MIRAFLEX™ Fiber, the Insulation Glass Fiber for the Twenty-First Century

Clarke Berdan II, Owens Corning

The glass fiber insulation industry is experiencing a surge in product innovation and fiber technological advancement. The Miraflex™ fiber provides an outstanding example in both of these areas. The first new glass fiber since glass was initially used for insulation production is a bicomponent fiber composed of two glasses, shown in equal semicircles when viewed in a cross section. As the glass cools, the two components contract at differing rates yielding the final, irregularly-shaped fiber. This irregular shape is necessary for the resulting ''uniform volume filling'' nature. It allows each fiber to contribute individually to superior thermal and recovery performance without a binder.

Additionally, the development process was unique in many ways. It focused on colocation of dedicated resources and parallel efforts, all geared to enhance the ''speed to market'' commitment.

These unique properties came together to form a product which addresses some of the critical issues in the retail insulation market. The product is a poly-encapsulated, compactly-rolled attic insulation. These highly-resilient fibers are packaged into less than half the volume of the products with which they currently compete, taking less space on store shelves and making them easier to transport. Furthermore, this new fiber addresses the issue of irritation, a major deterrent for many who wish to insulate their attics. The longer, nonstraight fiber yields a ''virtually itch-free'' product. Finally, the unbonded fibers surrounded by a polyethylene sleeve form a conformable insulation that the consumers can easily custom fit to their individual attics.

INTRODUCTION

This is an exploration of the development process and implications to the retail insulation marketplace of Miraflex™ fibers. Details are provided of a fiber technology breakthrough represented by the production of bicomponent glass fibers. These binderless bicomponent fibers are compared to the existing bindered technology which is comprised of single-component glass fibers. A look at what technologies were important and how they blended together will help show why these new fibers were important. Equally important is the environment that fostered good science. The environment within which this development effort thrived will be laid open.

The value of this new technology can only be understood in terms of what it meant to the customers. What does this new fiber now allow which wasn't possible before? What advances does this technology suggest for the future? The marketplace is full of customer needs. The secret is to uncover the right technology to address each need. Details are provided of the key factors from the marketplace that aligned with the attributes of this new fiber. This discussion revolves around a new product designed for the do-it-yourself (DIY) segment of the retail attic insulation market. How did this product capture the known benefits of the new fiber? What benefits have not as yet been captured? That which has been learned from the work already completed will be used to provide a glimpse into the future.

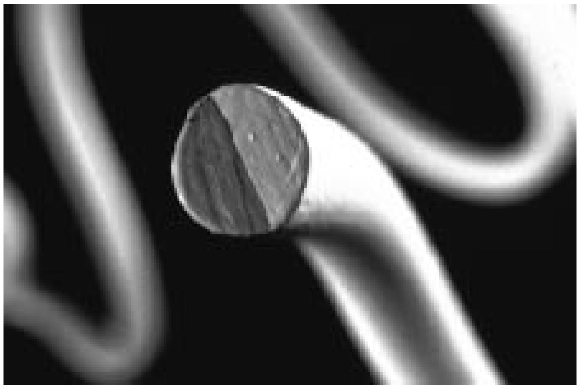
TECHNOLOGY BREAKTHROUGH

What constitutes a fiber technology breakthrough? A breakthrough can be defined as a product form which achieves that which the customer believes is impossible. This could come in the form of enhanced product performance features. Alternately, it could come in the form of a cost reduction. Both of these advancements have been accomplished with this new fiber. The details will be presented during the discussion of the product design and its implications in the marketplace. To gain some fundamental understanding of this fiber's benefits, a first look at the physical attributes of this new fiber will be made. The fibers are bicomponent and they are very long. These features will be explored in greater detail so that their significance in the marketplace can be appreciated.

The fibers are bicomponent, giving a ''uniform volume filling'' pack.

