CC	WO	SUB	CA SER	QTY
DK 1					0001AC400	20

D | ORDERED BY | DATE ORD | PLN DATE | TOT QTY 20

MATERIAL SPECIFICATIONS

PART NUMBER 180-59004-1 | OPP | OR T | FILE | REL | PCR

IDENTITY | MODEL | EFFECTIVITY S/N 001 - 020

NOMENCLATURE
CABLE ASSY - FIBRE OPTIC

GR CODE DK | NW PL DT 3-9-80 | RV PL DT | REPLACES

PLAN BY LUNZ | PLNG APPR J Lunz | ~~QC APPR~~ T Wright | CUST APPR

REV BY LUNZ | PLNG APPR J Lunz | QC APPR E Arnold | CUST APPR N/R

STOCK SIZE

DRAWING/DOCUMENT	DCN ADCN ADRN	SHEET	CHANGE	SUP/UER SER	PART NUMBER	QC APPR	QC DATE
1ST SHOP 2-3352							
REPLINE AUTH PER MEMO 2-3622-LFB-479							
SERIALIZATION REQD							
FUNCTIONAL TEST REQD							

PAGE | JOB NUMBER | RV | PART NUMBER | INSPECT | INSP | REC | CUST

TRANS | PART NUMBER 18 59004-1

CH | PROJ F/O | JOB NUMBER | RV A | FORM 1 | PAGE 2

PLN LUNZ | QC | SERIAL NO IR TH | DATE 3-4-80

CUST APPR

D1 4002 6030 ORIG. 3/71

BOEING
INTEGRATED RECORD SYSTEM
DRAWING INDEX
SECOND PAGE

LN	T	DRAWING/DOCUMENT	DCN ADCN ADRN	SHEET	CHANGE	SUP/UER SER	PART NUMBER	QC APPR	QC DATE
04									
05									
06									
07		180-59004	NEW, 21	BK	REDLINE				
08									
09	A	EBP 180-59004	NEW	1	REDLINE				
10									
11	A	EBP 180-59004	NEW	2	REDLINE				
12									
13									
14									
15		D180-24693-20	NEW	BK	REDLINE				
16									
17									
18									
19		D180-24693-21	NEW	BK	REDLINE				
20									
21									
22									
23		D180-24693-22	NEW	BK	REDLINE				
24									
25									
26									
27									
28		D180-24693-26	NEW	BK	REDLINE				
29									
30									
31									
32		D180-24693-27	NEW	BK	REDLINE				
33									
34									
35	A	D180-25451-2	NOT RELEASED	BK					
36		(FUNCT TEST PRO)							
37									
38									
39									
40									
41									
42									
43									
44									

PAGE	JOB NUMBER	RV	PART NUMBER		INSPECT	INSP	REC	CUST

PART NUMBER 13C 59004-1

PLNT ..UNZ

QC APP.

123 39

SERIAL NO

FR

TH

P 3

DATE 1-80

PROJ F/O

JOB NUMBER

RV A

FORM AF

D1 4802 8840 ORIG. 3/71

BOEING
INTEGRATED RECORD SYSTEM
PARTS AND TEST EQUIPMENT LIST

CUST APPR

PCA

PART NUMBER	NOMENCLATURE	PROC	QTY	SERIAL NO LOT ID NO TEST INST SER	FROM DWG OR MODEL NO	INST LOC	UER OR SUPPL SER NO	INSP STMP	DATE	CERT EXPR DATE
GALITE 1020-200MS	FIBER BUNDLE CABLE	BPP	500 FT							
GALITE 5020 JT	SINGLE FIBER CABLE		60 FT							
M27500-22TGU00	WIRE		150 FT							
M22759/18-22-9	WIRE		5 FT							
HUGHES C210020 P03BN	CONNECTOR		3							
HUGHES 1093827-S	CONTACT		34							
HUGHES 1093201-09051105	CONTACT		6							

NOTES

PAGE	JOB NUMBER	RV	PART NUMBER		INSPECT	INSP REC	CUST

TRANS PART NUMBER 18C 59004-1 | CH | PROJ E/O | JOB NUMBER | RV A | FORM AF | PAGE 2

PLNR LUNZ | OC. | L21 | SERIAL NO FR TH | P | DATE APR 28 | D1 4802 8840 ORIG. 3/71

BOEING
INTEGRATED RECORD SYSTEM
PARTS AND TEST EQUIPMENT LIST

CUST APPR

PCA

ET	PART NUMBER	NOMENCLATURE	PROC	QTY	SERIAL NO LOT ID NO TEST INST SER	FROM DWG OR MODEL NO	INST LOC	UER OR SU SER NO	IN MP	DATE	CERT EXPR DATE
	HUGHES C21P1620A0	CONTACT	BPD	20							
A	HUGHES 1023995-1Ø ①	BACKSHELL	BPD	3							
A	HUGHES 1127650-1Ø ②	CONNECTOR	BPD	4							
	BIPAX	EPOXY POTTING COMPOUND	BPD	(AR)							
	THERMOFIT	HEAT SHRINK SLEEVING	95	(AR)							

NOTES

① -2Ø, -3Ø OR -4Ø OPT TO -1Ø

② -2Ø, -3Ø OR -4Ø OPT TO -1Ø

PAGE	JOB NUMBER	RV	PART NUMBER		INSPECT	INSP REC	CUST

TRANS | PA. UMBER 180-54004-1 | CH | PROJ F-O | JOB NUMBER | RV | FO. AU | PAGE 5

IN | FT | PLN BY LUNZ | QC APPR T. Wright | PLN DATE 3-4-80 | X-6365 ORIG. 1/70

BOEING
INTEGRATED RECORD SYSTEM

CUST APPR | COMBINED FORM | SECOND PAGE

ORGN	PART NO + SCH	OP SEQ	ENGR CONFG FWC	SET	UP	NOMENCLATURE RUN	TOOL	PROC	QTY	LOT ID/DWG SERIAL NO	INSP	UER/SU	SHOP	INSP	DATE	QTY
			NOTE: OBSERVE FACILITY & PERSONNEL RESTRICTIONS PER D180-24693-26													
2-3352		020	L/O CABLES ON FORM BOARD & CUT TO LENGTH. NOTE; ALLOW 5% OVERLENGTH OR 6", WHICHEVER IS GREATER. ASSURE THAT LENGTHS ARE SUFFICIENT FOR (3) TERMINATION ATTEMPTS. RECORD START-STOP TIMES													
			S/N			HRS										
			001													
			002													
			003													
			004													
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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7519-A									
2-3352		040	TERMINATE OPTICAL CONDUCTORS PER DWG:									
			INSTALL THERMOFIT ID & CRIMP SLEEVES.									
			STRIP OUTER JACKET.									
			INSTALL CONTACTS & POT WITH BIPAX EPOXY,									
			CURE AT ROOM TEMP FOR 12 HRS									
			IN PROCESS CONTINUITY TEST PER D180-24695-22									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 10 & 11									
			S/N		HRS							
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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

CUST APPR

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7519-A									
2-3352		060	POLISH CONTACTS PER DWG & D180-24693-27									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 10 & 11									
			S/N		HRS							
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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	VER/SU	SHOP	INSP	DATE	QTY
			D75?9-A									
2-3358		080	TERMINATE ELECTRICAL CONDUCTORS									
			PER DWG B									
			RECORD TOTAL HOURS									
			RECORD BUYOFFS ON P. 10 & 11									
			S/N		HRS							
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CUST APPR

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7519-A									
2-3352		100	ASSEMBLE CONNECTORS PER DWG &									
			D170-84693-26.									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 10&11									
			S/N		HRS							
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BOEING
INTEGRATED RECORD SYSTEM

ITEM NO.	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		GRIND & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONTINUITY OK TO CLOSE		ASSEMBLE CONNECTOR	
D7519-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	QC
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PLN NZ	QC APPR	SERIAL NO. FR TH	DATE	BOEING INTEGRATED RECORD SYSTEM
CUST APPR				

ITEM NO. D7519-A	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		GRIND & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22 GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONT[illegible] OK TO CLOSE		ASSEMBLE CONNECTOR	
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CUST APPR

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7516-A									
2-3352		120	TERMINATE OPTICAL CONDUCTORS PER DWG:									
			INSTALL THERMOFIT ID & CRIMP SLEEVES.									
			STRIP OUTER JACKET.									
			INSTALL CONTACTS & POT WITH BIPAX EPOXY,									
			CURE AT ROOM TEMP FOR 12 HRS									
			IN PROCESS CONTINUITY TEST PER D180-24695-22									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 16 & 17									
			S/N		HRS							
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PAGE	JOB NUMBER	RV	PART NUMBER		INSPECT	INSP	REC	CUST

PART NUMBER 100- 004-1

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CUST APPR

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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			OPERATIONS									
			D7518-A									
2-3352		140	POLISH CONTACTS PER DWG & D180-24693-27									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 16 & 17									
			S/N		HRS							
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PAGE	JOB NUMBER	RV	PART NUMBER		INSPECT	INSP	REC	CUST

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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7518-A									
2-3357		160	TERMINATE ELECTRICAL CONDUCTORS PER DWG B RECORD TOTAL HOURS RECORD BUYOFFS ON P. 16 & 17									
			S/N		HRS							
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CUST APPR

BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	VER/SU	SHOP	INSP	DATE	QTY
			D751B-A									
2-3352		180	ASSEMBLE CONNECTORS PER DWG &									
			D190-24693-26.									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P.16 & 17									
			S/N		HRS							
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		190	QA INSPECT PRIOR OPER									

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CUST APPR					RV A	PAGE 16

BOEING
INTEGRATED RECORD SYSTEM

ITEM NO.	INSTALL IP & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		GRIND & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONTINUITY OK TO CLOSE		ASSEMBLE CONNECTOR	
D7518-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	QC
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BOEING
INTEGRATED RECORD SYSTEM

ITEM NO.	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		CRIMP & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONTINUITY OK TO CLOSE		ASSEMBLE CONNECTOR	
D7518-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	QC
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PAGE	JOB NUMBER	RV	PART NUMBER		INSPECT	INSP	REC	CUST

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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

CUST APPR

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D4709-A									
2-3352		200	TERMINATE OPTICAL CONDUCTORS PER DWG:									
			INSTALL THERMOFIT ID & CRIMP SLEEVES.									
			STRIP OUTER JACKET.									
			INSTALL CONTACTS & POT WITH BIPAX EPOXY,									
			CURE AT ROOM TEMP FOR 12 HRS									
			IN PROCESS CONTINUITY TEST PER D180-24695-22									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 22 & 23									
			S/N		HRS							
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CUST APPR

BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D4704-A									
2-3352		220	POLISH CONTACTS PER DWG & D180-24693-27									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 22 & 25									
			S/N		HRS							
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PAGE	JOB NUMBER	RV	PART NUMBER		INSPECT	INSP	REC	CUST

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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D4704-A									
2-3352		240	TERMINATE ELECTRICAL CONDUCTORS									
			PER DWG B▷									
			RECORD TOTAL HOURS									
			RECORD BUYOFFS ON P.22 & 23									
			S/N		HRS							
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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D4704-A									
2-3352		260	ASSEMBLE CONNECTORS PER DWG & D180-24693-26: RECORD TOTAL HRS RECORD BUYOFFS ON P.22 & 23									
			S/N		HRS							
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DATE
MAR 23 1980

CUST APPR

BOEING
INTEGRATED RECORD SYSTEM

ITEM NO.	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		CRIMP & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22 GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONT [illegible] OK TO CLOSE		ASSEMBLE CONNECTOR	
D4704-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	Q
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BOEING
INTEGRATED RECORD SYSTEM

ITEM NO.	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		GRIND & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONTINUITY OK TO CLOSE		ASSEMBLE CONNECTOR	
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SERIAL NO FR TH

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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

CUST APPR

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			DT580-A									
2-3352		280	TERMINATE OPTICAL CONDUCTORS PER DWG:									
			INSTALL THERMOFIT ID & CRIMP SLEEVES.									
			STRIP OUTER JACKET.									
			INSTALL CONTACTS & POT WITH BIPAX EPOXY,									
			CURE AT ROOM TEMP FOR 12 HRS									
			IN PROCESS CONTINUITY TEST PER D180-24695-22									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 27 & 28									
			S/N		HRS							
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CUST APPR

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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7580-A									
2-3356		300	POLISH CONTACTS PER DWG & D180-24693-27									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P.27 & 28									
			S/N		HRS							
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			& OK TO CLOSE.									

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QC APPR

SERIAL NO FR TH

PLN DATE APR 23

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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

CUST APPR

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATF	QTY
			D7480-A									
2-3352		320	ASSEMBLE CONNECTORS PER DWG & D190-24693-26. RECORD TOTAL HRS RECORD BUYOFFS ON P. 27 & 28									
			S/N		HRS							
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QC APPR

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TH

DATE APR 1980 23

CUST APPR

BOEING
INTEGRATED RECORD SYSTEM

ITEM NO.	INSTALL IP & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		GRIND & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONTINUITY OK TO CLOSE		ASSEMBLE CONNECTOR	
D7580-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	QC
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BOEING
INTEGRATED RECORD SYSTEM

CUST APPR

ITEM NO.	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		CRIMP & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONT[illegible] OK TO CLOSE		ASSEMBLE CONNECTOR	
07580-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	QC
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CUST APPR

BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7581-A									
2-3352		340	TERMINATE OPTICAL CONDUCTORS PER DWG:									
			INSTALL THERMOFIT ID & CRIMP SLEEVES.									
			STRIP OUTER JACKET.									
			INSTALL CONTACTS & POT WITH BIPAX EPOXY,									
			CURE AT ROOM TEMP FOR 12 HRS									
			IN PROCESS CONTINUITY TEST PER D180-24695-22									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 32 & 33									
			S/N		HRS							
			001									
			002									
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		350	QA INSPECT PRIOR OPER									

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CUST APPR

BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	VER/SH	SHOP	INSP	DATE	QTY
			D7531-A									
2-3352		360	POLISH CONTACTS PER DWG & D180-24693-27									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 32 & 33									
			S/N		HRS							
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		370	QA INSPECT PRIOR OPER, VISUAL ONLY									
			& OK TO CLOSE.									

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CUST APPR

BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7581-A									
2-3352		390	ASSEMBLE CONNECTORS PER DWG & D180-24693-26:									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P.32 & 33									
			S/N		HRS							
			001									
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		390	QA INSPECT PRIOR OPER									

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INTEGRATED RECORD SYSTEM

PART 501-1

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DATE 23

CUST APPR

ITEM NO.	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		CRIMP & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22 GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONTINUITY OK TO CLOSE		ASSEMBLE CONNECTOR	
D7591-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	QC
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BOEING
INTEGRATED RECORD SYSTEM

ITEM NO.	INSTALL D & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		GRIND & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONTINUITY OK TO CLOSE		ASSEMBLE CONNECTOR	
D7581-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	Q
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CUST APPR
SERIAL NO
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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7855-A									
2-3356		400	TERMINATE OPTICAL CONDUCTORS PER DWG:									
			INSTALL THERMOFIT ID & CRIMP SLEEVES.									
			STRIP OUTER JACKET.									
			INSTALL CONTACTS & POT WITH BIPAX EPOXY,									
			CURE AT ROOM TEMP FOR 12 HRS									
			IN PROCESS CONTINUITY TEST PER D180-24695-22									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 37 & 38									
			S/N		HRS							
			001									
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AIRBORNE-FIBER OPTICS MANUFACTURING TECHNOLOGY, AIRCRAFT INSTAL--ETC(U)
AUG 80 G KOSMOS, R A GREENWELL   N00123-78-C-0193
UNCLASSIFIED   NOSC-TR-591   NL

3 OF 5
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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7855-A									
2-3352		420	POLISH CONTACTS PER DWG & D180-24693-27									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 37 & 38									
			S/N		HRS							
			001									
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			& OK TO CLOSE.									

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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

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OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7855-A									
2-3352		440	ASSEMBLE CONNECTORS PER DWG &									
			D180-24698-26.									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P.37 & 38									
			S/N		HRS							
			001									
			002									
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		450	QA INSPECT PRIOR OPER									

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BOEING
INTEGRATED RECORD SYSTEM

CUST APPR

ITEM NO.	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		CRIMP & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22 GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONT[illegible] OK TO CLOSE		ASSEMBLE CONNECTOR	
P7856-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	QC
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QC APPR

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BOEING
INTEGRATED RECORD SYSTEM

ITEM NO.	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		GRIND & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONTINUITY OK TO CLOSE		ASSEMBLE CONNECTOR	
D7856-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	QC
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CUST APPR

BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7956-A									
2-3352		460	TERMINATE OPTICAL CONDUCTORS PER DWG:									
			INSTALL THERMOFIT ID & CRIMP SLEEVES.									
			STRIP OUTER JACKET.									
			INSTALL CONTACTS & POT WITH BIPAX EPOXY,									
			CURE AT ROOM TEMP FOR 12 HRS									
			IN PROCESS CONTINUITY TEST PER D180-24695-22									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 42 & 43									
			S/N		HRS							
			001									
			002									
			003									
			004									
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		470	QA INSPECT PRIOR OPER									

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BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

CUST APPR

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATE	QTY
			D7856-A									
2-3352		480	POLISH CONTACTS PER DWG & D180-24693-27									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P. 42 & 43									
			S/N		HRS							
			001									
			002									
			003									
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		490	QA INSPECT PRIOR OPER, VISUAL ONLY									
			& OK TO CLOSE.									

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FR
TH

PLN DATE

BOEING
INTEGRATED RECORD SYSTEM
PROCESSING

OPERATIONS

ORGN	SCH	OP SEQ	FWC	SET UP	RUN	TOOL	INSP	UER/SU	SHOP	INSP	DATF	QTY
			D7356-A									
-3352		500	ASSEMBLE CONNECTORS PER DWG &									
			D180-24693-26.									
			RECORD TOTAL HRS									
			RECORD BUYOFFS ON P42 & 43									
			S/N		HRS							
			001									
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		510	QA INSPECT PRIOR OPER									

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FR
TH

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CUST APPR

ITEM NO.	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		GRIND & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONTINUITY OK TO CLOSE		ASSEMBLE CONNECTOR	
P785C-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	Q
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ITEM NO.	INSTALL ID & CRIMP SLEEVES. STRIP JACKET OK TO POT		INSTALL CONNECTOR PINS & POT		GRIND & POLISH TERMINALS		CRIMP SLEEVE		STRIP 22GA WIRE		TERMINATE 22 GA WIRE		VISUAL & CONTINUITY OK TO CLOSE		ASSEMBLE CONNECTOR	
D7056-A	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QC	SHOP	QA	SHOP	QC	SHOP	QC	SHOP	Q
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	ORGN	PART NO + ENGR CONFG				NOMENCLATURE		PROC	QTY	LOT ID DWG	INSP	VER. SU	SHOP	INSP	DATE	QTY
03																
04		SCH	OP SEQ	FWC	SET UP	RUN	TOOL			SERIAL NO						
05																
06																
07																
08																
09			520	QA VERIFY CABLE DIMENSIONS PER DWG												
10				& RECORD OVERALL LENGTH												
11																
12																
13				S/N		LENGTH										
14																
15				001												
16				002												
17				003												
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TRANS | PART NUMBER 18c 59004-1

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ORGN	PART NO / ENGR CONFG SCH / OP SEQ	FWC	SET UP	NOMENCLATURE RUN / TOOL	PROC	QTY	LOT ID DWG SERIAL NO	INSP	UER SU	SHOP	INSP	DATE	QTY
	530	ID CABLE ASSY PER DWG NOTE 1 & D180-24693-20 & -21 :											
		INSTALL 1 INCH WIDE RED TAPE ID APPROX 2 INCH FROM EACH CONNECTOR & AT 5 FT INTERVALS ALONG BUNDLE											
		INSTALL MATE WITH , ASSY & PL MARKER PER D180-24693-21, PARA 4.0.2											
	535	QA INSPECT PRIOR OPER											

INSPECT | INSP | REC | CUST

TRAN' | PA NUMBER 180-59004-1 | CH A | PROJ F/O | JOB NUMBER | RV A | FOR AB | AGE 46

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INTEGRATED RECORD SYSTEM
COMBINED FORM
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CUST APPR

ORGN	PART NO SCH	OP SEQ	ENGR CONFG FWC	SET UP	NOMENCLATURE RUN	TOOL	PROC	QTY	LOT ID/DWG SERIAL NO	INSP	UER/SU	SHOP	INSP	DATE	QTY
2-3352		540	FUNCTIONAL TEST PER DWG & D180-24693-22												
			FOR OPTICAL ATTENUATION.												
			SINGLE FIBER : MAX ATTENUATION 3dB BELOW												
			10 METER REFERENCE CABLE.												
			FIBER BUNDLE : MAX ATTENUATION 3dB ± .01												
			dB/INCH BELOW 10 METER REFERENCE CABLE												
			RECORD ATTENUATION OF EACH OPTICAL CONDUCTOR.												
			RECORD TOTAL HRS												
			S/N		HRS										
			001												
			002												
			003												
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BOEING
INTEGRATED RECORD SYSTEM

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JOB NUMBER

RV

FORM AB

SH: 7

CUST APPR

ORGN	PART NO SCH OP SEQ	ENGR CONFG FWC	SET UP	NOMENCLATURE RUN	TOOL	PROC	QTY	LOT ID DWG SERIAL NO	INSP	UER, SU	SHOP	INSP	DATE	QTY
	CONNECTOR:	CONDUCTOR:			ATTENUATION (DB)									
	D7519-A:													
		808												
		809												
		810												
		811												
		812												
		813												
		814												
		815												
		816												
		817												

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TRANS | PART NUMBER 18C 9004-1

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SECOND PAGE

CUST APPR

ORGN	PART NO / SCH	OP SEQ	ENGR CONFG FWC	SET UP	NOMENCLATURE RUN	TOOL	PROC	QTY	LOT ID DWG SERIAL NO	INSP	VER. SU	SHOP	INSP	DATE	QTY
	CONNECTOR:		CONDUCTOR:			ATTENUATION (DB)									
	D7518-A:														
			B01												
			B02												
			B03												
			B04												
			301												
			302												
			303												
			B05												
			B06												
			B07												
		550	QA WITNESS PRIOR OPER & VERIFY TEST EQUIP CAL/CERT VALID AT TIME OF TEST.												
			(COMPLETES -1 PER DWG)												
EPS 3			RECORD & STORE. ROUTE COMP ORDER TO QA RECORDS												

INSPECT	INSP	REC	CUST

TRANS | PART NUMBER 18C 9004-1 | CH | PROJ 56 | JOB NUMBER | RV | FORM A | PAGE 4

PLNG LUNZ | QC APPR R Wright | SERIAL NO FR TH | PL. DATE 3-4-80

CUST APPR

D3 4802 GR70 REV 3/69

BOEING
INTEGRATED RECORD SYSTEM
LOT QUANTITY SERIAL NO RECORD

SERIAL NO	ACCP	UER	INSP	SERIAL NO	ACCP	UER	INSP	SERIAL NO	ACCP	UER	INSP
001				011							
002				012							
003				013							
004				014							
005				015							
006				016							
007				017							
008				018							
009				019							
010				020							

PAGE	JOB NUMBER	RV	PART NUMBER		INSPECT	INSP REC	CUST

APPLICATION

PART NUMBER	NEXT ASSY	USED ON	EFFECTIVITY	REV

DIMENSIONS ARE IN INCHES EXCEPT AS NOTED

CONTR N00123-78-C-0193

DR OR MULKEY 2/15/80

CHK

STRUCT

DWG ORIG BY

ENGR

5/29/80

GR

PROJ

CHANGE NO.

