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FLAT CONDUCTOR CABLE FOR ELECTRICAL PACKAGING

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16. ABSTRACT

Flat conductor cable (FCC) is a relatively new, highly promising means for electrical packaging and system integration. The first FCC, essentially a flexible printed circuit, was designed and produced by the military in 1956 using costly print-and-etch techniques. Today, FCC is manufactured by numerous commercial industries as well as the Government, using methods geared to rapid mass production and high quality products. No longer confined to small experimental projects, FCC offers numerous desirable traits (weight, volume and cost savings; flexibility; high reliability; predictable and repeatable electrical characteristics — to mention a few) which make it extremely attractive as a packaging medium. FCC, today, finds wide application in everything from integration of lunar equipment to the packaging of electronics in nuclear submarines. This report will acquaint the reader with the cable construction and means of termination, applicable specifications and standards, and total FCC systems. A list of additional sources of data is also included for more intensive study.

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FLAT CONDUCTOR CABLE FOR ELECTRICAL PACKAGING

FCC CONSTRUCTION

Cable General Description

FCC is made up of flat, parallel conductors — usually bare or plated copper — which are laminated between thin flexible plastic insulating films, or otherwise held in a flat, rectangular configuration.

Fabrication of the Basic Unshielded Cable

Cable production techniques include lamination under heat and pressure (used for the bulk of FCC), weaving, extrusion, or simply cementing dielectric films together with contact cement without application of heat.

In the laminated form of FCC, conductors are sandwiched between protective dielectric films and held in place by a dielectric adhesive. Typical materials used in cable construction are polyesters (e.g., Mylar), polyimides (e.g., Kapton), and fluorocarbons (e.g., Teflon). Materials are selected on the basis of various environmental, electrical, and physical requirements, as well as cost limitations.

The production of woven cable uses commercial weaving techniques to apply the insulation thread, to space and securely hold the conductors in place. The weaving material may be glass fiber for high temperatures or other fibers depending on requirements. The woven cable usually uses pre-insulated (varnished) conductors or is impregnated against moisture using a material such as silicone. The weaving process for making FCC has great potential for various reasons: (1) Weaving is an old and well-developed technology and is extremely inexpensive; (2) the conductor center spacing can be accomplished with very high accuracy; and (3) the woven FCC will never delaminate due to excessive heat and vacuum and will never form a short circuit between neighboring conductors unless the weaving fiber melts.

The extrusion process for producing FCC is often used when thicker insulation is desired for achieving a certain level of characteristic impedance between conductors, especially when the cable installation requires several layers of cables in a harness assembly and shielding foils between cable layers should be eliminated.

Shielded Cable

Shielding FCC can be very effectively accomplished in several ways, depending on requirements. In many applications in which round wires, if used, would need to be shielded, no separate shields are required for FCC. This is because enough shielding is provided either by (1) physical separation of sensitive conductors from disturbing circuits or by (2) mounting the FCC to a grounded metal substrate or by (3) grounding alternate conductors to achieve electrical separation. Only in a few critical conditions will a shield foil be needed. This shield foil may be an insulated copper foil lying on one or both sides of the cable to be shielded, or it can be laminated, galvanically deposited or vacuum deposited to the FCC. Laminating the shield makes the cable considerably less flexible. On the other hand, it produces a more substantial cable with less danger of accidental shield damage.

TRANSITIONS

Many cable applications will involve the addition of FCC to an existing round wire matrix and, thus, will require use of transition hardware. Such cable transitions have been developed and used. The first transition developed by NASA/MSFC was designed for solder connections and uses a molded plastic part to locate and isolate the junctions. After all connections between the two cables are made and inspected for quality, the assembly (Fig. 1), including a quarter inch of both cables, is potted for stress relief and environmental protection. Another approach, a low-profile design which has been tested at NASA/MSFC, involves welding of conductors, applying a conformal coating, then laminating the welded area between strong plastic films. Refinement for automatic welding is still needed.

