CORNING

GUIDE LINES

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Sarah Creath
EDITOR OF *GUIDELINES* MAGAZINE

Editor's Note:

This issue of GuideLines offers another exciting look at what's going on in the optical fiber industry, highlighting Corning's newest product line — Corning® InfiniCor CL™ optical fiber. To learn more about InfiniCor CL, which promises to provide local area networks with the capacity and flexibility to meet the needs of the data-communications industry, turn to page 12 for the full story.

As customer demands for bandwidth continue to increase, Conectiv Communications, Inc. must balance meeting current network demands with on-going network growth. Our article on page 8 provides a conceptual overview of the challenge Conectiv — like many other CLECs — faces in evaluating different options for network growth.

Also in this issue, we introduce to you the SHARC team — a group of Corning professionals who consistently gaze into their collective crystal ball to predict how optical fiber will react in certain circumstances. To learn more about what mechanical reliability means to you, check out the article on page 2.

In past issues, we've given you fiber to the tallest buildings in the world, fiber to the barn, fiber to the home and fiber to NASA — in this issue, we present fiber to the factory floor, at American Video Glass. See our article on page 5 to learn how this installation improves the efficiency of another high-tech company.

I'd like to ask each of you for a special favor — we're always looking for new article ideas and want to know what you'd like to see in future issues of *GuideLines*. Please take a moment to look at the card attached in the center of this issue and let us know what you think of the story ideas we've listed. If you'd like to see an article that's not listed on the card, please write it down and send it in. We're eager to put together interesting articles that you'd like to see.

Sincerely,

Sarah Creath

Sarah J. Creath

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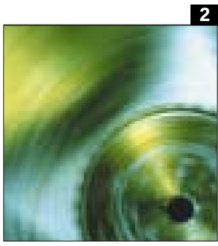

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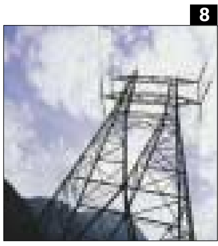

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Summer 1999

OPTICAL FIBER

MECHANICAL RELIABILITY

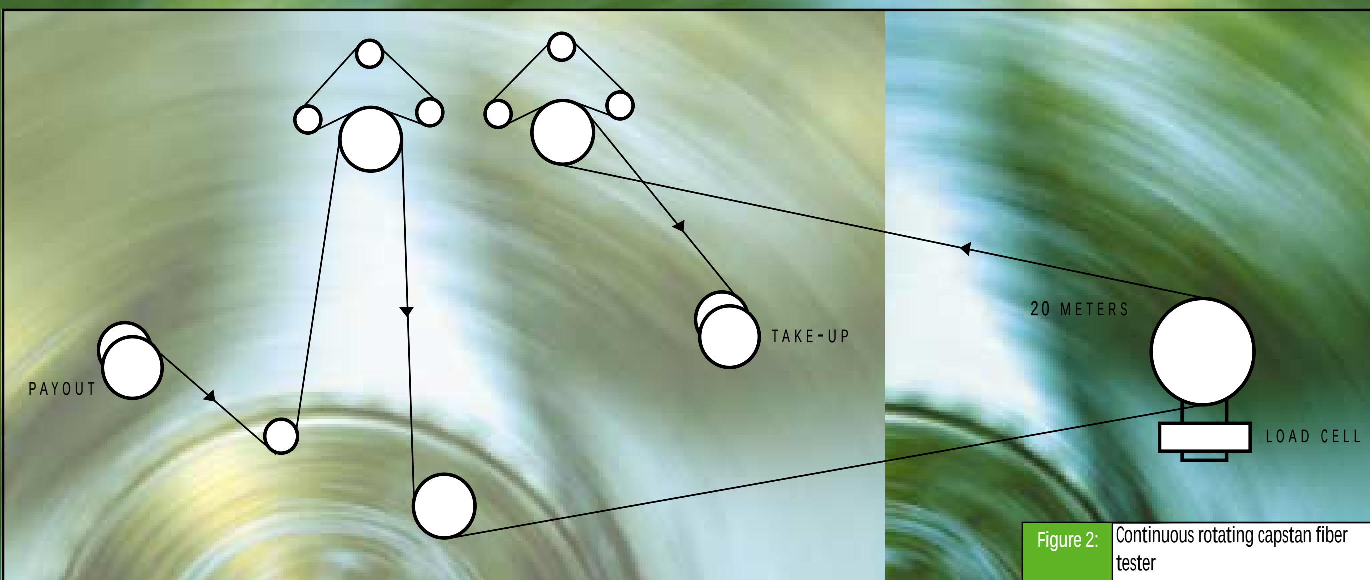


Figure 2: Continuous rotating capstan fiber tester

What does it mean to you:

The world's leading optical fiber manufacturer studies mechanical reliability and it's long and short term relevance in our networks. As part of our effort to continually improve our offerings, we have a team of experts who are dedicated to understanding and predicting the mechanical reliability of optical fiber.

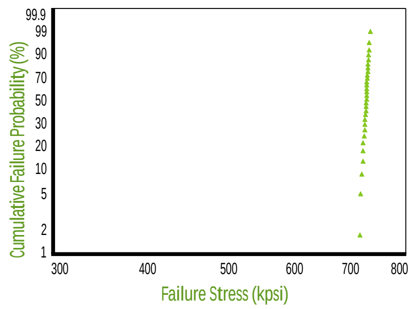


Figure 1: Typical strength distribution for silica fiber measured using FOTP-28

Fiber reliability — a simple statement that encompasses so much. Ever since optical fiber became a practical medium for communications, Corning has been committed to ensuring the mechanical strength and reliability of this product. As a result of this commitment, the Strength, Handleability, and Reliability Committee (SHARC) was formed to address mechanical reliability questions and study application issues. The SHARC is a multi-functional team, designed to bring together scientists and the commercial community. Together, they have worked to further understand the mechanical behavior of optical fiber over time and in different service conditions.

