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FLAT CONDUCTOR CABLE FOR LIMITED ROTARY OR LINEAR MOTION

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This report describes the capabilities and limitations of flat conductor cable (FCC) relative to bending, flexing, and folding. These characteristics are exemplified in a number of various applications which show how electrical connection is maintained between equipment units during linear and/or rotary movement of such units relative to each other.

The flexibility characteristics are exemplified by the typical FCC configurations shown in this report. The information concerning bending and torque characteristics of FCC, as disclosed and illustrated with charts, graphs, and other data, is intended for use by FCC application designers and manufacturers.

Editor's Note

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FLAT CONDUCTOR CABLE FOR LIMITED ROTARY OR LINEAR MOTION

SUMMARY

There are applications where limited linear and rotary motion must take place while maintaining electrical interconnection. This report presents some of these applications and describes many of the unique features of flat conductor cable (FCC) relative to bending, flexing, and folding. By considering these features of FCC, the designer can open new avenues of approach for electrically interconnecting equipment having relative motion between them.

Flat conductor cable should be considered in all applications where a high tensile strength (20 000 psi) and low bending torque (up to 1/40 that of conventional round wire cable) and high flexing requirements must be met.

Applications involving FCC for limited linear motion, such as rolling loop for drawers, rotational motion, and cables designed for use in 6 degrees of freedom, are described and illustrated.

Because of the versatility of FCC, of which this report only illustrates a few, much more flexibility is made available to the electrical interconnect designer.

INTRODUCTION

There are several applications involving limited rotary and/or linear motion between two pieces of electrically interconnected hardware. The use of standard round wire for these interconnections is often not very practical since it does not always provide the flexibility at the extremly low torque needed for most of these applications.

The advent of FCC with its high flex endurance and reliability opens new avenues for the designer of rotary and linear motions of electrical connections. For example, this has been demonstrated in the Pegasus applications where the micro-meteorite detector panels had to be unfolded after the satellites were in earth orbit. Rolled FCC has proven to be reliable and practical in numerous applications of rack-mounted drawer assemblies.

This report describes and illustrates a selection of typical FCC applications which are categorized into rotary and linear types and are shown by simple schematics. A discussion of bending torque, flexibility, and round wire versus FCC comparison tests is included to support these applications.

MECHANICAL PROPERTIES

An understanding of the mechanical behavior of the FCC is fundamental to the design of an application. The following discussion concerns the mechanical properties of FCC.

Tensile Strength

FCC insulation materials consist mostly of mechanical and electrical high strength dielectric films. In contrast to round wire cables, the FCC is very strong, not only because of the better insulation materials, but also because the cable has the collective strength of all conductors. The tensile strength of various cables and insulation materials is shown in Tables 1 and 2.

TABLE 1. TENSILE STRENGTH OF CABLE INSULATION MATERIALS AT ROOM TEMPERATURE (25° C)

Material	Tensile Strength MN/m^2 (psi)
Mylar (polyester)	138 (20 000)
Kapton (polyimide)	124 (18 000)
Teflon	20.7 (3 000)
Polyvinylchloride	20.7 (3 000)
Polyethylene	13.8 (2 000)

TABLE 2. TENSILE STRENGTH OF TYPICAL KAPTON-FEP INSULATED CABLES AT ROOM TEMPERATURE (25°C)

Cable		Conductor		Number of Conductors	Tensile Strength MN/m^2 (psi)
Width	Thickness	Width	Thickness		
in.	mil	mil	mil		
1	11	40	4	12	100 (14 500)
1	10	50	3	12	96.5 (14 000)

Bending Torque

Before the many rotary and linear FCC applications are presented, it is necessary to discuss the bending behavior of some FCC types. Only cables with Mylar and Kapton-FEP insulation are considered. Because of the widely varying material data, it is recommended that the torque and fatigue data be established by physical testing. For general information, some bending test results are listed in Table 3. The stiffness per cable of 10 cables stacked is, for reasons not yet determined, about 30 percent less than the stiffness of an identical single cable. Because of its greater thickness (0.018 in.), the higher stiffness of the power cable reasonably meets the expected value.

TABLE 3. BENDING TORQUE RESULTS

No. of Cables	Cable		No. of Cond.	Conductor		Lever Arm Length (cm)	Load N (g)	Defl. (cm)	Spring Const. =Load/Defl. N/cm (g/cm)
	Width (in.)	Thick-ness (mil)		Width (in.)	Thick-ness (mil)				
1	0.5	10	6	40	4	2	0.098 (10)	0.3	0.33 (33)
10	0.5	10	60	40	4	2	1.37 (140)	0.6	2.29 (234)
1	1.0	18	2	410	10	2	1.57 (160)	0.34	4.62 (470)

Flexing Endurance

The flexing endurance test is designed to determine the number of flexures that an FCC can withstand under a tension of one pound per inch of cable width at low and high temperatures. The scheme of the test apparatus (Fig. 1) consists of two 1-in. diameter mandrels rotating in unison ±180 degrees from the neutral position. The cable being tested will bend in both directions under load. MIL-C-55543 requires 800 cycles (min.) of flexure at 30 cycles per minute at low and high temperatures for 0.004-in. conductor thickness.

