"Judge" Glanzer outlines the pitfalls and anatomy of coaxial cable. Read about what to look for and how to check coax before buying it.

Understanding Coaxial Cable

BY KENNETH W. GLANZER*, K7GCO

Coax cable causes more trouble in the communications link than perhaps any other component. Poorly installed coax connectors and rain easily gaining entry are the most common problems even though the cable itself may be OK. The new foam dielectric coax has *not* proven to be as useful as you might have been led to believe except that it is lighter and more flexible. There are, however, some exceptions. Its loss at 28 MHz is about 0.8 dB /100 ft. as compared to about 1 dB/100 ft. for the regular solid dielectric. The claimed 0.2 dB lower loss has turned out to be closer to 0.1 dB more often than not according to my measurements. The one exception has been some solid center conductor coax made by Times Wire and Cable.

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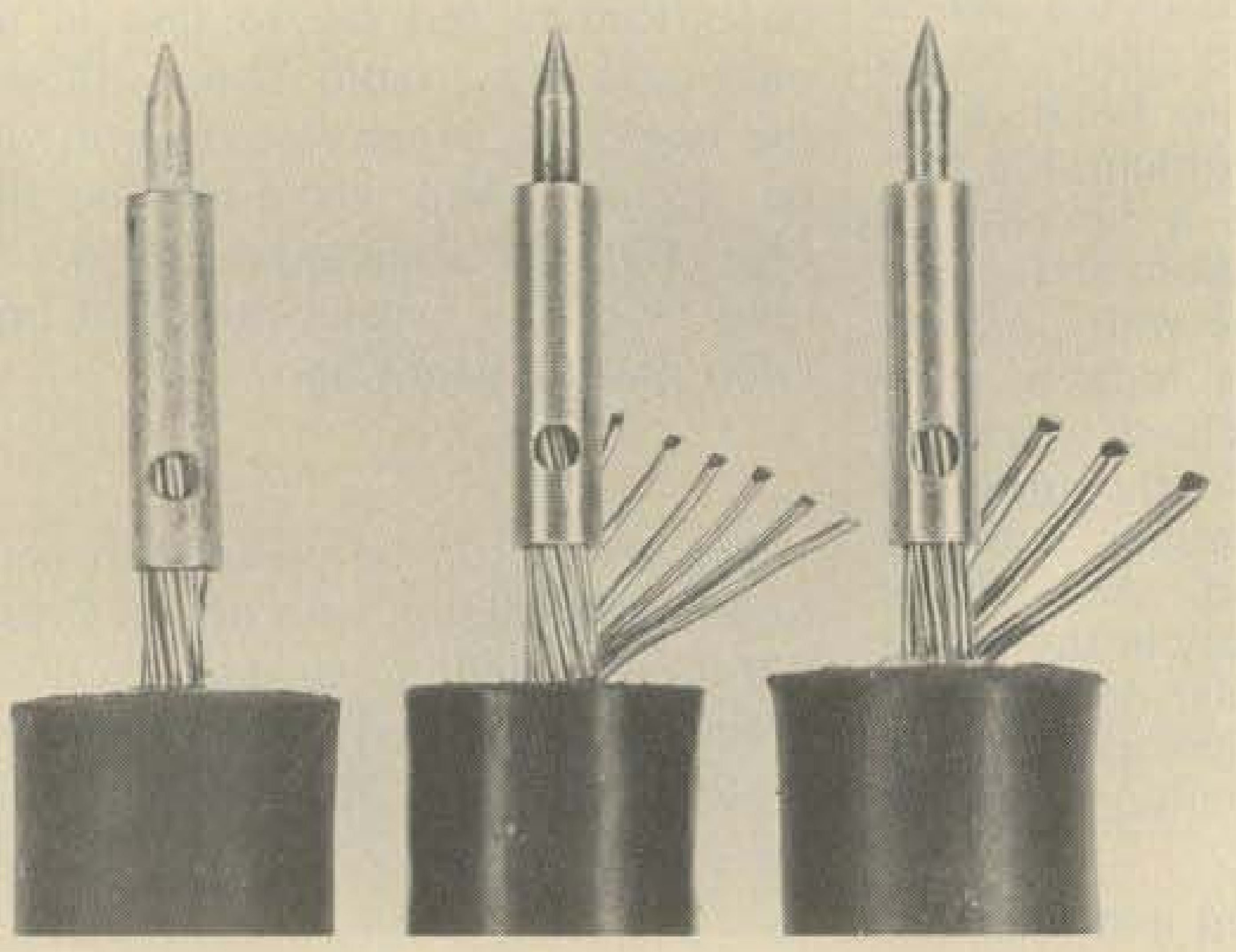


Fig. 1—A test for poor quality foam coax due to a small center conductor is to try to slip the center tip of an N-type connector over the wire. The wire on the left accepts the tip and is thus unsatisfactory. The center and right coax do not accept the tip without peeling off strands of the center conductor. These two are Columbia Superflex and Belden 8214.