Figure 1 shows a cross section of the new fiber. The interface between the two glasses is clearly shown. The interface is

Figure 1. *An Enlarged View of the Cross Section of a Bicomponent Fiber*

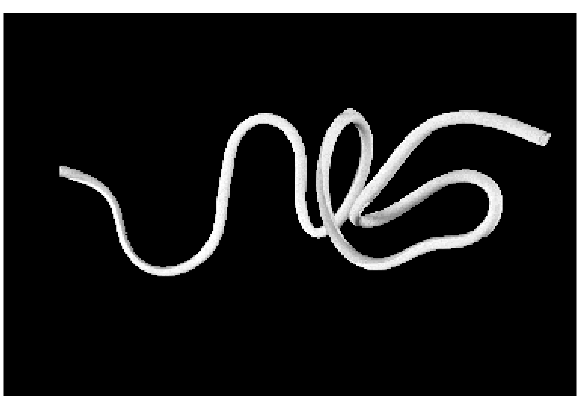


formed from the molten state and cooled until the two glasses solidify and form a rigid interface. As the fiber is further cooled, the differing rates of thermal expansion force the fiber to curl.

Figure 2 contains an artist's rendering of a typical fiber section if allowed to float freely. It is described as irregularly shaped as opposed to curly or straight. By this it is meant that the shape along one segment of the fiber does not foretell the shape along any other segment. Thus, the fiber shape is constantly changing along its length and does not repeat itself at any regular intervals. Some fibers naturally fold back on themselves to form a very compact structure while others are more elongated as seen in the figure.

The reason for this irregularly-shaped fiber is best understood by first recalling the behavior of the more familiar bimetallic strip. A bimetallic strip is composed of two strips of metal tightly bonded together along an interface. The two metals are chosen to have different coefficients of thermal expansion, the interface will bend towards one metal and away from the other as the ambient temperature is changed. If the strip is heated, it will curl in a circular fashion away from the metal that has the greater thermal expansion coefficient.

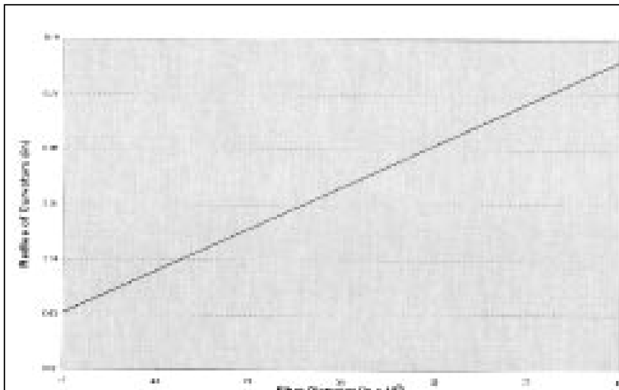
Figure 2. *A Single Miraflex™ Fiber Section*



In this case of glass fibers, the radius of curvature is well defined by the fiber diameter and the difference in thermal expansion between the two glasses for known forming and measurement temperatures. The local curl of the fiber can be ''tuned'' based on the desired tightness by changing the glasses involved and/or changing the fiber diameter. This relationship is shown in Figure 3 where the radius of curvature in millimeters is plotted against the fiber diameter for two typical glasses that might be formed at some known temperature and measured at room temperature. The reason the fiber does not curl back on itself can be understood by referring to Figure 1 and noting that this interface is not simply drawn out in a linear fashion as the fiber is being formed. The fiber and interface in the molten form are being spun out into a very turbulent environment that causes this interface to randomly rotate about the forming axis. Thus, even though the radius of curvature is relatively constant along the length of the fiber, this random gyration of the interface along the forming axis produces a fiber that is irregularly shaped, as it is neither constantly circular, nor helical in appearance.

This irregular shape is key to the production of a fibrous pack that is ''uniform volume filling''. Because of their shape, neighboring fibers and segments of the same fiber are unable to nest. Thus, for a given density, the fibers will naturally distribute more uniformly than straight or curly fibers that are able to nest. The major advantages involve

Figure 3. *Impact of Fiber Diameter on the Radius of Curvature of Bicomponent Fibers*



higher compression packaging, better thermal performance, and higher label thickness.