THE **BOEING** COMPANY

CORPORATE OFFICES SEATTLE, WASHINGTON 98124

FIBER OPTIC

RACK INTEGRATION HARNESS

SIZE A

CODE IDENT NO. 81205

180-59004

SCALE NONE

REV

SHEET 1

21 4000 3700 REV. 4/74

J15-047

ACTIVE SHEET RECORD

SHEET NO.	REV LTR	ADDED SHEETS				SHEET NO.	REV LTR	ADDED SHEETS			
		SHEET NO.	REV LTR	SHEET NO.	REV LTR			SHEET NO.	REV LTR	SHEET NO.	REV LTR
1											
2											
3											
4											
5											
6											
7											
8											
9											
9A											
10											
11											
12											
13											
14											
15											

SIZE A	CODE IDENT NO. 81205	180-59004
SCALE NONE	REV	SHEET 2

DI 4801 3840 REV 5/73

13-047

REVISION			
LTR	DESCRIPTION	DATE	APPROVAL

SIZE A	CODE IDENT NO. 81205	180-59004
SCALE NONE	REV	SHEET 3

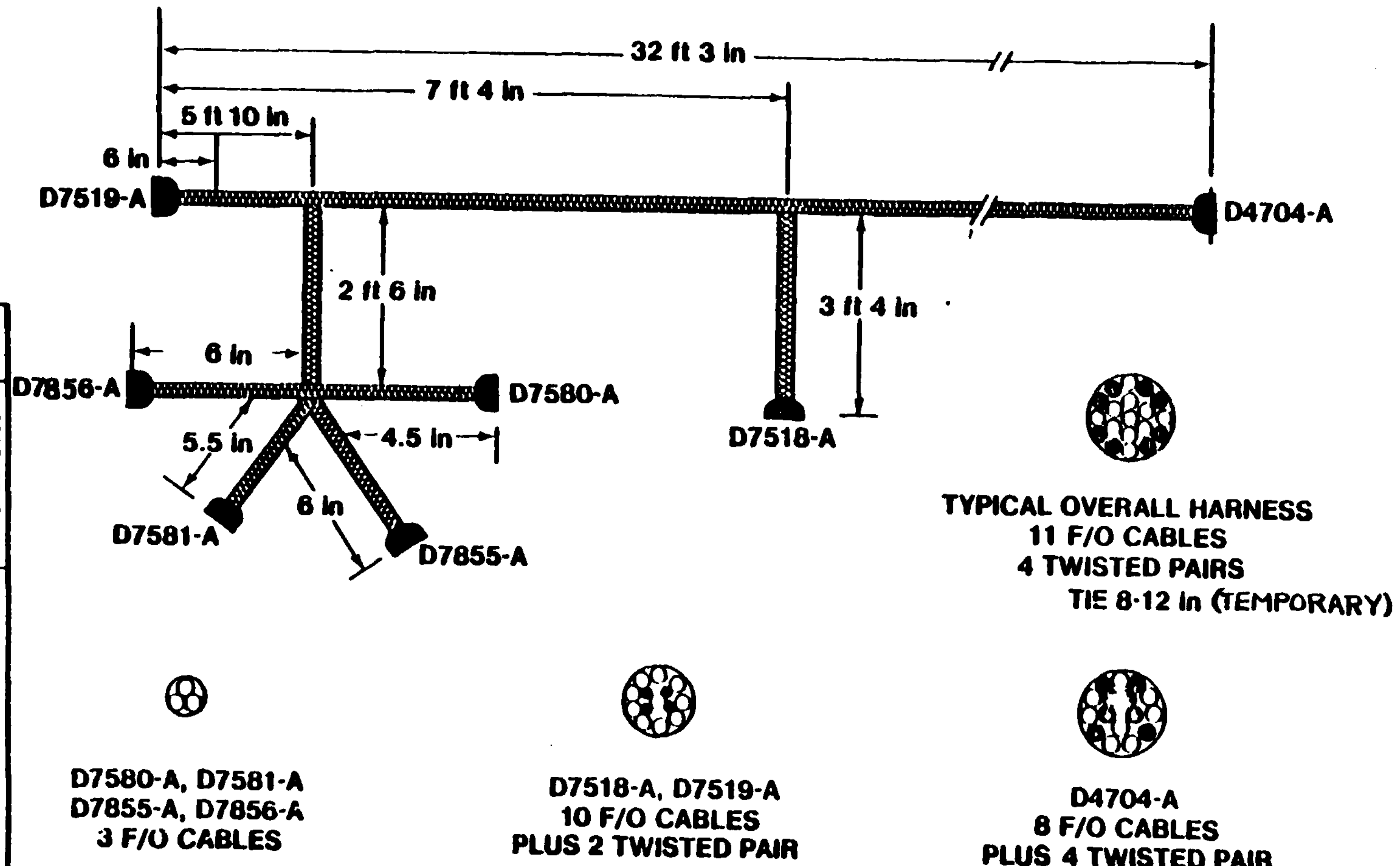
D1 4315 8006 REV. 9/73

J15-047

QTY REQD	QTY REQD	PARTS LIST						
	–1	FIND NO.	PART OR IDENTIFYING NUMBER	NOMENCLATURE OR DESCRIPTION	SH NO.	CODE IDENT NO.	NOTES	REV LTR
	500 FT		GALITE 1000-200MS	FIBER BUNDLE CABLE				
	60 FT		GALITE 5020	SINGLE FIBER CABLE				
	150 FT		M 27500 – 22TGU 00	22 GA WIRE, TWISTED PAIR				
	5 FT		M 22759/ 18-22-9	22 GA. WIRE				
	3		HUGHES C210020 P03BN	CONNECTOR, PLUG, 20 CONTACT				
	34		HUGHES -1093827-S	CONTACT, FIBER BUNDLE				
	6		HUGHES 1093201 080S1105	CONTACT, SINGLE FIBER				
	20		HUGHES C21P1620A0	CONTACT, WIRE				
	3		HUGHES 1093995-1S	BACKSHELL ASSY			11	
	4		HUGHES 1127650-1S	CONNECTOR ASSY, 4 CONTACT PLUG			12	
			–1	CABLE ASSY			1	

SIZE	CODE IDENT NO.	DWG NO.
A	81205	180-59004
SCALE NONE	REV	SHEET 4

Harness



TOLERANCES +16.0 in
−0.0 in

SIZE A	CODE IDENT NO. 81205	180-59004
SCALE NONE	REV	SHEET 5

USE FOR DRAWINGS AND HAND PRINTED MATERIAL ONLY - NO TYPEWRITTEN MATERIAL

CABLE PREPARATION ORDER

FROM					DATA					TO	
EQUIP.	TERM	LUG	SPL	NOTE	CABLE NO.	TYPE	MRK	INCH	FAM	EQUIP.	TERM
D7518A	1				B01	FB		432		D4704PA	1
D7518A	2				B02	FB		432		D4704PA	2
D7518A	3			YD	201	JG		432	A	D4704PA	3
D7518A	4			YD	202	JG		432	A	D4704PA	4
D7518A	5			YD	203	JG		432	B	D4704PA	5
D7518A	6			YD	204	JG		432	B	D4704PA	6
D7518A	7				B03	FB		432		D4704PA	7
D7518A	8				B04	FB		432		D4704PA	8
D7518A	9			YJ	001-22	IE		3		D7518A	10
D7518A	11				S01	SF		156		D7855A	1
D7518A	12				S02	SF		156		D7855A	2
D7518A	13				S03	SF		156		D7855A	3
D7518A	14				B05	FB		156		D7580A	3
D7518A	15				B06	FB		156		D7580A	2
D7518A	16				B07	FB		156		D7580A	1
D7518A	17			YJ	002-22	IE		3		D7518A	18
D7519A	1				B08	FB		444		D4704PA	9
D7519A	2				B09	FB		444		D4704PA	10
D7519A	3			YD	205	JG		444	C	D4704PA	11
D7519A	4			YD	206	JG		444	C	D4704PA	12
D7519A	5			YD	207	JG		444	D	D4704PA	13
D7519A	6			YD	208	JG		444	D	D4704PA	14
D7519A	7				B10	FB		444		D4704PA	15
D7519A	8				B11	FB		444		D4704PA	16
D7519A	9			YJ	003-22	IE		3		D7519A	10
D7519A	11				B12	FB		108		D7856A	1
D7519A	12				B13	FB		108		D7856A	2
D7519A	13				B14	FB		108		D7856A	3
D7519A	14				B15	FB		108		D7581A	3
D7519A	15				B16	FB		108		D7581A	2
D7519A	16				B17	FB		108		D7581A	1
D7519A	17			YJ	004-22	IE		3		D7519A	18

ASSEMBLY CONNECTION LIST

MODEL
AWACS

TYPE

FB: FILAMENT BUNCH
IE SINGLE 22 WIRE
SF: SINGLE FILAMENT
JG TWISTED PA

SIZE	CODE IDENT NO.		
A	81205	180-59004	
SCALE NONE	REV		SHEET 6

D1 4310 2001 REV. 1/74

J15-047

REVISION

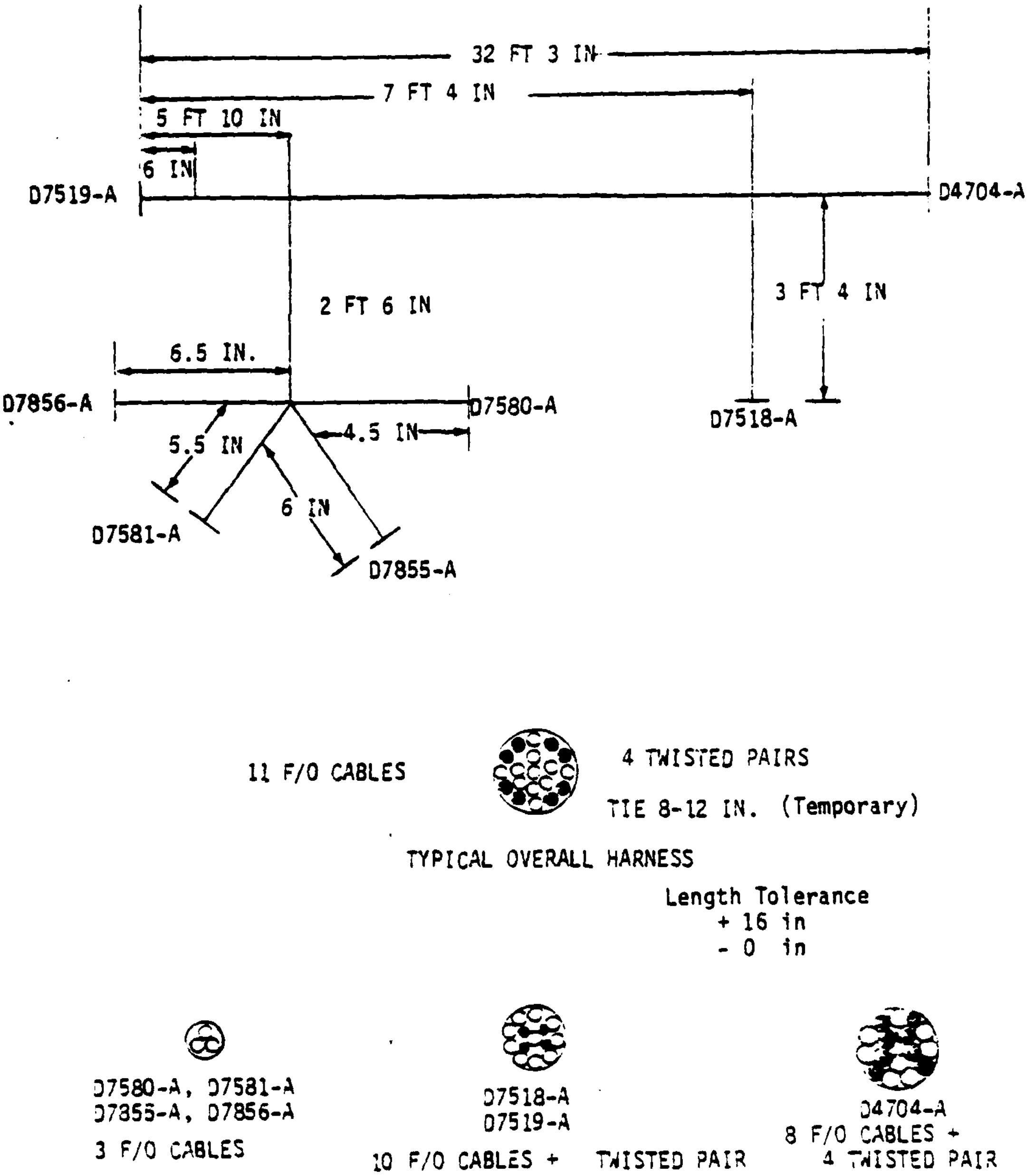
LTR	DESCRIPTION	DATE	APPROVAL

YJ CUT WIRE TO 3 +/- .1 INCHES AND INSTALL CONTACTS. INSERT BOTH CONTACTS INTO CONNECTOR.

YD MAINTAIN TWIST OF THIS FAMILY TO WITHIN / 1/2 INCH OF CONNECTOR INSERT.

SIZE A	CODE IDENT NO. 81205	180-59004
SCALE NONE		SHEET 7

D1 4315 8000 ORIG. 3/71



180-59004 AND 180-59005 HARNESS, WITH FIBER OPTICS

FIGURE 6.0.1

SIZE	CODE IDENT NO.	
A	81205	180-59004 —
SCALE	REV	SHEET 8

REVISION			
LTR	DESCRIPTION	DATE	APPROVAL

MATE WITH DATA

CONNECTOR	MATES WITH
D7518A	PLUG - B169 J1
D7519A	PLUG - B171 J1
D4704PA	PLUG - E11
D7855A	RECP-OPER HDST-MIC
D7580A	RECP-OBSV HDST-MIC
D7856A	RECP-OPER HDST-MIC
D7581A	RECP-OBSV HDST-MIC

SIZE	CODE IDENT NO.	
A	81205	180-59004
SCALE NONE		SHEET 8A

D1 4315 0000 ORIG. 3/71

HARNESS ASSEMBLY NOTES

1) Install one-inch-wide red tape on bundle near each connector and at 5' ± 3" intervals along bundle and identify per D180-24693-20 and -21.

2) Terminate cables per D180-24693-27.

3) Assemble connectors per D180-24693-26.

4) Repair harness per D180-24693-23.

5) Test per D180-24693-22. Tool BCX 230969 may be used for photographs. See D180-25451-2

   TEST LIMITS

   Single Fiber Channel -- 3dB (50%) maximum below single fiber reference cable 10 meters long. Terminated using identical contacts and cable.

   Fiber Bundle Channel -- 3dB (50%) maximum below fiber bundle reference cable 10 meters long terminated using identical contacts and cable plus .01dB/inch allowance or decrease for length difference (Note 10M = 394 in.). Broken fiber limit - 15% or 35 fibers maximum (170 good fibers are acceptable).

6) Braid outer jacket (white nomex) per 204-10900-1.

7) Lay out harness using form board drawing FB180-59004-1 and -2.

   VISUAL INSPECTION CRITERIA

   Surface Finish -- Fiber ends shall appear smooth and flat and free of major scratches, chips or epoxy smears. Small imperfections that do not degrade the insertion loss below test limits are acceptable (Insertion loss test may be done out of sequence for this verification) for crimped terminations inspect per D180-24693-27 Par. 6.3.

8) Crimp 22 GA wire using tool called in D180-24693-27.1 strip wire .25 to .30 inch using 22 ga Stripmaster tool.

9) All cable ends may be cut and terminated 6 inches longer than the drawing dimensions so that if broken they may be reused in another harness.

10) No Cal Cert is required on crimp, insertion and removal tools.

11) Hughes 1093995-1S, 2S, 3S and 4S are identical and may be used interchangeably.

12) Hughes 1127650 1S-4S are identical and may be used interchangeably.

13) Anodization scrapes or slight deformation of the crimp on the crimp sleeves and ferrules is acceptable.

14) Seal plugs not required on connectors on the 1st 21 units.

SIZE	CODE IDENT. NO.		
A	81205	180-59004	
SCALE		REV	SHEET 9

15) Hollow plugs may be used in lieu of the solid plugs on back shell.

16) When using crimp tool No. M22520/1-01 (Daniels) use Select No. 5 with setting 4. (Contacts No.'s C21P1620** & C2151620**)

17) Spare (unwired) contacts of the 1093995 connector may be filled with either pin or socket (used and potted) type. This case refers only to the four channel connectors. No sealing plugs are required for the spare contact.

18) File metal burrs from retaining clamp (PN 1127644-1) where necessary when installing crimp ferrules (PN 1127764).

19) Add a 3" ± .5" length of heat shrink (BAC T63A) on Hughes 1127650 Is/cable interface after braid operation.

20) Shop aids per D180-24693-29 may be used for assembly and test.

SIZE A	CODE IDENT. NO. 81205	180-59004
SCALE	REV	SHEET 9A

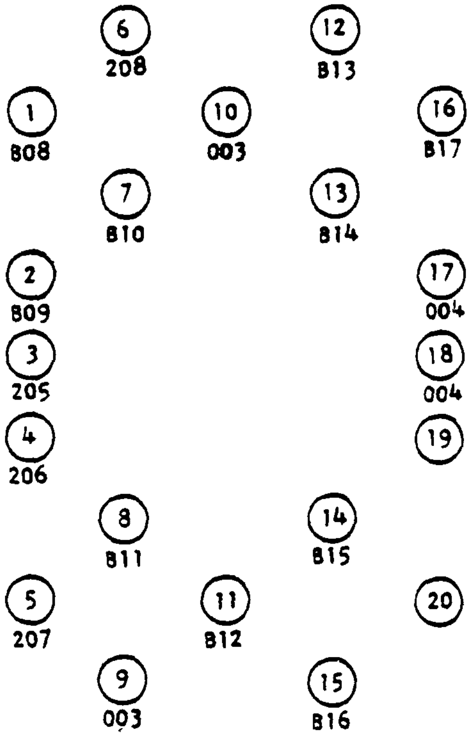
PART NO. C210020P038N

CONTACT PART NO.

WIRE PIN C21P1620A0

F/O BUNDLE PIN 109 3827 046 S000

WIRE COUNT 18



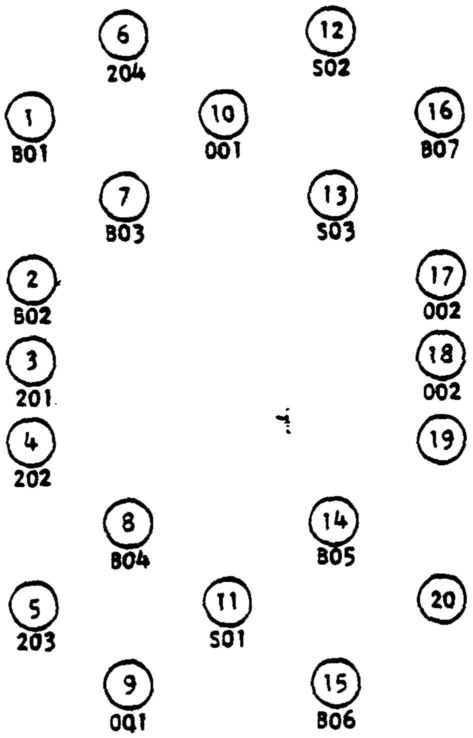
(PLUG) D7519A

SIZE A	CODE IDENT NO. 81205	180-59004	
SCALE NONE	REV	SHEET 10	

PART NO. C210020P03BN

WIRE COUNT 18

CONTACT PART NO.
F/O BUNDLE PIN 109 3827 046 S000
F/O SINGLE PIN 109 3201 081 S210
WIRE PIN C21P162)0A0



(PLUG) D7518A

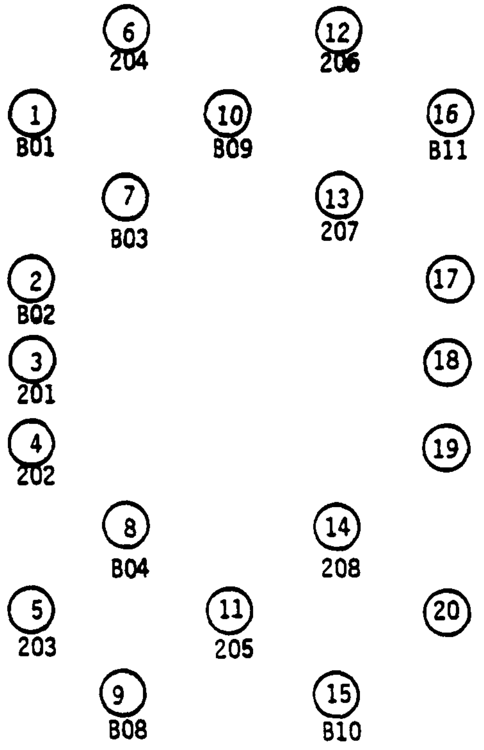
SIZE A	CODE IDENT NO. 81205	180-59004
SCALE NONE	REV	SHEET 11

PART NO. C210020P038N WIRE COUNT 16

CONTACT PART NO.

F/O BUNDLE PIN 109 3827 046 S000

WIRE PIN C21P1620A0



D4704PA

SIZE	CODE IDENT. NO.	
A	81205	180-59004
SCALE NONE	REV	SHEET 12

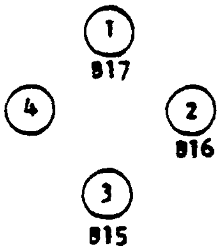
REV LTR

PART NO. HUGHES 1127650-25

CONTACT PART NO.

HUGHES 109 3827 046 5000

WIRE COUNT 3



D7581A

SIZE A

CODE IDENT NO. 81205

180-59004

SCALE NONE

SHEET 13

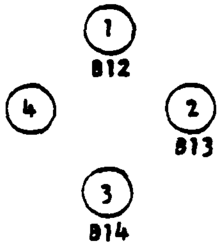
REV LTR

PART NO. HUGHES 1127650-2S

WIRE COUNT 3

CONTACT PART NO.

HUGHES 109 3827 046 5000



D7856A

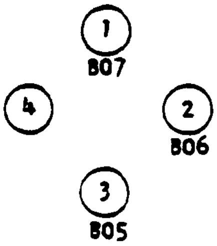
SIZE A	CODE IDENT NO. 81205	180-59004
SCALE NONE		SHEET 14

REV LTR

PART NO. HUGHES 1127650-2S **WIRE COUNT 3**

CONTACT PART NO.