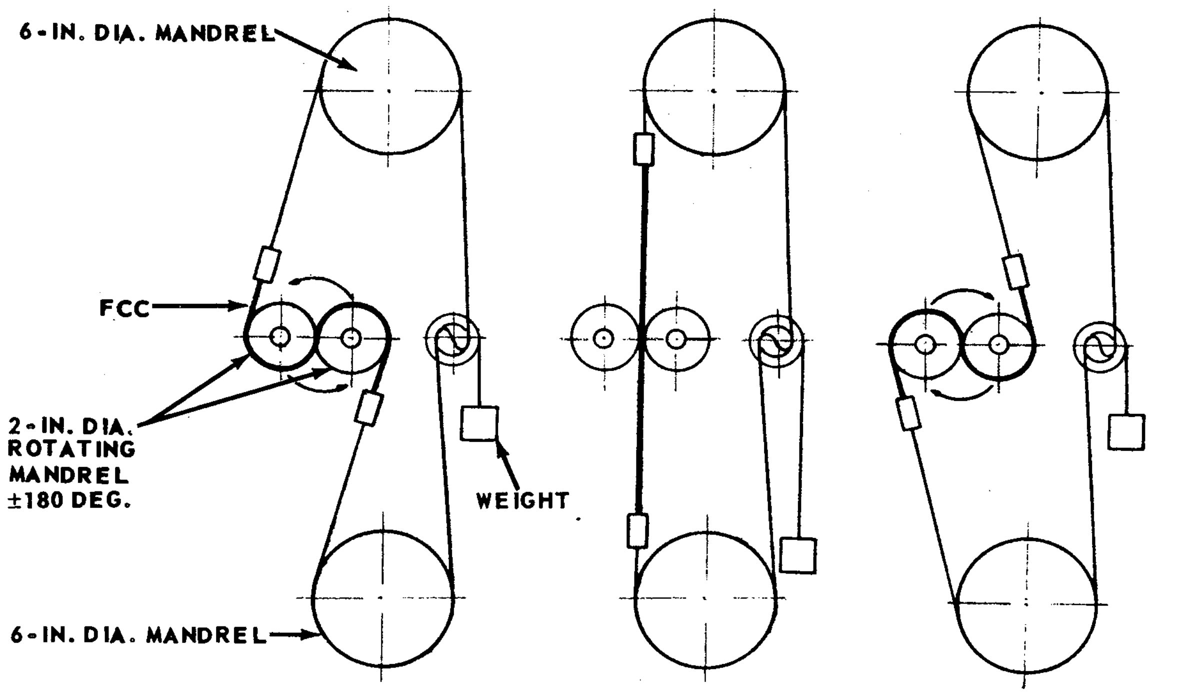


Figure 1. Flex tester.

Table 4 shows the results of flexure testing for four samples of polyester (Mylar) and three samples of polyimide (Kapton) FCC; each sample was 2.5 in. wide, 0.011 in. thick, and had 4- by 40-mil conductors.

The high temperature for Mylar was 100°C; whereas, it was 210°C for Kapton. The low temperature tests were made at -65°C for both types. The data shown in the table are typical. A large number of cable types and sizes has been flex tested to destruction. Before conductor fatigue failure occurs, 5000 cycles can be assumed.

TABLE 4. FLEX TEST RESULTS

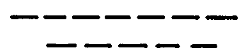
Material	Test Cablé Specimen No.	No. of Cycles Before Conductor Failure		
		-65° C	100° C	210° C
Mylar	1	—	6813	—
	2	—	6140	—
	3	5638	—	—
	4	5285	—	—
Kapton	1	—	—	5049
	2	—	—	5269
	3	5026	—	—

Stiffness Comparison of FCC and Round Wire Cables

To reemphasize the bending ability of FCC, some bending torque comparison tests between FCC and the equivalent standard round wire are presented. The results listed in Table 5 are for four test specimens with equal length and equal copper cross-section area.

It can be seen from Table 5 that the FCC is far more flexible than the equivalent round wire cables (round wire even in ribbon form).

TABLE 5. CABLE STIFFNESS COMPARISON[a]

Specimen No.	Description	Shape	Stiffness mN·m/deg angle (in.-lb/deg angle)	Stiffness Ratio
1	8 Kapton-insulated round wire AWG 20, laced to a bundle 0.150 in. in diameter		20.7 (0.183)	45
2	8 Kapton-insulated round wire AWG 20, laced flat, 0.028 in. thick, 0.425 in. wide		17.3 (0.153)	38
3	2 FCC's, 4 × 40 mil copper AWG 27, one with 25 conductors was 2 in. wide, the other with 18 conductors was 1.5 in. wide		2.71 (0.024)	6
4	1 FCC, 3 × 250 mil copper, 8 conductors, 10-mil thickness and 2.5-in. width equal to 8 round wires AWG 20		0.45 (0.004)	1

a. These tests were made at room temperature (25°C).

FCC FOR LINEAR MOTION

There are numerous applications where two or more pieces of electrically interconnected hardware move in a linear direction in relation to each other. The configuration of the FCC makes it extremely well suited to applications involving small storage space and short or long lengths of dispensing and retracting cable. This discussion shows how linear motion with uninterrupted electrical connection is achieved by utilizing different flat conductor cable configurations. Configurations that are described and illustrated are the loop, accordion fold, bifilar spiral coil, and helical coil, some of which are preformed to desired configurations by the heat-set method. Most conventional wires are relatively stiff and unsatisfactory for repetitious linear movements; whereas, the FCC is extremely flexible and has very little friction, thereby permitting almost unlimited repetition of flexing.

Rolling Loop for Drawers

Much electronic equipment, especially the ground support equipment, is made up of cabinet-type consoles housing a series of standard panel and chassis assemblies deployed in a drawer-like fashion. To interconnect these moving drawer assemblies to the stationary console, a flexible FCC can be used with great advantages.

Figure 2 shows the loop method of maintaining electrical connection between the stationary console and the moving drawer. The FCC is terminated with standard FCC connectors. The interconnecting cable should be of sufficient length so that when the drawer is pulled to the extended position the cable and its terminals will not be under tension. One end of FCC is fastened to the console and the other end to the drawer. By utilizing the loop method, greater repetition is attained, providing a longer life expectancy and greater ease in cable replacement. The loop needs very little space to function; 0.5 in. between the drawers is sufficient for unshielded cable, and 1 in. is sufficient for shielded cable.

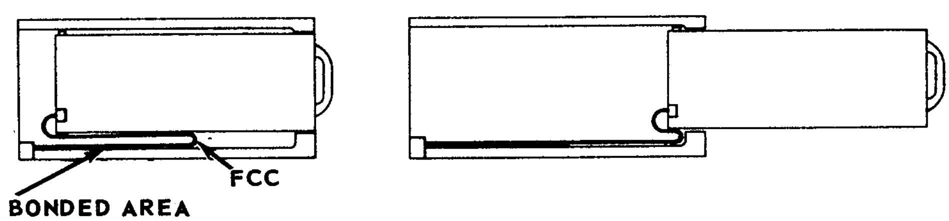
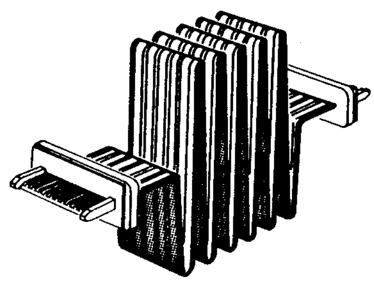


Figure 2. Rolling loop for drawers.

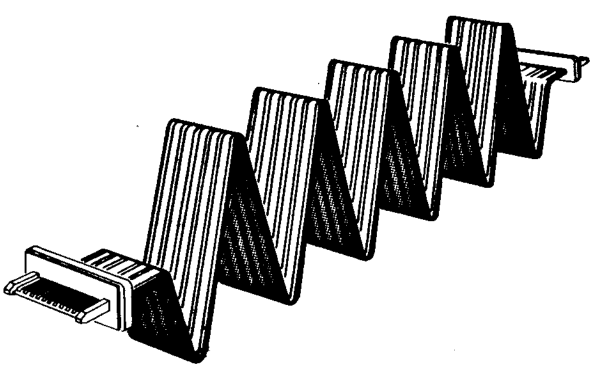
No linkages or other mechanisms are needed. The only requirement is to provide two smooth surfaces, one above and one below the cable. The lower, or support, surface is stationary, while the upper surface is the bottom of the moving drawer. About 40 percent of the cable length at the stationary end should be cemented to the lower surface.