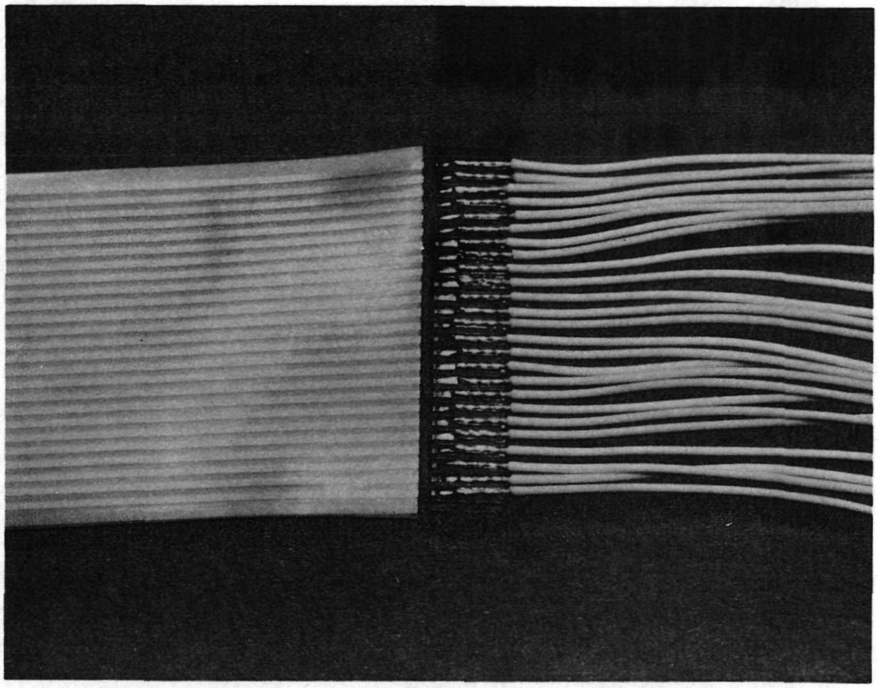

Figure 1. FCC to RWC transition (before potting).

SEPARABLE CONNECTORS

In numerous reports concerned with FCC systems, authors have been almost unanimous in the belief that the single greatest impediment to widespread application of FCC is lack of suitable termination hardware. Thus, in the following discussion, extensive attention has been devoted to NASA/MSFC's latest connector design.

Termination hardware for FCC has been developed by various connector companies, as well as by the Government. Most round wire cable (RWC) connector designers use pins and bushings for their FCC connectors, as they do for RWC connectors. The only difference is that the FCC connectors are usually rectangular, whereas most RWCs are round. When pins are used they are added to the flat cable conductors by soldering, crimping, or welding. Processes have been developed for crimping and welding which do not require stripping of cable insulation.

Other designs use the flat conductor as a contact surface, thus eliminating the necessity for additional metal pins or other metal hardware. Figure 2

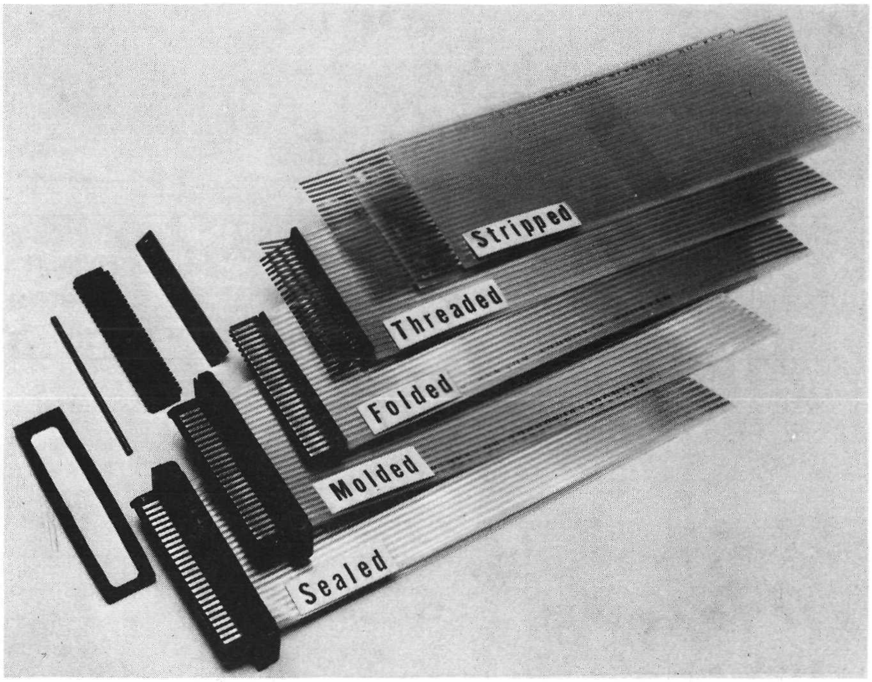

Figure 2. Fabrication of a plug in which cable conductors are used as contacts.

illustrates such a contact design. The FCC is simply stripped and inserted into a molded part (plug) and conductors formed in place by a comb-like tool. This latter technique is applied to NASA/MSFC's connector designs.

