Are Epoxy/Polish Connectors Still The Best Bet for Field Installation?

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I field-tested a innovation recently that will aid greatly in the field installation of epoxy/polish fiber optic connectors, especially on job sites that may not have AC power yet. It is a 3 way powered curing oven. This oven can cure up to six connectors at a time and will work for ten or more hours on one battery charge. It can also be plugged into the cigarette lighter in your vehicle, or if you have 120-volt AC supply, it can work with the adapter that is part of the kit.

This oven is the newest in the FOTEC Line of fiber optic tools. It is physically small, (about the same diameter as a hockey puck, twice the thickness, the same color and it is rubber, so it's indestructible.) It will hold six connectors at a time, so it is easy to set up an assembly line operation for multi-conductor fiber optic cables. The battery that is used to power the oven is a sealed, 12-volt, gelled, lead acid type, the same type that is used in fire alarm panels and emergency light units. Thus we have a respectable life expectancy; replacement cost and future availability is not a problem.

It requires about 20 minutes initial warm up. I found that Tracon epoxy No. F112 or 113 works great with ST or SC connectors and they will cure in less than ten to twelve minutes.

Now many connector manufacturers will scoff at the use of 2 Part Epoxy connectors that require the use of an oven in the first place. Many customers are being fooled into thinking that non-adhesive connectors save so much labor time that they will compensate for the high connector and tooling costs. They may not be a bad type of connector for small jobs like restoration, but they are not as good as the epoxy/polish connectors for big jobs, where cost, yield and reliability are extremely important.

In fact, the use of this oven got me to thinking about the real time and cost of field installation of fiber optic connectors. Now you folks down south (especially from Missouri, I'm told), are known for being skeptics. But we Canadians have long cold winters to think about things, and we are quite skeptical too! So I've tried to analyze the real time and cost of terminating fiber optic connectors. Jim Hayes, the inventor of the oven had been thinking about the same thing, so we collaborated on the analysis given below, and I think you'll find the results surprising.

Background

A year ago, an article in Electrical Contractor Magazine[1] reported on a test done as part of a training session by a well-respected team of trainers, John Highhouse and Kent Norris of Lincoln Trail College's Telecom Training Program. They taught the students how to install standard epoxy/polish ST connectors, then had them follow manufacturer's directions to install three types of so-called "quick termination" connectors. The results were somewhat disturbing, in that two of the three connectors (of the type we call "cleave and leave") had very low yields of acceptable terminations.

This led us to investigate the real issues of termination. Was using a epoxy in a connector the real issue in the time needed for termination? Or was it only one of a

number of issues that should be considered? We decided to take a more analytical look at the process.

How are fiber optic connectors terminated?

Most connectors use epoxies to hold the fiber in the connector. Use only the specified epoxy, as the fiber to ferrule bond is critical for low loss and long term reliability! We've seen people use hardware store epoxies, Crazy Glue, you name it! And they regretted doing it!

Epoxy/Polish

Most connectors are the simple "epoxy/polish" type where the fiber is glued into the connector with epoxy and the end polished with special polishing film. Every factory patchcord is made that way. This provides the most reliable connection, lowest losses (less than 0.5 dB) and lowest costs, especially if you are doing a lot of connectors. The epoxy can be allowed to set overnight or cured in an inexpensive oven. A "heat gun" should never be used to try to cure the epoxy faster as the uneven hear may not cure all the epoxy or may overheat some of it which will prevent it ever curing!

"Hot Melt"

This is a 3M trade name for a connector that already has the epoxy (actually a hot melt glue sort of like a glue gun) inside the connector. Fast and easy, low loss, but not as cheap as the epoxy type, it has become the favorite of lots of contractors who install relatively small quantities of connectors. Be careful though - they are hot when they come out of the oven!

Anaerobics or quick set adhesives

No, no, it has nothing to do with exercise - that's "aerobics." These connectors use a quick setting glue with a curing agent to replace the epoxy. Several techniques are used, not all of which guarantee that all the adhesive will set fully. They work well if your technique is good and you work fast. Otherwise you will have fibers sticking halfway into the connector and solidly glued in place. You throw them away. If you want to use these, practice, practice, practice!

Crimp/Polish or Crimp/Cleave

Rather than glue the fiber in the connector, these connectors use a crimp on the fiber to hold it in and some don't even require polishing. Early types offered "iffy" performance, but today they are pretty good, if you practice a lot. Expect to trade higher losses for the faster termination speed, more for each connector as they are more costly than epoxy polish types, and tooling can be expensive. A good choice if you only install small quantities and your customer will accept the higher losses.

Prepolished/splice

Some manufacturers offer connectors that have a short stub fiber already epoxied into the ferrule and polished perfectly, so you just cleave a fiber and insert it like a splice. While it sound like a great idea, it has several downsides. First it is very costly, especially when you consider the lower yield most installers get. Second, you have to make a good cleave to make them low loss, and that is not as easy as you might think. Third, even if you do everything correctly, you loss will be higher., obviously, because you have a connector loss plus two splice losses at every connection! These are good for quick restoration, but look at the cost carefully before you commit to a job with them.

