A COAXIAL CABLE CONNECTOR DESIGN TO OVERCOME COLD FLOW CHARACTERISTICS OF CABLE MATERIALS

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Coaxial cables used by the CATV industry utilize aluminum for the outer conductor and aluminum or copper for the inner conductor.

Both aluminum and copper are "soft" materials and exhibit cold-flow characteristics under compression.

Electrical connectors used on coaxial cables employ compression connections on both the inner and outer conductors. The very best electrical connectors that exhibit fine electrical characteristics when initially installed will deteriorate as soon as cold-flow occurs. Cold-flow will occur. There is no way to prevent it. How long it takes for this action to be significant depends upon the initial pressures employed in the connector design and the ambient temperatures encountered.

By the very nature of the compression connection, even a very minute increment of cold-flow results in a gap in the circuit. The obvious answer is to back the compression connection up with a spring.

How to do that and still release the cable when desired constituted the problem.

The solution was obtained with a unique clamp design and by taking advantage of the "spring" characteristics of the newer plastic materials.

In the new design every increment, however minute, is immediately compensated for by a spring back-up force. In this manner initial electrical chacteristics can be expected to be maintained for many years of severe service.

Electrical connectors, to most engineers, are a necessary evil. This is due, at least in part, to the tendency of engineers to leave selection of connectors until the very last thing. In every project connectors are taken for granted, and little thought is given to them until trouble occurs.

Engineers should consider connectors a vital part of the CATV system, and give full attention to them in the early stage of design.

JUST WHAT IS A GOOD CATV CONNECTOR?

Cost, appearance, and ease of assembly are all factors to be considered, but a good connector is one that will guarantee against signal distortion under severe usage and adverse weather conditions; one that will continue to do so for years on end.

Perhaps the single, biggest, problem encountered today with CATV connectors is not their initial performance, but deterioration of performance after months and years of usage. What matters cost, appearance, or ease of assembly if a connector doesn't do a good job?

WHY SHOULD AN APPARENTLY GOOD CONNECTOR, WHEN PROPERLY INSTALLED, DETERIORATE?

The answer lies in the materials used to fabricate the cable itself, not in the connector. What do we mean by this? Shall we blame the cable and look for better cable? No, I think not. We would do better if we accepted the cable as it is, and designed our connector to overcome, if possible, or at least live with, the apparent shortcomings of the cable.

The first step is to recognize that all cables utilize copper and/or aluminum for both the inner conductor and the outer conductor. Both are soft materials, and both are subject to large increments of cold-flow. The very nature of a connector magnifies the results of cold-flow in the cable, and this is where the problem starts.

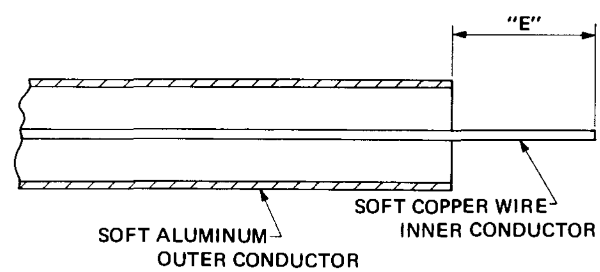

FIGURE 1

We will illustrate this with a few slides. A typical cable is illustrated in Figure #1. In this instance the inner conductor is a solid copper wire and the outer conductor an aluminum tube. Because of difference in the coefficient of expansion between these two materials and the difference in mass between the two components, movement of the center conductor relative to the outer conductor will take place with ambient temperature changes.

Referring to Figure #1, extension "E" on any particular cable is not a fixed dimension. In other words, if not properly clamped in place, the extension of the inner conductor from the outer conductor will vary according to weather conditions and other noncontrollable factors.

What is the solution? There is only one. Clamp both conductors with sufficient forces to overcome the stresses encountered.

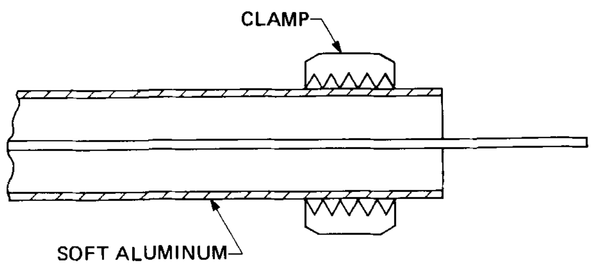

FIGURE 2

In Figure #2 we have a pictorial illustration of a connector. A cable clamp, or grip, is placed around the outer conductor or soft aluminum tube. All coaxial cable connectors are built in this manner. This is just what the doctor ordered to promote cold flow in the aluminum.