HUGHES 109 3827 046 S000



D7580A

SIZE A	CODE IDENT NO. 81205	180-59004
SCALE NONE		SHEET 15

31 4310-2001 ORIG 3/71

APPENDIX G

FIBER OPTIC ASSEMBLY PROCEDURE, GENERAL

D180-24693-26

FIBER OPTIC CONNECTOR ASSEMBLY PROCEDURE, GENERAL

O. R. Mulkey

Boeing Aerospace Company
P.O. Box 3999

Seattle, Washington 98124

4 June 1980

Final Report for Period 15 December 1979 through 4 June 1980

Phase IV of NOSC Contract N00123-78-C-0193

Prepared For:

NAVAL OCEAN SYSTEMS CENTER
Code 9313
San Diego, California 92152

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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4. TITLE (and Subtitle)
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5. TYPE OF REPORT & PERIOD COVERED
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P.O. Box 3999
Seattle, WA 98124

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4 June 1980

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15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fiber optics
Fiber optic connectors
Fiber optic terminations

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

This document describes the procedures, techniques, tools, equipment, and materials required for the assembly of fiber optic connectors for both single fiber and fiber bundle cables. This document is formatted as a general specification covering general requirements plus detail specifications for each connector type.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

1.0 SCOPE

a. This specification describes the general requirements for the assembly of fiber optic connectors. Engineering drawings shall have precedence over this specification.

b. Assembly of a particular type or family of fiber optic connectors is contained in dash-numbered supplementary specifications which form a part of this specification. To aid in determining the applicable dash-numbered specification, a complete connector index (by part number) is provided.

c. In some cases electrical contacts may also be included in particular supplementary specifications which are capable of handling both types of contacts.

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-26
SCALE	REV	SHEET 1

USE FOR TYPEWRITTEN MATERIAL ONLY

2.0 CLASSIFICATION

None.

3.0 REFERENCES

Except where a specific issue is indicated, the current issue of the following references shall be considered a part of this specification to the extent indicated herein.

a. D180-24693-27, Termination of Fiber Optic Cables

b. D180-24693-20, Preliminary Installation Procedures

c. D180-24693-5, Routing Techniques

d. D180-24693-21, Fabrication and Installation Procedures

e. D180-24693-22, In-Process Testing of Fiber Optic Cables and Harnesses

4.0 CONTENTS

5.0 MATERIALS CONTROL

a. Adhesive

Thermofit S-1005
Raychem Corporation

b. Braid

(1) Flat woven, synthetic fibers, 0.0125 ± 0.0030 inch thick and 0.070 to 0.100 inch wide, color white or tan, unwaxed, mildew resistance effectiveness in accordance with MIL-T-713 and 48 pound minimum breaking strength.

(a) Airtex 417X (Dacron) or Airtex 217 (Dacron)
Eon Corporation

(b) Dacron Flat Braided Lacing Tape, G. E. Finish
Heminway and Bartlett Mfg. Company

(2) Flat woven, fiberglass, Teflon coated, approximately 1/8 inch wide x 1/64 inch thick, and minimum breaking strength 90 pounds.

(a) BH 7140121
Bently Harris Mfg. Company

(b) E-775-303
Dodge Industries, Inc.

c. Compound

Epoxy, Trabond BB-21430D (Bipax) Tra-con Inc.

d. Filler

Rod, red, synthetic rubber, nominal diameters 1/16, 1/8, 3/16, 3/8, 1/2, 5/8, or 3/4 inch.

(1) K-1045N or K-1046N
Union Carbide Corporation

(2) Silastic 52 or S-2071
Dow-Corning Corp.

e. Lubricant

(1) Molykote, Type G
Dow-Corning Corp.

(2) Parker-O-Lube
Parker Seal Co.

(3) Versilube G-300
General Electric Co.

(4) WD-40
Rocket Chemical Co.

f. Solvent

(1) Alcohol isopropyl

(2) Cleaning, naphtha, aliphatic in accordance with Specification TT-N-95

g. Strip

Plastic, vinyl, transparent, flexible (material same as for sleeving in accordance with MIL-I-7444), 0.020 ± 0.0015 inch thick, width as required (tolerance ± 5 percent) in 1/4 inch increments.

CT-93
The Borden Chemical Div., Borden, Inc.

h. Tape

(1) Insulation, electrical pressure sensitive, black, plastic for low temperature applications in accordance with HH-I-595.

(2) Electrical, nonpressure sensitive, Mylar, MIL-I-631, Type G, Form T, Grade A, Class I, Category 1, one inch width.

E. I. duPont deNemours and Co., Inc.

i. Insulation Sleeving

(1) Electrical, flexible, Type I in accordance with MIL-I-7444

(2) Fiber glass, silicone rubber-covered, fungus resistant treated, color brown or white, Class H-B-1 (200C, 4000V minimum average dielectric strength) meeting performance requirements of MIL-I-3190 in standard sizes as required.

(a) "Turbo 117"
Brand-Rex Division, American Enka Corp.

(b) Class H-B-1, Type SR-9
Varflex Corp.

j. Rod, grommet sealing
Polytetrafluoroethylene in accordance with AMS 3651, sizes as required.

k. Strip

Plastic, polyvinyl chloride, black opaque, non-rigid, Type F, Form T, Grade a, Class 1, Category 1, in accordance with MIL-I-631, 0.020 inch ± 0.0015 inch thick, width as required (tolerance ± 5 percent) in 1/4 inch increments.

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-25
SCALE	REV	SHEET 6

USE FOR TYPEWRITTEN MATERIAL ONLY

1. Tape

Electrical, glass-cloth-backed, white, pressure sensitive, in accordance with MIL-I-19166, width as required in 1/4 inch increments.

Mystic Adhesive Products
"Mystic Brand #7000"

6.0 DEFINITIONS

a. See EIA STD RD-440 for definitions of fiber optic terms

b. A non-standard fiber optic termination is one that is not controlled by a government or government-approved industry standard.

SIZE	CODE IDENT. NO.	
A	81205	D280-24693-26
SCALE	REV	SHEET 8

7.0 MANUFACTURING CONTROL

To be added.

7.1 ENVIRONMENTAL CONTROL

a. Processes described herein shall be performed in an area meeting the requirements of Fed STD 209.

b. Activity restrictions - the following operating practices shall be observed.

(1) No paint spraying shall be performed in the area.

(2) All personnel assembling, inspecting handling, or otherwise touching those surfaces of cable assembly parts to be potted, molded, or encapsulated shall wear gloves to prevent contamination of the surfaces after they are cleaned. Cable assembly parts include bare conductors, connector contacts, terminals, splices, connectors, and primed or etched surfaces.

The gloves shall be made of rubber or a synthetic fiber of a quality which sheds a minimum amount of lint. Cotton gloves shall not be used. Finger cots may be used in lieu of gloves when handling small parts which will not contact the bare palm or uncovered parts of the fingers. The gloves or cots shall be replaced sufficiently often (at least once per shift) to ensure cleanliness and no transfer of perspiration, grease, oil, or other contaminants to the parts.

CAUTION: The presence of silicone in hair preparations, cosmetics, and other products presents a serious source of contamination. Gloves must be replaced at any time they come in contact with such contamination.

c. Remote Sites - When assembly drawings require the assembly of electric connectors to cable after the cable has been pulled through conduit at remote sites, environmental requirements as stated above, with the exception of 7.1b(3), may be waived. Precautions shall be taken to protect the assemblies from dust, rain, internal-combustion engine exhaust, or other environmental contaminants which may affect the serviceability of the completed assembly.

USE FOR TYPEWRITTEN MATERIAL ONLY

7.2 Operator Qualification

Personnel involved in the assembly of connectors to cables shall satisfy the following minimum requirements:

a. Be familiar with the general requirements of this specification.

b. Be capable of identifying tools required for stripping cables and assembling connectors.

c. Be trained in the use of tools and processes described in this specification.

7.3 Tool Requirements

a. The following tools must be certified in accordance for use in the processes of this specification.

   (1) Mechanical stripping tools.

   (2) Crimp tools.

   (3) Metal contact insertion tools.

   (4) Metal contact removal tools.

b. No certification is required for the following tools:

   (1) Expander barrel tools.

   (2) Tapered lead tools.

   (3) Plastic contact insertion tools.

   (4) Plastic contact removal tools.

7.4 Cable Stripping and Cable Jacket Removal

Perform stripping and cable jacket removal in accordance with D180-24693-27 termination.

7.5 Crimping

Perform crimping operations in accordance with D180-24693-27 termination.

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-26
SCALE	REV	SHEET 10

7.6 Spare Cable Stubs

a. Protect the ends of spare cable stubs by covering with heat shrink and secure them within or on the surface of the cable bundle.

b. When required by Engineering drawings, the empty contacts in all connectors to be potted shall be filled with spare cable stubs. Make the stubs of the same type which predominates in the bundles and of the sizes that correspond to the nominal contact size.

c. Make the shortest spare cable stub in a connector at least seven inches long, with each successive stub in the same connector 1½ inches longer than the previous stub.

d. Identify each spare cable stub with the connector contact letter and the cable size as shown in the following examples:

Identification	Explanation
A-16	Contact A, Cable Size 16
SMALL A-10	Contact a, Cable Size 10

e. Cable stubs having the same identification but which are attached to different connectors and running through a common group or bundle, should also have their respective connector numbers made a part of their identification as follows:

Cable	Connector	Identification Marking
A-8	P72	A-8-P72
A-8	J8	A-8-J8

f. Spare cable stubs which will eventually be used in a circuit shall be identified with a sleeve. The sleeve shall be marked with the circuit number of the cable to which it will be spliced and applied according to D180-24693-20 Appendix A.

g. Prepare deleted cables as spare cable stubs. Cut the cable according to 7.6c and provide the cable with an identification sleeve in accordance with 7.6d. Protect the cable end and secure it in place.

h. Place one bundle tie within 3/4 inch of the end of the spare cable stubs. Also place at least two ties between the connector and the end of the shortest spare cable stub.

7.7 Connector and Cable Protection

7.7.1 Handling

a. Handling of connectors and cables shall be done carefully and held to a minimum to reduce the possibility of connector or cable damage. Particular care shall be used in handling boxes which contain both connector and contacts.

7.7.1 (Continued)

b. Unassembled connectors and contacts shall be handled as follows:

(1) Except as necessary, do not open connector and contact containers until the time of assembly.

(2) They shall be guarded against contamination and must be returned to the original container as soon as practicable.

c. Uncoupled plugs and receptacles of production cables, and test cables which mate with production cables, are to be protected with metal or plastic dust caps. Metallic dust caps shall mate with the connector coupling devices. Plastic dust caps shall fit snugly over the coupling ring of plug connectors and over the mating end of receptacle connectors. Plastic bags may be used to protect connectors which standard type metallic or plastic dust caps do not fit. The open end of the plastic bag shall be closed and secured in place.

d. Polyethylene (or equivalent) bags shall be used to individually cover unpotted plugs and receptacles against contamination. These bags shall be secured in place by closing and fastening the open ends with tying cord, elastic bands, or tape. Do not allow tape adhesive to contact cable or contacts.

e. The protective requirements are as follows:

(1) Dust caps according to 7.7.1c above shall be provided on all uncoupled ends of plugs and receptacles except when necessary to work directly upon them. Where this is not feasible during potting or molding operations, connector ends may be protected by masking with tape, Permacel 2650 or Permacel 29. Tape adhesive shall not touch connector contacts, insert face or contact surfaces. Replace tape with plastic cap after potting and molding operations are complete.

(2) In addition, a protective cover in accordance with 7.7.1d above shall be provided on all unsealed plugs and receptacles (unpotted or without sealing grommet), whether coupled or uncoupled, under the following conditions.

(a) When located in an area where the plug and receptacles may be exposed to falling or flying metal particles from operations such as drilling, filing, chipping, soldering, cleaning, etc.

(b) When located in an area where the plug and receptacle may be contaminated by foreign matter such as water, dirt, oil, grease, carbon, etc.

(c) When transported through an area where the plug and receptacle may be exposed to metal particles or contamination as described in e(2)(a) and (b).

NOTE: For the purposes of this specification, the use of bags shall be held to a minimum consistent with the protective requirements herein.

USE FOR TYPEWRITTEN MATERIAL ONLY

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7.7.1 e. (Continued)

(3) Uncoupled plugs or receptacles protected in accordance with 7.7.1e(2) above shall be stored or stowed in a manner such that metal particles or contaminating materials will not fall or drain into the protective cover.

f. Provide tooling fixtures to support cable harnesses and cables while installing connectors if possibility of damage by strain exists. This precaution applies particularly to large diameter cables. Mere bending of such a cable tends to pull contacts out of their insert cavities, to bend contacts under compression by buckling them, and to tear inserts. Rejection of any connector for reasons of strain damage shall require examination of need for cable support fixture if the connector was assembled without the aid of such fixture. Cable support fixtures must be used consistently, thereafter, when assembling connectors of a type and size for which the need for support fixtures has been established.

g. Contacts which have been attached to cables must be kept free from damage where protection is required, two suggested methods are shown below:

(1) Tie a cushion of clean polyurethane foam rubber pad around the contacts. See Figure 5.

(2) Tie a clean, rigid, protective sleeve of nylon or polyethylene over the contacts. See Figure 6.

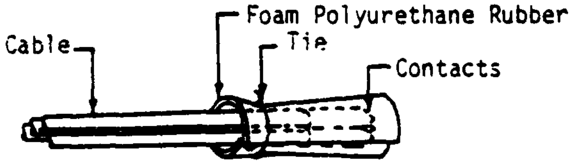


FIGURE 5
CONTACTS SAFEGUARDED WITH FOAM RUBBER

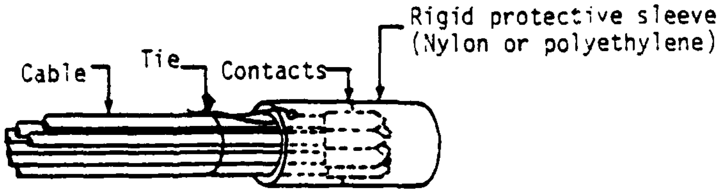


FIGURE 6
CONTACTS SAFEGUARDED WITH RIGID SLEEVE

7.7.2 Abrasion Protection

Provide abrasion protection for connector cabling.

7.7.3 Strain Relief

a. Provide all connectors with adapter clamps when specified on the Engineering drawings.

b. Form individual cables to provide natural strain relief for the connector terminations when the adapter clamp is tightened.

c. Use caution in dressing cables so that contact float is not destroyed. Exercise special care in providing strain relief for contact where resilient inserts are used to prevent the contacts from being pulled out of alignment.

d. Where necessary to build up jacketed cable diameter to fit connector adapter clamp, wrap the jacket with plastic strip (4 n.) or tape (4 o.). For cables in areas specified on the Engineering drawing as being high temperature use only tape (4 o.). Use the narrowest practicable strip or tape centered under the adapter clamp extending a minimum of 1/16 inch on both sides of the clamp.

The plastic strip may be held in place by heat sealing to itself. When the adapter clamp is tightened, the cable insulation shall not be cut or crushed and the cable(s) to connector shall show no apparent stress. The adapter clamp shall be bottomed only when gripping ground braid terminals and only on the side containing pigtail terminations.

7.8 Insertion and Removal of Contacts

a. Carefully insert the contact into the appropriate insert cavity required by the Engineering drawing and push on the tool handle until the contact is seated. Refer to connector and insert arrangement standards or drawings for correct cavity identification.

b. If an unterminated contact cannot be removed from the grommet by hand, a pair of pliers may be used to extract it. Any contact removed with the pliers must be discarded if dented or marred to the extent that the base metal is exposed.

CAUTION: Pins and sockets must be driven straight to avoid bending them or damaging the insert.

c. Do not use contact insertion and removal tools for any function other than inserting and removing contacts.

d. Protect tool tips with suitable guards when they are not being used.

e. Do not use tools which show visible defects to the extent that grommets, inserts, contacts, or taper pins may be damaged.

f. Align the contact and tool with the contact cavity and do not rotate the contact or tool during insertion or removal to avoid the possibility of bending the contact or damaging the insert.

7.8 (Continued)

g. Use only tools designated by specific connector assembly procedure. Substitution of other tools or modification of approved tools is not permitted without Engineering authorization.

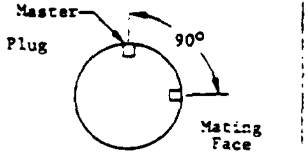
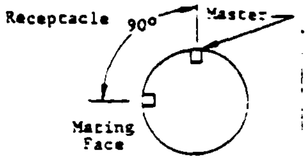
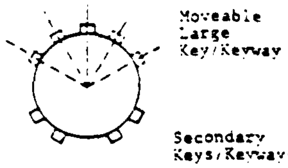
h. Do not straighten bent contacts except in preparation for removing the contact. Do straighten bent contact before removing them so as not to damage the insert while withdrawing the contact.

7.9 Polarizing and Clocking Connectors

a. Connectors, as purchased, are polarized (relative position between master key/keyway and insert) in accordance with Engineering requirements and may not be changed.

b. Identification of master key(s)/keyway(s) for various connectors is given in Table II.

TABLE II
MASTER KEY/KEYWAY IDENTIFICATION

Identification and Type / Connector Configuration	Specification Type	Master Key/Keyway
Single Key/Keyway	MIL-C-5015 MIL-C-83723 (Series II)	Single Key/Keyway
Two Keys/Keyways same size spaced 90°	BPS-C-11	 
Five Keys/Keyways 1-Larger-Fixed 4-Secondary-Fixed	MIL-C-26-32 MIL-C-83723 (Series I) NAS1599 (Bayonet)	Largest Key/Keyway
Five Keys/Keyways 1-Larger-Fixed 4-Secondary-Moveable	MIL-C-26500 MIL-C-83723 (Series III) NAS1599 (Threaded)	Largest Key/Keyway
Five Keys/Keyways 1-Larger-Moveable 5-Secondary-Fixed	MIL-C-27599 MIL-C-38999	

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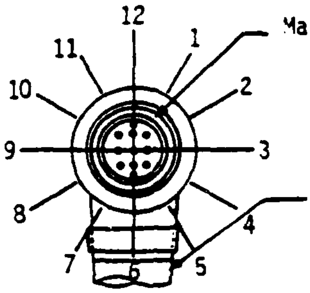
A	81205	D180-24693-25
SCALE	REV	SHEET 15

7.9 (Continued)

c. Clock angle accessories according to the Engineering drawings. Unless otherwise specified, the allowable clocking tolerance is ± 1 hour (30 degrees). See Figure 8.



Master Key or Keyway

Cable "take-off" downward with reference to clock numerals.

Plug or angle type receptacle clocked at 1'oclock.

FIGURE 8

TYPICAL CLOCKING
(FRONT FACE VIEW OF ANGLE TYPE CONNECTOR)

7.10 Connector Testing

Perform tests on cabling with connectors in accordance with D180-24693-8.

7.11 Connector Potting

a. Abrade all Teflon-insulated cable using No. 320 grit aluminum oxide paper before terminating cables to contacts.

b. Apply primer to cables and connectors after terminating cables to contacts.

c. Pot the connector and cables, using potting compound called out on Engineering drawings.

d. Do not use insulating sleeves on potted connector terminations.

e. Sleeves, or wrapping on cabling shall not project into or from the potting material unless later molded.

7.12 Installation of Connectors

See D180-24693-20.

7.13 Threaded Components

a. Avoid excessive tightening which might damage threads or connector parts.

7.13 (Continued)

b. Hand-tighten threaded parts, then tighten slightly beyond "hand-tight" with tool ST2596A or ST2596C, unless specific torquing values are given for the connector concerned. Spanner wrenches may be used provided connector components are not damaged.

c. Make checks for tightness by hand and only in the direction of tightening.

7.14 In-Process Corrective Action

a. Fully assembled connectors, which have not been potted or molded, may be disassembled for in-process corrective action. Disassembly, contact removal, contact insertion, and reassembly shall be in accordance with the applicable dash numbered specification.

b. Normal burnishing or other tool marks on connector components are acceptable provided that the base metal is not exposed when viewed with 5X magnification.

8.0 QUALITY CONTROL

Quality Control shall ensure that only the materials specified herein are used and that the procedures covered are observed with particular note to the following points:

a. Damaged cable jacketing which will not meet specification requirements and connectors with contaminated inserts (paint, adhesives, grease, carbon, metal chips, etc.) or with bent or corroded contacts are unacceptable.

b. Prior to attachment of the backshells or potting of connectors, visual inspection shall be made for the following:

   (1) Damage to inserts, contacts.

   (2) Quality of crimped terminations.

   (3) Proper seating of removable-type contacts.

   (4) Proper application of sleeves when required.

   (5) Clean inserts and contacts.

c. Check the tightness of connector fittings only in the direction of tightening.

d. Quality Control shall ensure compliance with the environmental control requirements of this specification.

e. Quality Control shall verify that only properly certified employees are performing or operating operations such as terminating, potting or other processes which are designated as "critical" by Operating Procedures.

f. Quality Control shall verify that all cable assemblies are tested in accordance with D180-24693-22.

APPENDIX H

FIBER OPTIC CONNECTOR ASSEMBLY PROCEDURE, HUGHES

D180-24693-26.1

FIBER OPTIC CONNECTOR ASSEMBLY PROCEDURE

- HUGHES CONNECTORS -

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15 June 1980

Final Report for the Period of 16 December 1979 Through 15 June 1980

Phase IV of NOSC Contract N00123-78-C-0193

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Fiber optic cables
Fiber optic connectors

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

This document is a detail specification covering the assembly procedures, tools, materials, and equipment required for the assembly of Hughes C21 series fiber optic connectors. This document is a subdocument to D180-24693-26.

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USE FOR TYPEWRITTEN MATERIAL ONLY

1.0 SCOPE

This specification defines the processes for assembling Hughes C21 Series and 11276XX series connectors. This specification supplements and is an essential part of D180-24693-26.

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-26.1
SCALE	REV	SHEET 1

2.0 CLASSIFICATION

None.

USE FOR TYPEWRITTEN MATERIAL ONLY

3.0 REFERENCES

The current issue of the following references forms a part of this specification to the extent indicated herein:

a. D180-24693-26

b. D180-24693-27.1

USE FOR TYPEWRITTEN MATERIAL ONLY

SIZE	CODE IDENT. NO.	
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4.0 TABLE OF CONTENTS

5.0 MATERIALS CONTROL

See D180-24693-26 (Materials Control).

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A	81205	D180-24693-26.1

SCALE	REV	SHEET 5

USE FOR TYPEWRITTEN MATERIAL ONLY

6.0 MANUFACTURING CONTROL

a. Table I lists the connectors covered by this specification, the appropriate assembly paragraph, whether adhesive or crimp contacts, contact part numbers, and contact insertion and removal tools.

b. When assembling the connectors herein, secure couplings by hand. A strap wrench may be used in inaccessible locations provided extreme care is exercised to avoid overtightening, or damage to connector or finish. Unless otherwise specified, threaded parts of connectors herein shall be tighted by hand, and then slightly beyond hand tight with tool ST2596C or equivalent (avoid damage to connector or finish).

c. The sequence of operations presented herein is intended only as a guide and may be modified to facilitate connector assembly.

6.1 Assembly of Connectors with Fiber Optic Contacts

See D180-24693-27.1.

Assure that backshell sleeve is crimped at end of outer jacket.

6.1.2 Rear End Components, C-21

The backshell assembly is assembled as illustrated in Figure 3 from the center section out. The jackscrew guide is used on the plug half of the connector pair, the jackscrew plug on the receptacle half.

6.1.2.1 Fasten a Backshell Center Section (P/N 1127188) to a C-21 Pin Body (P/N 1093827) or to a C-21 Socket Body (P/N 1035904) with Fillister Head Machine Screws.

6.1.2.2 Insert two pin or socket assemblies as appropriate into the applicable connector cavity with the right angle contact (P/N 114304S) provided.