How much time does it really take?

The time required for terminating fiber optic cable is not just the time needed to attach the connector to the fiber, as has been the focus of the non-adhesive connectors. We looked at the whole process for several connector types used with standard 3 mm jacketed cable and have determined that at least the following steps are involved. The times required are estimated based on experience. No entry in a space means that process is not involved with that type of connector.

Terminating <u>one</u> fiber optic connector of differing types

Steps of termination (all times in minutes)	Epoxy/ Polish	Hot melt	adhesive	crimp/ polish	crimp/ cleave	crimp/ prepolish
Setup tools						
Set up tools & workspace	10	10	7	5	5	5
Set up materials (connectors)	3	2	2	2	2	2
Cleanup/ pack tools	5	5	5	5	5	5
Total Setup	19	17	14	14	14	14
Terminate						
Strip cable jacket, cut kevlar, strip/clean fiber	0.75	0.75	0.75	0.75	0.75	0.75
Inject adhesive into connector	0.2		0.2			
Cleave and inspect fiber						1
Insert fiber into connector & crimp	0.5	0.5	0.5	0.5	0.5	0.5
Heat cure or adhesive set	10	10	1			
Cleave fiber and polish	1	1	1	1	0.5	
Termination Total Time	12.45	12.25	2.45	2.25	1.75	1.75
Test						
Inspect with microscope	0.5	0.5	0.5	0.5	0.5	
Test loss	1	1	1	1	1	1
Total Test Time	1.5	1.5	1.5	1.5	1.5	1
Total With Setup	32.95	32.75	18.95	17.75	17.25	16.75

These numbers differ from the numbers quoted by connector manufacturers for a number of reasons.

1. Many termination times quoted do not include cable preparation or are only applicable to buffered fiber, not normal jacketed cables.
2. Manufacturers do not normally include inspection with a microscope or testing in their termination times, yet these are certainly important to consider for the installer.
3. Setup and cleanup times are always a big part of the job, but never included in the manufacturers' estimates. Smart contractors know better!

The "Termination Total" time in the table above is the number the "quick termination" connector manufacturers would use for comparison with adhesive type connectors, and the "Total With Setup" is the time the copper cabling types would use to convince you that fiber takes too darned long. Both are bogus comparisons! Let's see why.

Real world field termination

Now the table above is still not real-world, because you are practically never doing just one connector. The real world is field installation of a dozen or more connectors in a telecom closet or two connectors at a work area. Let's analyze those situations more carefully.

Doing a dozen connectors at a time

To consider doing a dozen connectors at once, we multiply the actual termination time by 12, then add the setup time. For epoxy/polish and hot melt connectors, we don't have to wait the time required in the oven for each connector. Instead, we terminate one connector, place it in the oven, then terminate more while the first one cures. Polishing covers the cooling time out of the oven too. Thus we can subtract the oven time from the termination time. The times for epoxy/polish and hot melt connectors becomes about 4 minutes, just slightly longer than the "quick terminations!"

Steps of termination (all times in minutes)	Epoxy/ Polish	Hot melt	adhesive	crimp/ polish	crimp/ cleave	crimp/ prepolish
Setup tools	19	17	14	14	14	14
Terminate and test (same except no oven time for epoxy/polish and Hot Melt)	3.95	3.75	.95	3.75	3.25	3.25
X12	47.4	45	47.4	45	39	39
Total With Setup	66.4	62	61.4	59	53	53

Doing Two connectors at a work area

Now we have the same basic numbers, except the number of connectors has been reduced to only two. Our oven time can't be ignored on two connectors. Since we need about 3 minutes for terminating the second connector, we'll have to wait about 7 more minutes for the first epoxy/polish connector to come out of the oven and a few more minutes for the hotter Hot Melt to cool. Here's our table again:

Steps of termination (all times in minutes)	Epoxy/ Polish	Hot melt	adhesive	crimp/ polish	crimp/ cleave	crimp/ prepolish
Setup tools						
Total Setup	19	17	14	14	14	14
Terminate and test (same except no oven time for epoxy/polish and Hot Melt)	3.95	3.75	3.95	3.75	3.25	3.25
X2	7.9	7.5	7.9	7.5	6.5	6.5
Oven wait time/adhesive set	7	10				
Total With Setup	37.85	38.25	21.9	21.5	20.5	20.5

So now the differences in time are substantial. The fast cure connectors make a big difference if you are only doing one or two connectors. But the real difference is what we will examine next.

What effect does yield have on time?

Not every termination will produce an acceptable connector. Typical problems encountered differ according to the connector type.