The goal of this work is to be able to **predict** the mechanical behavior of Corning fiber given various conditions it may be subjected to. Two things are necessary when predicting mechanical behavior: the starting strength distribution and a model that accurately describes the way in which an individual flaw will grow.

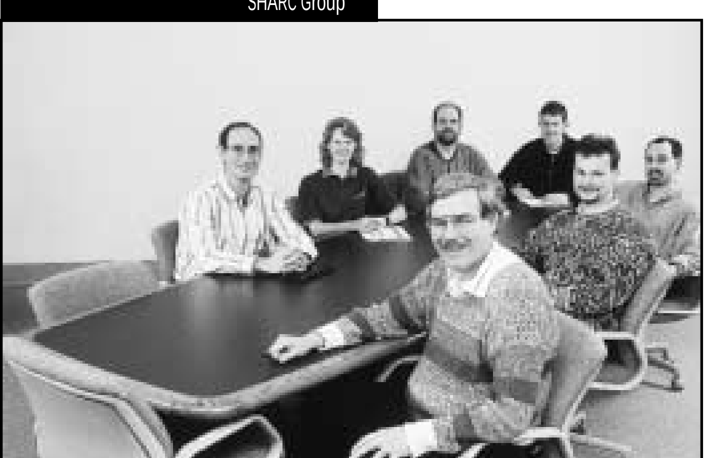
The strength distribution sounds easy to obtain. After all, standardized testing procedures are available for strength measurements, and all fiber manufacturers must show that their products' strength endures after exposure to accelerated aging conditions. But, in reality, that which is functionally important is not always measured in standardized tests. For example, consider EIA/TIA-455-28 (Fiber Optic Test Procedure -28) or IEC 793-1-B2A. These testing procedures describe a dynamic strength test, typically performed on 0.5 meter gauge lengths with a sample size of 30. All together, a total of 15 m of fiber has been measured, with typical median results on silica-clad fiber greater than 700 kpsi (4.8 GPa), as shown in Figure 1. Yet, these results do not describe the behavior of the infrequent random flaws found in long lengths of fiber, with strengths much closer to the proof test level; these flaws are the limiting factor or "weak link" in the overall long-term mechanical reliability of the fiber. The sample size of the standardized tests is much too small to consistently measure these random events.

In order to measure these infrequent random events, SHARC member Dr. Scott Glaesemann and co-workers developed a new testing technique: the continuous rotating capstan fiber tester (CRCFT). This machine, illustrated in Figure 2, is capable of accurately measuring the low strength distribution on very long lengths of fiber (hundreds of kms). This is done by continuously testing 20 meter sections of fiber up to a given stress level, typically 350 kpsi (2.4 GPa). If the fiber breaks, the load at failure is recorded; if not, then another 20 meter section is paid-out and tested. Using this method, we only look for the random low-strength sections of fiber that will truly cause the reliability concerns. Corning has been using this novel strength testing approach for over six years, and has tested more than 10,000 kms of fiber in order to build a comprehensive and accurate strength distribution of optical fiber as it leaves Corning's manufacturing facilities. We have published a paper on this testing approach[1], and a typical strength distribution of silica fiber measured using this technique is shown in Figure 3. The upper end of the strength distribution stops at the maximum stress level of 350 kpsi, as planned, and the lower end extends to a stress level slightly above the proof stress of 100 kpsi.

SHARC members shown: (L to R)
John Jay, Linda Baker, Scott Glaesemann, Tom Hanson, Lawrence Douglas, DJ Wissuchek, Robert Castilone

Not present in picture:
Aditi Paul, Gosakan Aravamudan, Matti Hopiavuori and Allen Allegretto

SHARC Group



The second item needed for accurate predictions of mechanical reliability is a good model that can predict how a flaw will grow. There are numerous models available in the literature, but none seemed to fully account for the experimental and field data that was available. One important data point was that there have been no field failures recorded when our applied stress design guidelines are followed. The power law model best described the experimental data, but there were discrepancies based upon the constants chosen for n and B, two parameters used in the model to characterize the environment dependent crack growth rates. Many researchers have attempted to measure the n and B values, and some conflicting data has resulted, based upon different collection conditions. Corning has pushed the envelope in this area, measuring the strength of optical fiber under very high and very low stressing rates, 0.001 to 2.2 x105 kpsi/s (7 x10^{-6} to 1530 GPa/s). In doing so, we again designed testing equipment, which far surpasses the limits of standard test ranges, 0.0425 to 42.5 kpsi/s (3 x 10^{-4} to 0.3 GPa/s).

This wide range of testing capability has shown us that the single-region power law does not fully apply. SHARC members Scott Glaesemann and Tom Hanson were the first to propose that a model with multiple crack growth regions is more appropriate.[2] The two-region power law (2RPL) includes parameters that dominate the crack growth for stresses applied over a long time such are as found during the service life of a fiber, and parameters that dominate the crack growth due to fast events such as in proof-testing or cable manufacturing. This allows the 2RPL model to include all the stresses that a fiber is exposed to, rather than just the long term applied stresses only. Since all stress can weaken a fiber, even if applied for only a very short time period, this provides a much more realistic result than those models that ignore the short-term stressing events. Corning was the first to propose the 2RPL model; others now have embraced it. One example is COST-246, a task group of the International Electrotechnical Commission (IEC).[3]

Once we had both of the ingredients necessary to make mechanical reliability predictions, it was important to put them in a form readily available for practical use by our engineers. SHARC, led in this effort by Tom Hanson, developed software that uses the starting strength distribution measured from greater than 10,000 km of silica-clad optical fiber and the experimentally determined n and B values to model cascading stress events. This allows us to use the 2RPL to generate the applied stress design guidelines given below. In addition, if customers have specific design cases which exceed the recommended applied stress guidelines, we are able to offer an assessment of the risk those specific designs may impart. If you would like to request this service, please contact your account representative.