In solid dielectric coax at frequencies up to 100 MHz about 80% of the loss is in the center conductor. The shield accounts for 19% and 1% is lost in the dielectric. So why change the dielectric if so little loss is caused by it? If the 0.66 velocity factor is increased to say 0.75 by a foaming action by mixing yeast with the material (actually done with nitrogen) it becomes part air and part dielectric. The dielectric constant (K) for the solid is 2.3 and about 1.5 for the foam.

The formula for the impedance of coax with spaced bead support is

$$Z = 138 \log_{10}\frac{D}{d}$$

where D = outside shield diameter

d = center conductor diameter.

For solid or foam dielectric coax the formula is modified to take into account the change in velocity factor.

$$Z = 138 \log_{10}\frac{D}{d}\,(1/\sqrt{K})$$

where K = the velocity factor determined by the insulating material used. Examination of the above formula will show that if K is lowered (2.3 to 1.5) the value of $1/\sqrt{K}$ gets larger. Since the outside shield diameter, D, is to be kept the same and therefore constant, the only other factor that can change in the formula in order to retain 50 ohm impedance is the center conductor diameter, d. Since the factor $1/\sqrt{K}$ is larger, the quantity, $138 \operatorname{Log}_{10} \frac{D}{d}$, must be smaller. Making d larger will balance the equation. This is just what is wanted, increased center conductor diameter, and therefore lower resistance. The conductor with the greatest loss was increased in diameter and this is why a larger center conductor is a *must* in foam coax. When foam coax first came out, one company just changed the dielectric and did not increase the center conductor size. This coax turned out to have a 60 ohm impedance which is great for matching 50 to 72 ohm loads with quarter wave stubs. Several outfits are still selling coax *without* the larger center conductor to save copper costs and the average customer doesn't seem to know the difference.

The larger center conductor in the good foam coax requires that 6 of the 19 strands (Columbia Superflex) be cut when trying to slip the center tip of a Type N conductor over the wire (3 of 7 must be cut on Beldon 8214). The regular center conductor of solid dielectric coax (and the 60 ohm foam coax) will just fit in this center tip of the N connector (see fig. 1).

One other way some outfits are cutting cost is reducing the percent of braid and this doesn't affect loss too much other than through leakage. So check for complete and partial braids also. There is no cheap but good coax.

Foam Problems

When you foam any material, it gets weaker and it is harder to control the density. Variations in density will cause variation in impedance and velocity factor. The former causes incorrect s.w.r. readings and the latter is of no problem except when lines are cut to a certain electrical length by formula rather than by grid dipping them.[1] I have an antenna that requires two feedlines of equal electrical length. In the past, with solid dielectric coax, I'd cut one to length by formula and then do a quick check with the grid dipper and then cut the other the same physical length with no problems. With the foam coax the velocity factor is higher and varies from manufacturer to manufacturer and from lot to lot. Not grid dipping the second length of foam coax turned out to be a disaster with this phased beam. Since the coax was the last thing I suspected, it took a systematic step by step check to isolate the problem. Upon grid dipping the other coax, I found it to be electrically longer and had to cut three feet off or 3% of the length. Upon checking the other double coax lengths, cut from the same 1500 foot batch, I found, in every case, one to be 3% to 4% longer. You would think that the law of averages would have two come out the same but didn't. It is kind of hard to tell a customer that they are really the same length. Even when cut to the right lengths, this coax gave phony s.w.r. values. I just replaced it with solid dielectric coax and had no more problems. It was a very costly lesson.

[1]Glanzer, Kenneth W., "Determining Resonant Lengths Of Transmission Lines," *CQ*, May 1974, p. 37.