1. The epoxy/polish and hot melt connectors have very high yields, about 95% or more for epoxy/polish and over 90% for hot melt.
2. The quick setting adhesive connectors use several types of adhesives and techniques, but all require inserting the fiber in the connector quickly. Any delay with cause the fiber to be stuck in the ferrule and the connector will have to be discarded. A good installer can get up to 90% yield with experience. Of course, gaining experience can be expensive.
3. The crimp/polish and crimp/cleave terminations are also dependent on user "touch" and cable or fiber used. We cannot generalize on the expected yield of these connectors with any confidence, but we doubt they are nearly as bad as reported in the EC article.

The referenced article had especially poor yield on the "cleave and leave" connectors. These connectors have a prepolished fiber stub in the ferrule and a mechanical splice in the back. Making a good connector is dependent on how well the fiber being terminated is cleaved. A poor cleave will mean high connector loss, leading to rejection of the connector. Sometimes, these connectors do not retain the fiber properly, so the fiber may pull out, requiring retermination. While the article had yields of less than 40%, we feel this may be pessimistic. However, 70-80% yield in the field may be more realistic.

Now if you have 95% yield, every other batch of 12 connectors will likely require one extra termination. At 90% yield, you have a high probability of having to make 13 connectors to get 12 good ones. 80% yield implies about 2 bad connectors out of the twelve. 70% and it will be 2 or 3 reterminations.

I hope you never get as bad as the 30% yield reported in the EC article, because you'll make 40 terminations to get 12 good ones, and you will rapidly go broke!

On a simple two fiber termination at a work area, you will have to reterminate one of the connectors occasionally, unless you get 30% yield and will have to do two sometimes, working your way to the poorhouse!

Real Connector Costs

The real cost of a connector is the total cost of the components and labor divided by the yield. Using our example of 12 connectors or 2 connectors at a location, typical connector costs (from current catalogs or quotes) and labor rates of $30/hour, lets figure the costs before yield for several connectors. Then lets estimate yields, based on some field feedback we have, and calculate final costs. We've taken an optimistic view on the "cleave and leave" connectors, assuming much better yield than in the earlier article, based on the installers having more experience with the product.

Analysis for 12 connectors

	Epoxy/ Polish	Hot melt	adhesive	crimp/ polish	crimp/ cleave	crimp/ prepolish
Total Time With Setup	66.4	62	61.4	59	53	53
Labor Cost @ $30/hr	33.20	31.00	30.70	29.50	26.50	26.50

Cost of 12 conn	30.00	60.00	30.00	90.00	90.00	144.00
Installed cost of 12 conn	63.20	91.00	60.70	119.50	116.50	160.50
Installed cost per connector	5.26	7.58	5.05	9.96	9.71	13.38
Estimated Yield	95%	95%	90%	80%	75%	75%
Final Cost per connector	5.54	7.98	5.61	12.45	12.94	17.83

Here's the same analysis for 2 connectors at one location:

	Epoxy/ Polish	Hot melt	adhesive	crimp/ polish	crimp/ cleave	crimp/ prepolish
Total Time With Setup	37.85	38.25	21.9	21.5	20.5	20.5
Labor Cost @ $30/hr	18.92	19.13	10.95	10.75	10.25	10.25
Cost of 2 conn	5.00	10.00	5.00	15.00	15.00	24.00
Installed cost of 2 conn	23.92	29.13	15.95	25.75	25.25	34.25
Installed cost per connector	11.96	14.57	7.98	12.88	12.63	17.13
Estimated Yield	95%	95%	90%	80%	75%	75%
Final Cost per connector	12.59	15.34	8.87	16.10	16.84	22.84

Conclusions

I'm sure you have already formed some concrete opinions by now, but let me put in my two cents worth.

The adhesive connectors are generally less expensive than prepolish/splice connectors. The epoxy/polish connector is by far the most reliable, and the least expensive connector if you are doing a bunch of them. The Fotec curing oven makes them possible in any field application, so they should probably be your first choice.

The fast setting adhesive connectors can be a good deal if you are familiar with the process. If you 're not, well, good luck. The other styles are more expensive, both from an initial cost and from a yield basis, so be careful, especially estimating. The variability of the yield can hurt!

Now what does this mean in the real world?

When you estimating costs of a fiber optic termination job, consider the following variables to make sure you have covered all the contingencies:

1. Number of locations to do terminations, to include setup/cleanup times at each location.
2. Number of connectors at each location, to estimate termination times and costs
3. Yield likely with those connectors, to estimate total number of terminations and cost of supplies.

Never leave the termination site without having tested every connector. If you have to come back and reterminate one connector, you can look at the first table to see how long it will take, because you will have to include setup time for just that one connector. Some installers have one crew terminating and another testing, but unless they work closely together, big cost overruns can happen. Better to have terminating and testing done by one crew.

Never, never, never take a new connector into the field without extensive training and practice. Never bid a job that calls for a connector that you are not personally experienced with. If you understand the time and yield issues discussed above, you know why.

[1] Electrical Contractor Magazine, May 1997

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