NASA TECHNICAL MEMORANDUM

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TESTING OF FLAT CONDUCTOR CABLE TO UNDERWRITERS LABORATORY STANDARDS UL719 AND UL83

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TESTING OF FLAT CONDUCTOR CABLE TO UNDERWRITERS LABORATORY STANDARDS UL719 AND UL83

I. INTRODUCTION

This report covers a type of flat conductor cable (FCC) designed for use in a surface nonmetallic protective covering. The FCC consists of three AWG No. 12 flat copper conductors laminated between two films of polyethylene terephthalate (Mylar) insulation with a self-extinguishing polyester adhesive. The total thickness of the FCC is 0.053 cm (0.021 in.)

The tests were performed on appropriate samples according to the test methods outlined in the Underwriters Laboratories, Inc. "Nonmetallic Sheathed Cables," subject UL719, dated July 1, 1969, and in accordance with, "Standard for Safety Thermoplastic-Insulated Wires," subject UL83, dated October 18, 1971.

II. DESCRIPTION OF CABLE TESTED

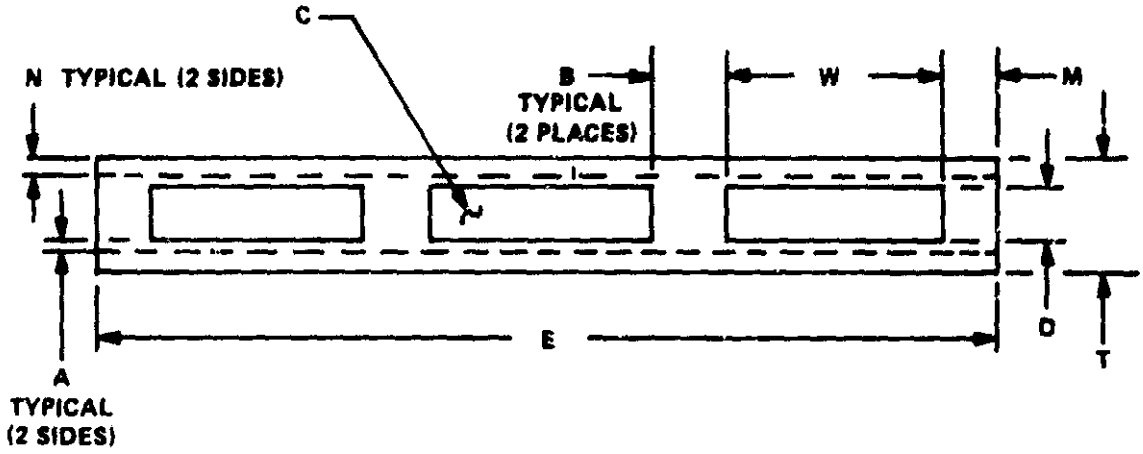
A. Product Covered

The product tested is a flat, multiconductor, flexible cable employing biaxially oriented polyethylene terephthalate (Mylar) insulation, MSFC style M5000 21, with three copper AWG No. 12 conductors, rated at 100°C (212° F) and 600 V. The adhesive used for laminating the cable is a self-extinguishing polyester with an antimony oxide as the flame retardant agent.

B. Use

The FCC covered in this report is intended for use in a surface nonmetallic protective covering in a dwelling or office application.

C. Flat Conductor Cable Construction (See Detail Dimensions, II.D)



D. Detail Dimensions (See FCC Construction, II.C.)

Number of copper conductors (C) — 3

Average conductor width (W) — 1.52 cm (0.60 in.)

Conductor thickness (D) — 0.023 ± 0.001 cm (0.009 ± 0.0004 in.)

Average adhesive thickness (A) — 0.0025 cm (0.001 in.)

Distance between conductors (B) — 0.508 cm (0.2 in.)

Mylar thickness each side (N) — 0.0127 cm (0.005 in.)

Overall cable thickness (T) — 0.053 cm (0.021 in.)

Cable width overall (E) — 6.35 cm (2.5 in.)

Cable margin (M) — 0.381 cm (0.150 in.)

III. PERFORMANCE TESTS

A. UL719 Requirements

1. SEPARABILITY

a. Method. The circuit conductors, the insulation thereon, the grounding conductor, and the insulation thereon, shall be readily separable from one another without damage to the insulation during separation and without damage to the conductor during insulation removal.

b. Requirement. During the conductor separation, the insulation shall not be removed such that the bare conductor is exposed. During stripping the conductor shall not be broken, and the conductor cross section shall not be reduced due to insulation removal.

c. Results. Because of perforations between the circuit conductors and grounding conductor, there were no conductors exposed as a result of conductor separation. The insulation was readily removed without damage to the conductors.

2. CONTINUITY

a. Method. Each circuit and grounding conductor shall be continuous throughout the entire length of finished cable. Finished cables shall be tested for continuity of each conductor by the FCC manufacturer.

b. Requirement. Any break in current flow in the test specimen is considered a failure.

c. Results. No breaks in the current flow of test specimens were found.

3. FLAME-RETARDANT PROPERTIES

a. Method. The finished cable samples shall, when tested, flame no longer than 1 min following five 15-sec applications of flame, the period between applications being 15 sec. The insulated conductor or cable shall not convey flame during, between, or after the five applications of flame. The test shall be conducted at room temperature. Two 45.7-cm (18-in.) specimens are to be cut from a sample length of the finished cable. The specimens are to be tested with the conductors in place at room temperature as received.