Folded FCC Accordion Type

The accordion type is an arrangement of one or more FCC's preformed into systematic folds like the bellows of an accordion. The number and dimensions of folds are determined by the available stowage space and the desired extended distance between the two interconnected electronic consoles. It can be deployed horizontally or vertically, permitting limited linear and/or rotary movement. If this configuration is used for the longer movements, it may require additional support during extension and retraction to eliminate excessive lateral and sagging movement. This support may be a housing, tray, or other lateral guidance. Figure 3 illustrates the accordion or corrugated configuration.



a. Retracted



b. Extended

Figure 3. Folded accordion type.

For forming the accordion, a fixture with two rows of removable dowel pins is used. The spacing and lateral distance of the dowel pins define the accordion dimensions. The diameter of the dowel pins should not be less than 0.125 in. to avoid overstressing the cable surface. The dowel pins can be staggered to reduce the stowage room. The cable is folded under tension into the forming fixture and is held in position during the application of heat and the subsequent cooling operation; this is similar to the method used in preforming coiled cables. The cable should not be extended to its full unfolded length because of overstressing the folds.

Self-Retracting Bifilar Spiral Coil

The self-retracting bifilar spiral coiled cables are preformed and used where the retractable length is relatively short (a few feet). To form the bifilar spiral coil, the flat cable is tightly wound (coiled) on a form, then it is heat treated. Polyester (Mylar) cables can be heat-formed since polyester is a thermoplastic material. Thermosetting plastics like Teflon (TFE) and polyimide (Kapton) are not recommended for forming. Preforming experiments have revealed that Mylar cables require a temperature of 110°C for up to 3 hours and a cooling time of approximately 3 hours, depending on coil sizes. Large coils need more soak time and cooling time. The cable must be kept tightly wound during the heating and cooling cycle. Tests should be made to establish the temperature and time for every new material and coil size.

Figure 4 shows a self-retracting bifilar spiral coil terminated with plugs. The center point of the flat cable's total length is located at the center of the bifilar coil. The cable center should be clamped to a core to prevent sliding.

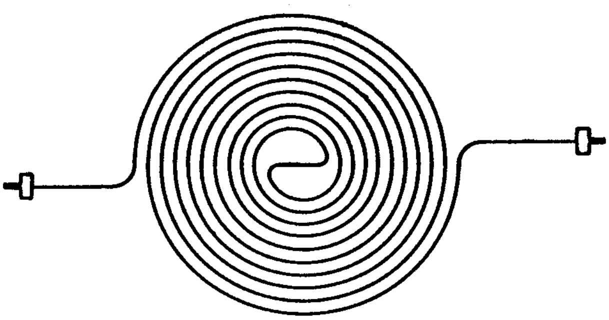


Figure 4. Self-retracting bifilar coil.

For long cable deployment and retracting length, it is recommended that a spring design be used similar to that employed in standard metal retractable measuring tapes. This metal spring will help to overcome the sliding friction caused by the added length.

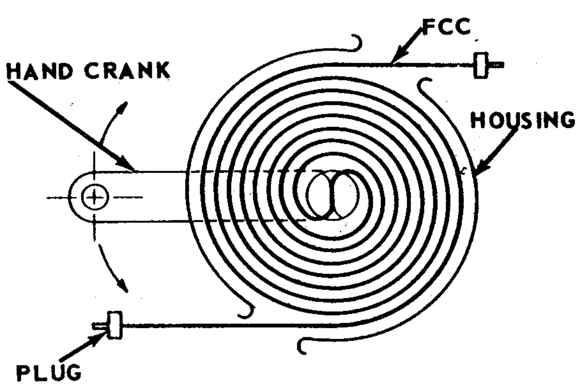


Figure 5. Bifilar coil for long extension.

Bifilar Cable Coils for Long Extensions

The hand-cranked spiral coil is used when the cable is very long and has more friction between the many layers than the preformed tension can overcome. Figure 5 shows a spiral coil confined in a housing with a hand crank. The cable is fastened at its center in the slit of the shaft. Then the cable can be wound up to the bifilar coil and is ready for use. For extension, the cable is pulled out of both sides of the housing; then, it is retracted by hand cranking.

Fixed-End Bifilar Cable Coil

Figure 6 shows a storage-dispenser-retractor concept for employing FCC between a fixed object and a moving object, for example, a drawer assembly or a portable piece of electrical equipment.