Although we have come a long way in understanding and predicting the mechanical reliability of optical fiber, SHARC is continuing its work. We will further investigate optical fiber crack growth parameters under various environmental conditions, and we will continue to refine and improve our model as we learn more. Corning is committed to providing our customers with the best mechanical reliability products and services possible, and the existence and work of SHARC is a concrete measure of that commitment.▪

References:

1. *G.S. Glaesemann, D.J. Walter, "Method for obtaining long-length strength distributions for reliability predictions,"* Opt. Eng. *30(6) (1991).*

2. *T.A. Hanson, G.S. Glaesemann, "Incorporating multi-region crack growth into mechanical reliability predictions for optical fibres,"* J. Mater. Sci. *32 (1997) 5305.*

3. *T. Volotinen et al., "Mechanical behavior and B-value of an abraded optical fiber," IWCS, 1998.*

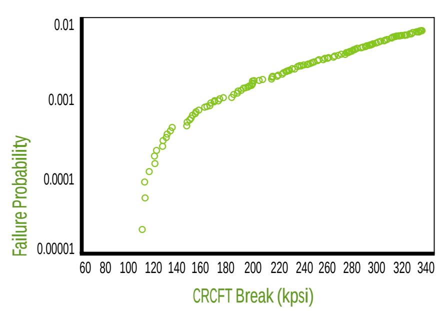
Table 1- Total allowable stress design guidelines for any length (σ_p is the proof-test stress level)

	Allowable Stress		Allowable Stress if $\sigma_p = 100$ kpsi	
Length of Time	Silica	SMF-28™ fiber with Duraclad™	Silica	SMF-28™ fiber with Duraclad™
40 years	1/5 σ_p	1/3 + 5 kpsi	20 kpsi	38 kpsi
4 hours	1/3 σ_p	0.45 σ_p + 5 kpsi	33 kpsi	50 kpsi
1 second	1/2 σ_p	0.6 σ_p + 5 kpsi	50 kpsi	65 kpsi

Table 2- Allowable stress design guidelines for bending (σ_p is the proof-test stress level)

			Minimum Bend Radius if $\sigma_p = 100$ kpsi	
Length of Fiber	Length of Time	Risk of Failure	Silica	SMF-28™ fiber with Duraclad™
> 1 km	40 years	0	30 mm	16 mm
> 1 km	4 hours	0	20 mm	12 mm
> 1 km	1 second	0	13 mm	10 mm
≤ 5 m	40 years	< 1 ppm	25 mm	10 mm

Figure 3: Strength distribution of silica fiber measured using the CRCFT



For more information

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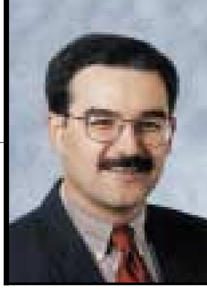
For more information on Corning's mechanical reliability testing and processes, please call the Corning Optical Fiber Information Center (COFIC) at 800-525-2524 ext. 3197 and ask for Comparison of Mechanical Reliability Models for Optical Fibers (WP 5049) and Mechanical Reliability: Applied Stress Design Guidelines (WP 5053).

Preston D. Buck
MARKET MANAGER - PREMISES
CORNING INCORPORATED



A Company Secures its Future with

Fiber-to-the-Factory Floor

The new headquarters of
American Video Glass Company
in Mount Pleasant, PA, features a state-of-the-art information-technology infrastructure with centralized fiber-optic cabling at its core.

Introduction

The term "fiber-to-the-desk" brings to mind workers sitting before computers in cubicles and private offices. Yet fiber-to-the-desk designs also have proven to be uniquely suited to large manufacturing facilities, mammoth hangar-like plants where people share space with big, noisy machines.

"Fiber-to-the-desk is very successful in manufacturing facilities," says George H. Sellard, president of Sellard Communications which specializes in low-cost fiber-to-the-desk solutions. "Large plants often have long cabling distances and lots of electro-magnetic interference, a principal cause of network downtime. So fiber is perfect for these installations."

Also, a fiber-to-the-desk design provides "future-proofing" against increasing bandwidth requirements, a concern in any environment. And all-fiber infrastructures, consisting of rugged fiber-optic cables, make network reconfigurations — all too common in large structures — easy and inexpensive.

(continued on next page)

Centralized All-Fiber Network at American Video Glass Company

One such installation recently was finished at the new home of American Video Glass Company (AV), which manufactures glass panels and funnels for television picture tubes. Their newly completed 500,000 square foot factory, in Mount Pleasant, PA, is equipped with a state-of-the-art information technology and controls infrastructure, the foundation for which is a centralized cabling, fiber-to-the-desktop network designed by Sellard Communications.

Two issues drove the decision to install an all-fiber network at American Video Glass. Most critically, planners wanted to be assured of sufficient information-carrying capacity to run whatever applications they might require in the not-so-distant future. Fiber's virtually unlimited bandwidth provides that assurance. Also, with plant expansion and cabling moves on the horizon, the robust and flexible fiber-optic centralized cabling plant will allow for quick and easy moves and changes.