The test is to be conducted in a three-sided enclosure that is 30.48 cm (12 in.) wide, 35.56 cm (14 in.) deep, and 60.96 cm (24 in.) high. The top and front are to be open. The specimen is to be secured with its longitudinal axis vertical in the center of the enclosure (Fig. 1). The faces of flat cable are to be parallel to the front and rear of the enclosure.

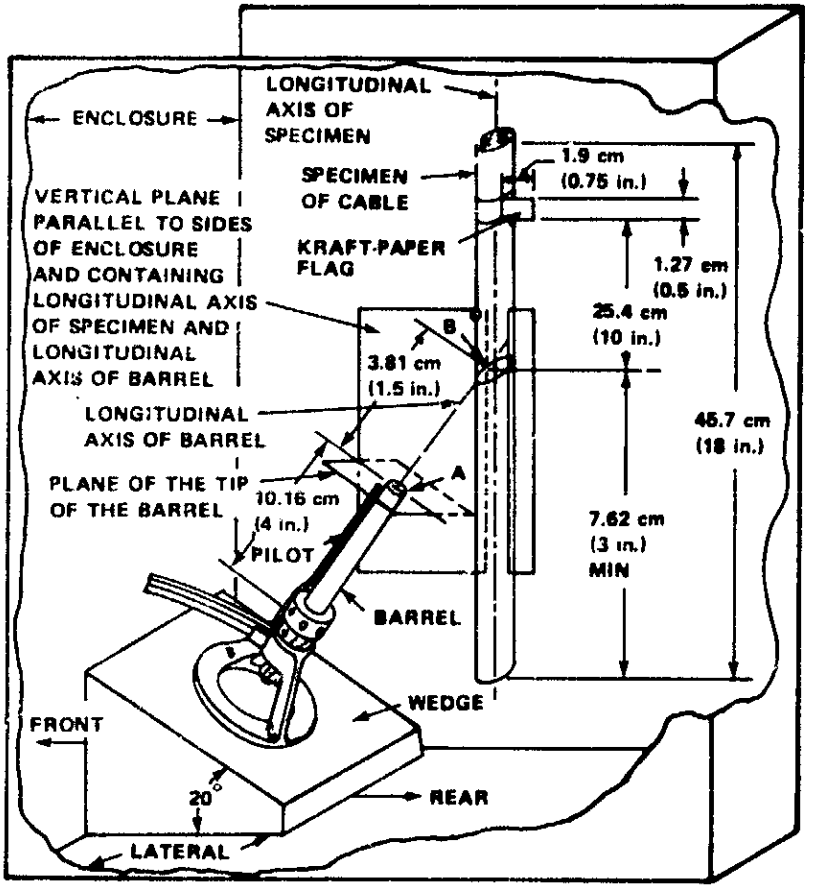


Figure 1. Essential dimensions of apparatus and specimen for vertical flame test.

A Tirrill gas burner, to which a gas pilot light is attached, is to supply the flame. The barrell of the burner is to extend 10.16 cm (4 in.) above the air inlets, and its inside diameter is to be 0.95 cm (0.375 in.). While the barrel is vertical, the overall height of the flame is to be adjusted to 12.7 cm (5 in.). The blue inner cone is to be 3.81 cm (1.5 in.) high. Without disturbing the adjustments for the height of the flame, the valves supplying gas to the burner and pilot flames are to be closed. A wedge to which the base of the burner can

be secured is to be provided for tilting the barrel 20 deg from the vertical while the longitudinal axis of the barrel remains in a vertical plane. The burner is to be secured to the wedge, and the assembly is to be placed in an adjustable jig that is attached to the floor of the enclosure. The jig is to be adjusted laterally (Fig. 1) to place the longitudinal axis of the barrel in the same vertical plane as the longitudinal axis of the specimen. The plane is to be parallel to the sides of the enclosure. The jig is also to be adjusted toward the rear or front of the enclosure, as illustrated in Figure 1, to position the point A, which is the intersection of the longitudinal axis of the barrel with the plane of the tip of the barrel, 3.81 cm (1.5 in.) from the point B at which the extended longitudinal axis of the barrel meets the outer surface of the specimen. Point B is the point at which the tip of the blue inner cone will touch the center of the front of the specimen. The specimen is to be adjusted vertically to prevent point B from being any closer than 7.62 cm (3 in.) to the lower end of the specimen. A 1.27 cm (0.5 in.) wide strip of unreinforced 0.0127 cm (0.005 in.) thick 27.2-kg (60-lb) kraft paper that is gummed on one side is to be used to make an indicator flag. The gumming is to be moistened sufficiently to permit adhesion. With the gum toward the cable, the strip is to be wrapped around the specimen once with its lower edge 25.4 cm (10 in.) above B, the point at which the blue inner cone will touch the specimen. The ends of the strip are to be pasted together evenly and trimmed to provide a flag that projects 1.9 cm (0.75 in.) from the specimen toward the rear of the enclosure with the flag parallel to the sides of the enclosure (Fig. 1). In the case of a flat cable, the flag is to project from the center of the rear broad face of the cable, and the flame is to be applied to the front broad face.

The room or hood in which the test is conducted is to be ventilated, but drafts are to be prevented from affecting the flame. The valve supplying gas to the pilot is to be opened and the pilot lit. The valve supplying gas to the burner is to be opened to apply the flame to the specimen. This valve is to be held open for 15 sec and then closed for 15 sec. This procedure is to be repeated four times for a total of five applications of flame to the specimen.

b. Requirement. If more than 25 percent of the indicator flag is burned away or charred (soot that can be removed with a cloth or the fingers and brown scorching are to be ignored) after five applications of flame or if flamming or glowing particles or drops fall from the specimen at any time, the cable or circuit conductor of which the specimen is representative is to be judged to have conveyed flame. The duration of flaming of the specimen after the final removal of the gas flame is to be recorded. Any cable from which a specimen continues to flame longer than 60 sec is not acceptable. Figure 2 shows the actual test apparatus.

c. Results. The cables passed the test.

