CONNECTORS, CABLE AND "SUCK OUTS"

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ABSTRACT

The connector cable interface is discussed in detail and some possible ways to avoid center conductor pull back or "suck outs" are presented. The effects of normal and sub zero temperatures on the cable and its core to sheath friction are charted with some explanations of the use of loops in CATV construction.

INTRODUCTION

One of the major areas of concern in a coaxial cable system should be the connector cable interface, but in many cases the proper attention is not given to this very critical union, the failure of which always results in a loss of service. We spend many days in selecting the electronics and passives for a system but often relegate the selection of connectors and their installation techniques to a "last minute" effort that is not given the proper attention.

The intent of this paper is to make people aware of some of the causes of cable-connector interface problems and what may be done to avoid some of them. Most connector suppliers offer installation help of one kind or another varying from video tapes and written instructions, to on site training sessions with the installation crews. All of these aids should be used in the field, so that the people actually doing the work know the "hows and whys" of connector installation.

Field crews very often have difficulty adjusting when changing from one connector brand to another but most problems can be avoided by a small amount of instruction early, rather than waiting for them to get in real trouble later. I find that when training people to do installation or splicing type work, they do much better if they not only know how to install connectors but also why they should be doing it that way.

Most cables are made by foaming a dielectric over a copper clad aluminum center conductor and then drawing this foam covered wire into an aluminum tube that is a bit larger than the finished size. The aluminum tube is then drawn through many forming dies that now bring it down to the finished outside diameter and inside diameter of the sheath.

This process "builds in" several stresses in the cable which tend to relieve themselves in handling, installation, and more importantly temperature change. The center conductor itself has quite a bit of tension on it when the bonding agent and the foam dielectric is applied. This is very necessary to maintain the correct centering and the very critical dimensional requirements to build good cable. Since the center conductor is at no time stretched past its elastic limit it stays under tension after the foam is in place, and exerts its own force on the foam dielectric, trying to compress the foam and relieve the built in tension.

When the center conductor and foam are pulled into the outer tube, and the tube is drawn down to the proper size, other forces are now imposed on the center conductor and foam. The foam must be compressed to some extent so that there is some friction between the dielectric and the outer aluminum sheath. Please note that I said "friction" and not adhesion because the foam is not glued to the outer conductor, but depends on the squeezing of the foam to produce friction to hold the dielectric in place. (There are other manufacturing techniques that do use adhesion or glue on the outer sheath but these cables are not yet in general use). The complete cable manufacturing process must be very closely controlled so that the mechanical parameters are met, as the electrical specifications can be met whether or not the outside of the foam dielectric is squeezed or not. That is, it's possible to have cable with excellent return loss and attenuation characteristics that has no core to sheath friction whatsoever. These conditions can take place at room temperature (70°) but cold temperatures make conditions much worse, principally, because of the following reasons: Plastic (foam) has higher co-efficients of expansion than does aluminum by a factor of 5 or 10 to one. So that even though there was enough squeeze of the foam dielectric at room temperature to provide sufficient friction to keep a cable core in place, when it is cooled by 70 to 100 degrees the cable core or dielectric is actually floating free in the aluminum sheath and thus can do whatever it feels like, which is usually get shorter and pull out of the connectors if they will allow it. All of the conventional hard line aluminum cables manufactured as described behave in this manner.

The plot shown in Fig. I shows very dramatically how most current foam cables behave with temperature. A sample piece of cable is prepared with the center conductor exposed on one end and trimmed so that 8 inches of dielectric or core is left in contact with the outer sheath, as in Fig. II.

