MIL-HDBK-278(NAVY)
3 August 1984

# MILITARY HANDBOOK

# SYSTEM DESIGN GUIDE

# FOR

# APPLYING FIBER OPTIC TECHNOLOGY

# TO

# SHIPBOARD SYSTEMS

FSC 60GP

DEPARTMENT OF DEFENSE

WASHINGTON, DC 20360

System Design Guide for Applying F.O. Technology to Shipboard Systems

MIL-HDBK-278(SH)

1. This Military (Navy) Handbook is approved for use by all Departments and Agencies of the Department of Defense.

2. This publication was approved for printing on 13 August 1984 and inclusion in the military standardization handbook series.

3. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Sea Systems Command, SEA 55Z3, Department of the Navy, Washington, DC 20362 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

# FOREWARD

1. The intent of this System Design Guide (SDG) is to orient the system designer to these component specifications and procedures. This SDG will identify the significant background considerations used to determine the physical and performance requirements of the components and the approaches to the procedures. The considerations involve the interrelationship of the fiber optic components and the shipyard and submarine environments. This knowledge will give the designer assurance that the characteristics of the systems he is designing shall be compatible with the components.

2. Evaluation of the potential applications revealed that the documentation program would be more effective if it were developed around general applications of fiber optic components rather than around one specific application. Through this program, the Naval Sea Systems Command is providing to system engineers and designers the general requirements for implementing systems with fiber optic technology. Qualified fiber optic components as well as approved design, installation, and installation checkout procedures are available to the communication system designers. Associated with these benefits are some others. With qualified parts being identified under one general specification for each type of component, the number of components will be limited. This eliminates a problem prevalent with electronics hardware-component proliferation. With fewer types of parts to be manufactured and stored, the probability that acceptable parts will be available when needed will be increased and the costs of components and the associated logistics costs will decrease. Another benefit this program provides is that system considerations have been identified, analyzed and documented. These include system interface points, interface parameters, terminology, and means for control and definition. Thus, the purpose of this program is to provide total system support for the engineer and designer by providing fiber optic components and related procedures which inherently result in minimizing part proliferation, increased part availability, better defined system interfaces and less costly systems.

CONTENTS



TABLES

# 1. SCOPE

1.1 Guidance. This System Design Guide (SDG) has been written to provide guidance to the system designer who will be using fiber optic technology onboard all ships. The SDG documents are the reasons for developing this series of fiber optic specifications and procedures. Also included is an analysis of the component evaluation tests used to assure component acceptability. The SDG then highlights specific design considerations for each of the components and highlights the special aspects of the installation and checkout procedures.

1.2 Purpose. This System Design Guide is the system oriented document which may be used in conjunction with the fiber optic component documents prepared for implementing fiber optic technology onboard all ships. Ten such documents have bee prepared including eight component specifications and two shipyard procedure documents. The subjects of these documents are as follows:

a. Fiber Optic Cable Specification

b. Fiber Optic Connector Specification

c. Fiber Optic Splice Specification

d. Fiber Optic Hull Penetrator Specification

e. Fiber Optic Bulkhead Penetrator Specification

f. Source Specification

g. Detector Specification

h. Coupler Specification

i. Cable Harness Assembly Specification

j. Installation Procedures

k. Checkout Procedures

# 2. REFERENCED DOCUMENTS

2.1 Issues of documents. The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of this handbook to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-E-16400 - Electronic, Interior Communication and Navigation Equipment, Naval Ship and Shore: General Specification for

STANDARDS

MILITARY

MIL-STD-961 - Military Specification and Associated Documents Preparation of

2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this specification to the extent specified herein.

NAVAL SEA SYSTEMS COMMAND

NAVSEA 0938-011-4010 - Nuclear Powered Submarines, Atmosphere Control

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

3. DEFINITIONS

(Not applicable).

4. GENERAL REQUIREMENTS

4.1 Approach. To provide the general requirements, NAVSEA elected to use the specification format identified in MIL-STD-961 for the components. Use of this document assures that all the information required to acquire fiber optic components shall be addressed general component design requirements, design details (specification sheets), quality assurance requirements and packaging requirements.

4.1.1 Shipyard workers. For guidance to the shipyards, NAVSEA selected the documentation approach that is currently used to provide instructions to shipyard workers. For guidance to engineers and designers, this System Design Guide has been prepared.

5. DETAIL REQUIREMENTS

5.1 Performance and reliability.

5.1.1 System requirements. The application studies that NAVSEA performed indicated that fiber optics could be used in almost any communications (voice and data) system. For example, radio, computer, sonar, and monitoring systems could all be implemented with fiber optics. The types of signals that can be transmitted include all low power signals on present day ships with characteristics such as analog, digital, discrete, and video. However, indiscriminately implementing fiber optics in these systems may not produce the most cost effective systems. At this point in fiber optic technology development and ship mission requirements, an analysis of fiber optic and electrical implementation of communication systems is required for most applications.