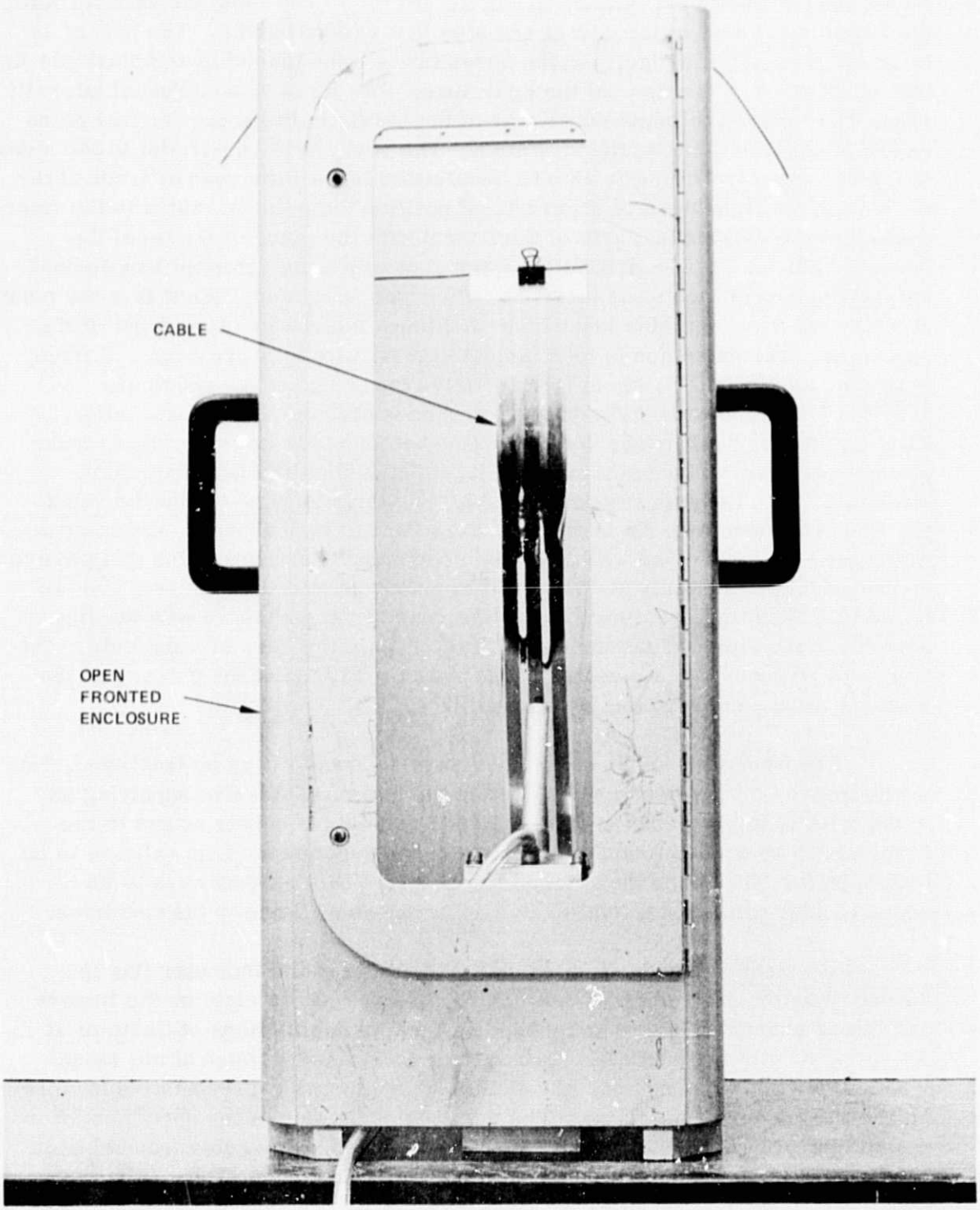


Figure 2. Flame retardant test apparatus (open front).

4. DIELECTRIC WITHSTANDING VOLTAGE

a. Method. After immersion in water at room temperature for 24 hours, and while still immersed, specimens from finished cable wound around a 1.9 cm (0.75 in.) diameter mandrel (Fig. 3) shall withstand for 1 min a 60-Hz essentially sinusodial potential of 5000 V. The potential shall be applied from each conductor separately to the other conductor or conductors, the ground conductor, and the water/mandrel ground. Figure 4 shows the test instrument used.

b. Requirement. If the specimen breaks down during the potential application, the cable for which it is representative is not acceptable.

c. Results. No breakdown occurred during the applied 5000-V 60-Hz test voltage.

The average breakdown voltage for the cable was as follows:

Conductor to water — 8.5 kV
Conductor to adjacent conductor — 11.0 kV

5. TENSION AND ELONGATION

a. Method. An Instron tensile tester may be substituted to apply 136.1 kg (300 lb) of tension to the specimen. A 40.6 cm (16 in.) long specimen of cable shall be clamped in the tensile tester jaws with at least 30.5 cm (1 ft) of FCC between the jaws. A measurement of the cable between the clamps shall be made before loading the cable. A load is then applied to the cable and held for 1 min. After the load is removed, the length of the specimen is again measured.

b. Requirement. Finished cables shall be capable of withstanding the application of 136.1 kg (300 lb) for 1 min without parting, opening up at any point, or showing a permanent elongation of more than 2.54 cm per 30.5 cm (1 in./ft) of original specimen length.

c. Results. A permanent elongation of 0.16 cm per 30.5 cm (0.0625 in./ft) of the orginal specimen lengths was recorded after the test was completed. No parting or opening of the cable occurred.