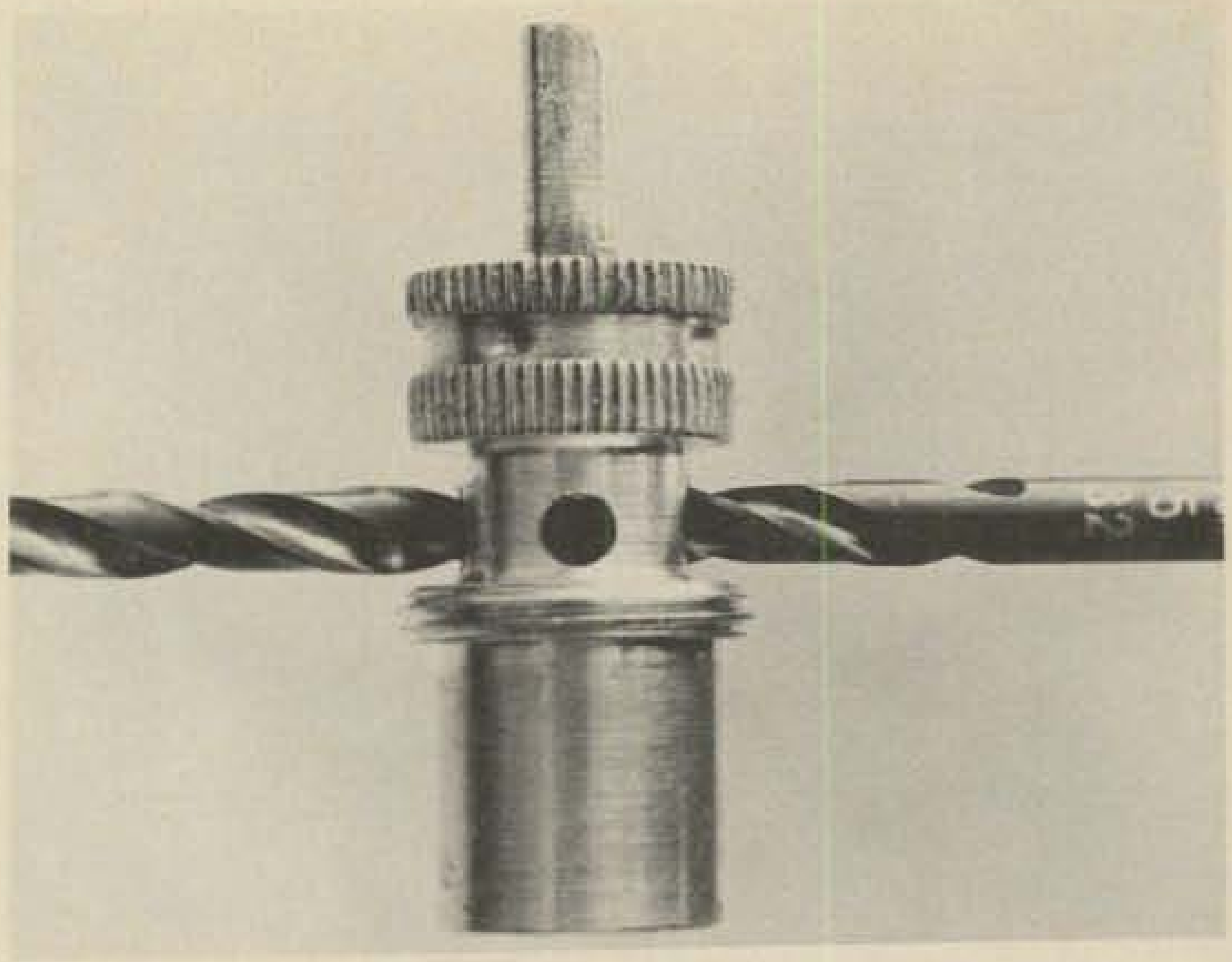


Fig. 2—Enlarging the holes on the PL-259 male connector with a 5/32 drill makes it easier to solder to the shield and thus provides improved contact.

When checking foam coax made by other manufacturers it was found that Belden 8214 and Essex 623-111 foam coax were stable and the impedance was 50 ohms. Apparently Belden and Essex know how to mix up the yeast in the dielectric.