5.1.1.1 Advantages (for sub system). Fiber optics is an extremely powerful media for communication. It can transfer much more information over longer distances than the typical present day ships has need for. However, fiber optics does reduce some concerns such as system electrical isolation, grounding potential differences, and electromagnetic interference and compatibility.

5.1.1.2 Advantages (analog and digital information). Fiber optics, on the other hand, can easily transmit analog signals to one gigahertz and digital signals into the hundreds of megabits per second over 10 to 20 kilometers. Signal conditioning and multiplexing can allow effective use of the tremendous information capacity capabilities of fiber optics.

5.1.2 Consistency. The prime concern with data transfer onboard all ships is the accurate and continuous reception of the transmitted signal. The transmission and reception equipment and transfer medium must be reliable to assure that data transfer can continuously occur. This transfer must be consistent even when the communication system components are exposed to physical stresses.

5.1.2.1 Assurance. The goal in developing the documents for this fiber optics program has been to assure that the components qualified for use on all ships would be rugged and reliable enough to withstand the physical stresses that they could experience over a 20 year life cycle. Identifying the physical and optical characteristics that the components must possess and then testing them to verify that they do, assures the performance goal will be met.

5.1.3 Installation compatibility. In addition to the operational performance characteristics of fiber optic components, another consideration in choosing fiber optics as the information transfer media is the installation method. The prime concern when installing data systems onboard all ships is to be able to do so without the use of hazardous, complicated procedures or materials. Although most current procedures for installing fiber optic components would not be hazardous during initial ship construction, some materials may pose a problem. There are some materials that are prohibited from use onboard submarines as identified in NAVSEA 0938-011-4010. Waivers to this document can be obtained; however, the use of hazardous materials onboard submarines cannot be taken lightly. During ship deployment other environments exist where some procedures could be hazardous. An example is fusion splicing of fiber in the battery compartment. Information relative to these installation concerns is provided under each of the component sections in this design guide.

5.2 Environments.

5.2.1 General. Fiber optic components will be exposed to a variety of physical stresses during their life-cycle. These stresses are a result of exposure to the variety of environments associated with transit, storage, installation, operation, and maintenance, and have a variety of origins. Nuclear radiation may be a source of physical stress for some of the components. Other sources are changing temperatures and their extremes, moisture and fluids, handling, mechanical stress, and aging. Stresses associated with handling include impact, tensile loading and bending (short term and long term). Mechanical stresses include vibration and mechanical shock. Fiber optic components must withstand each of these physical stresses that the environments place on them.

5.2.1.1 Stress capability. The capability of the components to withstand these stresses has been assured by requiring them to be subjected to tests which simulate the stresses. The amount of expected stress was identified through the use of MIL-E-16400, similar electrical component specifications, shipyard experience and laboratory experience.

5.2.2 Transportation. This portion of the fiber optic component life-cycle refers to the period when it is transported from the manufacturer to the shipyard, supply depot, or wharf. Characteristic of this environment is the minimal shelter and physical protection given to the component other than the packaging. Therefore, the component is expected to be exposed to temperature extremes, shock and vibration. The physical tests most representative of these conditions are thermal cycling (or thermal shock), mechanical shock and vibration.

5.2.3 Storage. The component is then stored in sheltered, but uncontrolled, environments for days or years until needed for installation. During this time, the protective packaging is still in place and the component is experiencing the effects of shelf life aging. The aging process is taken into account by performing a temperature life and jacket self-adhesive cable and cable harness tests.

5.2.4 Installation. From the storage area, the component is taken to the ship where the protective packaging is removed. (In the case of the cable, the packaging removal is expected to occur at the storage area where the necessary length of cable is cut from the reel, coiled and tied, and delivered to the ship).

5.2.4.1 Conditions. In submarine applications, the installation period exposes the components to the most severe stresses. New construction installation is particularly severe. Dust and dirt are predominant, and sparks from grinding, sanding, and welding are present. Depending on the weather conditions, location of the components in the ships and status of the construction, the components may also be exposed to freezing temperatures, rain, and snow. Cables may be pulled through, over and around sharp edges left from sawing or welding.

5.2.4.2 Stress tests. The pulling forces are a major concern. Experience has shown that installers are more cautious with small diameter cable than with large diameter cable; however, it has also shown that when a cable gets stuck, the first human reaction is to tug on it. Several tests are used to simulate this environment, this includes, but is not limited to tensile loading, cable pullout, axial compressive loading, thermal shock, mechanical shock, humidity, crush, impact, knot, corner bend, stuffing tube compression, twist-bending, twist, external bending moment, cyclic flexing, cable seal flexing, and etc.