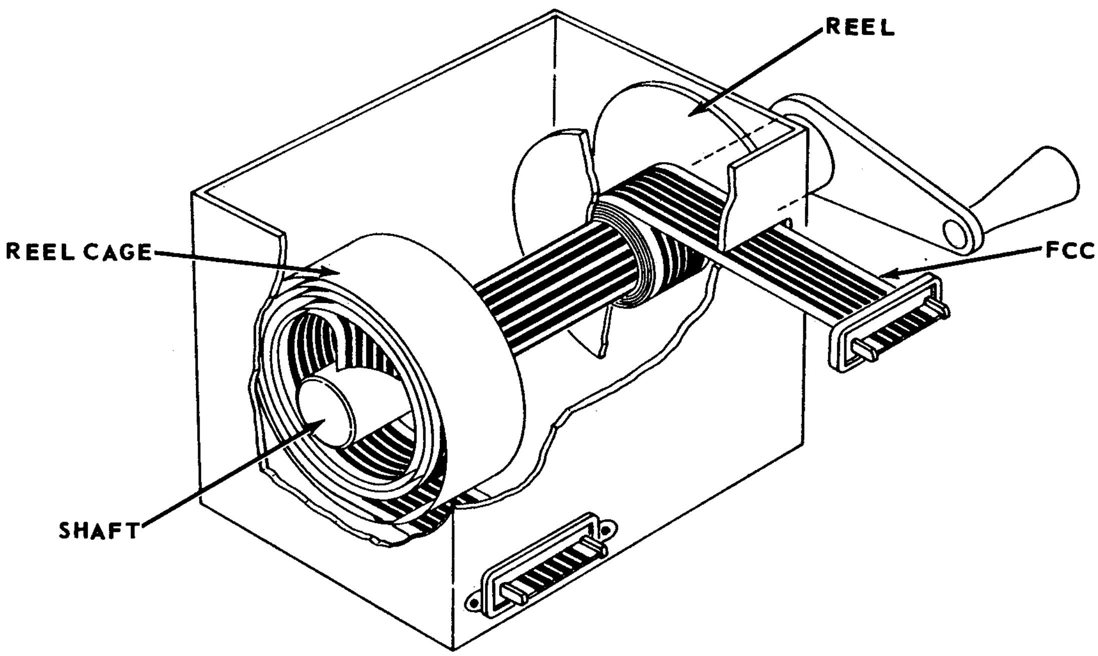


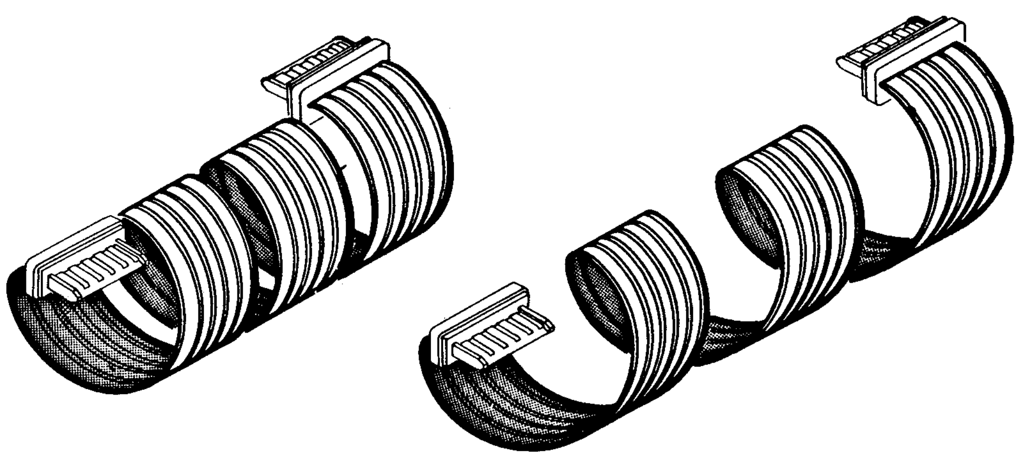
Figure 6. Fixed-end bifilar coil.

In this design, the center portion of the FCC is attached to a shaft on which a reel has been mounted at one end. A stationary reel cage is located at the other end of the shaft. The cable is then folded at each end of the shaft, in opposite directions 90 degrees to the longitudinal axis of the shaft, and is wound such that on the reel end the cable is wound tightly on the shaft and on the reel cage end the cable is wound against the outer reel cage housing. During operation the reel end of the cable is dispensed, while the reel cage end of the cable is wound tightly against the shaft.

The electrical cable can be retracted either by using a hand crank mounted to the shaft, a spring that is energized as the cable is dispensed, or by using a formed and heat-treated FCC (such as Mylar), where short lengths of up to 3 ft are needed. A reel assembly 2.5 in. in diameter could easily contain 100 ft of 10-mil FCC to dispense 50 ft of cable.

Helical Coil for Short Extensions and Rotations

Another way of maintaining electrical continuity while permitting linear movement between two pieces of interconnected equipment is the helical coil method. The helical configuration may be accomplished by cold forming in a natural state or preforming with the standard heat set method. Figure 7 illustrates the helical shaped cable. For heat forming, the FCC is wound to the desired diameter and length, either in a spiral on an arbor or in a helix on a mandrel, depending upon the functional requirement.



a. Retracted b. Extended

Figure 7. Helical coil for short extension.

This method can also be used to attain limited rotary and/or linear motion as necessary. One end of the coil has 6 degrees of freedom with regard to the other end.

FCC FOR ROTARY MOTION

This discussion concerns numerous applications and includes schematics showing how two pieces of electronic equipment, which rotate in relation to each other, are interconnected through the use of various configurations of FCC. This may be one electronic unit moving in relation to another connected only by the cable, or it may be a single electromechanical assembly with limited rotary movement about a shaft, hinge, or other mechanical device. By using FCC to maintain electrical connection, the restraining forces, such as friction and spring tension, would be very small and would have little effect on the different rotary moving applications. Besides the electrical connections, there are other interesting characteristics of the cable, such as torque, flex life, degrees of rotation, and others, depending on the application.

Rotor Loop Method

The rotor loop method is one of several FCC loop methods where electrical connection can be maintained while relative rotary motion is achieved between two pieces of hardware. Figure 8 shows how a shaft can rotate almost ± one turn, depending on terminal design and the ratio of the shaft diameter to the inner housing diameter inside a fixed housing interconnected by two or more FCC's. One end of the cable(s) is attached to the rotor with the other end(s) attached to the fixed housing. The cable forms a loop almost halfway around the rotor. As the rotor moves, the cable loop rolls. The same method can be used with the center stationary and the housing rotating or oscillating around it.

Figure 9 shows a single rotating loop design for an angular motion in both directions. The number of turns depends on the number of cable windings around the shaft. Several cables may be used in both Figures 8 and 9 if required for the application.

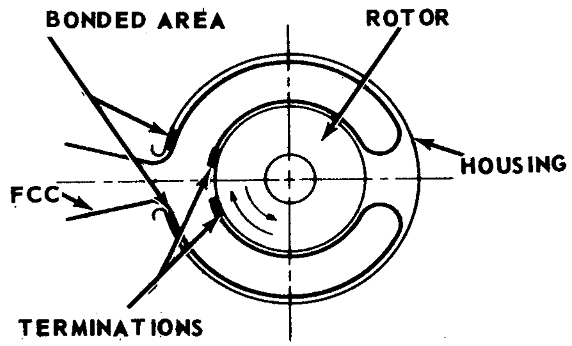


Figure 8. Double rotor loop.

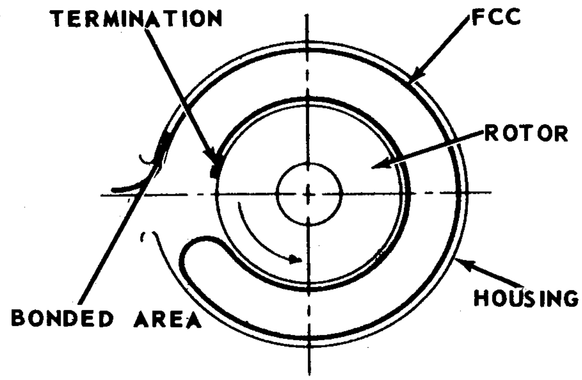


Figure 9. Single rotor loop.