6.1.2.3 The Hex Tool Guide (P/N 1127270) or the Plug (P/N 1127271) is positioned on the center section, depending upon which connector half is being assembled. The second Backshell Center Section (P/N 1127188) is placed to retain the ferrules and the Hex Tool Guide or plug and fastened into position with a Fillister Head Machine Screw and four Socket Head Capscrews.

6.1.2.4 Four pin or socket assemblies as applicable are inserted into each side of the Backshell Center Section, one side at a time, and a Backshell Middle Section (P/N 1127005) is attached to the sides with four Socket Head Capscrews, respectively.

6.1.2.5 Five pin or socket assemblies, as applicable, are now inserted into each side adjacent to the middle sections, one side at a time, and retained with a Backshell End Section (P/N 1127000) and four Socket Head Capscrews.

6.1.2.6 Unused positions in the backshell should be filled with filler plugs, Hughes Part No. 1127984-1 or 1127984-2 with yellow seal plug inserted. The 1127984-2 plugs should be used to brush the 22 ga wire pairs. (Loctite #416 may be used to bond the yellow seal plugs in hollow (-2) filler plugs). Assembly may be at any sequence.

6.1.3 Rear End Components, 11276XX

6.1.3.1 Run the assembled cables through O-ring (P/N AS568-012). Insert the contacts into the plug body (P/N 1127641-1) with insertion tool (P/N See Table I). Put the crimp ferrules (P/N 1127764) into the retaining clamp (P/N 1127644-1) and slide the O-ring (P/N AS568-012) down the cable and into the retaining groove in the retaining clamp. (See Figure 1)

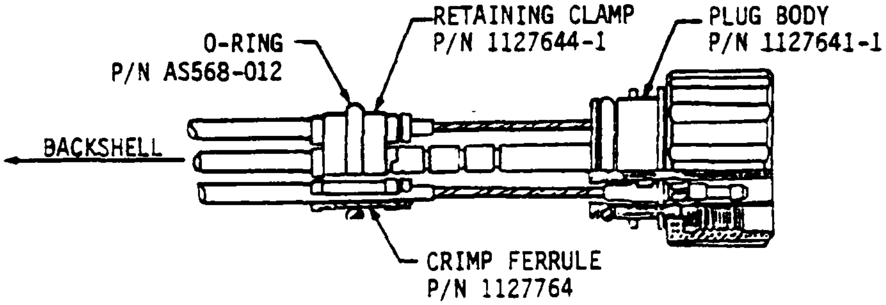


FIGURE 1

<u>NOTE:</u> Contact is shown in locked position. The crimped ferrules are in their engaged position and are being retained by the o-ring.

6.1.3.2 Hold the cables firmly in one hand and pull the backshell (P/N 1127539-3) down the cables and over the retaining clamp (P/N 1127644-1). (See Figure 2).

6.1.3.3 Depress the two (2) locking pins in the plug body (P/N 1127641-1) and slide the backshell (P/N 1127539-3) over the plug body. Rotate the backshell until the locking pins engage in the nearest holes in the backshell. (See Figure 2).

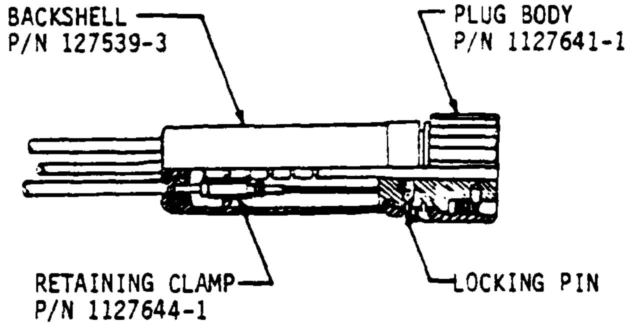


FIGURE 2

6.1.4 Contact Insertion

Insert contact into cavity using insertion tool listed in Table I. On contacts using an alignment sleeve, place sleeve into cavity from the front side of the connector using the tool listed in Table I.

6.2 Assembly of Connectors with Crimp Contacts

6.2.1 Contact Identification

See D180-24693-27.1

6.2.2 Wire Preparation

See D180-24693-27.1

6.2.3 Contact Crimping

See D180-24693-27.1

6.2.4 Rear End Components

See 6.1.2 & 6.1.3

SIZE A	CODE IDENT. NO. 81205	D180-24693-26.1
SCALE	REV	SHEET 8

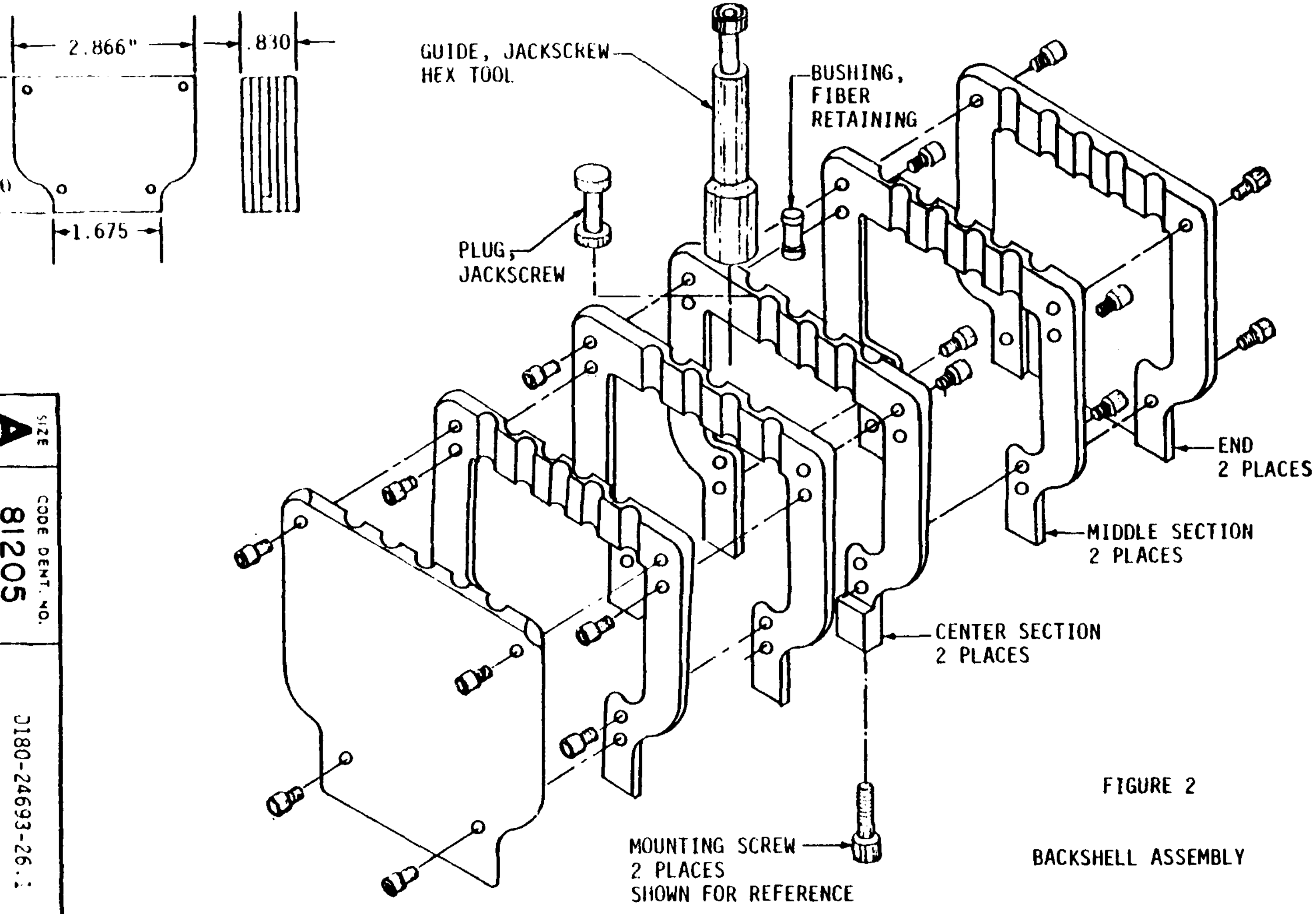


FIGURE 2

BACKSHELL ASSEMBLY

SIZE	CODE DENT. NO.	
A	81205	D180-24693-26.1
SCALE	REV	SHEET 9

TABLE I

CONNECTORS, CONTACTS, AND INSERTION AND REMOVAL TOOLS

Connector Part Number	Assembly Paragraph	Contact Size	Contact Part Number	Tools		
				Insertion	Removal	Special
C210020S00BN (Receptacle)	6.2	16	C21S1620A0 Wire (Socket)	TK0161PS01 Pull thru	TM016RT006 (Green)	
	6.1	16	1093827046S000 F.O. Bundle (Socket)	1093784S-2	TM016RT006 (Green)	1093202-7S (Alignment Sleeve)
		16	1093202081S210 F.O. Single Fiber (Socket)	1093784S-1	TM016RT006 (Green)	1093202-7S (Alignment Sleeve)
C210020P03BN (Plug)	6.2	16	C21P1620A0 Wire (Pin)	TK0161PP01 Pull thru	TMF16RT006 (Silver)	
		16	1093827 046S000 F.O. Bundle (Pin)	1093784S-2	TMF16RT006 (Silver)	
		16	1093201 081S210 F.O. Single Fiber (Pin)	1093784S-1	TMF16RT006 (Silver)	
1093995-1S Backshell	6.1					1143046 (Crimp Sleeve)

TABLE I (Continued)

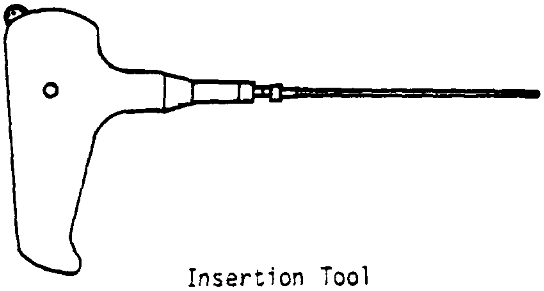
CONNECTORS, CONTACTS, AND INSERTION AND REMOVAL TOOLS

Connector Part Number	Assembly Paragraph	Contact Size	Contact Part Number	Tools		
				Insertion	Removal	Special
1127650-3S[1] (Plug Assy.)	N/A	16	C21P1620A0 Wire (Pin)	TK0161PP01	TM16RT006 (Silver)	
	6.1		1093827046S000 F.O. Bundle (Pin)	1093784S	TM16RT006 (Silver)	
	6.1		1093201081S210 F.O. Single Fiber (Pin)	1093784S	TM16RT006 (Silver)	
1127668S (Receptacle)		16	C21S1620A0 Wire (Socket)	TK0161PS01	TM16RT006 (Green)	
	6.1	16	1093828046S000 F.O. Bundle (Socket)	1093784S	TM16RT006 (Green)	
	6.1	16	1093202081S210	1093784S	TM16RT006 (Green)	
						1143046 (Crimp Sleeve)

[1] Part No.'s 127539-3, 1127641-1, 1127644-1, A5568-012, 1127764 are part of the connector assy.

6.2.5 Contact Insertion

a. Insert the Hughes Pull-Thru Insertion Tool into the contact cavity at the mating face of the connector until the tip protrudes from the rear of the connector, free of the wire bundle. Next, insert the contact into the tip of the tool. Pull the locking lever on the tool back with the thumb to lock the contact into the tool. Carefully draw the tool back through the connector block until the contact retention clip locks into place with a click. Then push the contact forward to insure that contact is locked in the connector. When locked, release the contact from the tool by pushing the thumb locking lever forward. Withdraw the tool carefully and repeat the operation until all contacts are seated.



Insertion Tool

b. Check for the proper seating of each contact by grasping one wire between the thumb and forefinger of one hand and pulling slowly, in line with the contact, without jerking, until the thumb and forefinger slip on the wire.

c. Fill all unused contact cavities with spare (unwired) contacts, in accordance with 6.2.5a and 6.2.5b, followed by seal plugs selected from Table II. Insert seal plugs (small end first) until plug butts against back of contact, or shoulder on seal plug bottoms on seal plug bottoms on rear grommet face.

TABLE II

SEAL PLUGS

Contact Size	Seal Plug	
	Color	Equivalent Part No.
20	Red	NAS1668-1
16	Blue	NAS1668-2
12	Yellow	NAS1668-3

6.3 In-Process Corrective Action

Should it become necessary to remove contacts from connectors which have not been potted or molded, disassemble rear end components, slide them back on cable, and proceed as follows:

CAUTION: Maintain axial alignment of tool with contact cavity and avoid rotating removal tool any time tool is within contact cavity.

6.3.1 Wired Contact Removal

a. Insert removal tool selected from Table I into the contact cavity.

NOTE: Remove alignment sleeve first, if present.

b. Push until contact releases.

c. Remove contact from rear of connector.

7.0 QUALITY CONTROL

The Quality Control organization shall maintain necessary surveillance to ensure compliance with this process specification.

APPENDIX I

FIBER OPTIC CONNECTOR ASSEMBLY PROCEDURE, AMPHENOL

D180-24693-26.2

FIBER OPTIC CONNECTOR ASSEMBLY PROCEDURE

- AMPHENOL CONNECTORS -

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

This document is a detail specification covering the assembly procedures, tools, materials, and equipment required for the assembly of Amphenol 811 series fiber optic connectors. This document is a subdocument to D180-24693-26.

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1.0 SCOPE

This specification defines the processes for assembling Amphenol 801 Series circular connectors. This specification supplements and is an essential part of D180-24693-26.

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-26.2
SCALE	REV	SHEET 1

2.0 CLASSIFICATION

None

3.0 REFERENCES

The current issue of the following references forms a part of this specification to the extent indicated herein:

a.

b.

c.

d.

USE FOR TYPEWRITTEN MATERIAL ONLY

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-26.2
SCALE	REV	SHEET 3

D1 4316 2000 REV. 4/73

4.0 MATERIALS CONTROL

See D180-24693-26 (Materials Control)

5.0 TABLE OF CONTENTS

USE FOR TYPEWRITTEN MATERIAL ONLY

6.0 MANUFACTURING CONTROL

a. Table I lists the connectors covered by this specification, the appropriate assembly paragraph, whether solder (fiber optic), or crimp contacts, crimp contact part numbers, and crimp contact insertion and removal tools.

b. When assembling the connectors herein, secure bayonet couplings by hand until coupling ring is fully engaged and in completely locked position. A strap wrench may be used in inaccessible locations provided extreme care is exercised to avoid overtightening, or damage to connector or finish. Unless otherwise specified, threaded parts of connectors herein shall be tightened by hand, and then slightly beyond hand tight with tool ST2596C or equivalent (avoid damage to connector or finish).

c. The sequence of operations presented herein is intended only as a guide, and may be modified to facilitate connector assembly.

TABLE I

CONNECTORS CONTACTS AND INSERTION/REMOVAL TOOLS

CONNECTOR PART NUMBER	ASSEMBLY PARAGRAPH	CONTACT SIZE	CONTACT PART NUMBER	TOOLS INSERTION REMOVAL	SPECIAL
801-104-5208 Receptacle	6.2	12	M39029/4-12-12 Pin (Wire)	227-909-2018 Yellow end White end	
801-104-5004 Receptacle	6.1	12	801-999-5125 Pin (F.O.)	Yellow end White end	
801-105-5208 Plug	6.2	12	M39029/5-12-12 Socket (Wire)	227-909-2018 Yellow end White end	
801-105-5004 Receptacle	6.1	12	801-999-5124 Socket (F.O.)	Yellow end White end	
801-5030 Backshell					

6.1 Assembly of Connectors With Fiber Optic Contacts

6.1.1 Wire Preparation

Terminate per D180-24693-27. Protect with heat shrink cover.

6.1.2 Rear End Components

Rear end components (backshells) are supplied as part of the connector herein.

6.1.2 (Continued)

Slide the rear end components on the cable bundle in the reverse order as shown in Figure 1.

6.1.3 Contact Insertion

a. Snap insertion half of tool selected from Table I on wire (without damaging wire insulation) and slide tool against contact shoulder (See Figure 2).

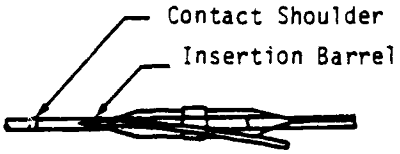

FIGURE 2

INSERTION TOOL

b. Insert contacts straight into proper cavities until a slight click and further resistance to further motion are noted; then carefully withdraw tool. Maintain axial alignment of tool with cavity, and do not rotate tool while it is in contact cavity.

c. Check for the proper seating of each contact by grasping one wire between the thumb and forefinger of one hand and pulling slowly, in line with the contact, without jerking, until the thumb and forefinger slip on the wire.

d. Fill all unused contact cavities with spare (unwired) contacts, in accordance with 6.1.3a and 6.1.3b, followed by seal plugs selected from Table II. Insert seal plugs (small end first) until plug butts against back of contact, or shoulder on seal plug bottoms on rear grommet face.

TABLE II

SEAL PLUGS

CONTACT SIZE	SEAL PLUG		
	PART NUMBER	COLOR	EQUIVALENT PART NO.
20	M83723-28-20	RED	NAS1668-1
16	M83723-28-16	BLUE	NAS1668-2
12	M83723-28-12	YELLOW	NAS1668-3

To Be Added

FIGURE 1

SIZE A	CODE IDENT. NO. 81205	D180-24693-26.2
SCALE	REV	SHEET 8

6.1.4 Backshell (Rear End Components) Assembly

Assemble backshell components.

6.2 Assembly of Connectors With Crimp Contacts

6.2.1 Contact Identification

Crimp contacts for the various connectors covered herein are shown in Table I.

6.2.2 Wire Preparation

Remove cable jacket as required for backshell assembly. Strip wire insulation in accordance with standard procedure.

6.2.3 Contact Crimping

Crimp contacts on wire in accordance with standard procedure.

6.2.4 Rear End Components

Rear end components (backshells) are supplied as part of the connectors herein.

Slide the rear end components on the wire bundle in the reverse order as shown in the appropriate table.

6.2.5 Contact Insertion

a. Snap insertion half of tool selected from Table I on wire (without damaging wire insulation), and slide tool against contact shoulder (see Figure 2).

b. Insert contacts straight into proper cavities until a slight click and further resistance to further motion are noted; then carefully withdraw tool. Maintain axial alignment of tool with cavity, and do not rotate tool while it is in contact cavity.

c. Check for the proper seating of each contact by grasping one cable between the thumb and forefinger of one hand and pulling slowly, in line with the contact, without jerking, until the thumb and forefinger slip on the cable.

d. Fill all unused contact cavities with spare (unterminated) contacts, in accordance with 6.2.5a and 6.2.5b., followed by seal plugs selected from Table II. Insert seal plugs (small end first) until plug butts against back of contact, or shoulder on seal plug bottoms on rear grommet face.

6.2.6 Backshell (Rear End Components) Assembly

Assemble backshell components.

6.3 In-Process Corrective Action

Should it become necessary to remove contacts from connectors which have not been potted or molded, disassemble rear end components, slide them back on cable, and proceed as follows:

CAUTION: Maintain axial alignment of tool with contact cavity and avoid rotating removal tool any time tool is within contact cavity.

6.3.1 Terminated Contact Removal

a. Snap removal half of tool selected from Table I on cable (without damaging jacket).

b. Carefully slide tool straight into rear of contact cavity and over rear of contact until tool bottoms.

c. Hold cable against serrations on tool and pull both tool and terminated contact straight out of contact cavity.

6.3.2 Unterminated Contact Removal

a. Manually remove seal plug.

b. Carefully push unterminated contact removal tool (selected from Table I) straight into rear of contact cavity, and over rear of contact until bottomed. Apply no pressure to plunger of tool.

c. Pull both tool and unterminated contact out of contact cavity.

d. Depress plunger to free unterminated contact from tool.

7.0 QUALITY CONTROL

The Quality Control organization shall maintain necessary surveillance to ensure compliance with this process specification.

APPENDIX J

FIBER OPTIC TERMINATION PROCEDURE, GENERAL

D180-24693-27

FIBER OPTIC TERMINATION PROCEDURE

- GENERAL -

O. R. Mulkey
Boeing Aerospace Company
P.O. Box 3999
Seattle, WA 98124

4 June 1980

Final Report For the Period of 16 December 1979 Through 4 June 1980
Phase IV of NOSC Contract N00123-78-C-0193

Prepared For:

Naval Ocean Systems Center

Code 9313

San Diego, CA 92152

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Fiber optics
Fiber optic cables
Fiber optic contacts
Fiber optic Terminations
Terminus

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

This document describes the procedures, techniques, tools, equipment, and materials required for the termination of fiber optic contacts (terminus). The document is formatted as a general specification containing requirements or all terminations. Detail specification include information peculiar to termination or specific cables/contacts.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

1.0 SCOPE

a. This specification provides the requirements and procedures for fiber optic contact terminations.

b. In case of conflict between this specification and the Engineering drawings, the information on the Engineering drawing shall have precedence.

2.0 CLASSIFICATION

None.

3.0 REFERENCES

None.

4.0 CONTENTS

5.0 MATERIALS CONTROL

6.0 MANUFACTURING CONTROL

6.1 Environmental Control

a. Processes described herein shall be performed in an area meeting the requirements of FED-STD-209 1,500,000.

b. Activity Restrictions - The following operating practices shall be observed:

No paint spraying shall be performed in the area.

c. All personnel assembling, inspecting, handling, or otherwise touching those surfaces of cable assembly parts to be potted, molded, or encapsulated shall wear gloves to prevent contamination of the surfaces after they are cleaned. Cable assembly parts include bare conductors, connector contacts, terminals, connectors, and primed or etched surfaces. The gloves shall be made of rubber or a synthetic fiber of a quality which sheds a minimum amount of lint. Cotton gloves shall not be used. Finger cots may be used in lieu of gloves when handling small parts which will not contact the bare palm or uncovered parts of the fingers. The gloves or cots shall be replaced sufficiently often (at least once per shift) to ensure cleanliness and no transfer of perspiration, grease, oil, or other contaminants to the parts.

CAUTION: The presence of silicone in hair preparations, cosmetics, and other products presents a serious source of contamination. Gloves must be replaced at any time they come in contact with such contamination.

6.2 Operator Qualification

Personnel involved in terminating operations shall:

a. Be familiar with the requirements of this specification and associated dash-numbered specifications.

b. Receive instructions explaining the process requirements pertaining to stripping and polishing operations.

c. Receive training in the operation of tools employed in the specific process phase.

d. Be skilled in the identification and use of tools required for the particular termination hardware.

6.3 General Requirements

a. All terminating devices shall be examined for conformance with the Engineering drawing parts requirements.

b. Crimping shall not cause terminals, connector contacts, or any other terminating device to exhibit fractures, cracks, or base metal when viewed under five power magnification.

6.3 (Continued)

c. If damage occurs to a contact or terminal, while crimping and it is not readily apparent that this damage was caused by operator, contact, terminal, or splices, the crimp tool must be recertified before further use.