In a centralized cabling design, all data electronics reside in one location. From this single point, optical fiber cables run all the way to desktops either by way of two-fiber cables running directly to workstations; or within high-fiber-count riser cables (24-fiber cables at AV) to passive cross-connects, then on to work area outlets via two-fiber cables. Maintenance and trouble-shooting are vastly simplified, and speed upgrades are quick, easy and economical. The passive cross-connects require little real estate. Also, unlike intermediate distribution frames containing active electronics, they require no power, air-conditioning or grounding. Due to its distance performance, optical fiber is the only medium that offers the superior bandwidth and attenuation required to design centralized networks, where users are more than 100 meters from servers or switches.

The centralized cabling network at AV is simplicity itself. At its center is a computer room — with network hubs and servers — housed in a two-story core structure in the middle of the factory. From this point, Siecor MIC® cables each containing 24 Corning® 62.5/125 micron multimode optical fibers run to telecommunications closets. Siecor two-fiber MIC cables connect closets with workstations inside the building. In addition, three Siecor FREEDM™ cables, each with 24 Corning multimode fibers, travel from one telecommunication closet directly to closets in three out-buildings.

FREEDM Cable is an indoor/outdoor cable that eliminates the need for a transition splice at building entrance points. Due to a special loose tube design, the cable is riser rated, allowing AV to extend its centralized network to three buildings near the central factory by way of aerial conduit. Each cable runs directly from the telecommunications closet, outdoors, into another building, and straight to other telecommunications closets — with no splicing along the way. This capability reduces installation costs by eliminating the material and labor expenses associated with the building entrance transitions.

Without optical fiber, none of this would be possible. Other media, particularly copper, cannot meet the bandwidth and attenuation requirements at the distances used in a centralized cabling design such as the one at American Video Glass.

Says Ralph DiNinno, IT & controls manager, "It's more cost feasible to use the fiber-optic centralized cabling design, because there are no closet build-outs and minimal maintenance." With no active electronics distributed throughout the network, there are no large closets to build and maintain — just small cabinets containing wall-mounted splice centers. This reduction in multiple closets played a major part in reducing the cost premium traditionally associated with fiber.

With optical fiber running from a single computer room to personal computers in offices and on shop floors throughout the cavernous building and several out-buildings, AV has combined on a single network all computer-based applications:

- Enterprise Resource Planning (ERP) — runs the supply chain, finance and manufacturing
- Manufacturing Execution Systems (MES) — collects real-time information from the shop floor and sends commands
- Miscellaneous applications: word processing, payroll, maintenance management, engineering, quality and others.

Future-Proofing with Fiber

Upfront savings were important to AV network designers. But even more crucial was the opportunity to "future-proof" their cabling infrastructure against soaring bandwidth demands by installing optical fiber throughout their facility. The huge bandwidth offered by optical fiber has already paid off at AV, according to DiNinno.

"The MES (Manufacturing Execution Systems) is a relatively high volume application compared to our other applications," he says. "Its summarization of control and manufacturing parameters from the shop floor may demand high bandwidth as the plant grows."

Yet DiNinno has gained even greater peace of mind from knowing that his network will not suffer bandwidth bottlenecks any time soon.

"Fact is, we're a brand-new company," says DiNinno. "We have limited history and information about our network and capacity requirements. So, when we designed the network, we installed Ethernet knowing that the bandwidth available on optical fiber could support a change to new electronics, like ATM, as our needs grow."

Expanding the network or adding applications will not present problems either. "If we decide to deploy additional workstations," DiNinno says, "the fiber is there to do it. And the capability is there for real-time video, too."

Quick Change – No Problem

An all-fiber centralized network makes cabling changes fast and simple. This was a critical factor at AV because of plans to expand and reconfigure the main building in the near future. Currently, the factory is joined to an administration building by a short breezeway, which is the route for the optical fiber cable. Eventually the breezeway will be demolished, the administration building will be expanded, and the two buildings will become one. Obviously, this will mean rerouting the cable.

Reconfiguration expense is of concern to network planners. The solution at AV was to use Siecor's new Plug & Play™ Systems, which feature MTP connectors and factory preconnectorized cables. Changes can be made with minimal downtime. Also, Plug & Play Systems simplify connectivity, and reduce installation time and cost.

When AV is ready to begin new construction, the optical fiber cable will be unplugged at the administration building end and rolled back into the factory. Later, the cable will be rerouted — installers left plenty of slack — and reconnected with the MTPs.

An All-Fiber Network Offers Many Benefits

As noted earlier, maintenance and trouble-shooting are vastly simplified with an optical fiber centralized cabling network. This translates into real savings.

"Long term maintenance is an issue," says DiNinno. "But with the centralized cabling and fiber, maintenance and trouble-shooting do not require going out to hubs. We have homeruns, so troubleshooting is easy. We just test through the hubs in the central computer room."

"The fiber allowed us to go with a very simple cable design," DiNinno says. "That eliminated a lot of trouble. The design is excellent."

The new network has proven to be exceptionally reliable, despite rapid construction and cabling installation.

"We broke ground in January of 1996, and we were operational in June '97," boasts DiNinno. "In that brief period, we deployed a complete information and controls infrastructure, and multiple reconfigurations were necessary. Still, we have not had a single issue with the optical fiber cable plant — not one. Network and cabling reliability have been absolutely excellent." DiNinno is confident that installing an all-fiber network at American Video Glass has been a smart move — strategically, commercially, financially.

"This is an investment in a stable, reliable medium, which is not constrained by capacity. It was a straightforward decision to install fiber." ▪

For more information

FROM *CORNING INCORPORATED*

For more information on the benefits of centralized architecture and how it works, call us at 1-800-525-2524, ext. 4119 and ask for the Centralized Architecture Series from *Cabling Business Magazine.*

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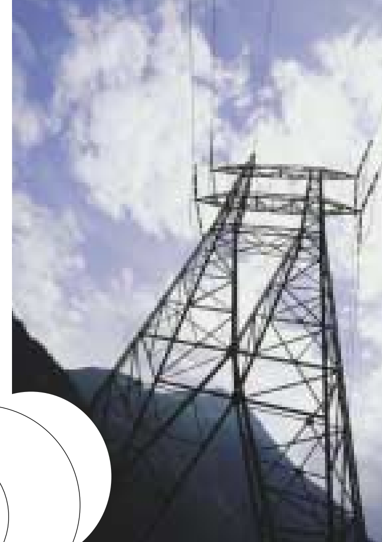

Conectiv Communications, Inc.