Compact packaging is best thought of in terms of the relationship between compressed density and product design density. Compressed density is the density of the product in the shipping package. While the product design density is the density of the product when held at the label thickness (i.e. installed density). All bindered glass fiber building insulation can physically be compression packaged to 20 lb/ft^3 given the right packaging equipment. The problem is that the density after removing the packaging will normally be close to 18 lb/ft^3. Many of the fibers have been broken into small pieces that can no longer store the energy needed to recover to a much lower density. Figure 4 shows the impact of compression on bindered glass fiber products and compares this with the new fiber. Clearly the impact of an irregularly-shaped fiber is most evident for target products where the product design density is below 1.0 lb/ft^3. This allows for compressed densities above 6.0 lb/ft^3 to be easily achieved for unconstrained product with a product design density below 0.5 lb/ft^3. This compares quite favorably to bindered products that are commonly packaged at around 3 lb/ft^3 and thus occupy roughly twice the volume in the package. Some samples of the new fiber, not shown in Figure 4, have been tested in the 10 to 12 lb/ft^3 package density range and continue to perform as labeled. This represents up to a four-fold increase in compression from current bindered products. It is worth noting that the packaging forces are increasing at roughly the rate of the density to the third power. Consequently, equipment costs increase rapidly as target levels of compression are increased. The practical limit for package density appears to be in the 10 to 15 lb/ft^3 range, taking into account freight savings, fiber quality requirements, and packaging costs.

The phrase ‘‘uniform volume filling’’ is meant to suggest that the fiber density is more uniform on a smaller scale than seen in the traditional, bindered glass fiber insulation. The significance of this for thermal performance is that more of the fibers are acting independently for radiation scattering. The thermal conductivity for the new fiber shown in Figure 5 indicates a seven percent improvement as compared to bindered glass fibers of the same diameter. This thermal conductivity improvement translates directly into an area weight (i.e., cost) reduction for a given product design. Building insulation production costs are roughly linear with and a strong function of area weight.

Figure 4. *Impact of Compression on Product Recovery*

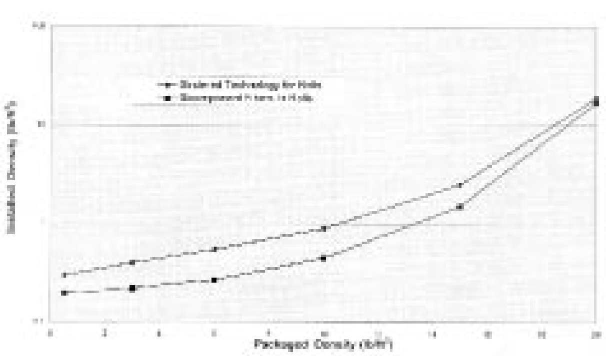
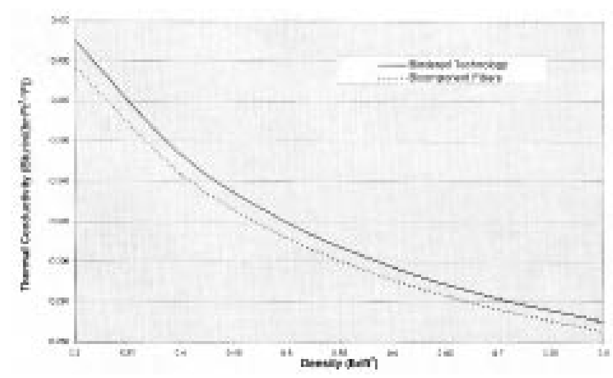


Figure 5. *Thermal Performance: bicomponent fibers vs. bindered technology at equivalent fiber diameters*



Finally, the independent fibers contribute significantly to the high label thickness that is a part of the product design. Again, as noted for improved thermal conductivity, a weight reduction is realized as the label thickness is increased, in this case 8.75 inches for the bicomponent fiber R-25 product. R-25 bindered glass fiber products range in label thickness from 7.25 to 8.25 inches and in product density from 0.4 to 0.6 lb./ft^3.