6.4 Tool Requirements

6.4.1 Tool Approval

a. New types of tools, including power units, modifications to existing tools and new applications for tools shall be approved by Components, Processes, and Standards Group of Engineering.

b. Suitability of Engineering approved stripping and crimping tools to production requirements shall be determined by the responsible Manufacturing organization. Any tool listed herein for the intended application may be selected, or Manufacturing may submit a request to Engineering for approval of new or modified tools.

c. Mechanical stripping tools and crimping tools shall be periodically certified. A sticker or dab of sealing putty with inspection symbol shall be attached to each tool indicating that the tool has been certified. The lack of a certification sticker or symbol on a tool indicates it has not been certified for production work and is not approved for use under this specification.

6.4.2 Tool Handling and Maintenance

a. Manufacturing may perform the following subject to Quality Control verification:

(1) Interchange crimping dies or contact locators in tool heads or frames when they are furnished with the tool or as a tool kit.

(2) Interchange locators of infinite die closure adjustment crimping tools.

(3) Change die closure selector position number on crimping tools having this feature.

(4) Adjust blades of adjustable wire stripping tools.

b. Protect all tools as provided below:

(1) During transportation and storage keep each tool in a clean separate compartment or container which will protect the tool from mechanical damage.

(2) While in use the tools may be deposited on benches or other working surfaces but not on hardware.

(3) Tools accidentally dropped or hit with other objects shall be recertified prior to future use.

6.5 Cable Preparation

6.5.1 Stripping Tool Requirements (Mechanical and Thermal)

a. Mechanical stripping tools shall satisfy the following requirements:

(1) Fibers shall not be nicked, gouged, or cut.

(2) The end of the jacket shall be cut as squarely and cleanly as required to meet subsequent operation requirements. Excess fibrous strands or extruded plastic protuberances may be removed provided that the minimum bend radius requirement of the cable is not violated.

b. Thermal stripping shall satisfy the mechanical stripping tool requirements in addition to the following:

(1) Fiber strands shall be clean with no evidence of plastic film deposit resulting from the stripping operation.

(2) The cable jacket shall not be blistered, but a slight discoloration or deformation is acceptable.

6.5.2 Approved Stripping Tools

a. Approved manual mechanical stripping tools are listed in Table I.

b. A sharp edged instrument may be used to remove insulations from cable sizes not covered by mechanical strippers, or when space limitations will not permit use of mechanical strippers, subject to the requirements of 6.5.1a.

6.6 Visual Inspection Guidelines

6.6.1 Scope

This section provides general guidelines for the visual inspection of single fiber and fiber bundle cable terminations and may be used as inspection criteria unless otherwise indicated on the detail termination procedure or assembly drawing.

6.6.2 Fiber Bundle Cable Termination

The finished termination should have a smooth (specular) surface when viewed under magnification. A few (less than 5) surface scratches may be tolerated. The surface should be free from epoxy smears and voids. The packing fraction (ratio of area of fibers to the total usable area of contact) should be greater than 50%. The number of chipped lit fibers should be less than 10% when viewed with transmitted light. The number of unlit fibers shall be less than 15% of the total number of fibers present in the cable. The total number of fiber in the cable shall be greater than 85% of the nominal number of fibers

6.6.2 Fiber Bundle Cable Termination - Continued

for the cable type (45 mil bundle cable nominally contains 210 fibers); partially lit fibers may be counted as 1/2 of a lit fiber.

The termination should be viewed with a magnification such that the fiber containing portion of the termination covers at least 1/2 but less than the total viewing diameter.

6.6.3 Single Fiber Cable Termination

The finished termination shall have a smooth specular finish, when viewed under magnification. One scratch may be present on the fiber end surface. No epoxy smears or edge chips greater than 20% of the end area are allowed.

7.0 QUALITY CONTROL

a. The Quality Control Department shall maintain the necessary surveillance to ensure the following:

   (1) Complete compliance with the requirements of this specification and associated dash-numbered specifications except operator qualification.

   (2) Verification that only approved tools are used and that the tools have been certified to the applicable requirements of Document D2-6438.

   (3) Label each machine setup by size and type.

b. Quality Control shall ensure compliance with the environmental control requirements of this specification.

Cable Type	Layer	Tool	Die	
Galite 5020ST	Outer Jacket	Stripmaster	14 GA Bevelled	1
	Inner Jacket	Nonik	0.031 in	
	Buffer	Nonik	0.010 in	
Galite 1000-210S	Outer Jacket	Stripmaster	12 GA	
	Inner Jacket	Stripmaster	18 GA	

1 Modified per D180-24693-29 Sheet 5

TABLE I

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-27
SCALE	REV	SHEET 5

APPENDIX K

FIBER OPTIC TERMINATION PROCEDURE, HUGHES CONNECTORS

D180-24693-27.1

FIBER OPTIC TERMINATION PROCEDURE

- HUGHES CONNECTORS -

O. R. Mulkey

Boeing Aerospace Company
P.O. Box 3999
Seattle, WA 98124

15 June 1980

Final Report for the Period of 16 December 1979 Through 15 June 1980

Phase IV of NOSC Contract N00123-78-C-0193

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Fiber Optic Cables
Fiber Optic Contacts
Fiber Optic Terminations
Terminus

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

This document is a detail specification covering termination procedures for contacts used in the Hughes C21 connector. The general specification for termination is D180-24693-27.

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AD-A093 304 BOEING AEROSPACE CO SEATTLE WA F/G 20/6
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AUG 80 G KOSMOS, R A GREENWELL N00123-78-C-0193
UNCLASSIFIED NOSC-TR-591 NL

4 OF 5
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CONT.

1.0 SCOPE

a. This specification establishes requirements for termination of fiber optic cables using Hughes C21 series connector contacts. This specification complements D180-24693-27and is an essential part of that specification.

b. In the event of conflicting requirements, this specification shall have precedence over D180-24693-27, and the Engineering drawing shall take precedence over both specifications.

2.0 CLASSIFICATION

None.

3.0 REFERENCES

None.

4.0 CONTENTS

5.0 MATERIALS CONTROL

Epoxy, Bi Pax 2143 D
Alcohol, isopropyl
Acetone

6.0 MANUFACTURING CONTROL

6.1 Tools - Also See Table I and Figure 1

Polishing tool Hughes 1093992S
  Hand fixture
Heat Gun, Ideal 4603A with Nozzle No. 46-922, No Certification Required

TABLE I

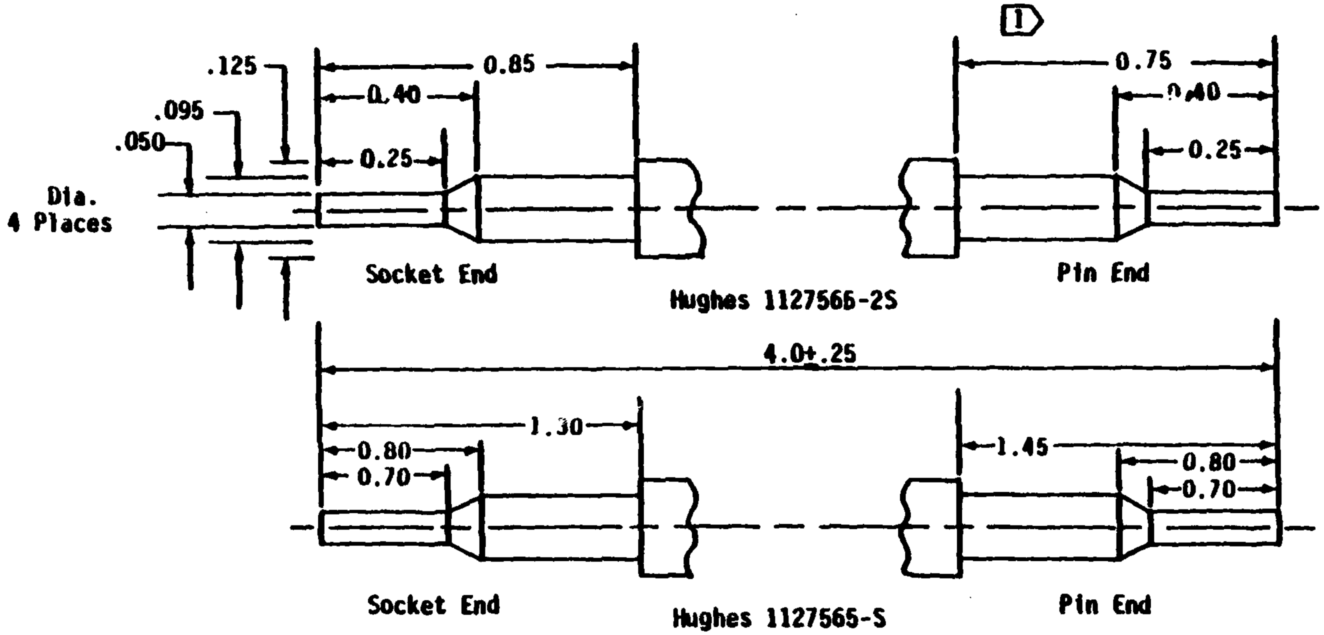
TERMINATION TOOLS

Cable	Crimp Ferrule	Crimp Ring	Crimp Tool (Ferrule)	Crimp Tool (Wire Contact)	Terminus (Type)	EPOXY	Shrink Tubing Tool	Shrink Tubing
Galite 5020ST	1127773 1 1127764	1127765	1143046S Middle		Pin F.O. Single 1093201-080S110S	B1 Pax 2143 D		
Galite 1000-210S	112773 1127764		1143046S Middle		Pin F.O. Bundle 1093827S	"	11275655-S Pin End	HCX-3/32 Black
M27500-22TGU 00	1127984-2		1143046S Middle	Daniels M22520/101 With TP4-303 Head	Pin 22 GA C21P1620A0	"		
Galite 5020ST	1127773 1127764	1127765	1143046S Middle		Socket F.O. Single 1093202 080S110S	"		
Galite 1000-210S	1127773 1127764		1143046S Middle		Socket F.O. Bundle 1093828S	"	11275655-S Socket End	HCX-3/32 Black
M27500-22TGU00	———		1143046S Middle	Daniels M22520/101 With TP4303 Head	Socket 22 GA C21S1620A0	"		

1 1127773 Used on flared backshell connector.

1127764 Used on 3 contact connector. An extra crimp on the Ferrule is required using the small (outside) crimp position.

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-27.1
SCALE	REV	SHEET 2



Shrink Tubing Tool Dimensions - All Dimensions in Inches ±.005"

Figure 1

1 Dimension modified from 1" to .75" by adding .125" dia sleeve

SIZE	CODE IDENT NO.	
A	81205	D180-24693-27.1
SCALE	REV	SHEET 3

6.1 (Continued)

Grinding Disk
  9 micron diamond impregnated plastic
  2000 grit diamond impregnated aluminum*

Polishing Disk
  Phenolic, polishing disk charged with 1 micron alumina
  Phenolic polishing disk charged with 1/3 micron alumina*
  1 micron diamond impregnated plastic
*Preferred
Epoxy Curing Fixture (Use Shop Aid)

6.2 Termination Instructions For Galite 1000 210S When Used With Hughes Flared Backshell △1

6.2.1 Place crimp ferrule (P/N 1127773) over the cable as shown in Figure 1.

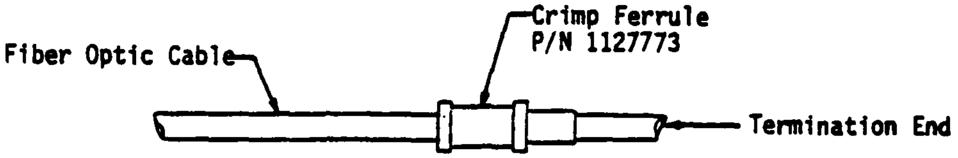


Figure 1

6.2.2 Remove three 4.50 ± .10 inches of the cable's outer jacket (blue Tefzel) using Ideal Stripmaster stripping tool with 12 gauge die. Comb out the braided Kevlar. Trim the Kevlar back .300 ± .050 inches from the end of the cable jacket. (See Figure 2.)

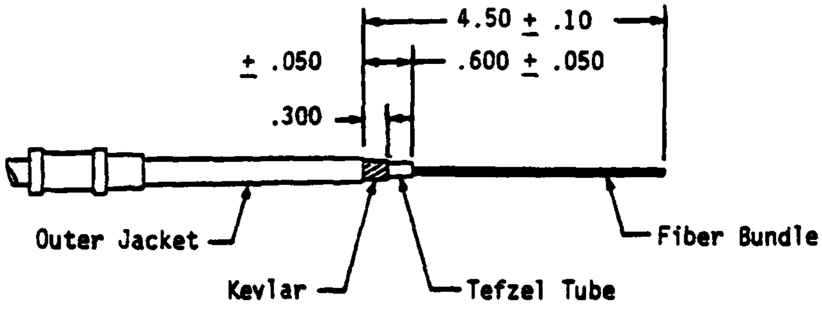


Figure 2

△1 Cut cable 2.25 ± .1 inches longer than the required end of contact position

SIZE A	CODE IDENT. NO. 81205	D180-24693-27 .1
SCALE	REV	SHEET 4

6.2.3 Place crimp ring (P/N 1127765) as shown in Figure 3, trapping the Kevlar braid between the crimp ring and crimp ferrule.

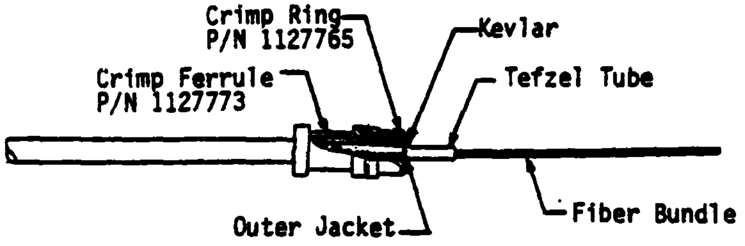


Figure 3

6.2.4 Strip the inner Tefzel tube covering the fiber optic bundle .600 ± .050 inch from the crimp ferrule. The stripping is done with the Ideal Stripmaster stripping tool with the 18 gauge die. See Figure 2.

6.2.5 Form at least three loops with the cable about no less than eight inches in diameter behind the stripped area and retain these loops with a piece of masking tape. See Figure 4. These loops allow glass movement during connector assembly and after the assembly has been completed. Allow tension on the cable without inducing stress on the fibers. NOTE: At the completion of the assembly these loops are removed.

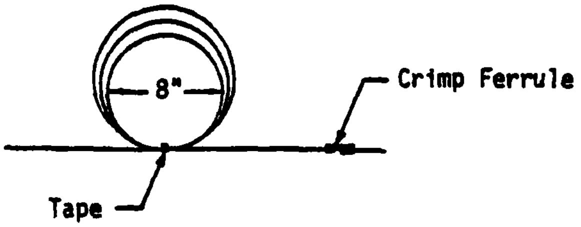


Figure 4

6.2.6 Clean the exposed glass fibers with acetone to remove any oil or grease.

6.2.7 Place the shrink tubing (part of kit) over the shrink tubing form tool (P/N 1127565-S) and cut the tubing to the length of the tool section. Note that each end of the tool is marked pin or socket. Use the pin side for the assembly of pin contacts and the socket side for the assembly of socket contacts. Shrink the portion of the tubing over the large section of the form tool, but leave the other end unchanged. See Figure 5. The tubing may be shrunk completely at this time if a pin contact is inserted into the free end up to the shoulder. See Figure 7.

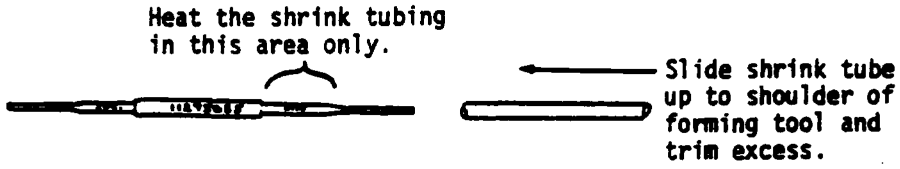


Figure 5

6.2.8 Place the shrink tubing over the bare glass fibers (pre-shrunk end first) and position the tubing over the 1/2-inch section of the inner Tefzel tube covering the optical bundle. See Figure 6.

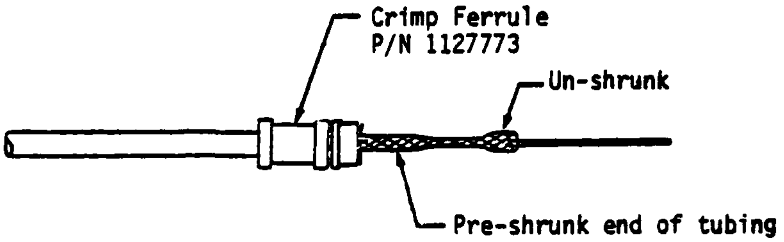


Figure 6

6.2.9 Place the pin contact (P/N 1093827) or socket contact (P/N 1093828) over the glass fibers leaving a 1." ± .1" space between tubing and back of pin.

6.2.10 Work the epoxy Bipax Tra Bond No. 2143D into the exposed glass fibers. Then remove any excess epoxy that has build up on back of the contact as it is being slid into position (Figure 7) and before the rear of the contact enters the shrink tubing.

Caution: Do not get epoxy on shrink tubing

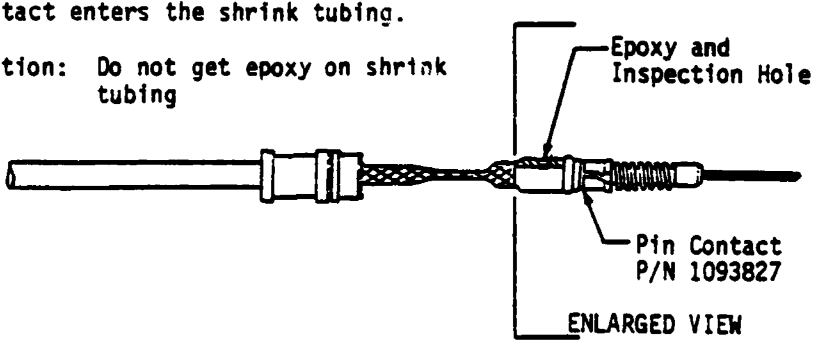


Figure 7

6.2.11 Push the glass fibers back into the cable (toward the loops) as far as possible. Shrink the tubing at the contact ends, but not at the Tefzel end.

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-27 .1
SCALE	REV	SHEET 6

6.2.12 Allow the epoxy to cure for 12 hours. The contacts should be cured with the contacts lower than the cable. This prevents epoxy from wicking up the fibers into the cable.

6.2.13 Crimp ring as shown in Figure 8 with the Hughes crimp tool (P/N 1143046S). /2

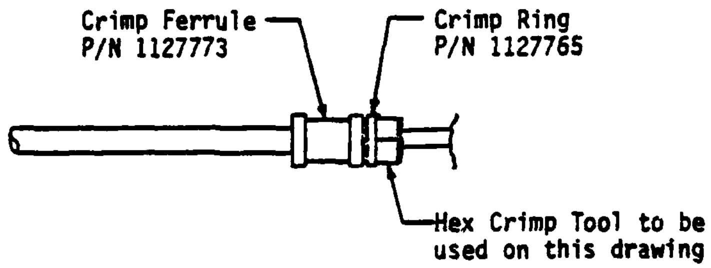


Figure 8

6.2.14 With a diamond disk and a Moto tool or equivalent, remove the excess fiber bundle protruding from the contact. The fibers should be cut at the end of the epoxy cone extending from the contact bushing. See Figure 9. (CAUTION: Do not cut into contact bushing.)

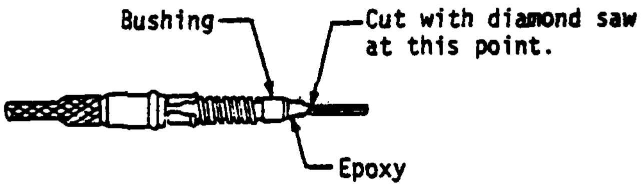


Figure 9

6.2.15 The fiber optic contact is now ready to be ground and polished. This is accomplished using the Hughes Hand Held Polishing Tool (P/N 1093992). See Paragraph 6.6.

6.3 Termination Instructions for Galite 5020 ST When Used With Hughes Flared Backshell /1

6.3.1 Place crimp ferrule (P/N 112773) over the cable as shown in Figure 1.

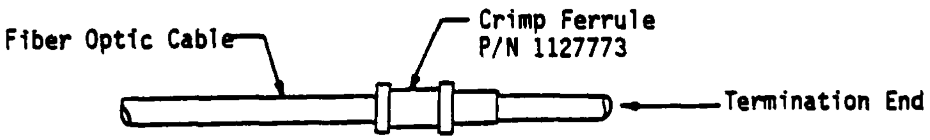


Figure 1

/1 Cut cable 2.25 ± .1 inches longer than the required end of contact position

/2 At any sequence before connector Assy.

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-27 .1
SCALE	REV	SHEET 7

6.3.2 Remove 4.50 inches of the cable's outer jacket using Ideal Stripmaster stripping tool with 14 gauge die. Comb out the braided Kevlar. Trim the Kevlar back .250 inch from the end of the cable jacket. (See Figure 2.)

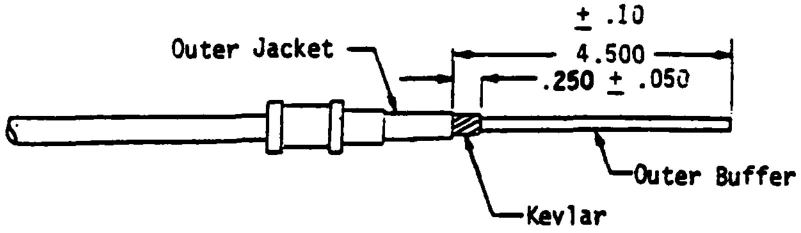


Figure 2

6.3.3 Place crimp ring (P/N 1127765) as shown in Figure 3, trapping the Kevlar braid between the crimp ring and crimp ferrule.

6.3.4 Using the .031-inch "No-Nik" wire stripper, remove the large outer buffer .250 inch from the crimp ferrule. (See Figure 3.)

6.3.5 Using the .010-inch "No-Nik" wire stripper, remove the inner buffer 1.700 inches from the crimp ferrule. (See Figure 3.)

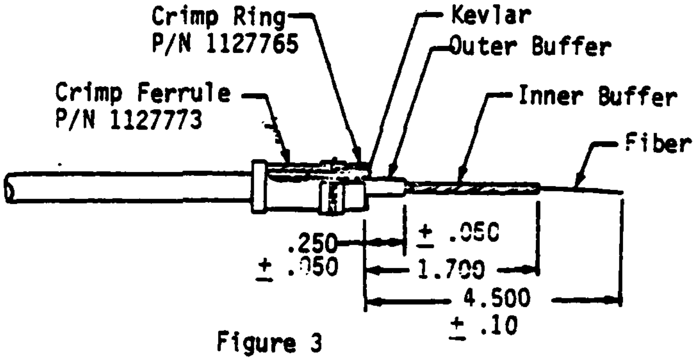


Figure 3

6.3.6 Clean the exposed glass fiber with acetone to remove any oil or grease.

6.3.7 Slide pin contact (P/N 1093201) or socket contact (P/N 1093202) down fiber until the inner buffer seats against the internal guide. This may be verified by checking the inspection slot in the contact and seeing that the internal buffer runs through the inspection slot. (See Figure 4.)