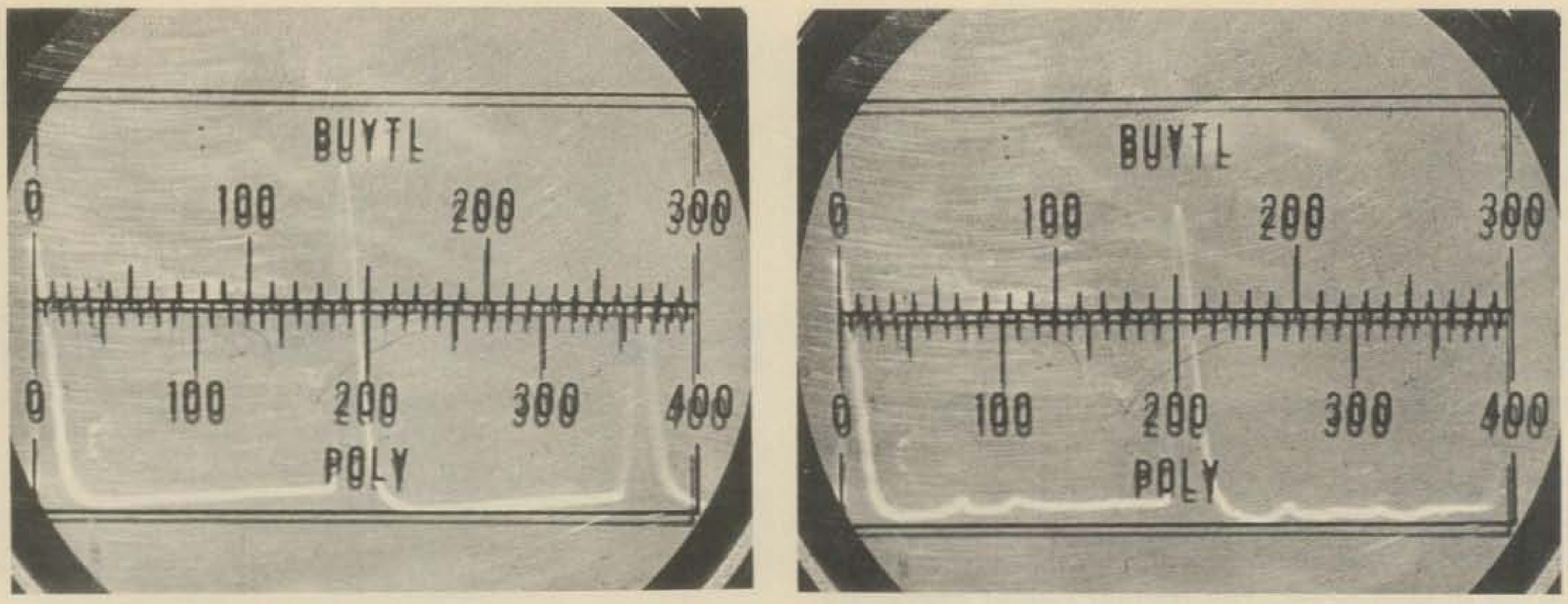
Connector Problems

Installing u.h.f. connectors is a problem for most. It is difficult to solder through the four small holes and if the heat is applied to the connector too long, the foam oozes out of the holes and prevents the solder from flowing. I drill these holes larger to aid in soldering (fig. 2) and prefer the heavy tipped irons that can deliver heat rather than the soldering gun types because the soldering should be done as quickly as possible. These larger holes give more area for the solder to grab the shield making a stronger connection.

Coax Testing

The best way to test coax is to what is called "impulsing." This is a technique of sending a video pulse down the cable and observing it on a scope on its way back. You can see "impedance bumps" and other discontinuities and their exact location. This technique was first used to check out underwater cables and the first patent was issued to Bell Telephone Labs in 1924. The old Tobe Capacitor Co. made the first Time Domain Reflectometer and it sold for $7000. Old telegraphers could tell if a line was shortened or open and about how many miles away by the echo. Back in 1946 a local professional engineer by the name of Bill Harrold, who had worked on radar at MIT, was asked to make an inexpensive Reflectometer, which he did. It is presently marketed by Radar Engineers, 4654 N.E. Columbia Blvd., Portland, Oregon 97218.

I borrowed this "Fault-Finder (fig. 3) to check out my *questionable* coax and found just about



(A) (B)

Fig. 3—(A) Belden and Essex foam coax tested with an open load showed perfect response on the "Fault Finder". (B) Some other brand of coax showed impedance "bumps" in the line when tested open.

what I had expected: 1. The impedance of the coax varied due to highly irregular density of the foam (on the particular piece under test.) 2. The Velocity Factor varied up to 3%. 3. Foam coax with "normal" center conductor diameter give about 60 ohm feedline impedance. 4. Solid dielectric coax velocity factor is fixed and I've yet to see any variations in impedance in any length tested (unless externally damaged.) The exceptions to the impedance bump and variations in "foam" coax was Belden 8214 and Essex 621-111 (fig. 3). You get just what you pay for and there is no "inexpensive" good coax. Whatever you buy, be sure to examine the braid density (fig. 4) before you buy either type coax and if you purchase foam coax, be sure that the center conductor is larger than that in solid dielectric coax. So take your calipers to the radio store when you buy foam coax. Make sure that the center conductor sizes are as shown in examples 4, 5, & 6 of the coax cross-sections pictured. ■