Twist Application

The twist is a high-torque, small-angle-of-rotation application. The cables lie loosely on top of each other; one end is fixed and the other end rotates or oscillates about the cables' longitudinal axes (Fig. 10). When torque is applied to create this twist, the edges of the cables are under tension; whereas, the cables' centers are under compression. This distortion and torque may be reduced by giving slack to the cables so they can form helicals with bending motion rather than form stretching deformations. The long, narrow type cables are more appropriate for the twist type application, with the amount of torque determined by the number, width, and length of the cables, as well as by the twist angle of the cable. In other words, a harness with a large number of conductors should have many narrow cables in stack form, rather than a few wide cables, to keep the torque small. Torque tests were made with a stack of 36 FCC's, of which each was 2 in. wide. The stack consisted of 12 power cables each having 3 conductors with 0.010 by 0.625 in. (AWG 11) cross section, and 24 power cables each having 3 conductors with 0.010 by 0.560 in. (AWG 12) cross section with a free length of 12 in. The average torque for a ± 45-degree angular motion (twist) was 0.28 N · m (40 in.-oz). Rubber bands were placed around the free length portion of the stack to prevent irregular deflection of the cables when applying torque. This reduced the average torque by about 10 percent.

Figure 10. Stacked FCC with 90-degree twist.

The stack of 36 cables was 2 in. wide and 0.850 in. thick. The torque could have been drastically reduced by using 108 single conductor cables of 0.75-in. width and a stack height of 2.5 in.

Flex Application

A 50-cable harness containing 1250 conductors was used for flex measurements. Each cable was 32 in. long, 2 in. wide, and had 4- by 40-mil conductors with 75-mil center to center spacing. Figure 11 shows a vertically suspended arrangement with the lower end free to move in any direction except down. It may be necessary to leave some slack in the cable system to facilitate the movement in the plane of the cables. A second test was made (Fig. 12) with the harness in a horizontal position, supported by floats on water to eliminate drag and to isolate the cables' bending resistances. The forces needed to move the harness about its fixed end were approximately 9.8 to 19.6 mN (1 to 2 g) per degree of angular motion.

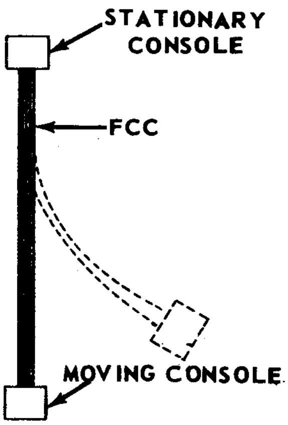


Figure 11. FCC bending vertically.

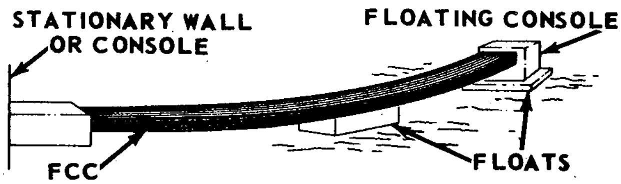


Figure 12. FCC bending horizontally.

Torque Compensating Loops

The torque compensating loop method of interconnection is used on a gimbal application. Figure 13 shows a mockup using FCC to attain the desired low torque electrical energy transfer across a two-axis gimbal system. The objective is to accomplish electrical energy and signal transmission for a very complex system using about 2000 electrical conductors, at a minimum of torque. The torque can be reduced to near zero by forming symmetrical cable loops on each side of the pivot. The illustration shows two loops about the pivot axis. As one loop is tightened at the right side, the loop is loosened at the left side while the gimbal is tilting. This compensates the torque needed for bending the cables. Each FCC acts as a leaf spring. The very small amount of friction between the cable layers causes the only torque that affects the movement of the gimbal, other than the bearing friction.

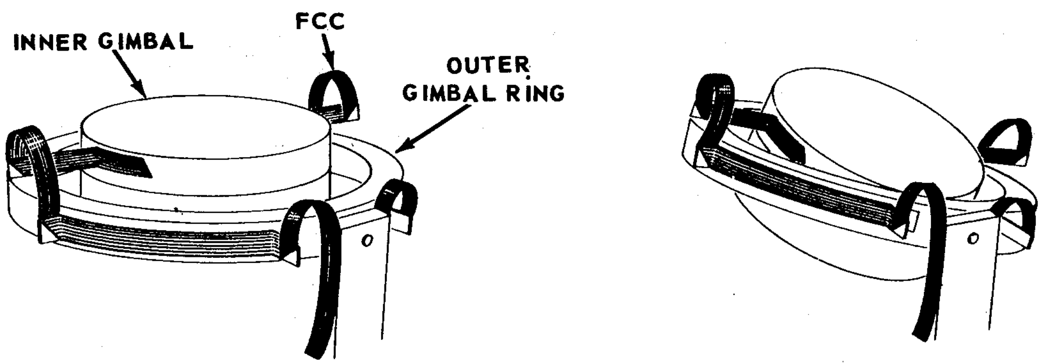


Figure 13. Torque compensating loop.

Rotor Loop, Cylindrical Types

This is an etched printed wiring configuration made of flexible copper clad plastic base material. The basic difference between this and other FCC methods is the geometry and the method of manufacture; it is printed and etched rather than laminated. The cable must be designed to the desired radius of rotation.

This etched circular pattern loop moves between two parallel discs, one rotating with regard to the other about a common center. These discs serve as supports for the cables interconnecting the two pieces of electronic hardware. The cable is attached to the top side of the lower disc and to the bottom side of the upper disc so that a moving circular loop is formed by the cable as one disc moves in relation to the other. This application is very similar to the drawer loop system. The drawer loop moves linearly, while this loop moves on a circle. One loop can be applied for almost ± one full turn.

The cable may be a single FCC, as shown in Figure 14, or it may be several layers of stacked circular cables. For more than ± one full turn, a spiral cable, as shown in Figure 15, may be considered.

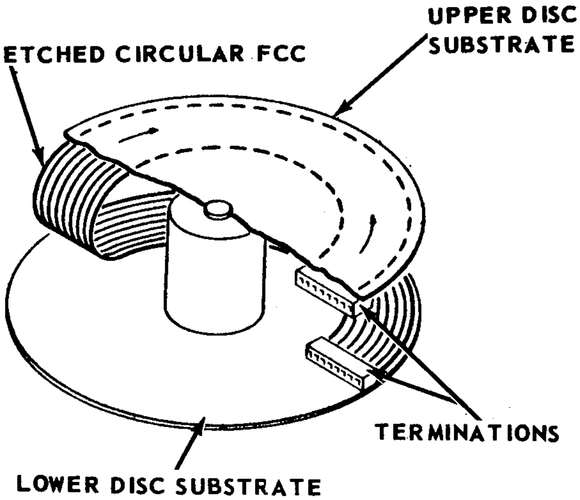


Figure 14. Rotor loop, flat type.