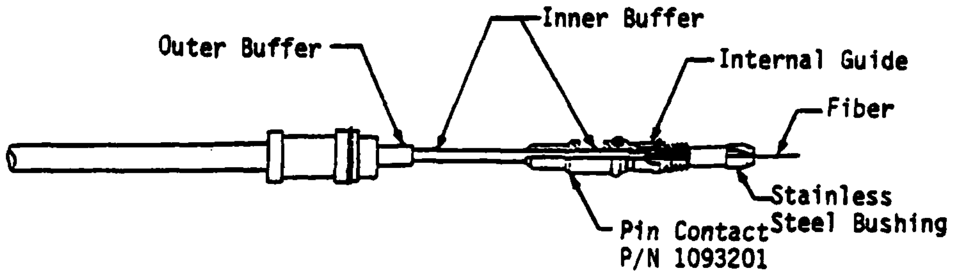


Figure 4

6.3.8 The fiber can now be epoxied to the contact. Apply Bipax 2143D epoxy at the inspection slot and at the front of the stainless steel bushing. Work the fiber in and out (<u>DO NOT</u> pull the fiber all the way through the bushing) several times. This process allows the back of the bushing to back-fill with epoxy. (See Figure 5.) (NOTE: Do not get the epoxy on the large outside diameter of the stainless steel bushing.

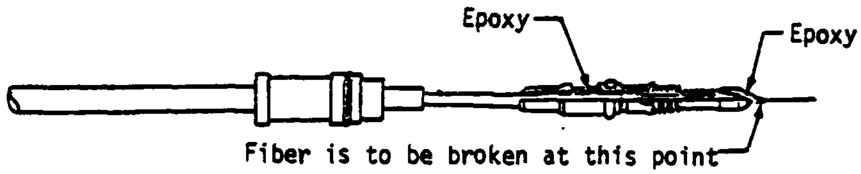


Figure 5

6.3.9 Allow the epoxy to cure for the appropriate length of time (12 hours).

6.3.10 Crimp the crimp ring as shown in Figure 6 with the Hughes crimp tool (P/N 1143046). /1

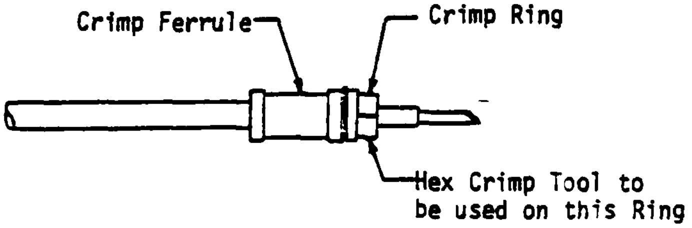


Figure 6

6.3.11 Using a pair of tweezers, break the excess fiber protruding from the contact off. The fiber should be cut at the end of the epoxy cone extending from the contact bushing. (See Figure 5.)

/1 At any sequence before connector assy.

6.3.12 The fiber optic contact is now ready to be ground and polished. This is accomplished using the Hughes Hand Held Polishing Tool (P/N 1093992). (See Paragraph 6.6.)

6.4 Termination Instructions For Galite 1000-210S When Used With Hughes Four-Channel Connector ⚠1

6.4.1 Slide backshell (P/N 1127539-3) over the cables to be assembled as shown in Figure 1.

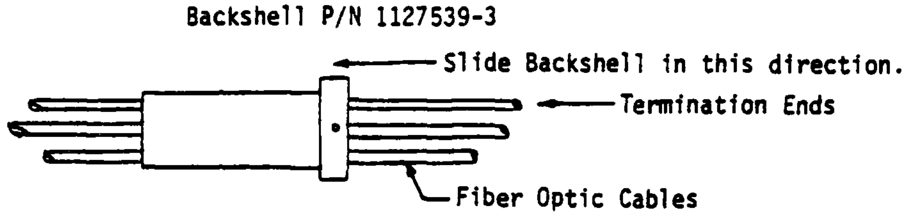


Figure 1

6.4.2 Place crimp ferrule (P/N 1127764) over the cable as shown in Figure 2.

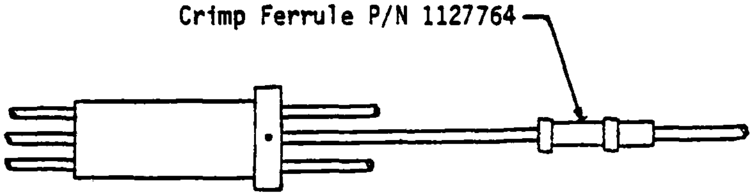


Figure 2

6.4.3 Remove 3.500 inches of the cable's outer jacket (blue Tefzel) using Ideal Stripmaster stripping tool with 14 gauge die. Comb out the braided Kevlar. Trim the Kevlar back .300 ± .05 inch from the end of the cable jacket. (See Figure 3.)

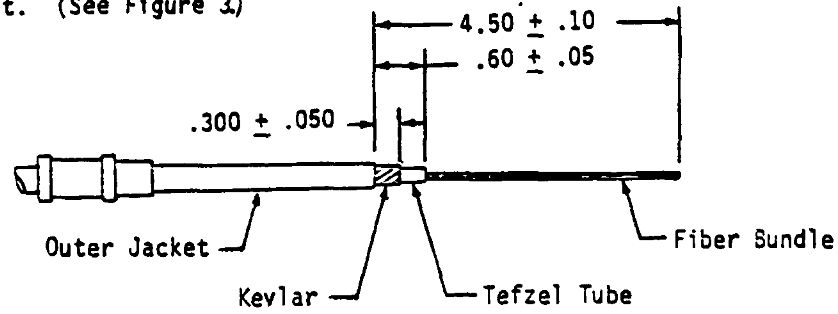


Figure 3

⚠1 Cut cable 2.25 ± .1 inches longer than the required end of contact position

6.4.4 Place crimp ring (P/N 1127765) as shown in Figure 4, trapping the Kevlar braid between the crimp ring and crimp ferrule.

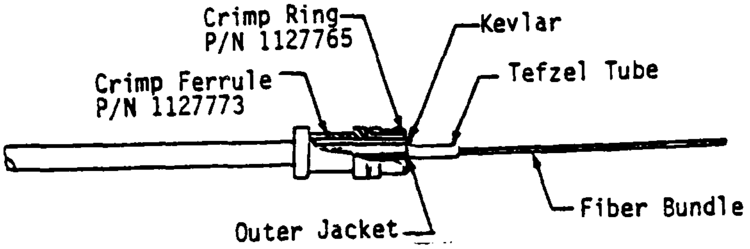


Figure 4

6.4.5 Strip the inner Tefzel tube covering the fiber optic bundle 1/2-inch from the crimp ferrule. The stripping is done with the Ideal Stripmaster stripping tool with the 18 gauge die. See Figure 3.

6.4.6 Form at least three loops with the cable no less than eight inches in diameter behild the stripped area and retain these loops with a piece of masking tape. See Figure 5. These loops allow glass movement during connector assembly and after the assembly has been completed. Allow tension on the cable without inducing stress on the fibers. NOTE: At the completion of the assembly these loops are removed.

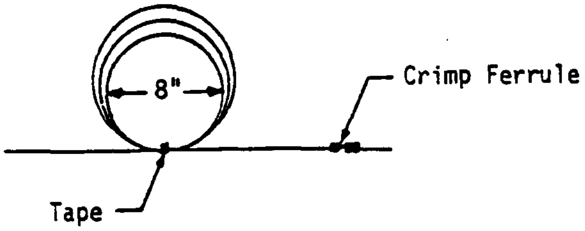


Figure 5

6.4.7 Clean the exposed glass fibers with acetone to remove any oil or grease.

6.4.8 Place the shrink tubing (part of kit), over the shrink tubing form tool (P/N 1127565-25) and cut the tubing to the length of the tool section. Note that each end of the tool is marked pin or socket. Use the pin side for the assembly of pin contacts and the socket side for the assembly of socket contacts. Shrink the portion of the tubing over the large section of the form tool, but leave the other end unchanged. See Figure 6.Δ

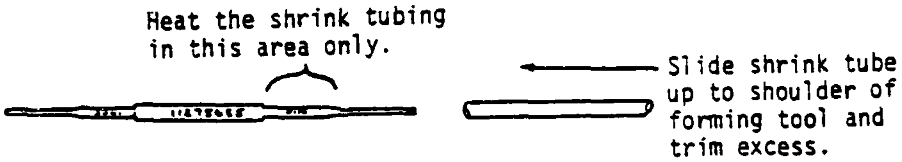


Figure 6

Δ The tubing may be shrunk completely at this time if a pin contact is inserted into the free end up to the sholder. See Figure 8

6.4.9 Place the shrink tubing over the bare glass fibers (pre-shrunk end first) and position the tubing over the half inch section of the inner Tefzel tube covering the optical bundle. See Figure 7.

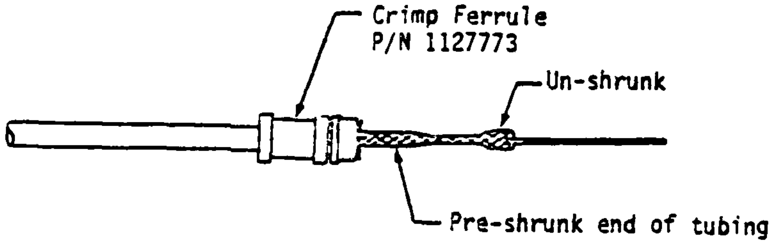


Figure 7

6.4.10 Work the epoxy Bipax Tra Bond No. 2143D into the exposed glass fiber ends, but do not allow the epoxy to contact the shrink tubing.

6.4.11 Place the pin contact (P/N 1093827) or socket contact (P/N 1093828) over the glass fibers and move the contact back, inserting it into the shrink tube, butting the contact shoulder against it. See Figure 8.

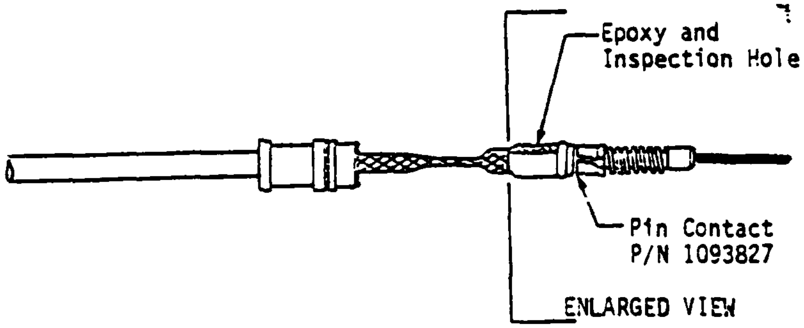


Figure 8

6.4.12 Push the glass fibers back into the cable (toward the loops) as far as possible. Shrink the tubing at the contact ends, but not at the Tefzel end.

6.4.13 Allow the epoxy to cure for 12 hours. The contacts should be cured with the contacts lower than the cable. This prevents epoxy from wicking up the fibers into the cable.

6.4.14 Crimp the crimp ring as shown in Figure 9 with the Hughes crimp tool (P/N 1143046)./1

/1 At any sequence before assembly of connector

SIZE	CODE IDENT NO.	
A	81205	0180-24593-27
SCALE	REV	SHEET 12

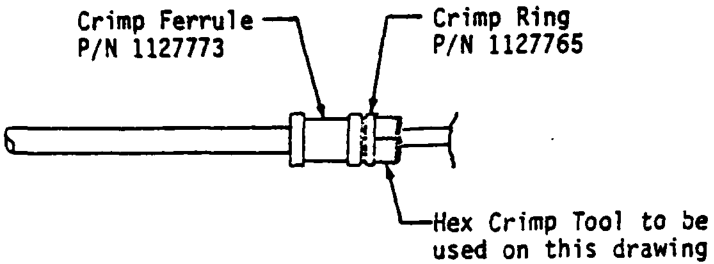


Figure 9

6.4.15 With the diamond disk (P/N 1093991) and a Moto tool or equivalent, remove the excess fiber bundle protruding from the contact. The fibers should be cut at the end of the epoxy cone extending from the contact bushing. See Figure 10. (CAUTION: Do not cut into contact bushing.)

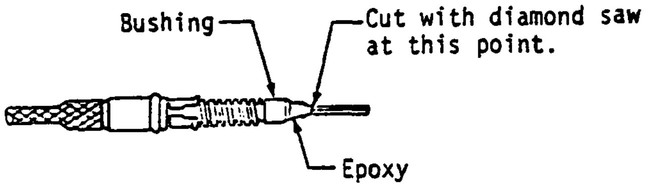


Figure 10

5.4.16 The fiberoptic contact is now ready to be ground and polished using the Hughes Hand Held polishing tool (P/N 1093992). See paragraph 6.6.

6.5 Termination Instructions For Galite 5020 ST When Used With Hughes Four-Channel Connector △1

6.5.1 Slide backshell (P/N 1127539-3) over the cables to be assembled as shown in Figure 1.

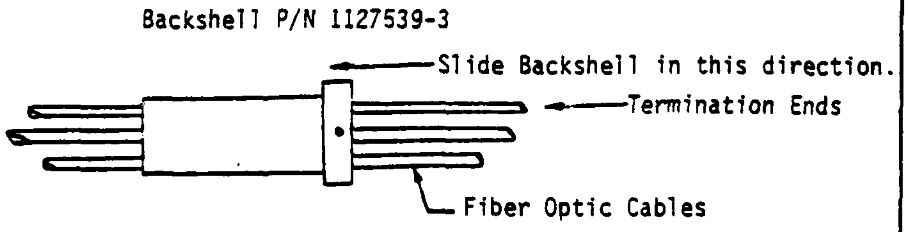


Figure 1

△1 Cut cable 2.25 ± .1 inches longer than the required end of contact position

SIZE A	CODE IDENT. NO. 81205	D180-24693-27 .1
SCALE	REV	SHEET 13

6.5.2 Place crimp ferrule (P/N 1127764) over the cable as shown in Figure 2.

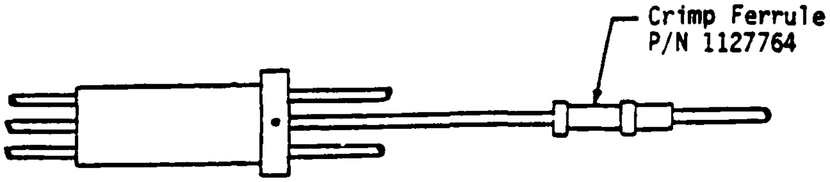


Figure 2

6.5.3 Remove 3.500 inches of the cable's outer jacket using Ideal Stripmaster stripping tool with 14 gauge die. Comb out the braided Kevlar. Trim the Kevlar back .250 inch from the end of the cable jacket. (See Figure 3.)

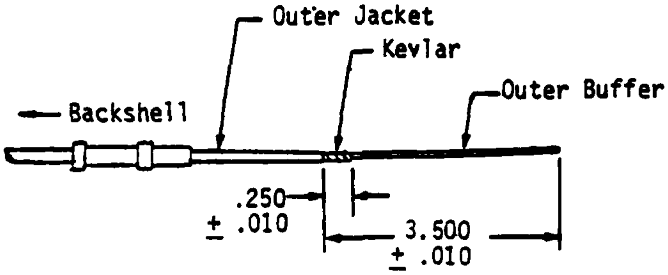


Figure 3

6.5.4 Place crimp ring (P/N 1127765) as shown in Figure 4, trapping the Kevlar braid between the crimp ring and crimp ferrule.

6.5.5 Using the .031 inch "No-Nik" wire stripper, remove the large outer buffer .250 inch frm the crimp ferrule. (See Figure 4.)

6.5.6 Using the .010 inch "No-Nik" wire stripper, remove the inner buffer one (1) inch from the crimp ferrule. (See Figure 4.)

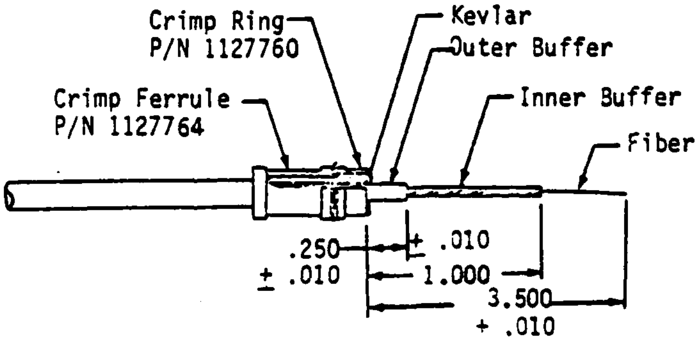


Figure 4

6.5.7 Clean the exposed glass fiber with acetone to remove any grease or oil.

6.5.8 Slide pin contact (P/N 1093201) or socket contact (P/N 1093202) down fiber until the inner buffer seats against the internal guide. This may be verified by checking the inspection slot in the contact and seeing that the internal buffer runs through the inspection slot. (See Figure 5.)

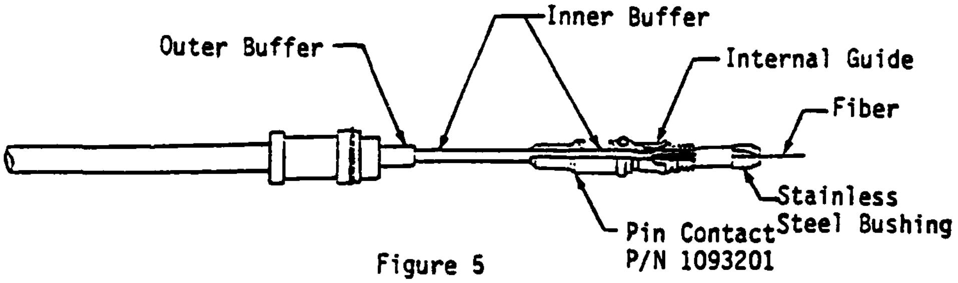


Figure 5

6.5.9 The fiber can now be epoxied to the contact. Apply Bipax 2143D epoxy at the inspection slot and at the front of the stainless steel bushing. Work the fiber in and out (DO NOT pull the fiber all the way through the bushing) several times. This process allows the back of the bushing to back-fill with epoxy. (See Figure 6.) (NOTE: Do not get the epoxy on the large outside diameter of the stainless steel bushing.)

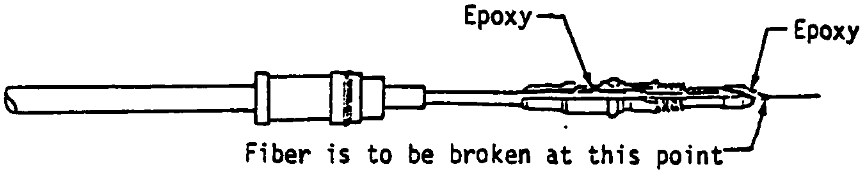


Figure 6

6.5.10 Allow the epoxy to cure for at least 12 hours.

6.5.11 Crimp the crimp tool ring as shown in Figure 7 with the Hughes crimp tool (P/N 1143046). Optional here or after step 6.6

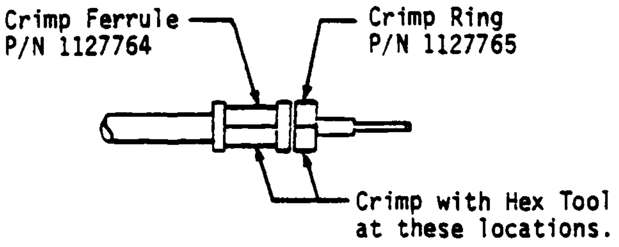


Figure 7

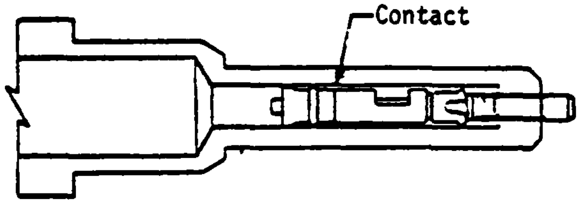
6.5.12 Using a pair of tweezers, break off or cut the excess fiber protruding from the contact. The fiber or cut off saw should be cut at the end of the epoxy cone extending from the contact bushing. (See Figure 6).

6.5.13 The fiber optic contact is now ready to be ground and polished. This is accomplished using the Hughes hand-held polishing tool (P/N 1093992). (See paragraph 6.6.)

6.6 Grinding and Polishing

6.6.1 Contact Mounting

Mount the contact in the split cradle making sure that the stainless contact bushing extends outside the cradle half. See Figure 1. Assemble the cradle halves using the cradle bushing, Figure 2, and insert the assembly into the polishing tool and lock into place (bayonet fitting). The large knurled depth adjustment knob must be backed off at least one full turn to allow the bayonet fitting to lock. Adjust depth so that the tip of the contact barely protrudes from the polishing surface. Turn the grind/polish positioning handle to the grind position (counterclockwise with "G" up). In this position the brass inner surface of the tool is retracted.



Split Cradle
With Contact in Position

Figure 1

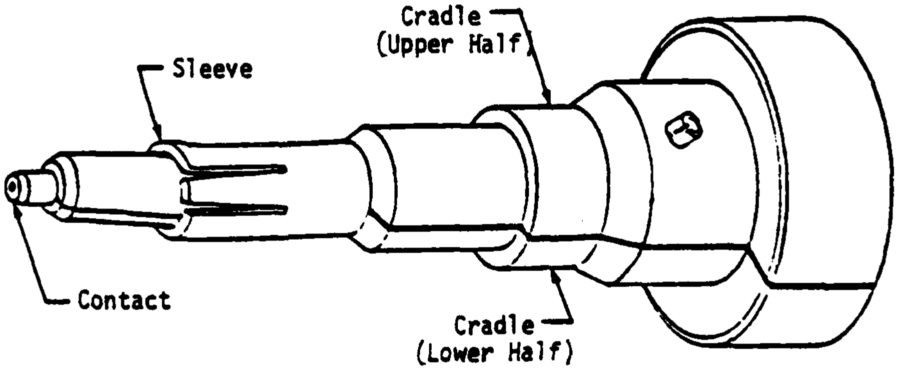


Figure 2

6.6.2 Grinding

Gently lower the polishing tool to the surface of the grinding disk rotating at 60 ± 20 RPM and lubricated with a small amount of running water. As the grinding operation progresses, the tool should be moved slowly radially on the grinding surface and rotated back and forth to provide uniform grinding and wear on the grinding surface. See Figure 3. The depth adjustment should also be lowered in approximately 1/4 turn increments until the stop engages. Note this operation should take approximately 1 minute to 3 minutes. (Until the contact is level with the grinding surface). Rotation rate may be obtained by manual visual count, i.e., 10-20 rotations in 15 seconds.

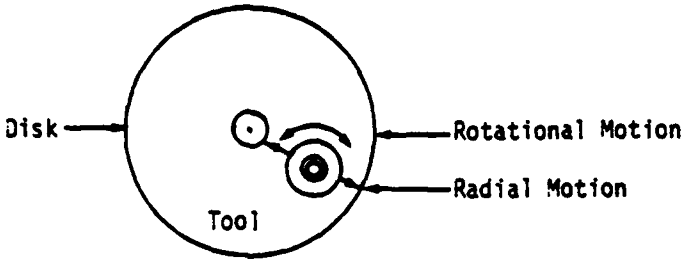


Figure 3

6.6.3 Polishing

Change the grind/polish positioning handle to the polish position (clockwise, P up) with the brass surface extended. Rinse the polishing tool with running water to avoid contamination of the polishing wheel and then gently lower the tool on the surface of the wheel. Use the radial and rotating motion described in Paragraph 6.6.2. During the polish operation which should take approximately one minute to 5 minutes or until grinding marks are removed.