This weight reduction is less obvious and is most easily appreciated by reviewing the relevant equations. The R-value can be expressed as the ratio of the product thickness (t) to its thermal conductivity (k).

$$R = \frac{t}{k} \qquad \text{Eqn. 1}$$

The thermal conductivity is most commonly expressed for fiberous glass insulations as a function of density (ρ) and three constants (A, B, and C).

$$k = A + B\rho + \frac{C}{\rho} \qquad \text{Eqn. 2}$$

In the region of product design densities of from 0.3 to 0.6

lb/ft^3, the term linear in density is so small that it is commonly just included with the constant A and labeled A′.

$$k = A' + \frac{C}{\rho} \qquad \text{Eqn. 3}$$

It is also noted that ρ is a function of thickness and area weight (w).

$$\rho = \frac{w}{t} \qquad \text{Eqn. 4}$$

Combining equations 1, 3, and 4 yields the interplay between thickness and area weight.

$$R = \frac{1}{\frac{A'}{t} + \frac{C}{w}} \qquad \text{Eqn. 5}$$

Equation 5 clearly shows that the area weight can be lowered as the product thickness increases when the desire is to hold the R-value constant. For unconstrained products, such as for attics, the ability to achieve a higher label thickness is worth up to about eighty percent of the weight reduction when compared with the savings due to improved thermal conductivity. For constrained products, such as side wall cavities, all of the weight savings would be due to improved thermal conductivity.

The fibers are long, giving a ''virtually itch-free'' pack.

The issue of fiber length is much more straightforward. Here, comparisons are made between the new fiber and single composition glass fibers and a discussion is presented on why long fibers are less irritating. The importance to the customer will be discussed later. Most glass fiber building insulation is manufactured by a rotary-forming process, whereby the fibers are formed from holes in the sidewalls of a spinner cup. In this process, fiber length is normally measured in terms of ''drape'' length. This is the length of fibers that drape over a roughly three-eighths-inch diameter rod when it is drawn just under the spinner or rotating cup. This action causes some of the fibers to hang onto the rod and a length can be measured as to how far the fibers hang below the rod when the rod is held horizontally. Traditional insulation glass fibers will have a drape length ranging from one-half inch to several inches, depending on the process settings. If the fibers are removed from the rod and pulled apart to be examined individually, it will be noted that they are indeed shorter than the measured drape length. Individual fibers will be commonly observed in the one-quarter to one-inch range. The drape length measured in this new fiber forming process commonly range from six inches to continuous. The 'continuous' measurement refers to those times when it is necessary to pull some of the fiber from the rod to remove the rod from under the forming process. The resulting individual fibers range from two inches up to one foot and more in length.

The new, longer fibers are important in reducing irritation because there are fewer ends to cause irritation. It is the numerous ends of short glass fibers pricking the skin that cause much of the irritation. These straight fibers act as rods that resist bending. The longer, nonstraight fibers recoil more easily away from the skin. Traditional fibers are not made longer because they will bundle together. As indicated above, bundled fibers are very hard to distribute uniformly within an insulation pack and also result in reduced thermal performance.

Compact packages, lower area weight, and low product irritation all have resulted from this new technology. Clearly this has met the definition given for a technology breakthrough. Any of these improvements would have been considered significant in the industry. Taken together, they represent a major leap forward for glass fiber insulation products.

THE DEVELOPMENT PROCESS

The science discussed here is very straight forward when viewed in hindsight. How does a company successfully commit the resources to turn a vision for a truly different technology into a reality? There were four factors that significantly contributed to the success of this new fiber development. They are: (1) management encouragement of and support for creative thinking; (2) access to significant levels of competence in a wide array of allied fields; (3) assembly, colocation, and dedication of a project team representing technical, marketing, manufacturing, and engineering expertise; and (4) goal setting owned by the team and fully supported by management. Now let's look at each of these in some detail.