New NASA/MSFC Connectors With Individually Sealed Contacts

After years of effort in designing and testing several types of FCC connectors, a new design has evolved. Designed for operation at 600 Vac in an aerospace environment, this series has the feature of individually sealed contacts. The new line, consisting of a group of connectors for flat to round wire cable connections and another group to interconnect FCC to FCC or FCC to PC boards, is now ready for initial production.

Although this family incorporates many proven features of earlier connectors, such as the use of conductor as contact for resulting increased reliability, many improvements have been made. The provision for individual contact seals has been mentioned. Additional major improvements are the one-piece plug design and the stronger safety latch. The sealing system for each mated contact occurs when the plug, containing recessed and individually housed contacts, is pressed against the receptacle interfacial seal. The resulting mated configuration provides complete corona safety at critically low gas pressures. The one-part plug design makes cable termination compatible with FCC in terms of weight, size, and cost. As an example, the weight of a plug (with potting) designed for two flat conductor cables, each 50 mm (2 in.) wide having a total of 50 conductors, is 8 g (0.3 oz) or 0.16 g per contact — a significant reduction when compared with earlier models. Also, by eliminating the 50 junctions normally needed to join pins with 50 wires, the overall reliability is improved. This is in line with the mounting requirements for improved safety, as well as reduction in weight, space, and cost.

The FCC to round wire cable connector consists of a plug, previously described, and a receptacle designed to receive the plug as well as provide the required seal and safety latch (Fig. 3). In addition to the molded part, the plug assembly includes potting at the rear for moisture protection and strain relief. The receptacle consists mainly of (1) a metal shell, (2) plastic insert containing the contact springs, (3) one-piece safety latch, and (4) a face seal. Both this connector and the FCC to FCC or PC board connector accommodate two cables with conductors spaced on 75-mil centers. Additional data on the FCC to RWC connector is provided in Table 1.

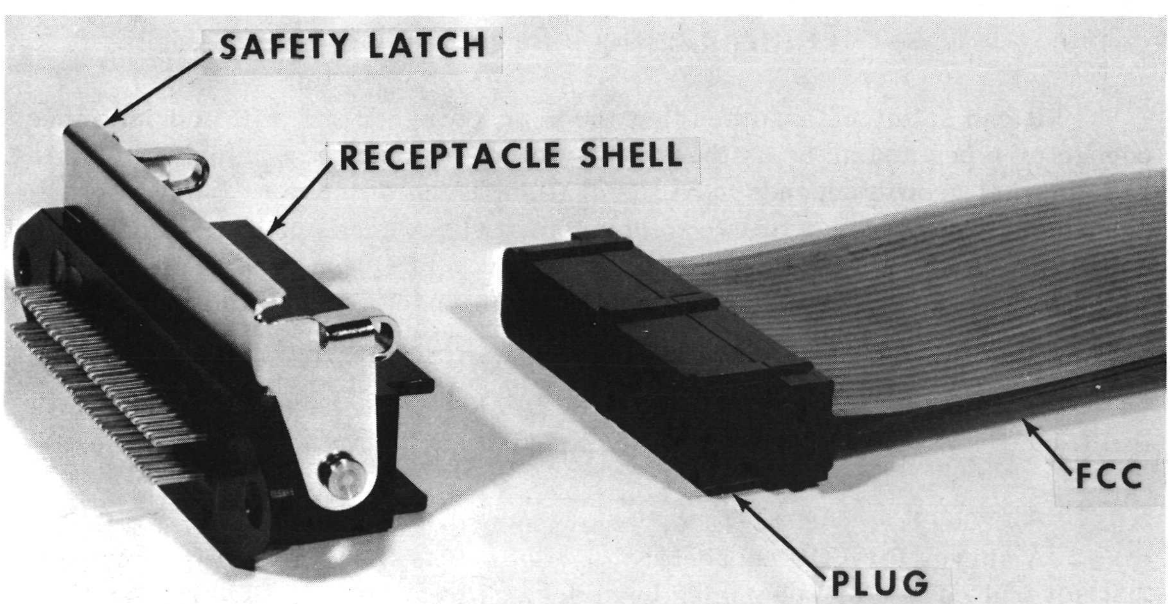

Figure 3. New NASA/MSFC FCC to RWC connector with individually sealed contacts.