CLEC pioneers new network territory

Introduction

Conectiv is one of the early players in the converging utility-telecommunications markets. Conectiv was formed by a 1998 merger involving two electric utilities, Delmarva Power & Light and Atlantic Energy. Conectiv Power Delivery provides electric service to the Delmarva Peninsula area of Delaware, Maryland and Virginia as well as southern New Jersey through more than 25,000 miles of electric lines. Conectiv also supplies gas to the Wilmington area through 1,600 miles of gas mains. Conectiv Communications, Inc., a wholly owned subsidiary, provides local and long-distance telephone service over a 650+mile fiber-optic network in Delaware and parts of Maryland, New Jersey and Pennsylvania.

As a facilities-based competitive local exchange carrier (CLEC), Conectiv Communications has invested heavily in its network infrastructure. As customer demands for bandwidth continue to increase, Conectiv must balance meeting current network demands with on-going network growth. This article provides a conceptual overview of the challenge Conectiv — like many other CLECs — faces in evaluating different options for network growth.

Conectiv Communications, Inc. Network Map

Background

In the mid 1980s, Delmarva Power & Light Company began to install a fiber-optic system to improve internal communications up and down the Delmarva Peninsula, its primary electric service territory. The first objective was to replace a microwave relay system used to monitor transmission and distribution throughout the peninsula with a more secure, reliable communications network. The initial fiber deployment covered several hundred route miles and consisted of optical ground wire (OPGW) along with some all-dielectric, self-supporting (ADSS) cable, creating a SONET ring that reached from Wilmington, DE to Salisbury, MD. In addition to Delmarva's internal communications traffic, the network also transported a limited amount of wholesale carrier traffic.

Through the mid-1990s, plans were laid to expand and update the fiber-optic system, providing the foundation for a new regional telephone company — Conectiv Communications, Inc. Additional backbone cables were installed to complete the network for commercial use, and a metropolitan ring was constructed throughout Wilmington, DE. The central office and network operations center was built in Newark, DE. Last mile customer access was accomplished through co-location in Bell Atlantic wire centers (Unbundled Network Element access) for most customers, and direct fiber builds to large, high traffic customers.

Conectiv Communications officially launched its public network services in November 1997, with a full range of voice and data services:

- Local dial-tone service
- Long distance
- Local and regional toll calling
- Voice and data networking
- Customized regional calling plans

As of February 1999, Conectiv Communications has established 27 co-location facilities in Bell Atlantic central offices, with an additional 40 to 60 co-locations planned for 1999. Recently, Conectiv Communications announced the deployment of digital subscriber line (DSL) services using Cisco's DSL networking equipment. Beta testing is under way, with a full launch planned shortly.

In its first 18 months Conectiv Communications has become the only facilities-based alternative for business and residential local and long distance telephone service in most of its service territory. They have been successful in leveraging the "good name" and reputation Conectiv maintains in the marketplace, while also providing reliable telecommunications services at competitive rates.

Current Network Configuration

Conectiv Communications' fiber-optic system now consists of almost 700 miles of fiber-optic cable, including rings into Maryland, Pennsylvania and New Jersey (via submarine cable across the Delaware River into Salem County, NJ). It is a combination of "inherited" infrastructure, deployed a decade ago, and new infrastructure, deployed within the past three to four years (see network map on previous page). Since the network is still growing, construction of new network segments is on-going.

The average fiber count in the network is 96 strands, with 144+ fiber counts in the newer segments. The vast majority is Corning® SMF-28™ fiber. There are a few portions of the network, however, with fiber counts as low as eight strands. Many of these eight strand segments consist of Corning® SMF-21™ fiber, which was the leading fiber technology in the mid-1980s but is no longer manufactured. These older segments are fairly typical of networks deployed a decade ago, as high-capacity fiber optics began to replace twisted-pair, copper wire circuits. In the mid-1980s the capacity offered by eight strands of fiber would have seemed limitless in comparison to a legacy copper network. Replacing these eight strand fiber segments is a high priority for Conectiv's network upgrade.

Combining these different types and counts of fiber, Conectiv Communications employs a variety of switching equipment and other electronics. The network platforms include a Nortel DMS-500 switching platform, Alcatel DACS products, and a Cisco Stratacom ATM backbone. The transport network, which consists of several hundred SONET nodes, is based largely on Fujitsu FLM-series multiplexors and Nortel transport nodes. Backbone rings are at OC-48, with OC-12 and OC-48 distribution and access rings.

Growth Strategies

Network growth is an on-going concern for all CLECs, including Conectiv Communications. From a facilities standpoint, Conectiv Communications must weigh several factors to determine an appropriate growth pattern that will meet all of its network requirements:

- Current network infrastructure
- Current network services
- Service reliability for current customers
- Future network demands
- Evolution of network technologies, particularly electronics

Conectiv's real challenge is knowing when and how to upgrade its network infrastructure. The most obvious place to start is the leanest part of the current network, specifically the eight strand sections of the backbone ring.

Upgrade Scenarios

There at least three options for upgrading Conectiv's current network, each with certain risks and rewards. Two of these options are based on maximizing existing fiber; the third involves network overbuild.