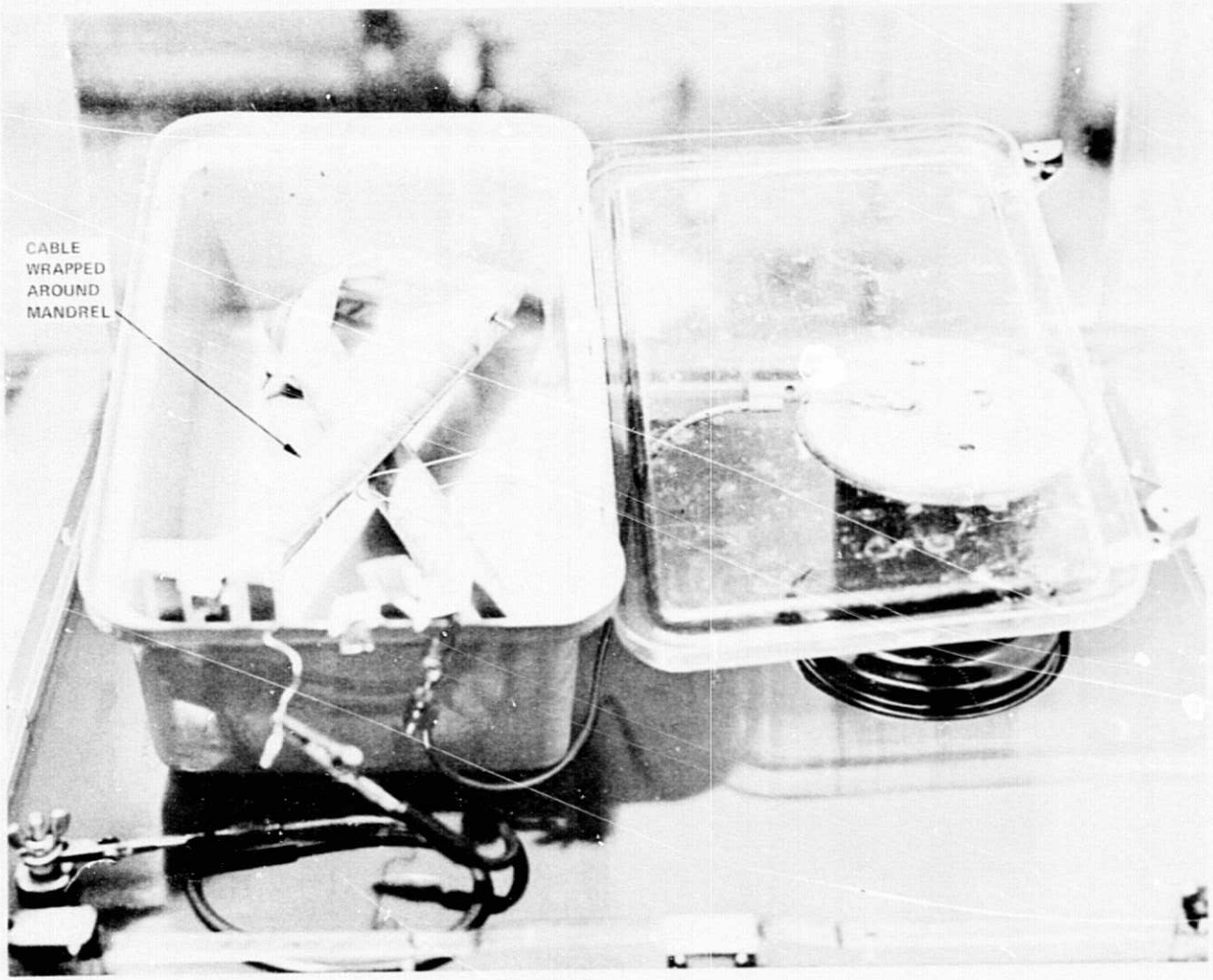


Figure 3. Mandrel assembly.