5.2.5 Operation. The operational period of the component's life-cycle exposes the components to light and moderate stresses depending on their location, such as the air conditioned compartment, engine room, and outboard. During warfare, however, the components may be exposed to extremely severe physical stresses.

5.2.5.1 Inboard environment tests. For the inboard environment during normal patrol operations, minor stresses are expected. The hottest areas that any of the components will experience are in electronics cabinets, where temperatures will reach 71 degrees celsius (°C). Most components will not be exposed to any significant water pressure. However, bulkhead penetrators are expected to continue operating during and after at least one high water pressure cycle (1000 lbf./in$^2$). Hull penetrators, however, are required to withstand many high pressure cycles and to operate during and after exposure. Humidity will be high in some areas where the components will be installed, such as the machine room and bilge.

5.2.5.2 Special environmental requirements. The specifications as they are prepared do not require the components to be qualified for use in the freezer or the reactor compartment. For applications in these areas, special environmental requirements shall be applied during the qualification or first article testing of the applicable components. These special requirements shall be documented on the specification sheets, thus allowing the use of the existing general specifications. The specifications are currently prepared to cover components which are capable of withstanding exposure to small amounts of both ultraviolet radiation and nuclear radiation, to operational temperatures of 0 to 71°C, and to typical fluids and gasses present in submarines.

5.2.5.3 Outboard environment tests. Outboard installed components are expected to withstand the same environments that inboard components do, plus, withstand multiple high pressure cycles and low temperature extremes. The greatest extreme that the components are exposed to during testing is -40°C. Again, nuclear radiation exposure is expected to be minimum.

5.2.5.4 Severe environmental tests. The extreme stresses that are associated with warfare have been considered by requiring the appropriate components to be exposed to underwater explosions and a gas flame assuring that they will operate during and after the exposure.

5.2.5.5 Stress tests. The stress tests associated with the operational environment include temperature life, thermal shock, mechanical shock, vibration, humidity, salt spray, water pressure, hermetic seal, hosing, hydrostatic pressure, fluid immersion, flammability, gas flame, wicking, cold working, oxygen pressure exposure, and etc.

5.2.6 Maintenance. Maintenance is the next environment to which the fiber optic component will be exposed. Maintenance shall be performed on the fiber optic components and the equipment of which the components are a part.

5.2.6.1 Handling. Consideration has been given to the various handling stresses that the component will experience during maintenance. There are various maintenance levels (e.g., shipboard, tender and shipyard) and maintenance reasons (e.g., part failure and preventive maintenance). Experience has shown that once fiber optic components are installed very little maintenance is performed on them. However, other components in the system have to be maintained during which the fiber optic components will see some stresses. These stresses are tested by exposing components to the following tests during the qualification period: Crush, impact, corner bend, cyclic flexing, cable seal flexing, twist, insert retention strength, terminus retention force, maintenance aging, coupling torques, mating durability, terminus cleaning, bending moment, and etc.

5.2.6.2 Transportation stresses. The foregoing five environments, transportation through maintenance, were analyzed to identify the stresses that fiber optic components will experience during their life-cycle. Tests which stress the components in a similar manner were identified and called out in the specifications to assure that the components will provide reliable, long-term service.

5.3 Shipyard procedures.

5.3.1 Installation.

5.3.2 Checkout. Checkout of the fiber optic equipment installed by the shipyard will be primarily limited to passive (nonlight producing and nonlight detecting) components assembled together to form an optical circuit. Therefore, a source of light and some means of detection are necessary. If there are active devices in the circuit between the passive input and output ends, they are tested by the same techniques as passive circuits except that the devices shall be turned on. For circuits having active devices at either end (i.e., sources and detector), the circuit shall be considered the same as any other electrical circuit and the devices and techniques required to check out general electrical systems shall be employed. Therefore, this System Design Guide shall not address this configuration.

5.3.3. Continuity. This test can be accomplished by simply shining a flashlight (or some other, convenient incoherent light source) at one end of the cable and viewing the presence or absence (bright or dim) of the light at the other end. The test is useful when checking out optical paths consisting of cables and connectors; however, it is not effective for optical paths which have devices in them that intentionally attenuate the signal. Such devices include couplers (other than a 1 x 2 or 2 x 2) and attenuators.

5.3.3.1 Attenuation. Accurately measure the attenuation of the optical path. Other measurements that also may be included in this technique are pulse and bandwidth responses. Attenuation measurements are usually made when link loss must be precisely known. To assure that the signal is in the proper range, a light source of known intensity and an optical power meter (or optical time domain reflectometer (OTDR)) shall be used. However, there is another consideration when applying the second technique which is related to launch conditions of the test equipment. This is covered in 5.3.4.