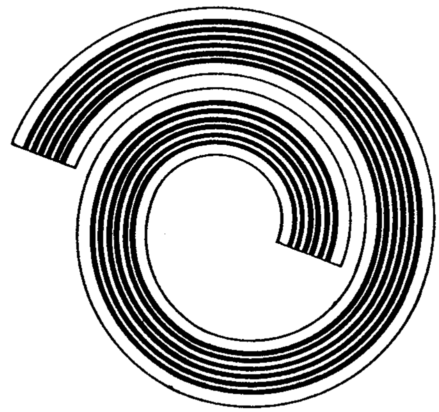


Figure 15. Rotor loop, flat type, flat spiral.

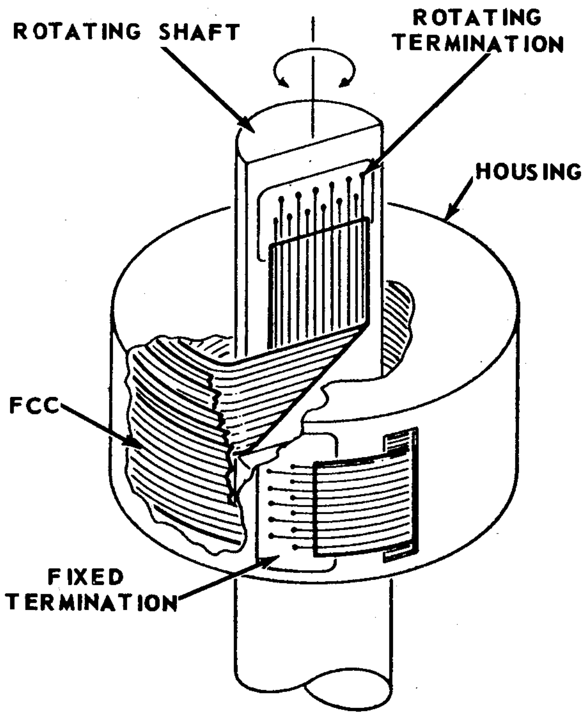


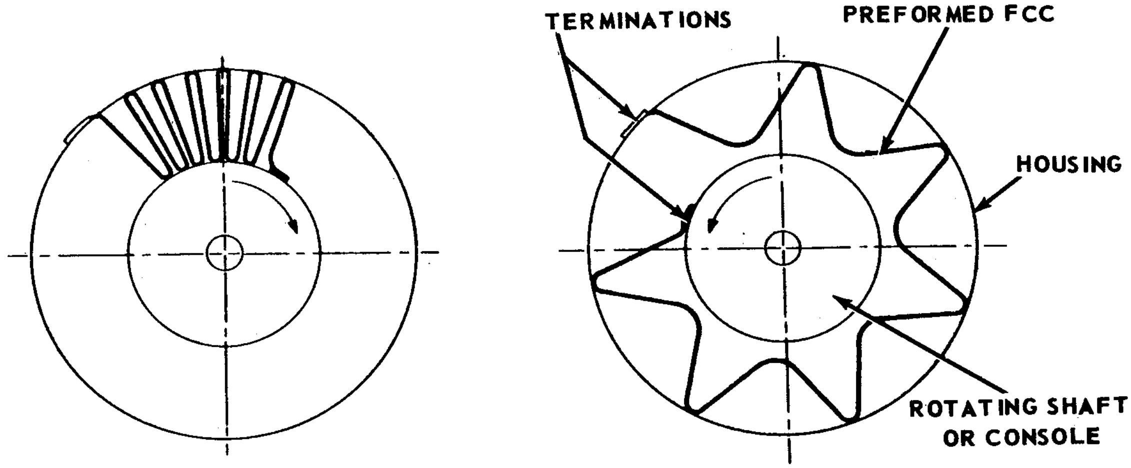
Figure 16. Cable for several turns without slip rings.

Angular Movement of Several Turns

For interconnecting two points of which one rotates several times without using slip rings, FCC can offer a practical solution. The FCC is contained in a housing of sufficient inside cable space, as in Figure 16. One cable end is connected to this housing; the other end is fastened and electrically connected to a rotating core. Ten turns of cable located between the housing and the shaft allow ± 10 turns of the shaft, i.e., 10 turns clockwise and 10 turns counterclockwise from a center position. The inner end of the FCC may be folded at a 90-degree angle and routed to a terminal plate located on the shaft, allowing easy access.

Corrugated Type

The accordion type configuration shown in Figure 3 is equally effective for limited rotary type applications, as shown in Figure 17. The outer terminal and housing are fixed with the inner terminal attached to the rotor. The corrugated shaped FCC interconnection allows the rotor to rotate about ± 150 degrees.



a. Stowed position   b. Extended position

Figure 17. Rotary motion with corrugated FCC.

Coiled Cable for Rotating Equipment Shaft

A coiled cable without slip rings is shown in Figure 18. The FCC is wound around a piece of equipment and interconnected to another piece which may have to be moved while electrically connected. This FCC interconnection may be one or more cables lying on top of each other. As the equipment is deployed, the equipment-shaft rotates, winding or unwinding the cabling as required.

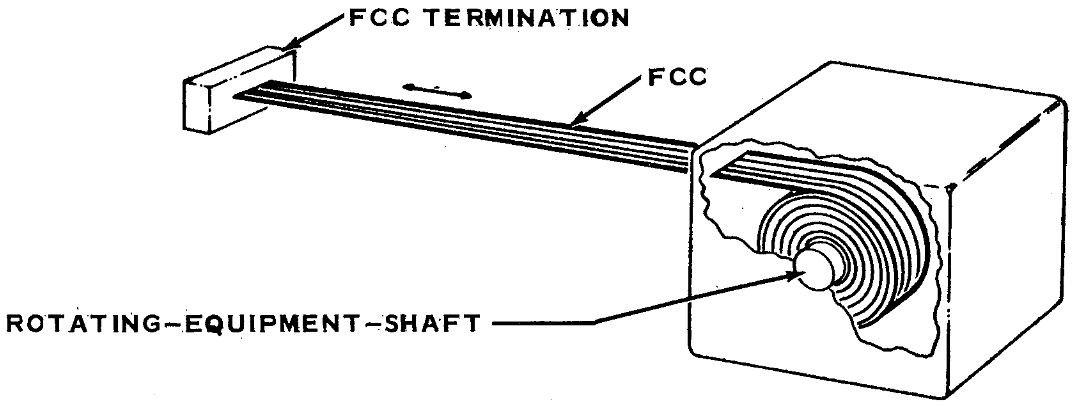


Figure 18. Linear movement using rotating-equipment-shaft method.

Hinge Designs

The last group of applications deals with hinge motions where the FCC is parallel to a hinge or where the FCC is used as a hinge accomplishing both the mechanical function and the electrical current transfer. The hinge requirements include angular motion, freedom of looseness (backlash), electrical and/or electrical load carrying capacities, limited spring torque, friction, etc. The following examples describe some of the typical applications.