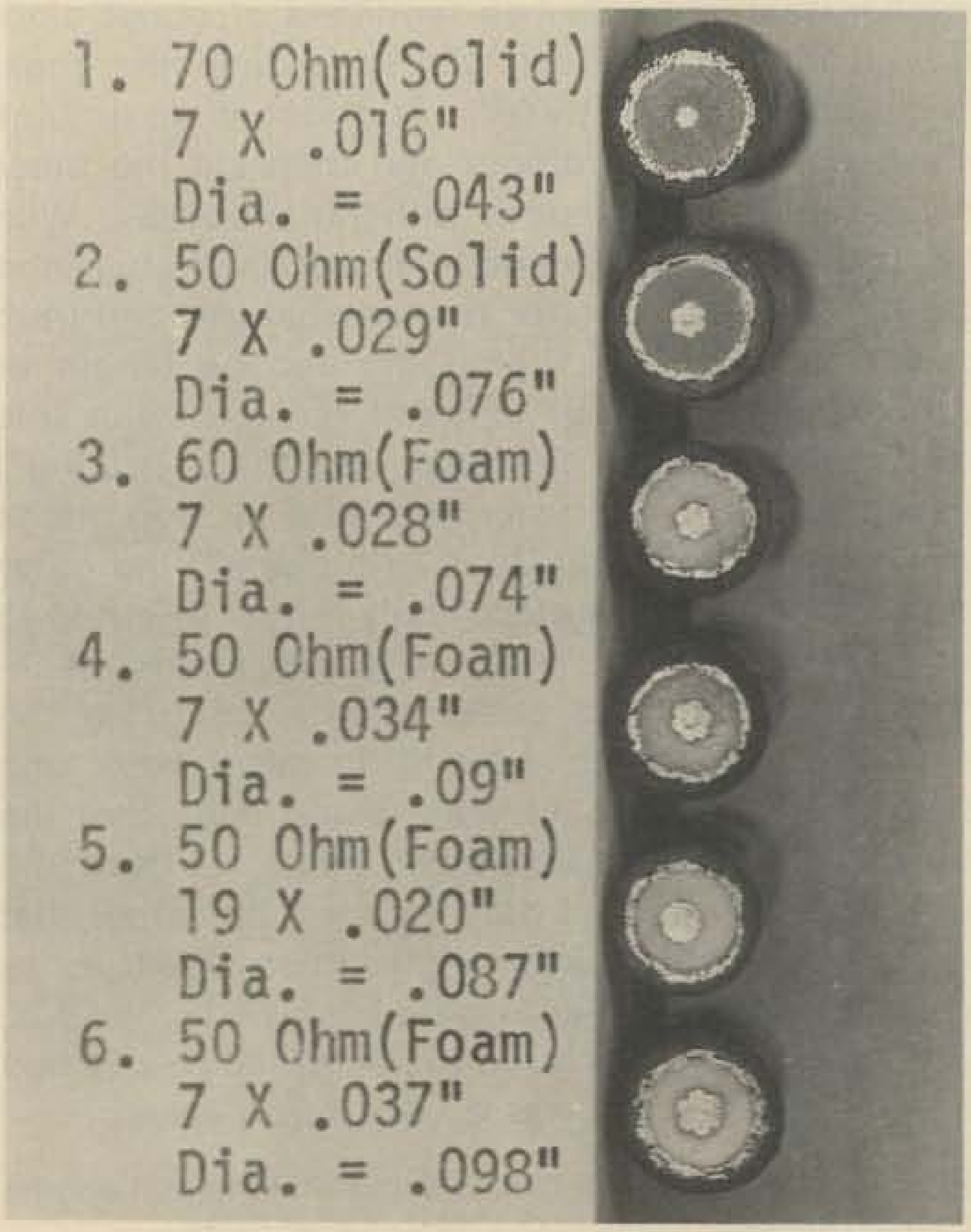


Fig. 4—Make certain that any coax purchased has a tight shield as shown above. Cheap coax often has 70 or 80% as much braid and will leak at the higher frequencies. Cross-sectional views of various brands of coax shows the relative sizes of their center conductors.