TABLE 1. FCC TO RWC CONNECTOR

Cable Width (in.)	Number of Contacts	Mounting Flange (in.)	Weight (grams)	
			Plug	Receptacle
1.0	24	0.75 × 2.137	4	25
1.5	36	0.75 × 2.587	6	32
2.0	50	0.75 × 3.112	8	42
2.5	64	0.75 × 3.637	10	51
3.0	76	0.75 × 4.087	12	59

The FCC to FCC connector consists of a feed-through receptacle (sectional view shown in Figure 4) and two of the previously described plugs. Receptacle design is similar to that of the FCC to RWC connector. Two shells are joined at the base flange. The interior simply consists of molded parts holding the contact springs. The internal permanent seal is accomplished by potting during assembly.

Future Connector Development

It can safely be assumed that the connector industry will provide more connector types and sizes as the market volume increases. Unfortunately, the FCC market growth depends upon the availability of connectors from stock, and while it takes a year or two to develop, tool up, mass produce, and market a connector, it takes only a few weeks to deliver FCC to order. This dilemma has been existing for several years and can only be solved by long term capital investment.

CABLE AND CONNECTOR STANDARDIZATION

A survey for FCC connectors, made in 1971 by NASA/MSFC, indicates that several connector companies have designs for various FCC sizes and conductor gauges. To limit the number of sizes and types of connectors, a necessity for optimum technology advancement, specifications and standards have been established. MIL-C-55543 and IPC-FC-250 are for FCC cables;