In the most straightforward upgrade scenario, some of the existing network systems can be upgraded to OC-192, which would temporarily alleviate the situation. Given the exponential growth of customer bandwidth requirements, this solution likely would only postpone the problem for one or two years. In other words, this solution may defer one of the other options, but a more substantial upgrade ultimately will be necessary.

This deferment may be very attractive for short-term capital conservation, while allowing for additional time to study the operational impact and changing pricing of the evolving DWDM technologies. An obvious downside to this approach is that it requires optical and/or electronics up-grades at each node in the ring, regardless of the actual origin and destination of the additional traffic.

A second option is to employ wavelength division multiplexing (WDM), or dense WDM products, which provide the ability to overlay multiple wavelengths onto each individual fiber. Each wavelength is a virtual path, equivalent to an additional fiber from an application standpoint. That is, a 12 wavelength system can carry 12 independent optical signals, SONET or otherwise. Effectively, an eight- fiber cable with 12 wavelengths per fiber is equivalent to having a 96-fiber cable. Of course, there are additional complexities to managing wavelengths rather than fibers, and this is an important factor to consider. In addition, we have to assess and manage WDM's impact on current software and hardware and the on-going training required for network engineers.

The third option is to overbuild, or replace the existing cable with a much higher fiber count. This is a very desirable option for future flexibility, but construction requires relatively high up-front capital investment. Overbuild and/or new network construction also has an impact on speed-to-market, given the full cycle of design, engineering, route acquisition (if any), permitting, outside plant and network testing.

Since the first option is a short-term fix, there are essentially two options left to compare in-depth — an overbuild or DWDM. To evaluate each of these upgrade scenarios fairly and determine which one (or combination) will provide the optimal growth plan, we must look at the constraints of each approach, the approximate costs and the long-term value. For the sake of simplicity, we'll consider just a portion of the Conectiv Communications network, a segment of the southern Delaware ring, in which there are nine backbone add/drop nodes. The total route mileage involved is approximately 100 miles, and includes nine add/drop nodes. Although the geography is rural, the relatively short distance between the nodes, and distribution-oriented nature of the network, essentially represent a metropolitan optical network model. For this analysis, we will assume that in either case (overbuild or WDM) the SONET, Ethernet, or other end equipment is equivalent, either feeding directly into a dedicated fiber, or into a dedicated wavelength. It should be noted that the compatibility of your existing and planned equipment with a particular vendor's DWDM products should be verified prior to committing to that solution.

We'll look first at the overbuild scenario, since typically it is considered the more expensive and time-consuming approach, and then draw comparison (first by cost) to the DWDM model.

Network Overbuild

A fiber overbuild has the attractions of familiarity, predictability, flexibility and fairly simple asset management. In the geography concerned here, replacing the OPGW and/or ADSS cable will cost, for the sake of the example, approximately $40,000/mile to construct, including a 144 strand Corning® SMF-28™ fiber cable. For the entire 100 route miles, the fiber overbuild would cost approximately $4,000,000. No additional systems or support would be required to manage the new asset.

The only real constraint on this approach is financial: network overbuild (or new construction) requires a substantial amount of capital up-front — an investment in facilities that will generate new revenues downstream.

Figure 1 - Overview comparison of three upgrade options

	Upgrade current network electronics	Deploy WDM/DWDM	Fiber overbuild
Initial cost	Relatively low	High	High
Initial complexity	Low	High	Low
Long-term capacity	Low	Variable	High
Long-term cost	Low	Medium-high	Low
Long-term complexity		Medium-high	Low
Pricing forecast	Prices expected to fall	Prices expected to fall dramatically	Stable

WDM and DWDM

With the pricing and availability of DWDM products changing rapidly, the best way to view this alternative is to identify the components, and price the system according to an application. For this example, we will identify the basic components and compare this approach to the network overbuild.

Theoretically, WDM would optimize the existing network, especially the sections with low fiber counts. Assuming that each fiber strand could handle 16 wavelengths/channels, the thinnest network segments could be upgraded to 8 X16, or 128 channels if we fully deploy DWDM on all eight fibers. This is a safe assumption for the segments utilizing Corning® SMF-28™ fiber. However, if it is an OC-192 environment, additional electronics may be required for dispersion compensation and extra amplification. These requirements depend upon the distance between nodes and the data rates.

The real constraint is that some of the thin network segments are Corning® SMF-21™ fiber. When the SMF-21™ fiber was deployed ten years ago, there were no systems operating at 1550 nm — specifications covered only 1310 nm. To determine whether it is even feasible to deploy WDM over the eight strands of SMF-21™fiber, we would have to test dispersion, attenuation and PMD for each strand on each segment. The cost of testing and the possible limitations we would find make this upgrade scenario more questionable than it appeared from a superficial view.

In addition, each of the nine network nodes will need to be equipped with more electronics to implement DWDM. Current DWDM system costs are still relatively high. For the purpose of this discussion let's assume a DWDM system costs $30,000/wavelength. To implement 16 wavelengths on a single fiber may cost approximately $480,000. To implement this solution on a pair of fibers at each of the nine add/drop nodes would then cost $960,000 per node, or a total of $8,640,000 for all nine nodes. Having upgraded only two of the eight fibers in the narrowest segments of the ring, the upgrade has netted an additional 30 wavelengths, so that 38 virtual paths are now available, as compared to 144 in the overbuild scenario.

Deploying the WDM solution with these assumptions is clearly prohibitive when considering cost as compared to the overbuild solution, and does not provide an equivalent number of transmission paths when completed. WDM vendors are working on Metro WDM systems that are less expensive and better equipped for metro applications, and prices of the electronics are forecast to drop as the technology continues to evolve.