The genesis of this new fiber technology came from a fiberizing research laboratory. Idea sessions were held to identify alternative processing techniques to create the next generation of glass fiber. One of these ideas was the concept for a fiberizing process to fuse two different glass compositions into a single fiber. The objective was to form nonstraight fibers and the selected method was to combine glasses with differing thermal expansion coefficient values. In 1992, the first small sample of fibers was produced and served to spark the imagination of others for what might be accomplished with these fibers.

To further accelerate the development process, it was necessary to seriously commit to the vision and formalize a development team. The researchers and project managers put together a vision for the future of a product containing the new fiber, much along the themes contained in this paper.

This vision was used with senior management to gain their support for proceeding with the necessary development effort to fully evaluate this technology. During the team formation, resources were selected from a broad range of backgrounds and experiences. The key was to merge the original owners of the invention with a supporting team and infuse all with a sense of ownership. The major R&D functions added to the core group of fiberizing and glass sciences included metallurgy, fiber collection, fiber processing and fabrication, product packaging, material science, and product development. The marketing, manufacturing, and engineering expertise was added to the technology function. To increase project ownership and to enhance the overall speed at which the program could move forward, team members were moved full time onto the project and colocated to enhance communications.

An additional factor in enhancing the speed of development, was that much of the work was done in parallel. At the same time that the product was being chosen, a production facility was being designed, and consumer focus groups being conducted. The theme, ‘‘speed to market’’, continued to drive much of the decision making which was related to project timing. This resulted in a record setting, industry development time for the product of just over two years, from idea generation to plant production. The objective for speed was driven by the philosophy that making and correcting mistakes sooner by pushing to market faster would increase the total value of the venture to the company.

CUSTOMER FITNESS-FOR-USE

What did all this mean to the marketplace? Although the driving theme for the first product was ‘‘speed to market’’, this did not mean that the product was not judiciously chosen. In fact, the first product from this new fiber was focused on meeting some very specific unmet customer needs. Both the retailer’s viewpoint and the consumer perspective were considered. The retailer was looking for ways to: (1) increase profitability per square foot of floor space, and (2) increase DIY customer traffic. The new fiber addressed both these issues. By making available a smaller size package without reducing the coverage, the retailer had the option of either increasing the available selection of insulation products or decreasing the amount of space allocated to that product category. In either case, the opportunity for increased revenue per square foot was apparent. The second big win for the retailer was in the area of increased store traffic. This was achieved through creating excitement in the product category as discussed next.

The consumer’s perspective is best viewed by describing the configuration details of the first product form. The product had an R-value of 25 and a label thickness of 8.75 inches. It came in 25 foot lengths, was packaged in a 14 inch roll diameter, and was available in both 16 and 24 inch widths to fit standard, attic framing spacings. The fibers were unbindered and held together in batt form by the polyethylene encapsulation material. Other R-25 products contain bindered fibers with and without encapsulation material. Equivalent material coverage is packaged in a size corresponding to a roll of a diameter of 22 inches. Based on this design, the major benefits for the consumer came in the areas of lower irritation, conformability, ease of installation, and compact packaging. The cost to the consumer has the potential to come into play over time. As noted, the product is less expensive to manufacture but it will take time for this savings to reach the consumer.

As a ‘‘virtually itch-free’’ product, this meant that most people could rub the product on their arms without saying it itches, while a few people still had some level of irritation. Focus groups of consumers were used to validate this statement. In fact, most participants guessed the fibers were polymer-based and not glass fibers. Even when told the fibers were glass, it was not uncommon for them to argue with the facilitator to the contrary, because they were not being affected by itching.