What then should we do? For one thing, we can place a stainless steel tube, or sleeve, inside the cable. This is illustrated in Figure #3. It is a big help and certainly improves the life expectancy of the installed connector. It has one serious drawback in that a special hollow mill, or tool, is required to core out the dielectric from the cable. This is a task that must be done by the installer on the job.

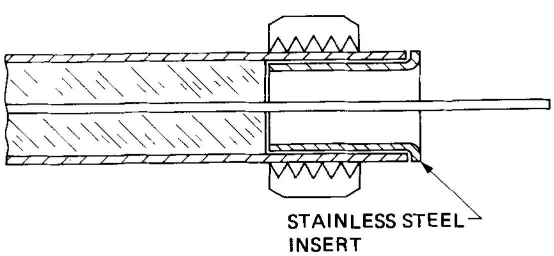

FIGURE 3

As will be seen later, the stainless sleeve becomes unnecessary in the connector design we are describing here.

Our next problem is to secure the inner conductor. This is smaller in cross section, and therefore a larger clamping force will be required to hold it securely. Our clamp must really bite into the copper, as shown in Figure #4.

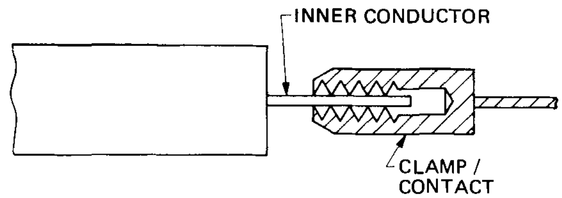

FIGURE 4

Unfortunately, these clamps are also our electrical circuits, and this is the problem. Any increment of cold-flow that occurs, either in the center conductor or the outer conductor immediately shows up as signal distortion. Sometimes this cold-flow doesn't show up for months, or even for years, but it is bound to show up sooner or later.

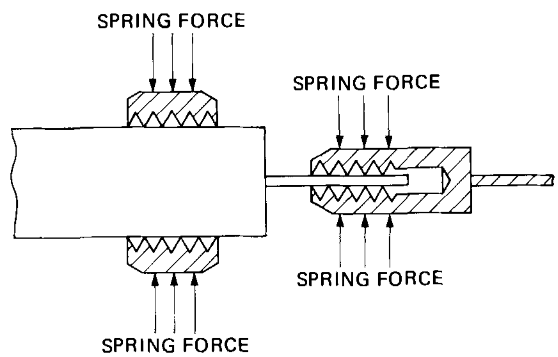

FIGURE 5

So, we again ask the question "What do we do about it?" After careful consideration of a number of ideas, we tried backing up both clamps with springs. This is illustrated in Figure #5. Since this spring force is constantly applied, any increment of cold-flow is at once compensated for. It can be seen that we now have a connector that can "live with" the inherent deficiencies of the cable.

Let us now see how this spring force is applied to the center contact. Figure #6 illustrates a partial section of a cable connector. Item "A" is a conventional brass contact with saw slots to obtain 'tines' or 'fingers' to grip the conductor. The contact is provided with a fine sharp thread to serve as teeth for gripping the copper conductor. The front of this contact is tapered on the outside to match a similar taper on the barrel (Arrow "B"). In the 'free' position the tines on the brass contact will be open and the copper conductor may enter freely. As the insulator "C" is moved forward, the taper on the insulator barrel closes the contact tines around the copper conductor.

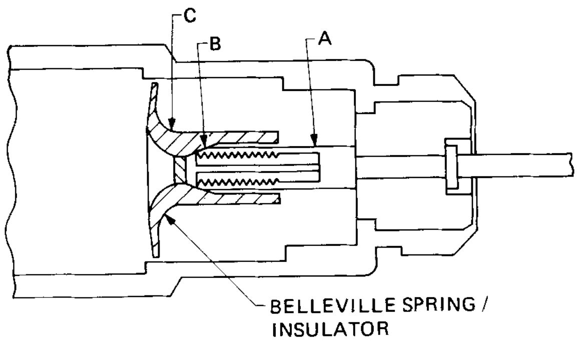

FIGURE 6

We would like to show you now just how a spring is added to the design. First we must look at one of the newer plastic materials. DELRIN is a trade name for Dupont's acetal molding compound. This material has been successfully used in spring applications of all kinds. It possesses a remarkable fatigue resistance. It is fortunate, indeed, for the connector designer to be able to find a material suitable for springs, yet which has good electrical characteristics and good moisture resistance. Best yet, this material performs remarkably well in the form of the well-known Belleville washer.