Figure 2 - Dense Wavelength Division Multiplexing (DWDM)

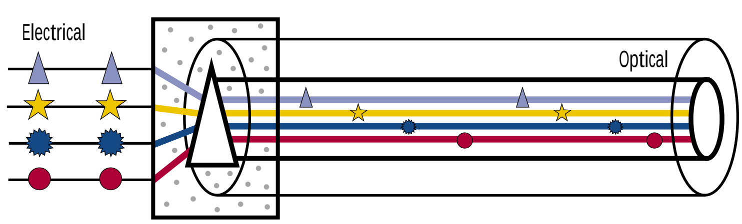

Figure 3 - Simple cost comparison to upgrade nine backbone nodes

	Fiber overbuild	WDM/DWDM
Cost per node	N/A	$960K per node (two fibers only), plus any necessary upgrades to existing hardware/software
Overall cost	$40,000 per route mile (estimated total = $4 million)	Highly variable
Capacity gained	144+ fiber paths	38 wavelengths
Deployment considerations	• ROW availability • construction permits • capital availability • time to market	• feasibility for Corning existing fiber segments • complexity of managing 128 wavelengths • impact on other applications and electronics • staff learning curve • time to market
Future upgrade options	add WDM/DWDM to new cable	possible future improvements in wavelength densities

Figure 4 - Fiber types and their application

Fiber	Network Electronics	Wavelength Range Specified	Ideal Architecture
Corning® SMF -21™	up to OC-48	1310 nm	short haul
Corning® SMF-28™	OC-48 to OC-192 (may require additional electronics for OC-192)	1310 nm for long haul; 1550 nm for short haul (e.g. metro area)	long haul for OC-48; metro area for OC-192
Corning® LEAF®	up to OC-768	1550 nm	long haul or short haul (high data rate on either)

It is important to note that the side-by-side comparison of initial expenditures is not a fair evaluation of the two approaches. While a complete fiber overbuild must be done for the full ring to have meaning, the DWDM solution can be deployed as needed, spreading the capital expenditures over a significant period of time. Initially, DWDM need only be implemented on a single pair of fibers to gain relief, providing an additional 30 wavelengths for use, exceeding the capabilities of the entire original cable. It will cost $960K or more to provide electronics to each of the nine nodes (two fibers only) up front. Given the time cost of money and spreading the other expenditures over the next 10 years or so, this option may be feasible, although much greater than the over-build cost. Furthermore, we haven't taken into consideration the additional cost over time of the DWDM option because of the increased complexity of managing 38 wavelengths versus managing 144 fibers. The management systems related to DWDM are in their infancy and are expected to decrease dramatically in cost, and gradually integrate into existing platforms.

Conclusions

Testing each fiber on every Corning® SMF-21™ fiber segment will be required to determine the feasibility of any WDM technologies. Given the uncertain wavelength limitation of the SMF-21™ fiber network segments and high cost of WDM systems, it appears that network over-build may be the only viable option for certain segments. Upgrading network electronics appears to offer an interim solution for increasing network capacity — perhaps during the construction phase. WDM/DWDM may prove very effective on network segments that are long haul in nature and have long spans between each node, where fiber cable construction cost would be significantly higher. In addition, the cost of electronics is dropping quickly, while their sophistication is rising; so delaying the addition of WDM/DWDM may actually prove more cost-effective in the long run. Given that the up-front cost of overbuild is much less expensive than the cost of intensive WDM deployment, the most logical solution may be to overbuild first, then deploy WDM.

The most effective network upgrade utilizes a combination of the approaches described above. Strategic network upgrading involves taking a careful inventory of all current network components, including types of fiber and fiber counts, and then weighing the options available for each. For most CLECs, as for Conectiv, it takes a combination of the possible alternatives to provide the best cost/value solution for both the short and long-term.

The exercise of comparing alternatives for legacy network upgrades suggests some rules of thumb for new network builds. The past decade has proven to all of us that no one ever wants *less* bandwidth. Once you have made the decision to construct (new or overbuild), implement the highest fiber count you can afford, and consider the inclusion of some newer fiber technologies, such as Corning® LEAF® fiber for maximum flexibility. ▪

For more information

FROM *CORNING INCORPORATED*

To learn more about Corning's LEAF® and SMF-28™ optical fibers, call the Corning Optical Fiber Information Center at 1-800-525-2524 ext. 2530 and ask for the 1310 product line (PB3187) and LEAF® product brochure (PB3101).

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InfiniCor CL™ Multimode Fiber: The Laser - Optimized Fiber Advantage™

Introduction of Revolutionary Multimode Fiber: The InfiniCor CL™ Series

With the introduction of the Corning® InfiniCor CL™ multimode fiber series, Corning has taken a major technological leap forward. The InfiniCor CL fiber is an advanced multimode fiber that will provide local area networks with the capacity and vendor flexibility to meet the ever-increasing needs of the data communications industry. This fiber represents the next generation of multimode fiber for high-speed, laser-based local area networks, with its ability to move one gigabit of data per second up to 2,000 meters.

High Performance Over Longer Distances. Guaranteed

In order to meet the explosive demand for data in local area networks (LANs), the Gigabit Ethernet standard was adopted in June of 1998. The standard enables Gigabit Ethernet LANs to transmit data at one gigabit per second using laser light sources in both the 850 nm and 1300 nm operating windows. Unfortunately, the Gigabit Ethernet standard de-rated the link lengths for multimode fiber to 220 meters at 850 nm and 550 meters at 1300 nm for FDDI-grade fiber. This was partially due to the centerline dips and peaks found in some manufacturers' fibers, which can decrease bandwidth in laser-based systems. Corning InfiniCor fiber, however, was designed specifically for use with lasers and has a smooth, consistent profile without centerline abnormalities. Figure 1a demonstrates the profile possible with other manufacturer's fiber, and Figure 1b demonstrates the Corning InfiniCor fiber profile.