1. Pivot Loop — The pivot loop is so designated to portray the specific design illustrated in Figure 19. It is basically a bending application for small or large quantities of FCC passing through the center of rotation. The torque is a function of cable stiffness and bending angle. To eliminate Coulomb's friction, the individual cables should be spaced so they do not touch. The bending torque is caused by the elastic and, to a lesser degree, plastic deformation of the cables. As angular motion takes place, the torque can be further reduced by forming two loops, one opening and one closing, as described in both the torque compensated loop method and the Rolamite principle. It may be necessary to put a band or other restrictive device around the cable assembly near the pivot point to insure that all cables will bend in the same direction.

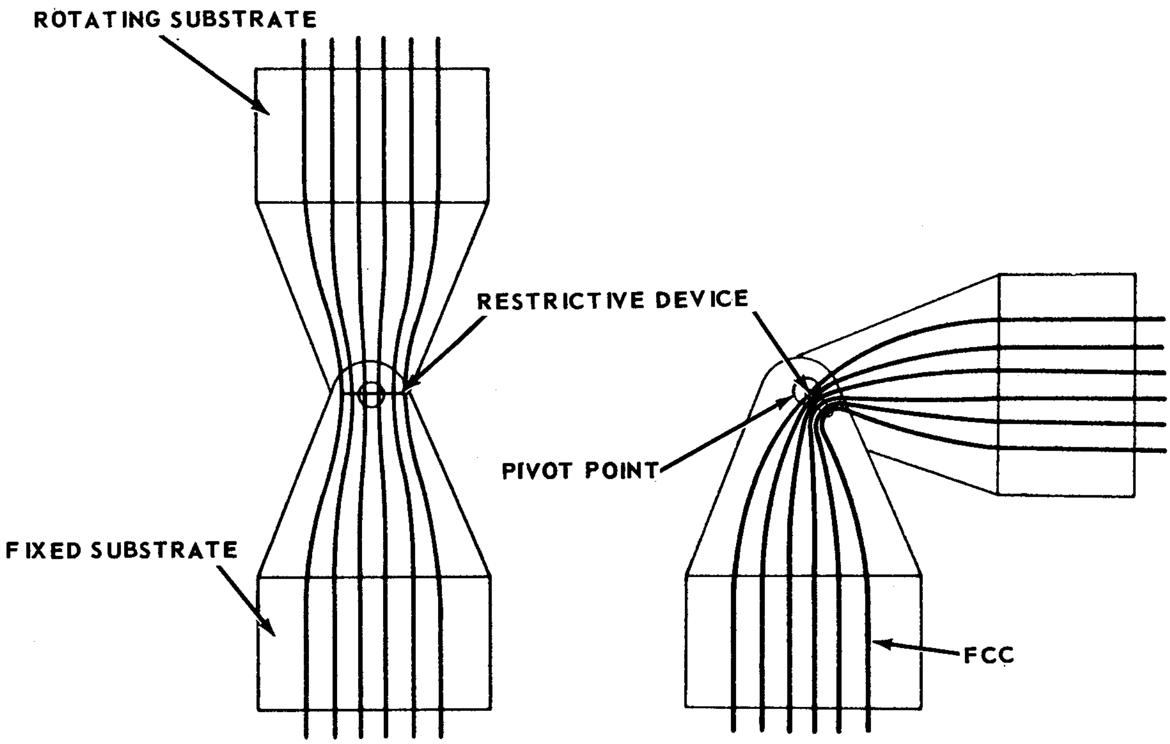
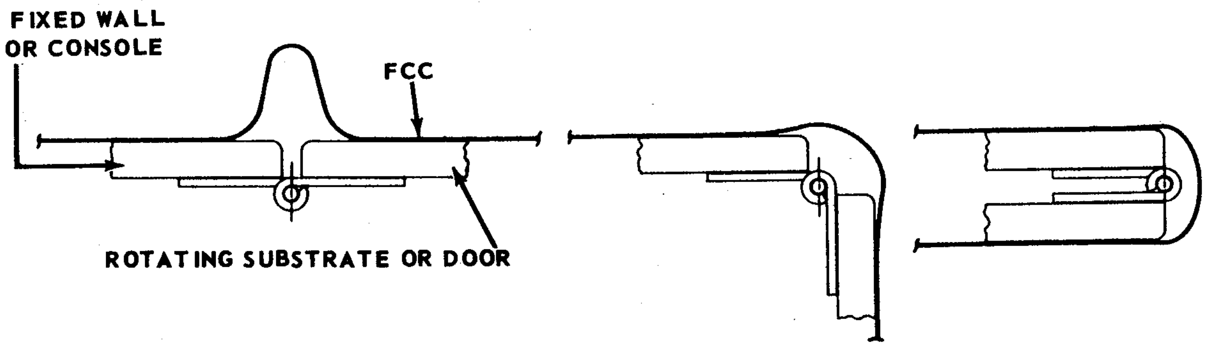


Figure 19. Pivot loop hinge.

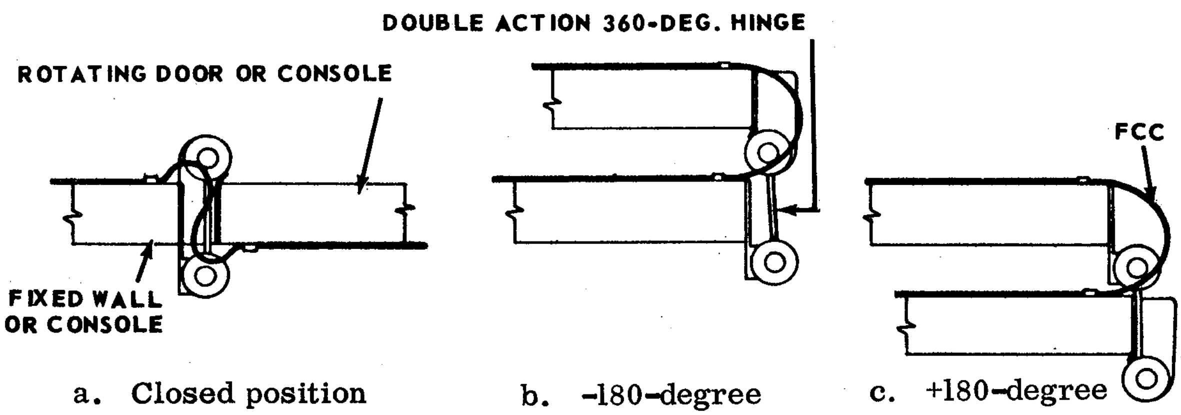
2. 90/180-Degree Door Hinge — There are several variations of simple door hinges where electrical circuitry must be carried across the hinge point. Normally, a door hinge swings through an arc of either 90 or 180 degrees. Figure 20 shows a door hinge in closed, 90-degree, and 180-degree positions with the FCC for electrical connections across the hinge. The cable should have a sufficient amount of slack, usually in the form of a loop, across the hinge to allow the desired swing. The slack or loop should be kept to the minimum so it will not interfere with other moving. The circuitry may require a single multi-conductor cable or several cables either stacked or located side by side. As the number of cables increases, the torque required to move the hinge will also increase. However, this torque is of little concern in most applications. Cables side by side cause less torque than stacked FCC.



a. Closed position b. 90-degree position c. 180-degree position

Figure 20. FCC mounted for door hinge application.