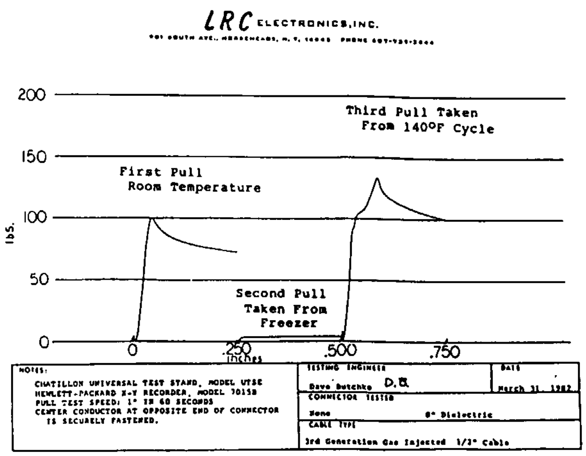
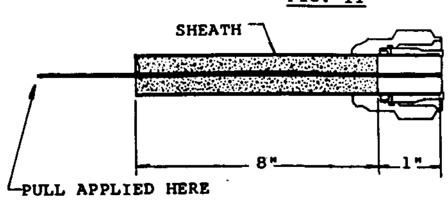


FIG. I

FIG. II



The jacket is anchored in a normal connector and a pull force is applied to the center conductor on the opposite end. The force required to move the cable core is shown in the vertical scale while the distance travelled is on the horizontal scale. In this test, the piece of cable was pulled three separate times, but all three plots are of the <u>same</u> piece of cable. The first pull was done at room temperature (approximately 70° F.) and the core held 100 pounds before it moved and was pulled for about 1/4 inch. The test piece was then cooled to about 0° F. and allowed to stabilize, it was then removed from the freezer and immediately pulled. As shown in the plot the cable only held 8 to 10 pounds and was pulled again for about 1/4 inch. The cable was then put in an oven and warmed to about 140° F. and allowed to stabilize, it was then removed from the oven and immediately pulled, and now took 100 pounds to move a slight amount, then rose to 130 pounds and slowly lost friction down to 100 pounds. Keep in mind this was the same 8 inch piece of cable and the plots show very well that this cable had no friction to hold the core in place when it was 0° F. but regains the friction when warmed.

I emphasize this because whenever there is a problem with center conductor pull back or "suck outs", the problem always appears at the connector and not in the cable. Since it is nearly impossible to manufacture cable that would have any core to sheath friction at -20° F. whatever. The only solution is to have the connector able to hold enough force to keep the center conductor in place. In order to understand this, one should consider a typical span of about 150 feet of cable. If possible most construction is done in the summer or in warm temperatures so it is not unreasonable to assume temperatures of 90° F. or more when the cable is installed. Most of the cable "suck out" problems occur in colder temperatures, which in some areas of the country can mean -20° F. or lower.

This means that the cable will undergo at least 110° change and with this much change it very much wants to be at least 2.3 inches shorter when cold than it was when it was put up. Much work has been done on proper sag and expansion loops at poles, etc., so that the cable does not destroy itself with temperature changes. Everyone who has been in cable for a while is familiar with the change from round bottom loops to flat bottom loops in order to spread out the stresses that are built up in expansion and contraction with temperature changes. Many papers have been written and many installation manuals produced that go into great detail as to how and where to put loops so that the cable sheath is not cracked due to movement with temperature changes.

We have come a long way and can now build cable plant that will maintain its integrity (by not cracking the cable jacket) for many many years, but we have generally not paid much attention to what happens to the cable center conductor through all of this. Think about it, the center conductor is made up of aluminum also, and it too would like to be 2.3 inches shorter with the cycling of the temperature by 110°. With no friction left in the cable and no loops, the connector must be capable of holding onto the center conductor hard enough to keep it from "sucking out" of the connector, which means that the center conductor must stretch a slight amount in order not to break. This will happen as long as the connector seizing device does not cut too deep into the center conductor as to weaken it past the point where it will stretch. That is, if the terminal cuts too deep into the center conductor and causes a fracture point that has a lower yield strength than that pull which will cause the center conductor to stretch, the center conductor will break away during the first cold temperature.

The connector designer must tread a narrow line in his calculations so that the center seizure terminal will hold the center conductor hard enough to stretch it but not so hard as to cut into it and cause a fracture point that has less strength than the yield strength of the aluminum. (Yield strength is generally defined as that point at which the elastic limit of the material is exceeded and the material now stretches).