5.3.4 Launch conditions. Components shall be tested by a method that will show a realistic result, a result that will permit comparison of products and comparison of vendor sources of a product. The completed system shall be checked in a manner depicting its use. In order to do the above, various launch conditions are possible, some of which can be erroneous and misleading.

5.3.4.1 Light modes. The use of an incoherent light source (LED versus laser) and the use of fully filled light modes (versus EMD) for launch conditions will provide the best results for component testing and system loss check out. An incoherent light source is less apt to give distorted or variable readings than a coherent source. Coherent light can result in unbalanced light modes that show as spackle patterns, patterns that are never repeatable. Equilibrium Mode Distribution (EMD) only occurs in long transmission lines which in some cases must be several kilometers long to achieve. The use of short transmit length fibers (2-4 meters) with fully filled core launch and a short receive fiber to test for component losses provides the most usable test result information. For system check out, fully filled launch conditions not only duplicate actual conditions more accurately, they are easier to achieve. Published test results on components have not always stated the launch conditions used. It is impossible to judge their effect on a system or to compare them with other components unless this known. Launch conditions shall use incoherent light and fully filled (short launch, short receive) core modes in order to obtain the most realistic usable information.

5.3.5 Field test resources. When accurate attenuation and pulse/bandwidth in-field measurements are desired, the greatest difficulty is the lack of resources. The several problems that may exist in general field measurements are the lack of appropriate on-site test equipment, ac power, tools, space (for setting up test equipment), and properly trained personnel.

5.3.5.1 Exceptions. The environmental conditions under which the tests will be made, many times, are less than ideal. Depending on the stage of construction of the ship, many tests will have to be made in unsheltered areas or areas without environmental control. These adverse environmental factors can affect both test equipment performance and operator performance.

5.3.5.2 Special factors. These equipment, environment, and personnel considerations have been factored into the checkout procedures. The adverse environmental factors have been addressed by requiring the erection of special shelters, the use of portable heating/cooling units, and the use of test equipment with wide operating temperature ranges. Appropriate electrical power supply is typically available in the shipyard through normal construction support services. Tools and on-site test equipment were identified in the procedures that meet the dynamic range, precision, accuracy, repeatibility, and space availability requirements for the optical in-field (onboard ship) measurements. Training courses, at the time of this writing, have not been prepared; however, NAVSEA is evaluating several approaches to establishing them.

5.3.6 Field test sequencing. The fiber optic telecommunications industry has shown that engineering, installation procedures, and personnel training can be developed to the point where the first optical field tests on the cable do not have to occur until after installation. The telecommunications industry has developed its capabilities to the point that the cables, connectors, and other passive components can leave the factory and be installed in a manner to reliably culminate in a working system. In other words, the intermediate handling of the cables (between manufacture and completed installation) does not cause the fiber to break. These reliable, positive results encourage the simplification of Navy installation checkout procedures.

5.3.6.1 Shipyard preventions and exceptions. The telecommunications industry has had much experience, investing time, energy, and money in refining component design and manufacturing procedures, streamlining installation procedures, and maximizing personnel capabilities. This experience, however, cannot be assimilated by the Navy. Even though the benefits of industry's engineering design experience can be utilized by having experienced cable manufacturers make Navy cable, the unique aspects of the shipyard environment prevent the adoption of unmodified installation procedures and personnel training programs. Until the Navy, including government and contractor personnel, has gained practical experience, a more conservative checkout approach is appropriate and has been included in the installation procedures and the checkout procedures. There are several stages of installation and two basic test techniques (see 5.3.3). The stages and the required testing at each stage are noted in table I.

TABLE I. Installation stage testing. 1/

| Stage | Component | Optical test |
|---|---|---|
| Received at warehouse | Cable | Continuity, each fiber |
| | Coupler | Attentuation |
| | Connector, penetrator and splice | None |
| | Source and detector | None |
| Issued from warehouse | All | None |
| Prior to installation on ship | Cable | Continuity, each fiber |
| | Coupler | Attenuation |
| | Connector, penetrator and splice | None |
| | Source and detector | None |
| After installation | Cable, coupler, connector, splice and penetrator | End-to-end attenuation |
| | Source and detector | Standard electronic test procedure |

1/ Once the Navy and associated shipyards have gained practical experience, all of the tests prior to those identified at the "After installation" stage may be deleted. Until then, the checkout approach in table I shall be followed and has been incorporated in the installation procedures and checkout

Custodian:
Navy - SH

Review activities:
Navy - AS, EC
DLA - ES

User activities:
Navy - CG, MC

Agent:
DLA - ES

Preparing activity:
Navy - SH

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