3. 360-Degree Double Action Door Hinge — This application is basically a duplication of a single pivot hinge or a simple two-way hinge. The cable is attached to the surface of the door and to the wall leaving the center section free to flex. The number of hinge cycles depends upon the surface stress of the most stressed section of the cable. Experiments on life testing in flexing have shown that several thousand cycles can be expected from cables of less than 15-mil thickness. The three positions of a double hinge are illustrated in Figure 21.



a. Closed position b. -180-degree position c. +180-degree position

Figure 21. FCC mounted for double action hinge.

4. Crossband Hinges — The crossband hinge has the FCC so arranged that the cables serve as load-bearing and also as the electrical interconnection. There are various shaped electronic consoles requiring hinged type action and having varying degrees of rotation. The load-bearing crossband hinges discussed in the following paragraphs are the square-cornered, round-cornered, and the reinforced type. The load bearing capacity depends upon the combined stiffness of all cables crossing the hinge axis (the free length of the cables, their thickness, relative distances, materials, etc.).

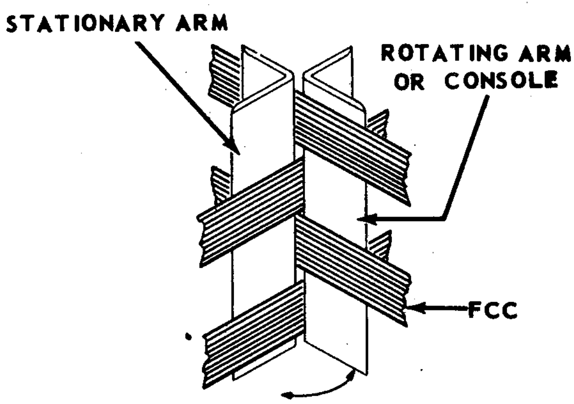


Figure 22. Square-cornered crossband hinge.

a. Square-cornered crossband hinge — This hinge has two groups of FCC crossing each other. They are alternately spaced and attached to the opposite sides of two consoles, one of which rotates about the other. This crossband arrangement keeps the rotating part aligned parallel to the hinge axis without backlash and maintains electrical connection across the hinge axis. Figure 22 shows two housings interconnected by four cables with a total excursion angle of 180 degrees.

b. Round-cornered crossband hinge — This method of hinge and electrical interconnection is similar to the square-cornered crossband hinge. The primary difference is the semicircle and the use of parallel surfaces to attain a greater swing angle. With this configuration, the swing angle will be 360 degrees, regardless of the size of the moving structure; however, as the size of these moving structures increases, the number of components they are capable of housing also increases. If the load is greater than the FCC's mechanical capability, additional support is required, as discussed in the next crossband method. Figure 23 shows a self-supporting crossband hinge made up of two moving substrates and three FCC's.

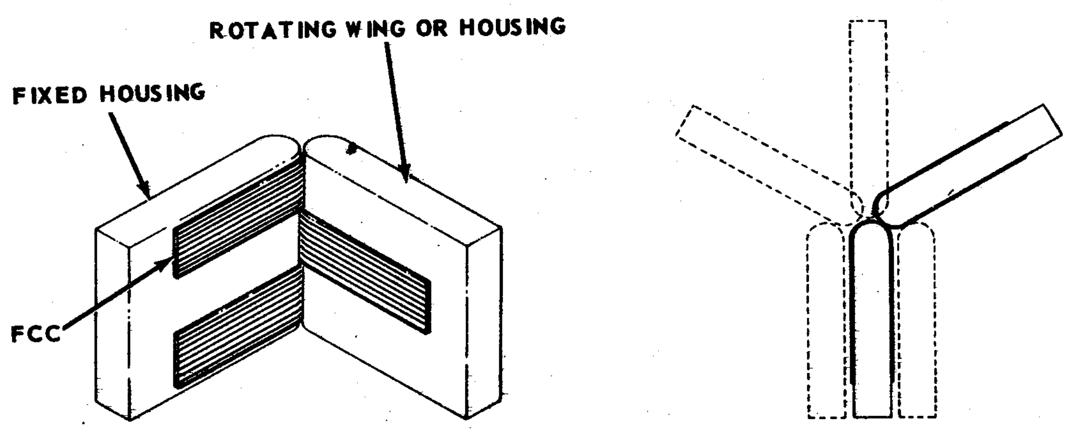


Figure 23. Round-cornered crossband hinge.

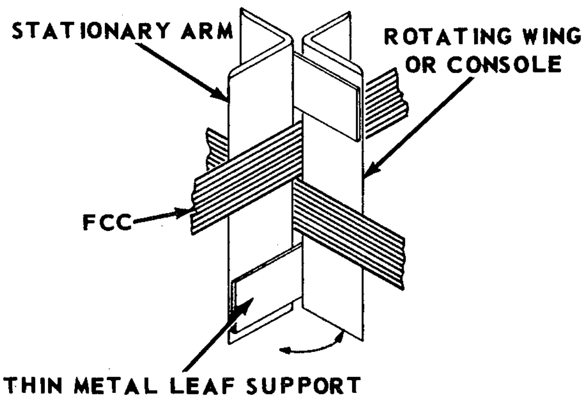


Figure 24. Reinforced crossband hinge.

c. Reinforced crossband hinge — A reinforcing leaf spring may be used on any of the crossband applications if additional mechanical support is needed. These springs are mounted parallel to the FCC, permitting essentially the same hinge action while providing the additional support. The necessary mechanical reinforcement is accomplished with a shim stock spring. Figure 24 shows a square-cornered crossband hinge with a metal leaf spring as the supplementary mechanical support.

CONCLUSIONS

It was found that flat conductor cable is far superior to standard round wire on applications where rotary and/or linear movement is made between two or more electrically interconnected pieces of hardware. Most of these applications involve repetitious or springlike movements in which the round wire has little endurance and requires much more torque than FCC.

APPROVAL

NASA TM X-53960

FLAT CONDUCTOR CABLE FOR LIMITED ROTARY OR LINEAR MOTION

By James R. Carden

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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