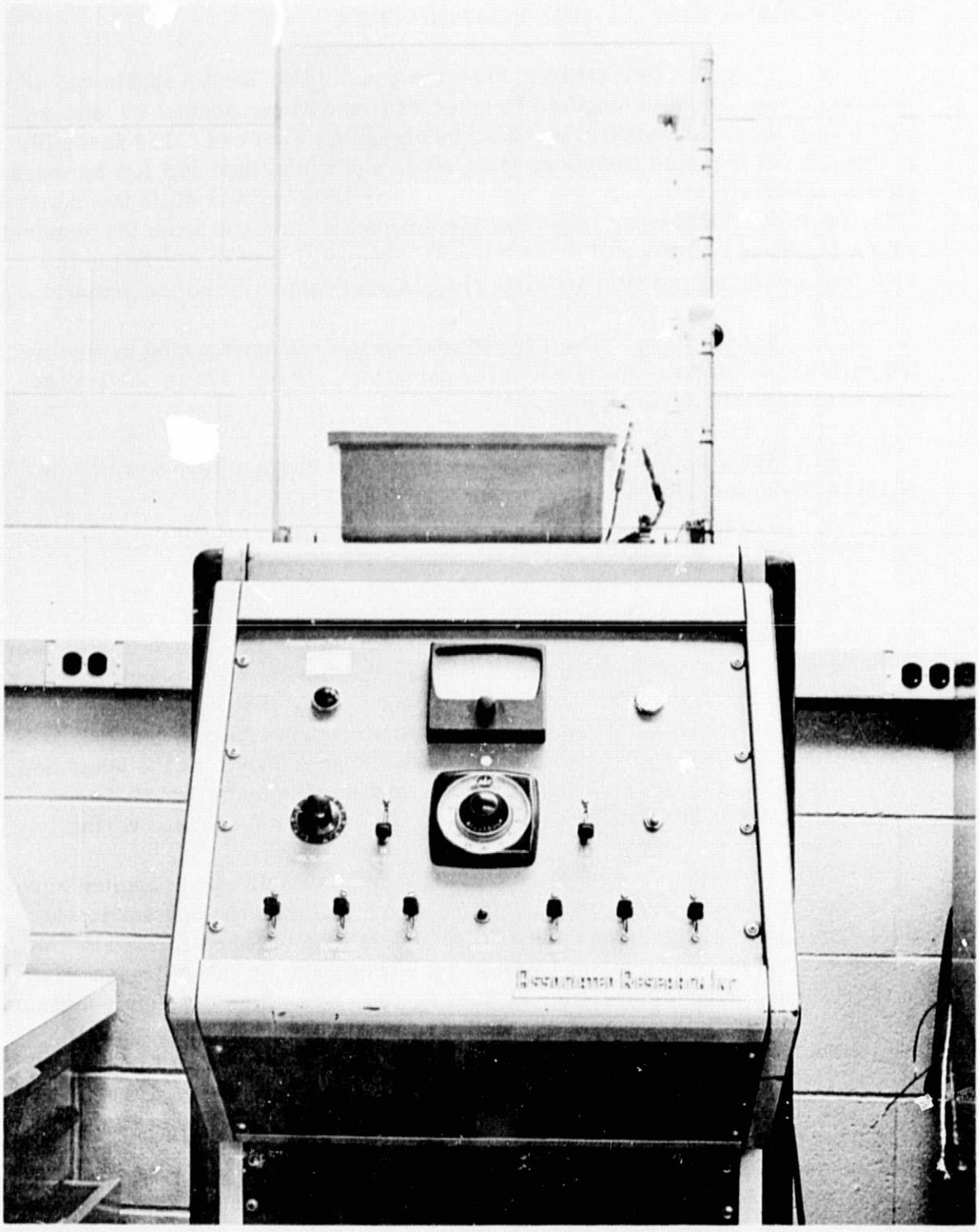


Figure 4. Dielectric withstanding voltage test instrument.

6. UNWINDING TEST AT LOW TEMPERATURE

a. Method. Two straight 91.4-cm (36-in.) or longer specimens are to be cut from a sample length of finished FCC and wound around a 1.905 cm (0.75 in.) diameter mandrel and held by clamps at each end. The assembly is then placed in a cold chamber, stabilized, and maintained at a low temperature of -25°C ± 1.0°C (-13°F ± 1.8°F). After 72 hours and while the chamber remains at the low temperature, the specimens are unwound from the mandrels with a 11.36-kg (25-lb) pull or with a pull force sufficient to straighten the FCC to its original position prior to wrapping the cable around the mandrel.

b. Requirement. The FCC insulation shall be undamaged by the low temperature unwinding described in the paragraph above. There shall be no cracks or tears in the insulation.

c. Results. After unwinding as described above, there were no cracks or tears in the insulation.

7. CONDUCTOR PULLOUT

a. Method. A 50.8-cm (20-in.) specimen is to be cut from a straight flat sample length of the finished cable. A 7.62-cm (3-in.) length of the outer covering is to be removed from one end of the specimen, and a pencil mark or other suitable mark is to be made on each conductor at the point at which it emerges from the outer covering. The conductors thus exposed are then to be bent together through approximately 180 deg to form a hook. At the other end of the specimen, the outer covering is to be slit longitudinally for 10.16 cm (4 in.) and the conductors are to be cut out of this portion of the covering.

With its hollow outer covering gripped in a suitable clamp applied across the major axis of the cable, the specimen is to be allowed to hang vertically and a 0.907-kg (2-lb) weight is to be placed gently on the hook formed by the conductors and left there for at least 30 sec. The cable of the representative specimen is not acceptable if the conductors slide more than 0.16 cm (0.0625 in.) out of the overall covering as measured by displacement of the pencil marks from their original position flush with the end of the overall covering.

b. Requirement. The construction of flat cable containing two AWG No. 12 insulated circuit conductors (with or without a grounding conductor) shall necessitate the use of more than 0.907 kg (2 lb) of force to pull all of the conductors (taken together) more than 0.16 cm (0.0625 in.) out of the overall cable covering.

c. Results. Because of the laminated construction of flat conductor cables, the conductors will be pulled apart before being pulled out. The FCC passed the test.

8. CRUSHING RESISTANCE

a. Method. The cable is to be crushed between a flat horizontal surface and the surface of a rigid cylinder 0.32 cm (0.125 in.) in diameter. The cylinder is to be a 8.89-cm (3.5-in.) length of 0.32 cm (0.125 in.) diameter steel drill rod weld along the length of a steel bar that is also 8.89 cm (3.5 in.) long and is T-shaped in cross section. The stem and cross of the tee are each to be approximately 0.32 cm (0.125 in.) thick, and the depth of the stem is to be about 2.54 cm (1 in.) from the cross to the free end of the stem. A sample length of the finished flat cable is to be laid flat with the length of the cable at right angles to the longitudinal axis of the tee and a point on the cable directly under the drill rod at least 30.48 cm (12 in.) from one end of the cable. The circuit conductors and the steel block and tee are to be connected to suitable low voltage indicators (buzzers, etc.) and appropriate power supplies. The steel block and tee are to be connected. The indicators should provide a signal whenever contact is established between one or more of the circuit conductors and the block or tee. The grounding conductor is to be out of the circuit. The cable, the apparatus, and the surrounding air are to be in thermal equilibrium with one another at a temperature of 23.0° C ± 2.0° C (73.4° F ± 3.6° F) during the test.