Our surveys have shown, that the possibility of irritation was the major noneconomic reason given by consumers for not adding additional insulation in their attic. The ‘‘virtually itch-free’’ nature of this new material almost completely removed that concern. Getting past the concern for irritation allowed those who understand the value of added insulation in the form of lower energy bills and increased occupant comfort, to upgrade their level of insulation. Additionally, the added expense of hiring a contractor to install the insulation, an expense that typically would forestall the installation altogether, was eliminated. This new fiber had the potential to actually effect an increase in the DIY insulation market, by significantly reducing, and in some cases, removing the major hurdle traditionally faced by the consumer.

The new fiber went through extensive focus groups and consumer field installations to explore the task of reinsulating the attic. The quality of the finished job was found to be a major concern and the conformability of this new fiber helped to addressed that concern. Consumers noted that it was easy to conform the insulation with this new fiber in the irregular spaces in their attics. Due to the unbindered nature of the product, the width could be compressed to practically any width without the need for cutting. The product was typically placed in the cavity, compressed in the tight spots and encouraged to expand around nonuniform obstructions. Conformability was a real boost for customer satisfaction.

In examining the consumer's point of view, the issues of ease of installation and compact size of the material are best addressed simultaneously. The installer benefited greatly from the compact nature of the package. Now enough material to cover a large area could easily be transported, without paying delivery charges, and without making multiple trips back and forth to the store. The volume of R-25 for a given job has already been noted as half that of bindered insulation.

However, the real value of the compact size came during the installation process. The 14 inch roll diameter allowed the product to easily be stocked into the attic through any scuttle hole that the installer was able to go through. Further, simply because of its small size, it was very easy to carry or slide the rolls through even obstructed, trussed attics. The rolls did not need to be opened before they were positioned where needed. As noted in the discussion of conformability, the product was easily compressed to slide through narrow sections. Cutting the length of the unbindered wool was easily accomplished by drawing a utility knife through the product when placed against a piece of wood for a cutting surface. Many consumers also noted that the insulation was most easily cut, just as it was being unrolled, and before it had reached full thickness. Finally, the fibers fluffed up easily to the label thickness as a result of the handling during the installation process.

CONCLUSIONS

This has been an exploration of the development process and technology of the first insulation product containing bicomponent glass fibers. The bicomponent construction of the new fiber has been shown to be a true technological breakthrough. Its irregular shape was demonstrated to be important to the insulation product for both density and thermal conductivity as installed. The creative environment within which this development effort thrived was presented. The ''speed to market'' concept was shown to be enhanced by the key points of team work, colocation, and goal ownership.

By next focusing on the retail and DIY customers, the performance attributes enabled by this new fiber were brought to light. The value of the attributes were put into context by reviewing customer needs that were addressed by this new product. The retailer liked the way this new fiber reinvigorated the DIY attic reinsulation segment and was thrilled with the compact nature of the new product. Likewise, the consumer liked its compact nature, but also focused on the fact that the insulation did not itch like the bindered insulation it replaced. It was shown how the new product met the previously unmet needs of the DIY retail insulation market.

IMPLICATIONS FOR THE FUTURE

Taking a step back allows one to reflect on what has been done and what else needs to be done. In review, the initial product offering was chosen with ''speed to market'' in mind. There simply was not the time allocated to the fundamental understanding of the many facets of the new fiber to optimize product selection for introduction into the marketplace. Although the initial product offering allowed some significant unmet needs to be addressed, even better fits may exist in other product applications and product forms. Relative to the insulation market as a whole, however, many key themes have been covered in this discussion of the new fiber. Clearly the better thermal performance seen in Figure 5 offers weight reduction opportunities for products designed for constrained spaces. When the target R-value is for a fixed space, the thickness is no longer a variable and the product weight is simply determined by the thermal curve. Additionally, compact packaging and low irritation would be important attributes for the insulation contractor market for both residential and commercial construction.

The key for the future is to apply what is known about the technology in a way that best meets customer needs. This project has shown that applying good science can lead to wonderful advancements in product performance. Success was shown to be directly related to an emphasis on customer commitment and recognizing that the customer was the ultimate judge of a product's value.

The twenty-first century is going to be an exciting time for glass fiber insulation and Miraflex™ fibers will be leading the charge.