6.6.4 Inspection

Rinse the contact and fixture to remove the polishing materials and inspect the surface for finish and/or defects using a microscope of from 60 to 120 power. No more than three major scratches may appear across the fiber surface. The fiber end should appear smooth and flat (mirror finish on connector) and shall be free from chips, epoxy smears or epoxy voids.*

6.6.5 Cleansing of Contact

Remove the polished contact from the fixture. Rinse off residuals with water and, finally, with alcohol. An ultrasonic cleaner may be utilized.

---

*A major scratch is one that is readily discernible across the surface of the pin at the above magnification.

6.7 Crimp Requirements

a. All crimp impressions shall be located on the crimp barrel. The inspection hole must remain useful after crimping. The crimp impressions shall not extend to the end of the crimp tarrel nor to any shoulder adjacent to the crimp barrel.

b. Crimped connector contacts shall show no evidence of being bent.

c: Crimped connector contacts shall not exhibit fractures, cracks, or base metal when viewed under 3X to 5X magnification.

6.8 Rework Procedures

6.8.1 Scope

This section provides alternate methods and materials which may be used to repair (reterminate) an existing cable in a harness or to prepare a new cable to replace a damaged cable in a completed or partially completed harness.

6.8.2 Additional Materials

Epoxy - Epotec 331, 353, or 353ND may be used and may be cured at 150°C ±5°C for 5 minutes ±1 minute or until the epoxy turns from amber to red.

Adhesive - Loctite Super Bonder 416

6.8.3 Additional Tools

Oven - Setable to 150°C or heat gun with controlled temperature head not to exceed 160°C air output at head face.

600° grit wet type abrasive or abrasive paper.

Shoe for polishing tool ---- 2-5 mils thick, with center hole (shop aid).

6.8.4 Termination of Galite 1000-210S

Follow the procedure for this cable and connector type except that the alternate epoxies and cure times may be used. Strip length may be shorter than indicated. In addition, apply a small amount of the adhesive in the inspection hole and cure before applying heat to the epoxy. This will act as a stop to prevent the heated thinned epoxy from wicking up the fibers.

6.8.5 Termination of Galite 5020ST.

Follow the procedures for that cable and connector type except that the alternate epoxies and cure time may be used. Strip length may be shorter than indicated. In addition, a small quantity of adhesive should be applied at the inspection hole to the fiber and cured before heat curing the epoxy to prevent wicking of the epoxy when thinned by the higher temperature cure.

6.8.6 Initial Grinding

An extra initial grinding step may be added using the 600 grit abrasive and the polishing fixture shoe. The course grit material will speed cutting time of the harder epoxy. The shoe protects the surface of the polishing tool and also acts as a depth limiter to this step.

6.8.7 Cleaning

The contact and the polishing tool must be thoroughly cleaned after the initial grinding operation to prevent contamination of the following grinding and polishing disks.

6.8.8 Grinding and Polishing

At this point return to the standard method for the cable and connector type .

7.0 QUALITY ASSURANCE

The Quality Assurance Organization shall maintain the necessary surveillance to ensure the following:

a. Compliance with the requirements of this specification and

b. Conformance of crimped contacts with the applicable crimp configurations of D180-24693-27.

APPENDIX L

FIBER OPTIC TERMINATION PROCEDURE, AMPHENOL CONNECTORS

D180-24693-27.2

FIBER OPTIC TERMINATION PROCEDURE

- AMPHENOL CONNECTORS -

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Boeing Aerospace Company
P.O. Box 3999
Seattle, WA 98124

15 June 1980

Final Report for the Period of 16 December 1979 Through 15 June 1980
Phase IV of NOSC Contract N00123-78-C-0193

Prepared For:

Naval Ocean Systems Center

Code 9313

San Diego, CA 92152

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Fiber optic cables
Fiber optic contacts
Fiber optic terminations
Terminus

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

This document is a detail specification covering termination procedures for contacts used in Amphenol 811 series connectors. The general specification for termination is D180-24693-27.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

1.0 SCOPE

a. This specification establishes requirements for termination of fiber optic cables using Amphenol 801 series connector contacts. This specification complements D180-24693-27 and is an essential part of that specification.

b. In the event of conflicting requirements, this specification shall have precedence over D180-24693-27, and the Engineering drawing shall take precedence over both specifications.

2.0 CLASSIFICATION

None.

3.0 REFERENCES

Except where a specific issue is indicated, the current issue of the following references shall be considered a part of this specification to the extent indicated herein.

4.0 CONTENTS

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-27.2

SCALE	REV	SHEET 1

5.0 MATERIALS CONTROL

Epoxy, Epotek-331
Isopropyl alcohol

6.0 MANUFACTURING CONTROL

6.1 Tools

a. Crimp tool, Daniels Mfg. Corp. HX4
M22520/5-01

b. Die set, Amphenol 227-909-2022

c. Polishing tools

Amphenol 227-909-2020
Amphenol 227-909-2021

6.2 Heavy Duty Kevlar Reinforced Fiber Bundle Cable

6.2.1 Cable Preparation

6.2.1.1 Remove outer jacket for a length of 1½". CAUTION: Do not cut or remove Kevlar strengthening fibers. See Figure 1.

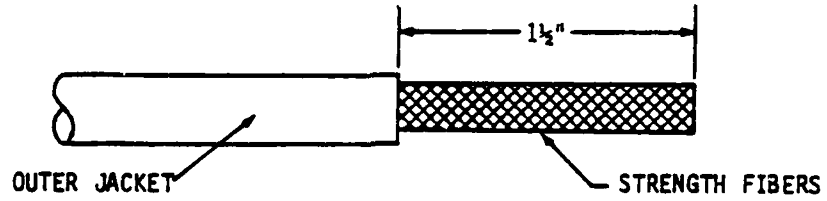


FIGURE 1

6.2.1.2 Draw strengthening fibers back over outer jacket. Remove 1.34" of inner cable jacket to expose the optical fibers. (Remove serving thread that is wrapping the fibers.) Be careful not to break any of the optical fibers. See Figure 2.

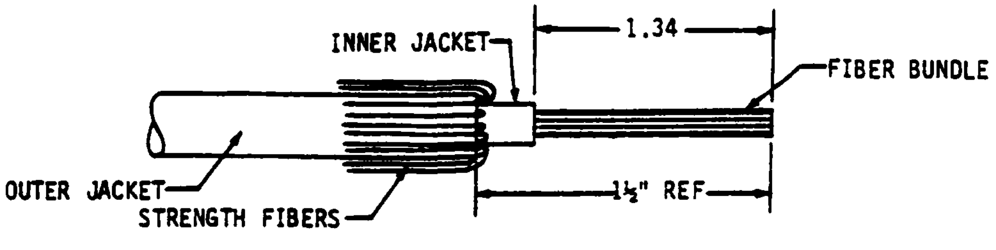


FIGURE 2

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-27.2
SCALE	REV	SHEET 2

6.2.1.3 Clean the exposed fiber bundle under the jacket using isopropyl alcohol, either by dipping or by use of a "squeeze bottle".

6.2.1.4 Apply epoxy to the inner jacket.

6.2.1.5 Reposition the strengthening fibers back over the fiber bundle and carefully slip the crimp ferrule over both fibers and up to the outer jacket.

6.2.1.6 Reposition the strengthening fibers back over the ferrule and apply epoxy to the glass fibers up to the ferrule. Work the epoxy well into the fibers but do not allow the epoxy to wick up over the jacket.

6.2.1.7 Slip contact onto glass fiber bundle until it butts against the crimp ferrule. Draw strength fibers tight, keeping contact in place against ferrule. Place assembly into crimping tool (Die Set Amphenol #227-909-2022) and register contact collar in recess provided for it. Check for maintaining positioning of contact ferrule and that strength fibers are held tight. Close handle of crimp tool affecting crimping of the ferrule. Put one drop of epoxy on fibers where they project through nose of contact.

6.2.1.8 Place crimped assembly under a source of heat and cure epoxy at a temperature of 120°C for 5 minutes. When epoxy on fibers at nose of contact turns red, the epoxy is cured. Care should be exercised so that curing temperature is not exceeded or cable jacket will be damaged.

6.2.1.9 Allow assembly to cool to room temperature.

6.2.2 Polishing Procedure

6.2.2.1 Snap off excess fibers that project from end of contact.

6.2.2.2 Insert contact into polishing tool.
Use Tool #227-909-2021 for contact 801-999-5124
and Tool #227-909-2020 for contact 801-999-5125

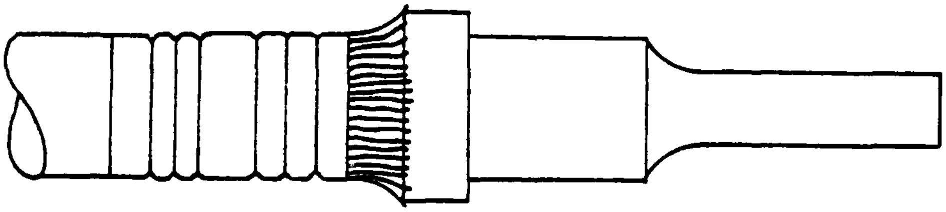
6.2.2.3 Polish using 9 micron polishing film, bring fibers to contact tip using water as a lubricant and coolant.

6.2.2.4 The final polishing step should be accomplished using 1 micron polishing film.

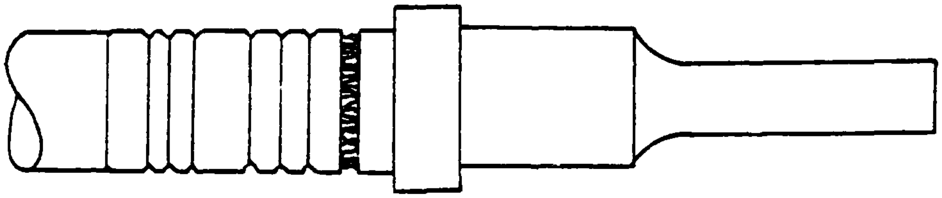
6.2.2.5 Dry and examine under 50X magnification for gross imperfections. Be sure the optical surface is flat and free of scratches, chips, or epoxy smears.

6.2.2.6 Remove strength fibers from front end of ferrule (cut flush with scalpel or razor blade). Inspect retention collar area of contact. Be certain that any stray epoxy is removed from the surfaces. See Figure 3.

CAUTION: If above procedure described in 6.2.2.6 is not adhered to during terminating a fiber optic cable, the contact retention system of the connector will be damaged and the contact will fail to remain captivated.



IMPROPER ASSEMBLY



This area to be free of projecting strength fibers and stray deposits of epoxy.

CORRECT ASSEMBLY

FIGURE 3

SIZE A	CODE IDENT. NO. 81205	D180-24693-27.2
SCALE	REV	SHEET 4

6.3 Medium/Light Duty Unreinforced Fiber Bundle Cable

6.3.1 Cable Preparation

6.3.1.1 Remove jacket for a length of 1".

6.3.1.2 Roughen the 1st 5/8" of jacket using 240 grit paper.

6.3.1.3 Slip a 5/8" length of 1/8 heat shrinkable tubing over jacket to a depth of 3/8" as shown in Figure 4.

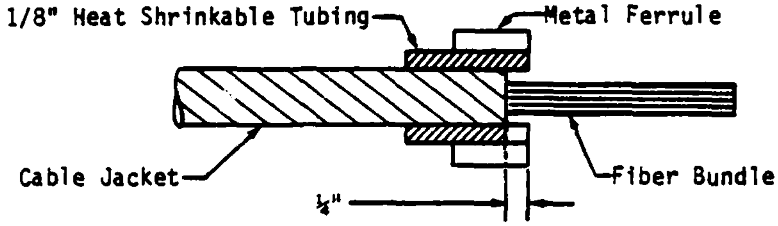


FIGURE 4

6.3.1.4 Coat fibers with epoxy working it between all fibers.

6.3.1.5 Slide contact over fibers and under the ferrule and heat shrinkable tubing until it bottoms on the jacket.

6.3.1.6 Crimp the ferrule onto the contact using the listed tool and die set.

6.3.1.7 Apply epoxy to the tip on the contact and cure for 5 minutes at 125°C.

6.3.2 Polishing Procedure

6.3.2.1 Polish per 6.2.2.

6.4 Light/Medium Duty Single Fiber Cable

6.4.1 Cable Preparation

6.4.1.1 Use the procedures detailed in Paragraph 6.3.1.

6.4.2 Polishing Procedure

6.4.2.1 Polish per Paragraph 6.2.2.

6.5 Heavy Duty Single Fiber Cable

To be added.

6.6 Crimp Requirements

a. All crimp impressions shall be located on the crimp barrel. The inspection hole, if present, must remain useful after crimping. The crimp impressions shall not extend to the end of the crimp barrel nor to any shoulder adjacent to the crimp barrel.

b. Crimped connector contacts shall show no evidence of being bent.

c. Crimped connector contacts shall not exhibit fractures, cracks, or base metal when viewed under 3X to 5X magnification.

APPENDIX M

FIBER OPTIC SHOP AIDS REQUIREMENTS, GENERAL

D180-24693-29

FIBER OPTIC SHOP AIDS REQUIREMENTS

-GENERAL-

O. R. Mulkey

Boeing Aerospace Company
P.O. Box 3999
Seattle, WA 98124

4 June 1980

Final Report For the Period of 16 December 1979 Through 4 June 1980
Phase IV of NOSC Contract N00123-78-C-0193

Prepared For:

Naval Ocean Systems Center
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San Diego, CA 92152

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Fiber optic contacts
Fiber optic Terminations
Terminus

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

This document describes the tools and equipment required for the termination and installation of fiber optic harnesses.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

1.0 SCOPE

a. This specification provides the requirements and procedures for fiber optic special tooling and equipment not otherwised identified or controlled which is required or aids in the fabrication, installation, repair or inspection of fiber optic harnesses. Items covered may be commercial, vendor furnished or shop built. Identification may be by name, part number or sketch type drawing. The items intended use should be noted.

b. In case of conflict between this specification and the Engineering drawings, the information on the Engineering drawing shall have precedence.

2.0 CLASSIFICATION

None.

3.0 REFERENCES

None.

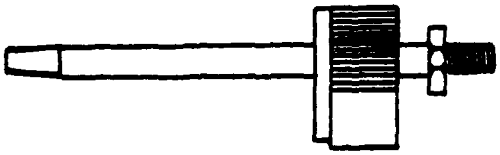
4.0 CONTENTS

5.0 MATERIALS CONTROL

Qualification of special tooling or equipment shall be by demonstration by the using organization of function and safety to product and personnel to Engineering and Quality personnel. Qualification or certification need not be noted on the item. Inclusion in this document is sufficient.

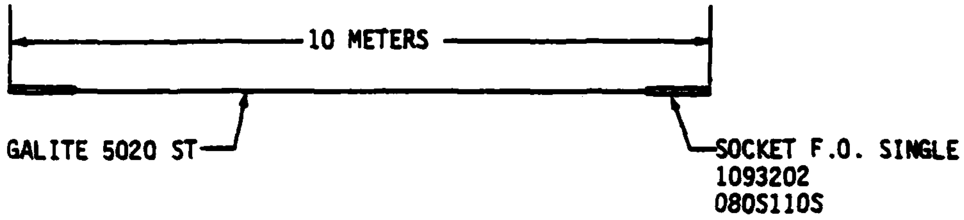
USE FOR TYPEWRITTEN MATERIAL ONLY

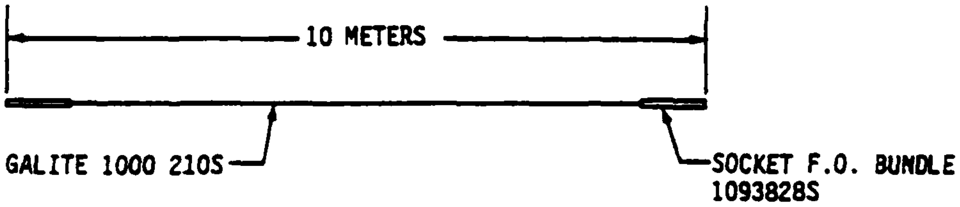
SIZE	CODE IDENT. NO.	
A	81205	
SCALE	REV	SHEET 1



Front Insertion Tool for Single Fiber and Fiber Bundle Contacts in Hughes C21 and 4 Contact Connectors

SIZE A	CODE IDENT. NO. 81205	D180-24693-29	
SCALE	REV	SHEET	2



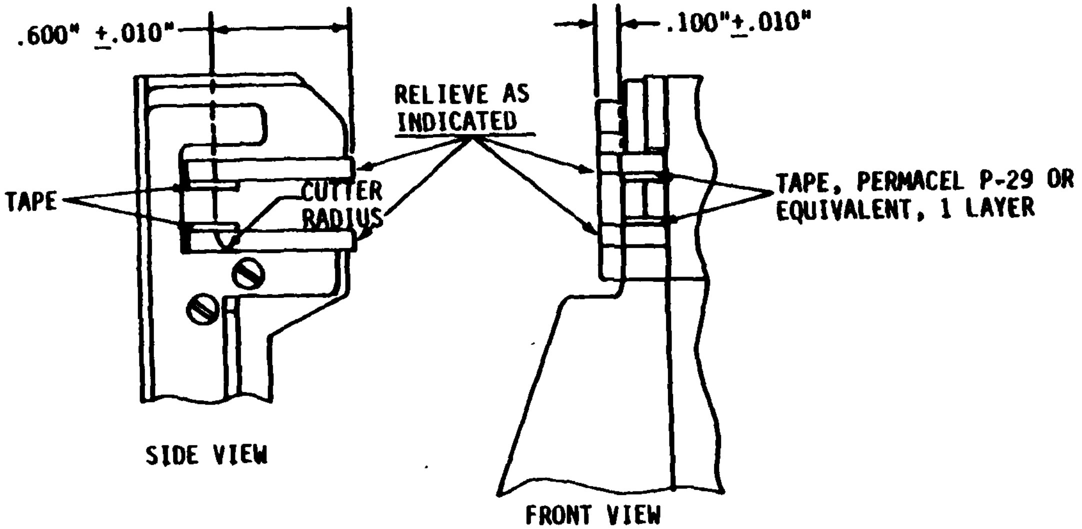


Reference Cables for Use in Insertion Loss Test of Cables Terminated with Hughes Pin Contacts and Connectors.

SIZE A	CODE IDENT. NO. 81205	D180-24693-29
SCALE	REV	SHEET 3

NUMBERED TOOL LIST

Tool Type	Part Number	Use
Insertion/Extraction	Hughes 1093663S	To apply or remove the alignment sleeve on Hughes sockets.
Cable Clamp, Small Large	Hughes 1143047 Hughes 1143048	Used in the Hughes polishing tool (Part No. 1093992S) to support the cable during the grind/polish operation. Use size which best fits cable being finished.
Grind/Polish Machine	Fac-Ette 8826	Used to rotate grinding & polishing disks during termination sequence.
Cut Off Wheel, Diamond	Isomet 11-1180	Used to cut off excess fiber(s) after epoxy cure in preparation for the grind/polish operation of termination
Ultrasonic Cleaner	Delta Sonic D1-3	Provides ultrasonic action in the cleaning of the grind/polish tool and termination during the termination sequence.
Light Source	D180-2451-2 (or small flashlight)	Used to illuminate fiber ends during continuity test and photography.
Test Cables Source Detector	None	Used with Photodyne optical multimeter to couple to reference cables and cables under test.
Insertion Tools	Hughes 1143042	Used to insert fiber bundle contacts into Hughes 4 contact connectors.
	Hughes 1143043	Used to insert single fiber contacts into Hughes 4 contact connectors.



IDEAL (STRIPMASTER) JAW MODIFICATION

SIZE	CODE IDENT. NO.	
A	81205	D180-24693-29
SCALE	REV	SHEET 5

APPENDIX N

ROUTING TECHNIQUES

D180-24693-5

ROUTING TECHNIQUES

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8 September 1978

Interim Report for Period 15 May through 8 September 1978

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Handling
Installation Hardware
Repairability
Fiber Optic Components

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

An analysis was made of the routing techniques for fiber optic interconnects, comparing them with conventional electrical wire. Three main areas were addressed. These areas were:

1. Hazardous/sensitive area about the aircraft.
2. The main aircraft locations and the expected environmental conditions.
3. Fiber optic component capabilities to operate in either of the two above areas.

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20. (Continued)

In addition, standard routing procedures applicable to fiber optics were identified as part of the overall routing technique analysis.

The results of the analysis showed that fiber optics can now be safely routed through hazardous/environmentally stringent areas without sacrificing safety or performance. This is true because the glass-on-glass fiber bundle can withstand temperatures up to 600°C prior to softening. The other well-established benefits such as no grounds and EMI immunity makes the fiber itself attractive for most aircraft applications.

There are some routing precautions with the fiber, however. It has been reported that moisture has caused fiber cracking in stress areas such as in the bend radius. This will require special moisture protection or routing instructions that will clearly limit tensile or compression loads and excessive axial twisting, bending, and flexing.

One disadvantage to fiber optic interconnect systems is that signals cannot be reliably terminated or generated in hazardous/high temperature locations. This is due to the temperature sensitivity of the active components, particularly the laser diodes. During the analysis, it was found that the component manufacturers did not have the data that would allow a thorough analysis of the component characteristics as a function of several different environmental conditions. Although optical data was generally sufficient, full parametric characteristics were not identified to fully assess the components for a variety of environments.

TABLE OF CONTENTS

1.0 INTRODUCTION

The wiring in an aircraft is designed to withstand a broad range of adverse thermal, mechanical, and chemical environments. The performance levels of the installations have been determined by careful evaluation and trial and error to such an extent that electrical system reliability is taken for granted. Even though a modern commercial or military airplane has thousands of connectors with tens of thousands of individual contacts and the wiring total lengths are measured in miles, a malfunctioning circuit is rare.

Fiber optics is a new but similar field. Many of the lessons learned in standard electrical wiring can be used as a starting point for designing reliable fiber optic installations. It is the purpose of this document to summarize the design criteria which apply to both standard wiring and fiber optic cables and use this for a design base to establish a philosophy for fiber optics routing. To do this, the families of areas in the airplane where fiber optics could be routed will be grouped and critical design listings made for each. The routing philosophy presently applied to each area in designing electrical installations will be tabulated.

Finally, the comparative properties of fiber optic cables and electrical cables will be used to determine what changes need be made and hardware developed in order to determine where fiber optic technology can be successfully utilized.

2.0 SUMMARY AND CONCLUSIONS

An analysis was made of the routing techniques for fiber optic interconnects, comparing them with conventional electrical wire. Three main areas were addressed. These areas were:

1. Hazardous/sensitive area about the aircraft
2. The main aircraft locations and the expected environmental conditions
3. Fiber optic component capabilities to operate in either of the two above areas

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One disadvantage to fiber optic interconnect systems is that signals cannot be reliably terminated or generated in hazardous/high temperature locations. This is due to the temperature sensitivity of the active components, particularly the laser diodes. During the analysis, it was found that the component manufacturers did not have the data that would allow a thorough analysis of the component characteristics as a function of several different environmental conditions. Although optical data was generally sufficient, full parametric characteristics were not identified. These characteristics include:

- Stability versus temperature
- Sensitivity versus temperature

- Activation energy
- Radiation effects
- Moisture/humidity resistance
- Stress (Mechanical)
- Electrical overstress effects on sources/detectors
- Thermal shock
- Contamination resistance

Although some research is being directed toward gathering data on the above areas, the data does not exist to firmly state that fiber optics can be used in all applications and locations. The trends for the active components, however, indicate that the active components may be used in hazardous/ environmentally stringent areas in the mid-1980's.