The head of a suitable compression testing machine, such as an Instron tensile tester, is to be started moving toward the bed at a rate of 1.27 cm/min (0.5 in./min). The travel is to be continued until the drill rod pushes through the insulating materials of the cable to contact one or more of the circuit conductors, at which time the crushing force being exerted by the machine is to be noted and recorded and the downward direction of travel of the head reversed. The crushing procedure is to be repeated at nine other locations.

b. Requirement. The average force needed to crush the finished FCC containing three AWG No. 12 copper circuit conductors shall not be less than 272.2 kg (600 lb) when the crushing force is applied to the FCC flat wire in accordance with paragraph a above.

c. Results. The cable withstood the 272.2-kg (600-lb) force as required but failed when a 2268-kg (5000-lb) load was applied.

9. ABRASION RESISTANCE

a. Method. The test is to be started when the plate on which the specimens are mounted is at rest at either end of the stroke. Enough weight is to be added atop the abrasion tool to make the combined weight of the tool and added

weight 1.36 kg (3 lb). The abrasion tool is to be lowered gently onto the specimen and the cable is to begin reciprocating immediately. The action is to be continued without interruption until the tool wears through the outer covering on the cable or until 70 full cycles have been completed without the tool wearing through.

b. Requirement. The coverings or jacket on the finished flat cable shall not wear through exposing the underlying protective sheath or conductor assembly in fewer than 70 complete cycles of the abrasion against sharp steel edges of the fixture shown in Figure 5.

c. Results. There were no failures during the abrasion test on the samples tested after 70 cycles. Only minor scratches were observed on the insulation surface.

10. PULLING-THROUGH-JOISTS TEST

This test is not applicable to FEC since this cable will be used in a surface nonmetallic raceway application and will not be pulled through any openings.

11. EXAMINATION AND MOISTURE AFTER PULLING THROUGH JOISTS

Not applicable for the same reason given in paragraph 10, above.

12. INSULATION FLOW

a. Method. A specimen of suitable length is to be tested on two wooden blocks, 5.08 by 5.08 cm (2 by 2 in.) in cross section. As shown in Figure 6, the blocks are to be secured parallel to one another and with their outer faces 20.3 cm (8 in.) apart. The outer edge of each block is to be notched to accommodate a steel rod 0.16 cm (0.0625 in.) in diameter. The cable is to be laid over the blocks and is to be bent down over the rods to form an inverted U. A 2.27-kg (5-lb) weight is to be attached to each end of the specimen, and the circuit conductors are to be connected in series. If there is a ground conductor, it is not to be in the circuit.

A current of 40 A is to be passed through the circuit conductors at low voltage for 1 hour, after which the specimens are allowed to cool to room temperature undisturbed. The specimen is then to be cooled and immersed in