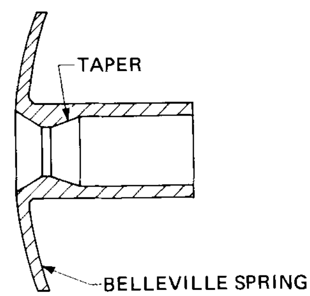

FIGURE 7

Referring to Figure #7 we see that our insulator is a modified Belleville spring, incorporating not only the spring member, but the taper barrel for a contact support. For obvious reasons this is referred to as a "mushroom".

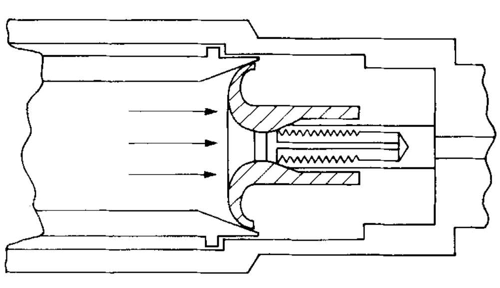

FIGURE 8

Now, in Figure #8 the spring action of this mushroom can be observed. As illustrated in a previous slide, a horizontal movement of the insulator will close the tines firmly around the copper wire conductor. A point is reached where further movement of the insulator is prevented when the teeth of the contact have firmly gripped the copper conductor. A continuing push in the outer periphery of the insulator, as illustrated in Figure #8 will force the insulator into a trueBelleville spring. Load calculations for practical purposes may be obtained by use of a conventional formula. Anyone interested in further information on this subject will find it in an article written by J. H. Crate, and published in a recent issue of Dupont Company's Engineering Design Magazine.

Figure #8 certainly makes it clear that the gripping action of the contact teeth is backed up with a continuous spring action tending to force the teeth forward into any increment of cold-flow that should occur in the copper conductor.

It will be observed that the spring action of DELRIN has been previously utilized by connector engineers, but in all cases this action opens the contact for conductor removal. In this unique design the spring action is utilized to close the contact, NOT to open it. It is easily seen that any spring action tending to open the contact would permit cold-flow increments to remain in the circuit.

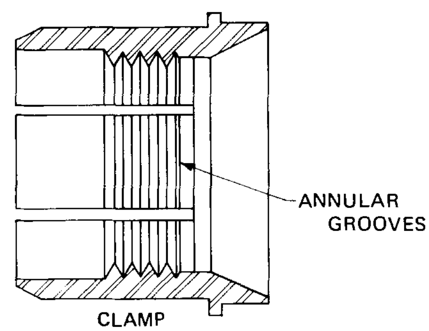

FIGURE 9

The problem has been solved so far as the center conductor is concerned. Our next problem is with the outer conductor, or aluminum tubing. We will see how the spring action was obtained here also. Figure #9 illustrates the clamp, or grip, designed for the aluminum tubing. This clamp is turned from a solid bar of 2024-T4 spring temper aluminum, and is provided with annular teeth for gripping the tubing. Milled slots in the outer wall provide tines, or fingers, for the best type of 360^{o} grip on the tubing wall.

In Figure #10 the clamp is noted as Item "A". A sealing ring, Item "B" is illustrated with a taper cooperating with a taper on the clamp. As the sealing ring is moved forward, the tines on the clamp are forced downward to engage the teeth with the tubing.

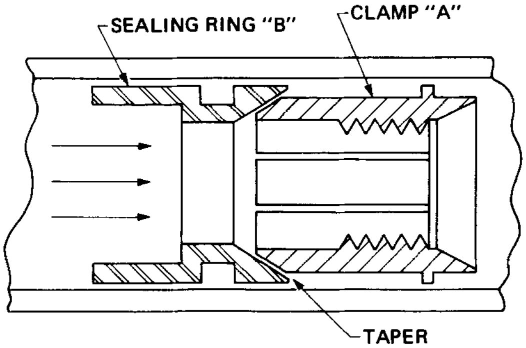

FIGURE 10

Turning to Figure #11 we see that in a manner similar to that described for the contact grip, a point is reached where the clamping action is complete. However, the cantilever action spring tine, Item "B", continues to be "loaded" as it bends in toward the tubing. Here, also, as with the copper wire, the aluminum tubing is constantly under a spring load so any increment of cold-flow in the aluminum is instantly taken up by the six cantilever springs. This provides the long life connector we are seeking.