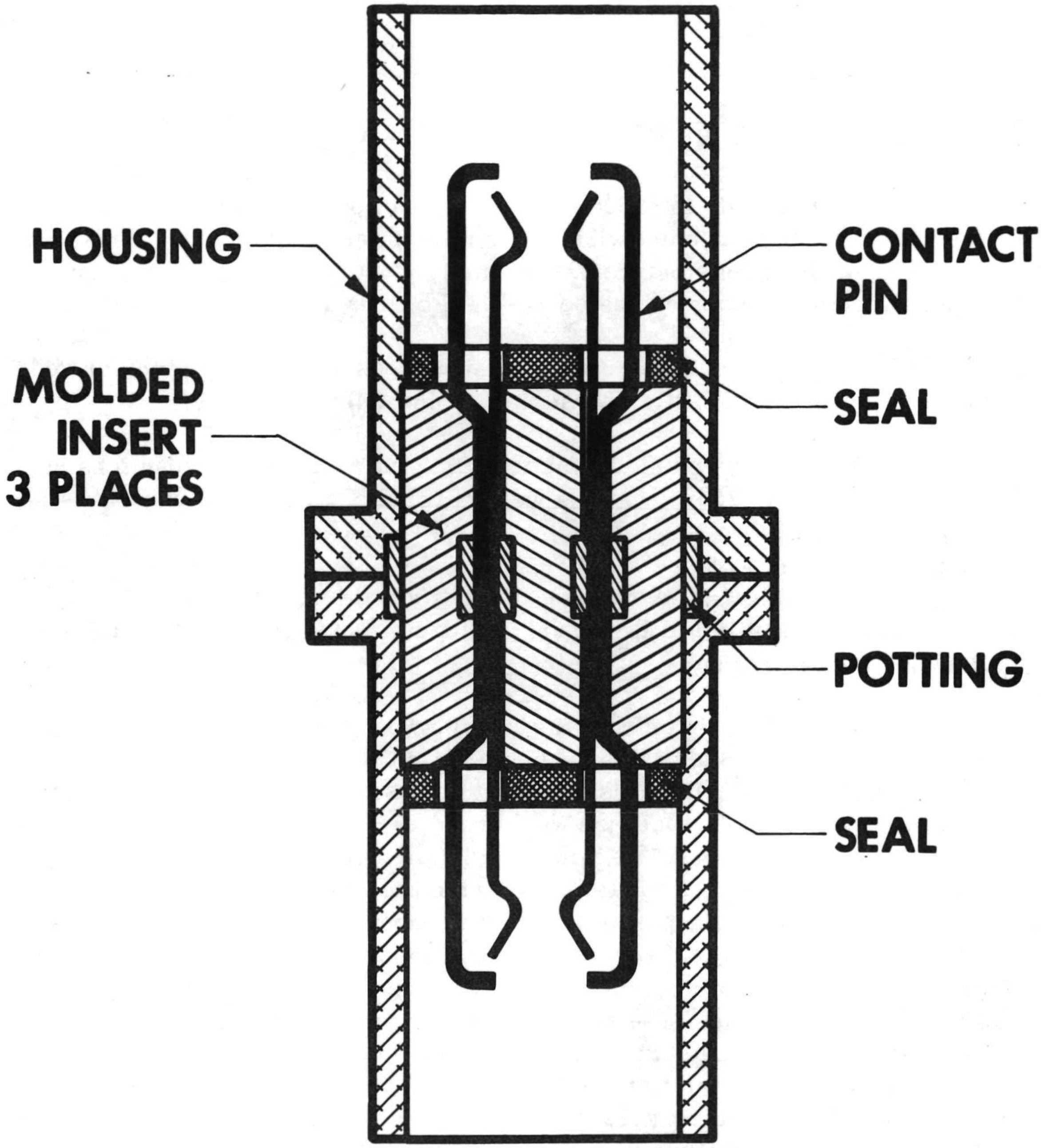

Figure 4. NASA/MSFC receptacle for FCC
to FCC or PC board connections.

MIL-C-55544 and IPC-FC-218 are for flat cable connectors. Also, an Institute of Printed Circuit handbook and a military FCC handbook are being published for the users information.

TOTAL FCC SYSTEMS

Determination of Need for FCC Systems

FCC is basically intended for interconnection of equipment boxes, rather than for point-to-point wiring within the interior of the box, for which the flexible etched printed circuit is normally more practical. An exception is the use of FCC jumper cables between PC boards and other substrates.

In terms of usefulness, there are numerous advantages to be derived from the application of FCC. These include the following:

1. Weight and Volume Reductions. Significant weight reductions have been achieved (50 to 75 percent) as well as volume savings (50 percent is an average reduction) .

2. Flexibility. The extreme flexibility and long flex-life of FCC, allowing it to be bent to fulfill unusual packaging requirements, are major advantages.

3. Cost. The big price difference between round and flat cable systems is in harness making. For example, an FCC of a given length and width with 25 conductors simply needs one length measurement and one cut, while the round wire cable of equal size would need 25 length measurements and 25 cuts, plus the handlacing or machine braiding. In addition, for terminating a round wire cable with a connector, each wire has to be electrically selected to be placed in the proper pin location. The conductors of FCC are always maintained in a set sequence, due to the cable's planar design. Thus, electrical selections are unnecessary, making wiring mistakes by the shop personnel virtually impossible. The same is true for the ribbon cable, which uses round conductors arranged in planar form like the FCC. Considering and comparing round wire and flat conductor cable systems by measuring, weighing, timing and testing results in suprising figures and facts. In addition to harness savings, another area of cost reduction is the cable itself. Although the present cost of FCC at moderate production quantity is about the same as round wire, it is expected that the FCC price will be reduced substantially as production volumes increase.

Procedure for System Development

For full realization of FCC advantages, a new approach to wiring systems design and harness manufacturing is strongly recommended. The FCC system design should be simple and without branches, if at all possible. This makes the harness production extremely inexpensive and fast. Complex electric cable systems should have one or more distribution boxes to facilitate wiring changes. Distribution boxes of various types and sizes have been developed to demonstrate simplicity and flexibility of wiring changes. Figure 5 depicts how a distribution box can vastly simplify an FCC system. A typical distributor is shown in Figure 6.