In the ideal combination of connectors and cable in a CATV plant, one would have cable that had enough friction of core to sheath to keep the center conductor in place mated with a connector that held the center conductor with enough force to stretch the center conductor of the cable. I say ideal, because this would present a situation with a 100% safety factor. That is either the cable or the connectors would stand on their own and not depend on the other for support. In the real world this does not happen, most cable (through no fault of the manufacturer) has little or no holding friction at low temperatures and some connectors (due to manufacturing tolerances) do not hold the center conductor with enough force to stretch it. These conditions would seem to indicate that there is always going to be a problem, but we do have one other means of helping to avoid a problem, that is construction practices that are aimed at preventing center conductor pull outs.

If you take a piece of cable that is straight and pull on the core when it is cold it is very likely that there will not be enough friction to prevent the core from pulling out, but take this same piece of cable and form a loop of any kind in it and you will find that you have increased the friction by an appreciable amount. I say any kind of loop will provide this needed friction, but I feel you must stay with flat bottom loops to avoid the cracking of the cable sheath.

FIG. III

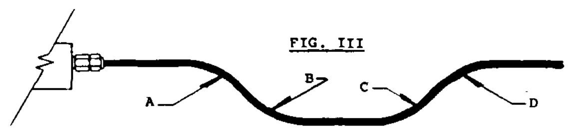
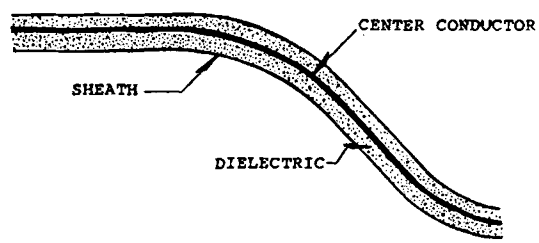


FIG. IV



In Fig. III note that there are the normal four bends present in the recommended flat bottom loop. A close up of these bends are shown in Fig. IV; note the sheath, dielectric, and center conductor. If one attempts to pull on the center conductor (which is glued to the dielectric) you have to pull the whole core around the bend which means it must be straightened coming out of the bend and bent going into it, thus causing considerable friction at points A, B, C and D in Fig. III. A normal flat bottom loop will add enough friction to generally keep the core from moving too far.

It is obvious then that I am strongly recommending <u>a loop at every connector</u> and not just a loop on one side of a device and not the other. In almost all of the cases of connector "suck outs" that have been investigated the pull out occurred where there was no loop present, even though the loop on one side of a device was sufficient to protect the cable sheath from cracking, it was not adaquate to prevent pull out of center conductor.

Another cause of connector failure is poor installation workmanship, generally due to not following the connector supplier's installation instructions. The common faults are:

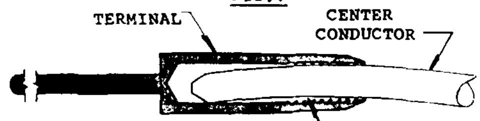
1. Improper preparation lengths(center conductor too long or too short). If the center conductor is left too long it bottoms in the connector terminal and prevents the sheath from bottoming in the connector ferrule, sacrificing gripping area on the sheath and possibly allowing the sheath to "let go" and cause a radiation problem.

2. Too short a center conductor preparation will limit the area of gripping available for the center terminal to hold the center conductor of the cable.

3. Improper cleaning of the center conductor of the cable will possibly leave plastic which can prevent the connector terminal from properly grasping the cable center conductor as the plastic provides a lubricant making the center conductor slide out easier.

4. A bent center conductor will limit the area that the teeth in the connector terminal can grasp the cable center conductor. (See Fig. V)

FIG.V



5. Score marks on either the cable sheath or the center conductor will cause stress points and hasten the failure of them.

6. Improper tightening of connectors seems to be the most prevalant flaw in construction. Different connector manufacturers write their instructions in different ways, some use torque specs, others so many turns and some have a positive stop, but whatever they say will be the right way to install that particular connector.

I know of no connectors on the market that do not function properly when the manufacturers instructions are followed, but real problems result if you install brand "A's" connectors to brand "B's" instructions.

(MAKE SURE YOUR PEOPLE ARE PROPERLY INSTRUCTED ON THE TYPE OF CONNECTOR THEY ARE USING).