Special routing techniques will also be necessary for termination and splicing aboard the aircraft. Splicing areas may have to be designated in order to allow for the necessary room and safety requirements necessary to make splices/ terminations. This is an additional consideration that is not needed for conventional wire.

The area of splicing and termination as applied to field repair techniques is not well understood and will be addressed in subsequent phases of the program. Until the equipment is developed to allow effective splicing of fiber bundles, the routing techniques must allow for adequate room to repair or replace a broken fiber. An interim solution to this problem can be achieved by running unused bundles in the harness. Then, if one bundle breaks, a spare would be available and could be connected at the backshell of the connector. Although this approach is feasible, it begins to defeat some of the projected cost benefits of fiber optic interconnect systems.

The advantages to fiber optic interconnects have been explored and are well understood. These advantages, the main one being the absence of electrical current, will allow fiber optics to be applied in most areas of a military type aircraft. The currently identified disadvantages to routing fiber optics are:

- Moisture protection requirements
- Active component reliability
- Splicing/termination areas
- Limited data base for routing concepts

The methods developed for routing conventional wire into an aircraft are believed to be sufficient for fiber optics. Precautions to address the areas above must be considered in the fiber optic routing technique to allow for successful installations. It is believed that the identified technology problems can be resolved and that successful, reliable routing of fiber optics will occur for all areas of a military aircraft by mid-1980's.

3.0 ROUTING ANALYSIS

3.1 Basis for Routing

The installation of fiber optic cables in aircraft can be done using the techniques adapted from the installation and routing of standard electrical and coaxial cables. The experience obtained in experimental commercial-type installations and comparison of the properties of fiber optics cables with comparable electrical wire characteristics supports the feasibility of adapting standard routing techniques to installing fiber optics cables.

The performance standards of installed electrical cables are tested with well established procedures and limits. The limits of MIL-E-5400 and MIL-STD-810 define a standard of performance to check the equivalent fiber optics cables.

The installation procedures defined in Volume D180-24693-2 are based on standard practices of airplane installation. The installations produced have a satisfactory history of withstanding airplane service life. The installation and routing of fiber optics cables in the same manner, then, can be expected to provide an equally serviceable installation.

The successful installation and routing of fiber optics cables in two Boeing military-type aircraft (the ASW B-504 and the YC-14 aircrafts) have shown that prudent selection of the processes developed for conventional electrical cables can be successful with fiber optic. This philosophy will be carried forward in the analysis of routing techniques for fiber optics.

The primary areas to be analyzed in the routing of fiber optics are:

1) Where can fiber optics be routed in a military-type aircraft?
2) What are the environmental constraints of the aircraft areas?
3) How mature are the fiber optic components to withstand the required environmental conditions?

These areas will be discussed in the following sections.

3.2 Hazardous/Sensitive Routing Areas

The most obvious hazardous area that fiber optics can impact is the fuel tanks. It is imperative that no sparks be generated in this area in order to prevent explosion. Similar "no spark" areas may exist in armament storage bays or areas of gaseous mixture with air: MIL-E-5400P considers a system explosion proof when the components are incapable of producing arcing or sparking.

With conventional electrical wiring, explosive areas are generally to be avoided because of the spark threat. However, when it is required to go through a fuel tank, for instance, the following routing additions are made:

- A metal conduit having a Teflon impregnated woven or wrapped glass fiber liner or a similar protective coating is used.
- All wiring within the conduit must be flame resistant per MIL-W-25038 or equivalent.
- Bond resistance for fire/explosion hazard area is applicable.
- All terminations in fire/explosion hazard areas should be potted or sealed using compatible material to prevent shorting or arcing.

This arrangement offers the greatest protection against fires or explosions resulting from shorted or overloaded wires, which otherwise would ground to the conduit wall and burn through.

Because fiber optics carries no electrical current, shorting or arcing is not a possibility. Therefore, the costly and complex steps listed above can be eliminated without sacrificing safety. This makes fiber optic fuel indicators and other control functions within fire/explosion hazard areas a reality.

High temperature areas also cause problems in routing interconnect systems. Typical hot areas include engines, engine nacelles, heaters, air conditioners, heat exchangers, and skin hot spot zones.

For conventional wiring, several precautions must be taken to prevent temperature damage. These rules include:

- Polyethylene dielectrics (used in coax) softens above 160°F. Bend radius must be 10D at any temperature.
- Bundle/route low temperature general purpose wire separately from high temperature wire and outside any area that may reach temperatures above 200°F.
- Provide clearance, thermal insulation, or baffles between wiring and heat generating parts such as electron tubes and power resistors to prevent deterioration.
- Route wires outside areas of thermal extremes.
- When routing wires or wire bundles in areas where there is heated equipment, thermal anti-icing ducts, or cabin air conditioning ducts, maintain the maximum spacing possible between the wire and the heater equipment.

Here, again, fiber optics technology eliminates extensive temperature damage protection schemes. Fiber interconnects, using a glass cladding over the silica (glass-on-glass) can withstand temperatures up to 600°C-800°C before softening occurs. Although the fibers can still be functional above this temperature range, it should be considered the upper limit of operation. Because of the high temperature capability, most of the precautions listed above are minimized in fiber optics. Common sense, however, must still prevail in that direct contact with a heating element such as a power resistor or heater heating element should be avoided. As a general rule, fiber optics cables should remain at least two inches away from heat generating sources.

Composite materials is a new technology that will be considered for future aircraft. The use of composites presents additional problems since the shielding effects of the aluminum structure will be lost. Shielding for conventional wire will be mandatory to reduce EMI/RFI susceptibility, guard against radiation (transmission) of data and protect against radiation damage. Figure 1 indicates some of the applications that require shielding and would be particularly important in composite structures.

FIGURE 1: CONVENTIONAL WIRE REQUIRING SHIELDING/GROUNDING

APPLICATIONS

- All analog signal cables feeding wideband receiver circuits
  - A/D Converters
  - High Gain Amplifiers
- All digital signal cables feeding transient sensitive electronics
- All excitation power and measuring power cables
- All video lines
- All rf signal cables

EXAMPLE - SHIELDING REQUIREMENTS (EXTERNAL)

- Multiple grounded to chassis in most cases
- Audio/instrumentation circuits of 10MV or less (full scale) must be singly grounded
- Shields should not be contacted together at the chassis
- Touching shields should be avoided
- Use caution with shields for return circuits
- Shields must be grounded

The shielding requirements shown in Figure 1 are just a partial listing of the rules that must be followed in protecting cables. The rules are extensive and add significantly to the cost of the system. Fiber optics would eliminate the need for this extensive grounding due to the fact that it does not carry current. In fact, for the fiber optic harness selected for this program, the conventional harness contains 114 terminations of wires, jumpers, shields, and grounds which was reduced to 56 terminations wires, shields, and grounds in the new fiber optic/conventional hybrid design. This reduction was due to the elimination of jumpers, shields, and grounds on the small signal lines which were replaced with fiber optics (the power lines remained in the new harness along with the associated grounds and shields).

Fiber optics, therefore, can be routed in composite structures without sacrificing cost, weight, and security. This is true not only in composites, but in other applications requiring extensive shielding or security. Security is one area where fiber optics can be very beneficial. Because it does not radiate energy or is difficult to tap into (particularly on an aircraft), the use of encryption techniques would not be necessary for on-board data processing and transfer of secure information.

In areas where interference coupling control is mandatory to minimize EMI, special precautions must be taken with conventional interconnect systems. Because EMI can be induced on the wires, certain circuit design criteria must be implemented. These factors include:

- Balance of Circuitry
  - minimize capacitive coupling
  - wires covered with high dielectric insulation
  - special isolation
  - properly twisted wires
- Impedance of Circuit
  - design for lowest practical impedance
- Bandwidth of Circuit
  - noise increases with bandwidth

Twisting the wires is a common practice in reducing mutual inductance (for a balanced circuit). Specific instructions are set forth to define and control the twisting.

Fiber optics on the other hand cannot be effected by EMI. Therefore, circuit design is simplified as well as the installation and routing procedures. No special precautions are known that will be necessary to route fiber optics in high EMI areas.

Protection from contamination should be the same for fiber optics technology as conventional wire. Some of the routing considerations are:

- Do not route wires under or near tubing connections.
- Route wiring at least three inches away from hydraulic lines.
- Locate wiring at least six inches from fuel and oxygen lines. If this spacing is impossible, a minimum separation of two inches is allowable provided both the wiring and lines are separately secured and clamped.
- Route wiring so that electric terminations will not occur adjacent to lines carrying oxygen or flammable substances (to prevent arcing due to use of service tools).
- Do not route wiring near batteries or under fluid lines (especially connections), sumps, or pumps. If such routing cannot be avoided, adequate protection must be provided against contamination.
- Fiber optic interconnects should avoid high moisture areas to reduce the effects of microcracking.

Sensitive circuits are those circuits which are susceptible to noise, cross-talk, or other anomalies that can adversely affect performance. These circuits include:

- Sensitive circuits over 5 volts or over 1/2 ampere.
- AC and switched dc power and control circuits.
- RF power circuits.
- Video and digital power circuits.
- DC and low-frequency signal circuits.

- Video and digital-logic signal circuits.
- RF signal circuits.

These circuits require special routing considerations to nullify induced noise. Although fiber optics cannot replace all of the above functions, they can replace video and digital lines which would reduce design costs and the associated cost of special routing techniques.

A summary of the hazardous/sensitive areas that can benefit from the routing of fiber optic interconnect is given in Table I.

3.3 Routing in Various Aircraft Environments

The environments in which fiber optic interconnects for avionic systems must operate are defined in MIL-E-5400P. The major environments are listed in Table II along with the limits in which the equipment must operate. The worst case environments were chosen as a goal for the utilization of fiber optics.

There are six major areas of an airplane in which routing of fiber optics will take place. These areas are:

- Nose gear
  Wheel gear } Special wiring and moisture resistance (SWAMP)
  Radome
- Vertical stabilizer
- Wings and tail section (Leading/trailing edges)
- Pressurized areas
- Fuel areas (wings) and other hazardous areas
- Engine and engine nacelle

These areas all have their own unique environmental conditions, all within the limits specified in MIL-E-5400P. Many of the applications mentioned in the previous section will be routed through these areas and it must be known whether or not fiber optics can survive.

TABLE I: COMPARISON OF ROUTING CONVENTIONAL WIRE AND FIBER OPTICS FOR SEVERAL HAZARDOUS/SENSITIVE AREAS

HAZARDOUS/SENSITIVE AREA	CONVENTIONAL WIRE	FIBER OPTICS
Fuel and Other Explosion Areas	Metal Conduit with Teflon Impregnated Glass Fiber Liner	No Special Routing Provisions
High Temperature	· Route Wires Outside of Thermal Extremes · Maximize Spacing from Heat Generating Parts	· Fibers Can Be Routed into High Temp. Areas with Proper Cladding · Sources/Detectors Suspect
Outer Skin of Composite Materials	· Protection Against EMI Susceptibility · Guard Against Radiation Transmission · Protection Against Radiation Damage	No Special Precautions Except Under Radiation Environment
High Energy Emission	· Balanced Circuits · Minimize Coupling · Bandwidth Limited	No Special Provisions
High Contamination	· Do Not Route Near Tubing Connectors · 3" from Hydraulic Lines · 6" from Fuel/Oxygen Lines	Same Basic Provisions as Conventional Wire
Sensitive Circuits	· Must be Routed Separately · Shielding/Grounding	· Can be Routed in Same Bundle · No Shielding Necessary

TABLE II: MAJOR ENVIRONMENTAL REQUIREMENTS PER MIL-E-5400P

ENVIRONMENT	REQUIREMENT
Altitude	100,000 Ft.
Temperature	-54^{o}C to $+125^{o}$C (+150 Intermittent)
Corona	MIL-STD-454, Requirement 45
Temperature - Humidity	Figure 3, MIL-E-5400P
Vibration	Figure 2, MIL-E-5400P (105 at 2KHz, Max.)
Shock	18 Impact Shocks of 15 g.
Sand and Dust	"As In Operational World"
Fungus	No Fungus Growth in Tropical Environments
Salt - Atmosphere	Exposure to Salt-Sea Atmosphere
Explosive Conditions	No Ignition

A matrix of aircraft areas (including composite material structures) as a function of environment is shown in Table III. A comparison of each environment was made as a function aircraft location, comparing fiber optics to conventional wiring. In the matrix, a benefit showed up as a (+), a drawback or item requiring special routing considerations, was indicated by a (-) and a blank meant that there was no advantage of one technology over another. In most cases, fiber optics is shown to behave better than conventional wiring mainly because of the absence of electrical current and the fact that the glass has a high transition temperature. The main drawback is that moisture can induce cracking in fibers when the fiber is in a stressed condition (such as at a bend radius).

Because the environmental conditions in which the interconnects must operate are known and controlled by specifications, the major question to be resolved is - can the individual components survive in the various aircraft locations and environments? This subject is addressed in the next section.

3.4 Component Selection

While the basic advantages of fiber optics as a technology are well known, the detailed parameters of the components making up the fiber optics systems are generally either obscured in various vendor specifications or left out completely.

The light output (optical power) of optical sources is a major parameter to consider in any system design. This parameter is quite sensitive to temperature and aging effects and this sensitivity varies from type to type and from manufacturer to manufacturer. The lower power edge emitters and cell type devices have a higher reliability record and are considerably less sensitive to temperature.

Injection lasers on the other hand are quite temperature sensitive, have a narrow temperature operating band, and are still subject to sudden catastrophic failure in seemingly well designed systems.

TABLE III. ENVIRONMENTAL REQUIREMENTS VERSUS AIRCRAFT LOCATION

Location \ Requirement		Altitude	High Temp.	Low Temp.	Temp. Shock	Temp.-Altitude	Moisture Resist.	Humidity	Salt Atmos.	Sand & Dust	Explosive Atmos.	Acceleration	Vibration	Electrical Noise	Mech. Shock	Temp./Humid/Altitude	Metallic Shielding	Corona	EMI	Anti-Jamming	Corrosion Resist.	
Nose Gear Wheel Gear Radome	C		-	-			+	+	+		-			-			-	-	-	-		
	F/O		+	+			-	-	-		+			+			+	+	+	+		
Vertical Stabilizer	C		-	-							-			-			-	-	-	-		
	F/O		+	+							+			+			+	+	+	+		
Wings and Tail Section (leading/ Trailing Edges)	C		-	-							-			-			-	-	-	-		
	F/O		+	+							+			+			+	+	+	+		
Pressurized Areas	C		-	-							-			-			-	-	-	-		
	F/O		+	+							+			+			+	+	+	+		
Fuel and Other Hazardous Areas	C		-	-							-			-			-	-	-	-		
	F/O		+	+							+			+			+	+	+	+		
Engine and Engine Nacelle	C		-	-			+	+	+		-			-			-	-	-	-		
	F/O		+	+			-	-	-		+			+			+	+	+	+		
Composite Material Areas	C		-	-							-			-			-	-	-	-		
	F/O		+	+							+			+			+	+	+	+		

Detectors used are of two general types: PIN and APD. The PIN type is quite stable, even being used as a reference standard for optical power measurement, while the APD may have from 100 to 600 times the gain of the PIN diode. Detection sensitivity (gain) is plagued with extreme gain vs. temperature sensitivity and a high noise figure at high gain settings. Reliability of both devices is good.

Fiber optic connectors are being rapidly developed by many of the old line connector companies as well as a few new ones. While parametric data on the materials used in these connectors is available, the variations in optical parameters to be expected during mechanical and environmental stress have not yet been documented so that operating life and performance degradation data are virtually unknown. While fiber bundle connectors appear to be more forgiving in terms of alignment tolerance, other characteristics such as high insertion and connector loss may relegate bundle technology to that of a 1st generation technology only.

Fiber optics cable optical parameters are based primarily upon the materials used for core and cladding (in the case of step index fibers), but changes in these parameters due to mechanical and environmental stresses are for the most part not too well known although studies are in progress, particularly with respect to radiation effects. Cold weather operation of some plastic clad silica fibers seems to be marginal, reportedly due to microbends caused by TC differences in the core and cladding. Data on the effects of shock and vibration are particularly lacking and must be characterized before the full potential of fiber optics can be exploited.

Table IV lists the main advantages and disadvantages of fiber optic components plus an outlook for resolving the major problems. It is shown that the limiting factors are not the cables but the electro-optic devices, which are now very temperature sensitive. Improvements are expected to be made in all areas so that fiber optics can be successfully utilized in most military aircraft applications by the mid-1980's.

TABLE IV. FIBER OPTIC COMPONENT OUTLOOK

COMPONENT	TYPE	ADVANTAGES	DISADVANTAGES	FUTURE OUTLOOK (1980-1985)
Source	Injection Lasers	Gallium Arsenide devices High power 1-10 MW	Stability (Operating Point) vs. Temperature Life vs. Temperature Coupling Loss to Cable	Both life & stability are improving
	Edge or Well Emmitters	Stability Life	Low Power 10μW - 1MW	Higher power devices becoming available
Detector	PIN	Silicon devices Stable Low Noise	Lower Sensitivity	Gradual improvement
	APD	Sensitivity	Operating Point Instability	Gradual improvement
Connector	Bundle	Available to a Mil Spec in single termination form	Termination time high Losses 3-5dB	Multi-terminal connectors becoming available
	Single Fiber	Low loss	Cost, lack of Availability, Alignment critical	Multi-terminal connectors becoming available
	Conventional Wire	Available at low cost		Mature technology
Cable	Bundle	Redundant paths Multiple sources Low insertion loss	Higher cost Higher loss Cannot be spliced	Will be a limited usage item
	Single Fiber	Low cost Low loss	High insertion loss Termination difficult	Usage going up Prices going down
	Wire	Can be spliced and coupled	EMI Higher cost Higher weight	Mature technology

3.5 General Routing Considerations

The major portion of this report has dealt with the subject of what applications and in which locations can fiber optics be successfully used. There are other considerations, however, to the successful implementation of fiber optics in an airframe. These considerations are discussed in this section.

3.5.1 Handling During Routing

During the installation process, the cable must be routed through conduit, bulkhead fittings, and around bulkhead grommets without damage. Damage could occur due to tensile breakage, impact, bend stress, or scraping, or by contaminating the prepared contact surfaces.

The protection of the contact surfaces from contamination or scratches requires capping of the connector if installed. Where the cable without connector must be pulled through conduit or bulkheads, the contact ends must be protected by covering each prepared surface with a lintfree cloth patch and tape or shrink sleevings covering the entire cable end for stability. The cable pull cord is the fastener as with a standard cable since the mechanical strength of the cable is as great as standard cabling.

A cable damaged from impact is more critical and, since the damage is unintentional, can be installed without detection. Only attention can prevent this type of damage completely. The construction of the cable types being used with strength members provides protection from many minor impacts. Installation within cables of standard electrical wiring further reduces the chance of such damage. Caution during installation and a post installation continuity check are sufficient checks to assure adequate installation.

Fiber optic cables can withstand the same bend stresses that electrical cables can. It is only at the ends, where stress concentrates due to connector hardware or the pull through process, that extra protection is required. Surface protection, or connector and backshell hardware, provides sufficient protection to prevent such inadvertent damage.

Scraping is seldom a problem and, since the jacket of fiber optics cable does not serve as a dielectric, only the integrity of the strength members under the jacket and the optic member need be of concern. Examination of the cable and continuity of the conductor is necessary to determine that no damage has occurred.

3.5.2 Installation Hardware

The standard electrical hardware is designed to prevent dielectric damage to electrical wiring. Hardware is available for each of the airplane areas. If the material strengths of the fiber optics cables are equivalent to the electric cable insulation, then equal performance will be obtained.

Additional installation and field repair hardware will be identified in subsequent phases of this program.

3.5.3 Physical Damage Prevention

Like conventional wire, fiber optics must use standard practice to prevent physical damage in the routing. These general practices will include:

- Route wiring to avoid damage from being stepped on, being used as handholds or support for equipment, and being damaged from cargo stowage and shifting.
- Where wiring passes through cutouts or holes in structures, specify that .25 inch minimum clearance be maintained. For applications using a clamp, grommet, or adapter close to the cutout, .125 inch clearance is recommended, with the design minimum .06 inch. Allowance should be made for clamp tolerances, possible movement due to acceleration or vibration, and for rough handling during installation and maintenance.
- Provide sufficient clearance to prevent the chafing of wiring against any object in the maximum envelope of movement due to gravity, acceleration, or vibration.
- Route wiring at least three inches away from control cables if possible. If this cannot be done, specify the minimum allowable spacing on the engineering drawing; specify rigid support of wiring and, if necessary, provide special mechanical or electrical protection between wiring and control cables.

3.5.4 Flight Vehicle Routing

As with conventional wiring, fiber optic systems incorporating redundant systems must be separated to minimize the effects of fire, explosion, or other damage which may take a system out of service. Other critical systems which should have separate bundle routing include:

- Electrical "Fly-By-Wire" flight control systems.
- Automatic flight controls
- Stability augmentation
- Stabilizer trim control
- Electroexplosive devices
- Engine controls
- Fire detection
- Fire extinguishing
- Fuel firewall valves
- Hydraulic fluid cutoff valves

Special routing considerations for flight vehicle equipment include:

- Route wiring to the pilot's and copilot's flight instruments separately.
- Do not route interphone wiring in a bundle containing wires from other systems except in the control columns. Service interphone wiring may be routed with passenger address wiring. In wings and nacelles this wiring may be routed with low power dc circuits.
- Route wiring to the control panels on the pilot's control stand to permit rearrangement of the panels without rewiring.
- Separate the generator control wires into individual bundles for each generator.
- Do not route wiring in emergency exit cut in or cut out areas.
- Route wiring in wheel wells and on landing gear to prevent damage from rocks, ice, and mud.

3.5.5 Repairability

Rework of an electrical cable can result from system redesign, replacement of components, damage, or random failures of parts. Provision is made for rework in both the component design and the cable installation for standard electrical cables. Contacts are removable from the connector to minimize replacement cost. The contacts are fastened to the wire by solder or by crimping. All of the steps can be accomplished with simple, handheld tools.

To perform the same functions on fiber optics cables, a more complicated process must be followed. In most cases, an epoxy glue is used to fasten the contact to the fiber optic conductor. The strength member must be fastened to the connector as an extra step which is not required for standard wiring. Some of the fiber optic connectors do not even have removable center contacts, requiring a "cut and throw" process to replace the contact. The contact face then must be polished or a clean face produced by fracturing, both procedures requiring a special tool.

To be economical from a production and in-service rework viewpoint, the epoxy step, as well as the fracture or polish step, must be eliminated or speeded up. The strength member fastening could be made as rapid as fastening a shield to a standard connector.

Because this termination activity is more complex than standard wire, special provisions must be made in the routing to allow adequate room and safety to perform this function. Similar consideration should also be given to the splicing of the fibers. Dedicated splicing areas should be defined in the initial routing analysis in order to minimize the impact of fiber breakage on the overall system availability.

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