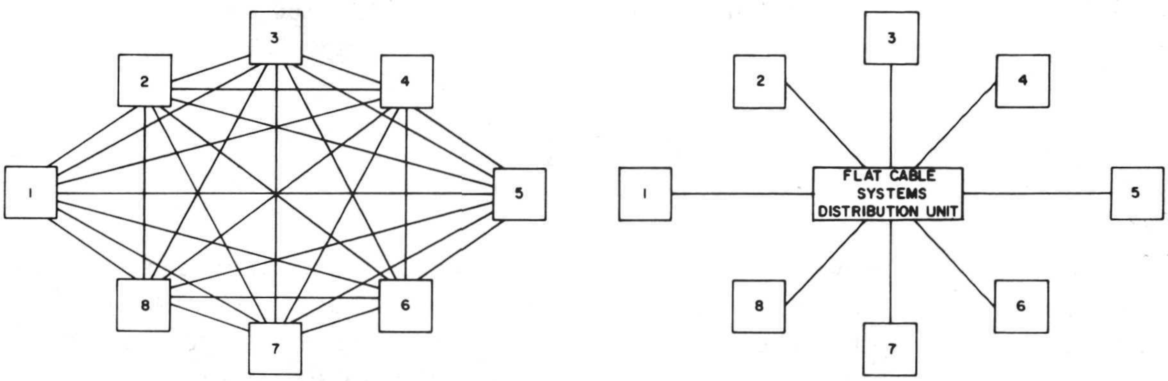

Figure 5. Electrical network with and without distributor.

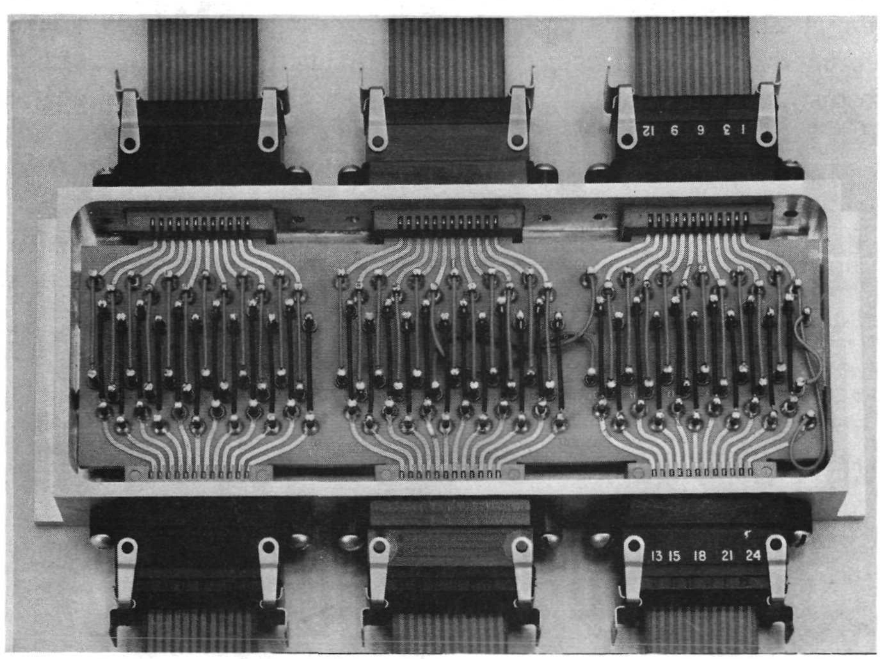

Figure 6. Distribution box with FCC to PC board connectors.

The establishment of harness dimensions should be made with the aid of a full-scale mockup of high fidelity in all measurements influencing cable routing, fastening, and length. Expensive time delays and waste have been experienced many times by trying to "get by" without a mockup and defining harness dimensions on paper. It costs an average of 10 minutes to cut FCC to length and add a plug to each end. Therefore, it is desirable to first construct a mockup and, then, make the cables right the first time. The mockup should be wired with dummy cables, consisting of tapes (e.g., Mylar) equal in width and length to the final cables. The dummy cables can be used for obtaining documentation data and as templates for the final cable making. Cable routing and location of fasteners can be studied by using the mockup, avoiding or covering sharp edges for FCC passage. Figure 7 is a typical completed installation, in which the mockup procedure was used to obtain the most effective wiring design.

CONCLUSIONS

A quick survey of current electronic trends — miniaturization of equipment, new packaging techniques, increased complexity of circuit design — indicates the need for compatible wiring able to meet rigid requirements of low weight and volume, and high reliability, while maintaining a competitive level of cost. For many applications, FCC is the perfect selection for interconnective wiring. FCC has been used in several submarine electronics assemblies which had severe operating, volume, and weight requirements. It has been used in aircraft assemblies, to meet similar requirements, and aerospace projects as well. In some cases the objective could only be accomplished with FCC. For example, the transfer of 2500 conductors across the sensitive gimbal system, at the low permissible torque, for the Apollo Telescope Mount in the Skylab Project necessitated use of FCC. FCC is not a panacea, yet it solves a lot of problems. The cost for realization of possible savings (weight, volume, cost) is re-education, familiarization, and training of design and shop personnel.