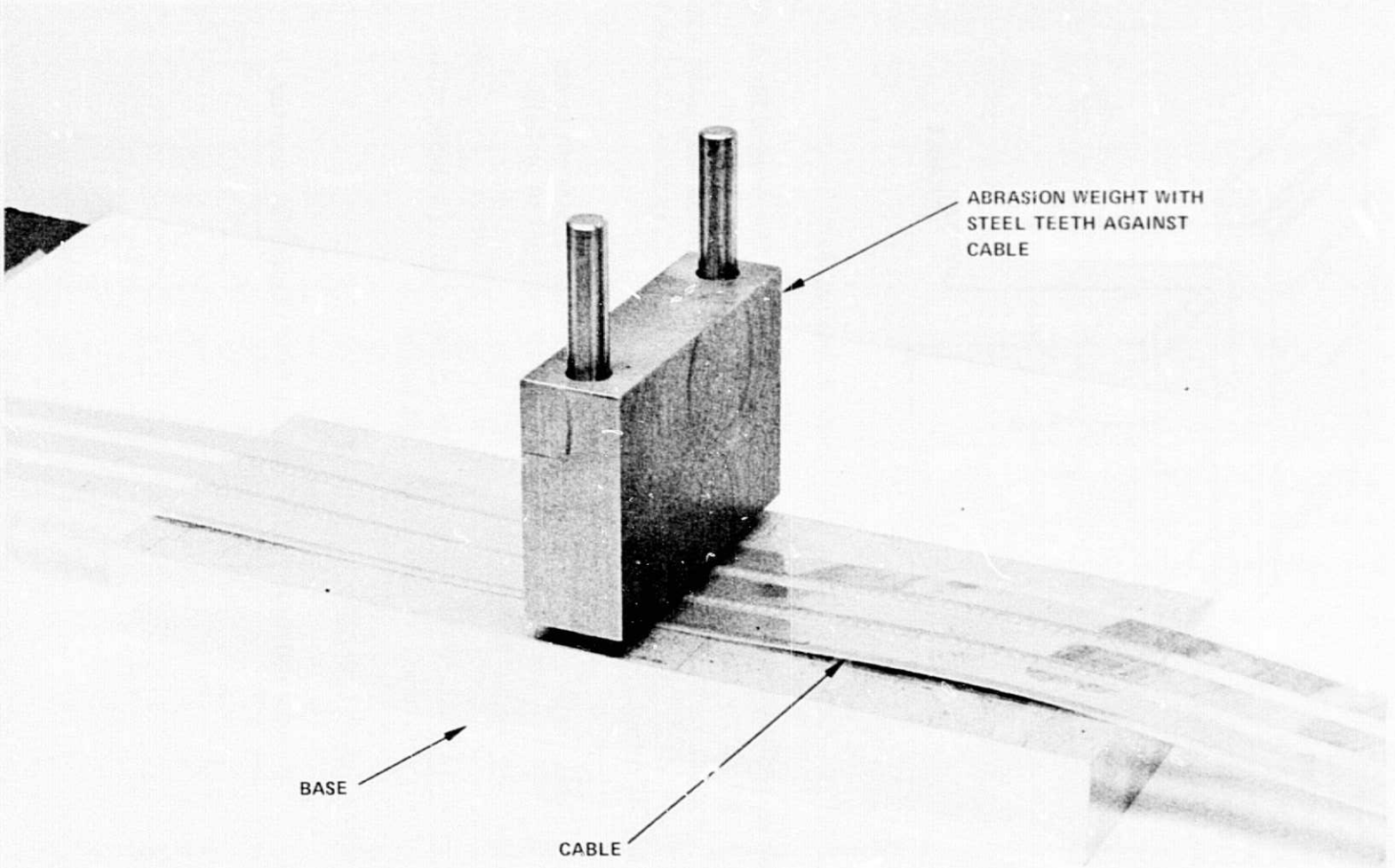


Figure 5. Abrasion resistance test apparatus.

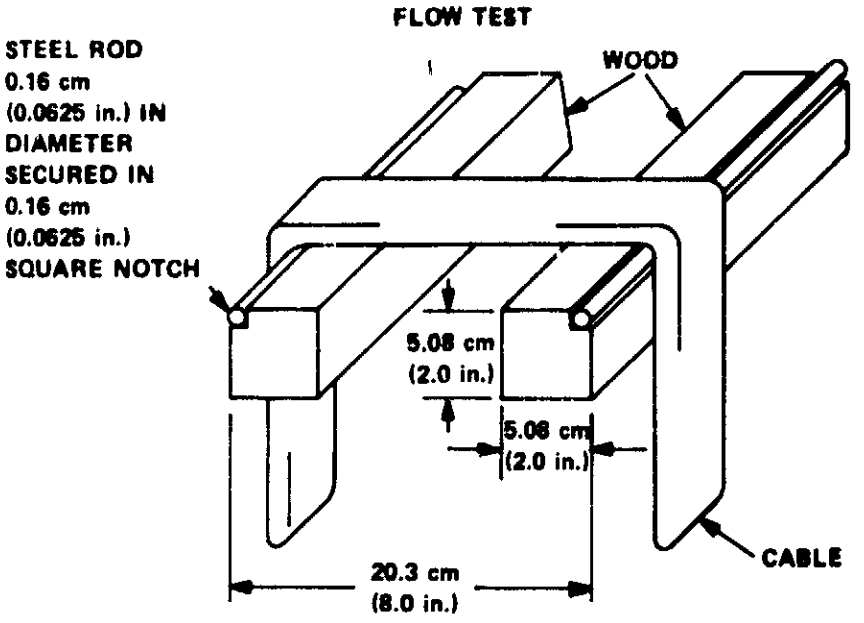


Figure 6. Detail of flow test apparatus.

tap water at room temperature, with care being taken that the ends of the specimen project sufficiently from the water to prevent flashover. A 60-Hz essentially sinusoidal test potential of 5000 V is then applied between each conductor and the water. The voltage is to be increased gradually from 0 to 500 V and is to be held at that level for 1 min.

b. Requirement. The cable of the representative specimen is not acceptable if it breaks down while the voltage is being increased or held. Figure 7 shows the testing apparatus.

c. Results. There was no breakdown or flashover of voltage while voltage was being increased or held on the test sample.

13. DRIPPING AND FLAKING

This test is not applicable to this type of FCC insulation covering.