Consequently, with the InfiniCor CL series, network planners can once again go the long distances they need at the high speeds their networks require. The InfiniCor CL series includes two new fibers: InfiniCor CL 1000 and InfiniCor CL 2000, which both offer extraordinary link lengths at high speeds. For Gigabit Ethernet compliant links, InfiniCor CL 1000 fiber is guaranteed* to transmit up to 500 meters at 850 nm and 1000 meters at 1300 nm; InfiniCor CL 2000 fiber is guaranteed* to transmit up to 600 meters at 850 nm and 2000 meters at 1300 nm. InfiniCor CL 1000 is a 62.5 µm core fiber, and InfiniCor CL 2000 is a 50 µm core fiber.

Lose "The Patch"

In addition to extraordinary link lengths, InfiniCor CL fiber is also the first multimode fiber in the industry to eliminate the need for a mode conditioning patch cord in the 1300 nm operating window for the Gigabit Ethernet protocol. When the Gigabit Ethernet standard was adopted, one of the requirements for operation at 1300 nm was a mode conditioning patch cord. With a patch cord, the laser light source enters the core of the fiber in an off-center position, instead of entering in the center of the core. The mode conditioning patch cord adds expense and complexity to a network. Eliminating the patch cord will save $80-$100 for each fiber termination, resulting in several thousand dollars in savings for each installation. No patch cord also means one less product to keep in inventory. With Corning InfiniCor CL fiber, it is no longer necessary to use the mode conditioning patch cord, allowing for an on-**c**enter **l**aunch (CL), unmatched ease of installation and use, and an economic solution.

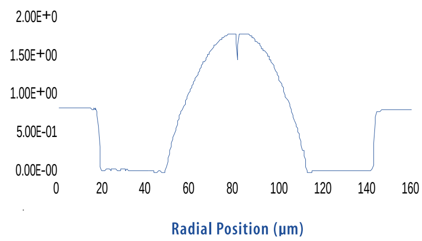

Figure 1a Non-Corning Fiber Profile

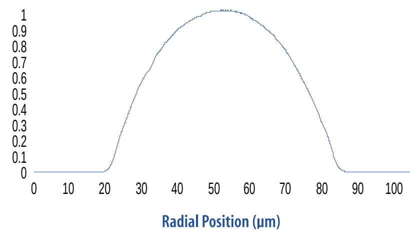

Figure 1b Corning InfiniCor Fiber Profile

The Capability to Take Your LAN into the Future

InfiniCor CL fiber offers network planners another important benefit: capability for the future. InfiniCor CL fiber not only offers the longest multimode link lengths at Gigabit Ethernet, but it also is designed to support operation at 2.5 and even 10 gigabits per second over hundreds of meters, another first in the industry. Additionally, InfiniCor CL fiber will optimize laser performance with a variety of laser sources — whether they are 850 nm vertical cavity surface emitting lasers, 1300 nm single-mode lasers, or tomorrow's low cost 1300 nm transceivers. InfiniCor CL fiber provides maximum flexibility and optimum performance. So, install InfiniCor CL fiber in your network today, and be ready for the future.

Measured Laser Bandwidth

Traditional light emitting diode (LED) based systems rely on overfilled launch (OFL) bandwidth to measure the relative performance of a fiber. OFL bandwidth is a reliable measure for LEDs, but does not correlate well to laser performance.

Figure 2 shows the weak correlation between OFL and laser bandwidth. Each point in Figure 2 represents the OFL and laser bandwidths for a given fiber. Only the points that fall on the black line are cases where overfilled launch bandwidth approximates laser bandwidth, and therefore accurately predicts laser performance. The orange points are cases where the OFL bandwidth is high, but laser bandwidth is low; laser-based performance would be questionable.

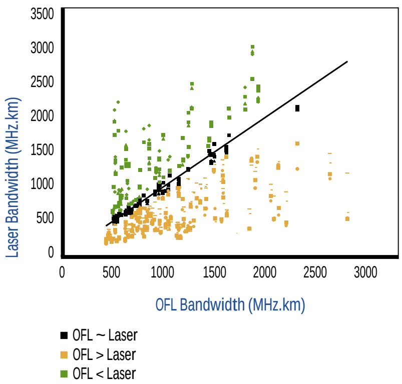

Figure 2	Correlation Between Overfilled Launch Bandwidth and Laser Bandwidth

In order to guarantee fiber performance, Corning measures actual laser bandwidth on its InfiniCor CL fiber. Laser bandwidth is required to accurately predict fiber performance in laser-based systems. Relying on only OFL bandwidth to predict performance in a laser-based system is a gamble.

Compatibility You Can Count On

Although InfiniCor CL fiber is a technical leap ahead of other multimode fibers, it is still fully compatible with the installed base. The InfiniCor CL series is compatible with standard 62.5 µm fiber, standard 50 µm fiber, and the entire high-performance InfiniCor product line. InfiniCor CL fiber is also standards-compliant; InfiniCor CL exceeds every major published standard for the local area network.

The Laser-Optimized Fiber Advantage™

Corning InfiniCor CL fiber offers the end-user several important benefits:

- Transmission distances up to 2,000 meters
- On-center launch
- 2.5 and 10 Gbps capability
- Laser bandwidth measurement
- Network upgradeability
- Compatibility
- The Corning guarantee*

InfiniCor CL fiber is the first and only *laser-optimized fiber*™ and is offered exclusively by Corning. ■

* Guaranteed through Corning-approved cable warranty programs.

For more information

FROM *CORNING INCORPORATED*

To learn more about InfiniCor CL fiber, call the Corning Optical Fiber Information Center at 1-800-525-2524, ext.4118 and ask for your free InfiniCor CL fiber technical packet (SC4089).