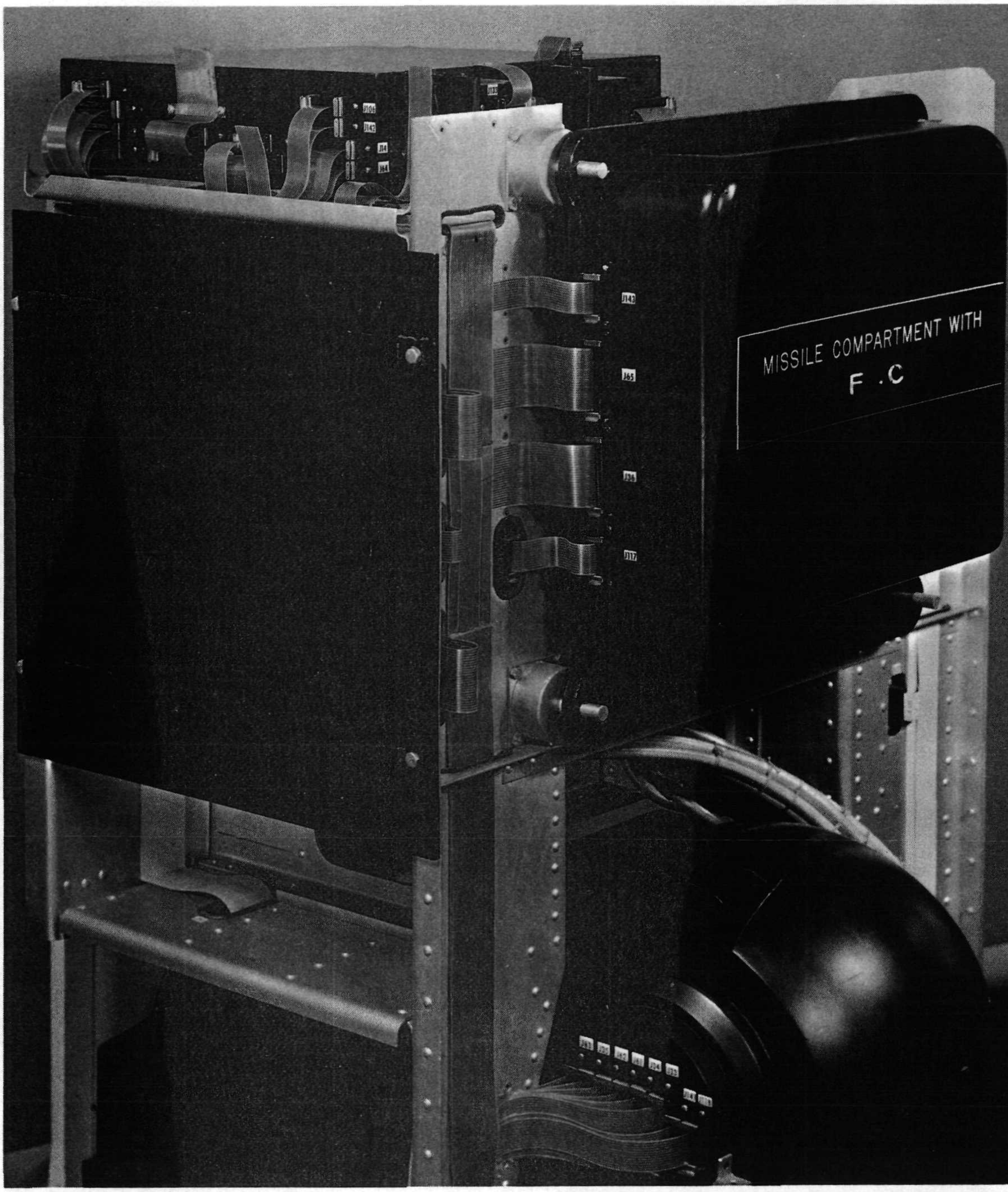

Figure 7. Typical FCC installation.

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APPROVAL

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

5/8/72

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