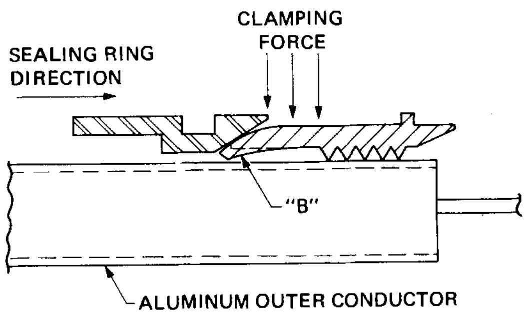

FIGURE 11

We cannot go into the calculations and details of design in this paper; There are many other features of the connector contributing to its' ability to continue year after year without deterioration in signal distortion. Therefore, we have included Figure No. 12 which illustrates a complete connector. A study of this cross-sectional drawing will reveal other reasons why this connector has been so successful in retaining its' initial qualities.

First, the center contact (a) is independent of the other components in that it is rigidly secured into the front insulator (b). The full stress load is transmitted directly to the outer shell (c).

Although the primary purpose of this paper is to show how to overcome the effects of cold-flow of the copper and aluminum conductor materials, there are other often overlooked factors that permit deterioration of performance after initial installation.

Good seals against moisture and dirt are absolutely necessary. "O" Ring seals are very satisfactory if properly lubricated when installed, and if the sealing surfaces are smooth. To properly seal the soft aluminum tubing, or outer conductor, a good rubber compression gasket is needed.

"O" Ring seals are used at (e) and (f) where smooth surfaces are encountered.

We thought you might be interested in seeing the results of some tests conducted on these connectors to be sure nothing was lost in one direction while pursuing another.

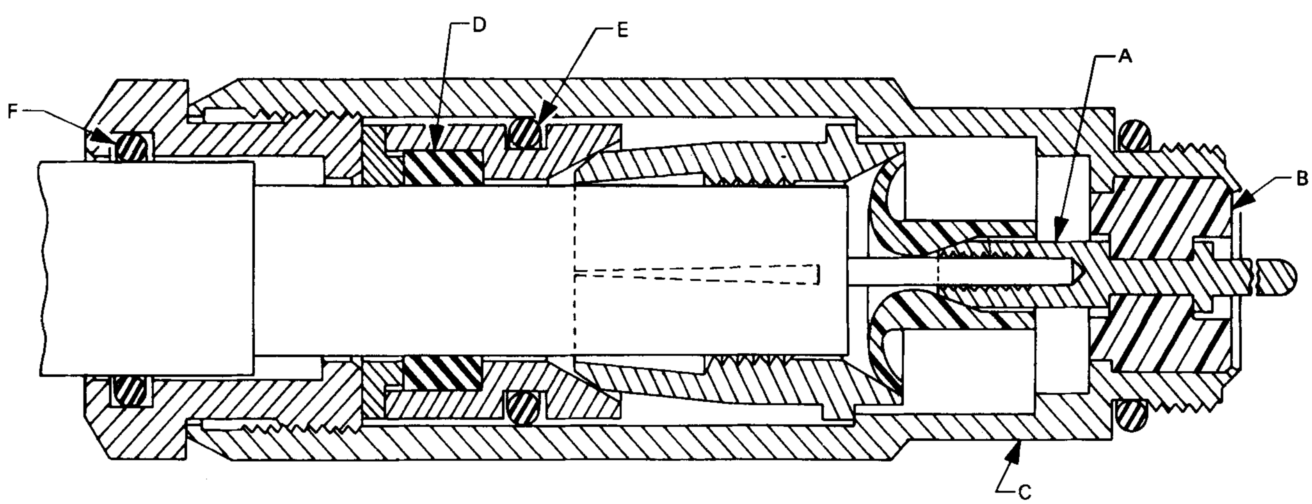

FIGURE 12

Connectors were subjected to environmental tests consisting of:

- Salt Spray
- Humidity
- Vibration
- Temperature Cycling
- Air Pressure
- Ozone
- Thermal Shock
- Conductor Pull-out

A test specification has been prepared for manufacturing quality control purposes. A copy is available to interested engineers.

Some results of these tests are:

RFI (Closed Loop Method-----	125-130 dbl
RFI (Enclosed Tube Method)--	73 db min.
Return Loss----------------	37-42 db.
Reflection Co-efficient-----	.01 max.
Impedance	75 plus or minus ½ ohm.
Pull out forces	
Center Contact	150 lbs. Min.
Outer Contact	200 lbs. Min.

SUMMATION:

Serious RFI problems and other difficulties, tending to shorten the useful life of CATV connectors have been overcome by adding spring forces to the clamping components of both the inner and outer conductors. These forces tend to eliminate the effect of cold-flow inherent to the "soft" conductor materials such as copper and aluminum.