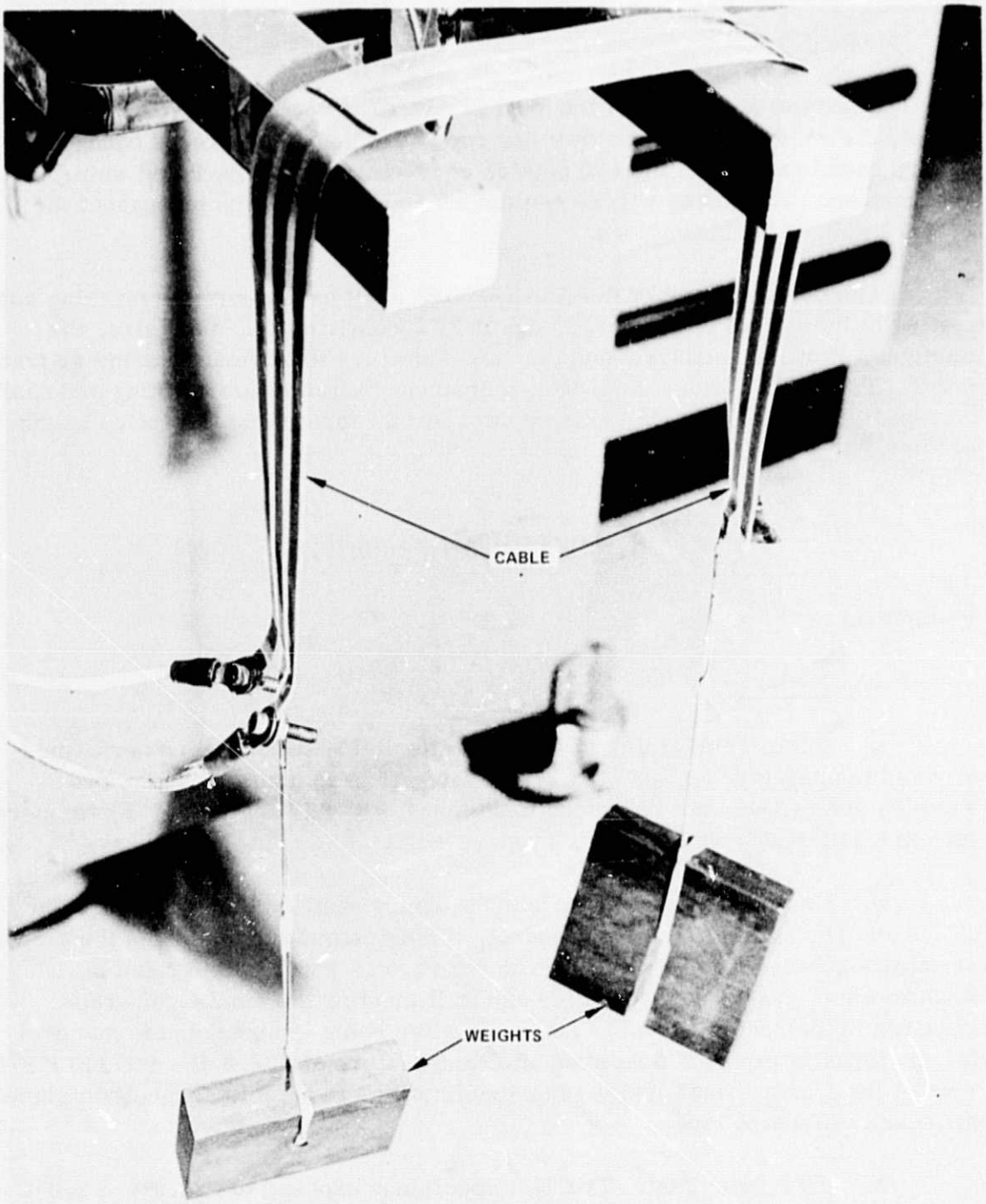


Figure 7. Insulation flow test apparatus.

14. MARKING

Since the Mylar insulation used to cover the conductors will be translucent, the conductors will be dyed for coding. The center ground conductor will be coded green with the two outside conductors coded black and white, respectively. All coding will be continuous and on both sides throughout the entire length of the conductors.

The outer surface of the finished FCC shall have a durable marking consisting of the letters M (Mylar), type of FCC construction, AWG size, the maximum working potential, and the manufacturers identification name or trademark. The outer surface shall be a permanent identification marking and shall be repeated no less than every 60.96 cm (24 in.) throughout the entire length of the finished FCC.

B. UL83 Requirements

FLEXIBILITY

1. Method.

a. Room Temperature Test. The flexibility test shall be performed at room temperature not less than 16 or more than 96 hours after the two samples are exposed for 168 hours to 113.9° C ± 1°C (237° F ± 1.8° F) temperature in a full draft circulating air oven.

b. Heat Shock Test. The sample cables shall then be wound around a 1.91 cm (0.75 in.) diameter mandrel. (This diameter mandrel is the smallest diameter around which a 6.35 cm (2.5 in.) wide cable could be wound without overlapping the cable and still meeting the number of wraps required in the specification.) The cable, after being wrapped on the mandrel for six turns, is exposed in an oven at a temperature of 102.8° C ± 1°C (217° F ± 1.8° F) for 1 hour. Both ends of the specimen are to be held securely in place by means of friction tape.

c. Cold Bend Test. Two test specimens exposed to -25.0° C ± 2.0° C (-13° F ± 3.6° F) temperature for 1 hour shall be wound six turns around a 1.91 cm (0.75 in.) diameter mandrel while at the test temperature. The winding shall be done at an approximately uniform rate of six turns per minute.

2. Requirements. The cable either unwrapped or wrapped and at elevated, room, or low temperature shall show no evidence of cracks internally or externally.

3. Results. See Table 1 for results.

TABLE 1. SUMMARY OF FLEXIBILITY RESULTS

Tests	Conditions	Results
a. Room Temperature (RT)	At RT after exposure to 113.9° C ± 1° C (237° F ± 1.8° F) for 168 hrs.	No cracks internal or external to the FCC*
b. Heat Shock	6 turns around a 1.91 cm (0.75 in.) diameter mandrel at 102.8° C ± 1° C (217° F ± 1.8° F) for 1 hour	Same as a*
c. Cold Bend	6 turns around a 1.91 cm (0.75 in.) diameter mandrel at -25° C ± 2° C (-13° F ± 3.6° F) for 1 hour	Same as a*

*Note: The FCC was then creased around a 0.076 cm (0.030 in.) diameter mandrel to determine if the FCC would stand a smaller bend radius. All samples passed this bend test without cracks developing internally or externally.

IV. CONCLUSIONS

The FCC tested passed all the requirements covered in UL719 and the applicable test requirements in UL83. Based on these tests, Marshall Space Flight Center recommends this FCC for use in a surface nonmetallic protective covering and further recommends that this FCC be submitted to Underwriters Laboratories, Inc. for approval.

Underwriters Laboratories, Inc., has tested and passed FCC of the same material construction as the FCC tested and described herein (file number E53726). This testing and approval by UL was accomplished for Parlex Corporation of Methuen, Mass. Their cable designation was style 2643, P/N MV12MV3, and style 2643, P/N M14M3. Parlex Corporation also manufactured the FCC tested and described in this report.

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.

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