ABSTRACT

From the stained glass windows of medieval churches to the Renaissance monopoly of Venetian mirror makers, flat glass has brought us protection from our environment, while also reflecting its beauty. Today’s flat glass still exhibits those ancient characteristics of form and function, while carrying us into the future as a performance platform for both practical and exotic technologies.

Using a wide variety of batch combinations, we take glass from our float lines and coat, bend, shape, laminate, and temper it. The resulting products provide us with year-round comfort, protect our fabrics from fading, reduce our energy costs, block sound transmission, improve our security, and allow us to replace walls of brick and mortar with panoramas of light and natural beauty. Flat glass products also support leading-edge technologies such as flat-panel displays, liquid crystal, and computerization.

Flat glass is a product that is common to all of us—but how we manufacture, distribute, fabricate, and market glass today is as unique as our individual cultures and customer bases. To prepare for the future, we simply have to listen to the needs of our customers—and respond with the kinds of innovations that have characterized our industry for the past 3500 years. While our customer base has changed from the local prince and bishop to thousands of product applications worldwide, innovation continues to be the key to meeting our customers’ needs—and carrying on a tradition of success.

1. INTRODUCTION

AFG Industries, owned by Asahi of Japan, is one of North America’s leading glass manufacturers, with expertise in flat glass, coating technologies, fabrication, and packaging. With 10 float lines located across North America, AFG supplies glass products to many leading window fabricators, with a special focus on flat glass with low-emissivity, energy-efficient coatings. AFG also manufactures auto-motive, tinted, low-iron, and patterned glass.

With 51 fabrication and distribution locations throughout North America, AFGD specializes in architectural and commercial flat glass. AFGD manufactures a wide variety of clear, mirror, laminated, tint, medium-performance, and high-performance products that can be found in buildings across North America.

This article will focus on the past, present, and future of the flat glass industry, and I’d like to begin by looking back briefly at the history of glass manufacturing, which began nearly 3500 years ago.

2. THE HISTORY OF GLASS MANUFACTURING

Though the earliest glass was obsidian, naturally formed by volcanic eruptions, the manufacturing of glass began around 1500 B.C. in Egypt and Mesopotamia. These ancient cultures manufactured glass beads and glass vessels, using crude molding processes. Early glassmakers shaped soft glass by wrapping it around a core of sand or clay, then cooling the glass and removing the core material. Finally, the cooled glass was cut and polished.

During the next millennium, glass manufacturing became more widely practiced throughout the ancient world, and several improvements were made in the basic glassmaking process, as well as the cutting of glass. Glassmakers learned to add different ingredients to the glass to improve its strength, produce clearer glass, or produce glass in a specific color. However, glass continued to be difficult to produce, and was used primarily by royalty or in religious services.

The glass industry saw its first revolution in about 300 B.C., when Syrian glassmakers invented the blowpipe, which enabled the production of glass in countless shapes and thicknesses. The invention of the blowpipe was soon followed by the introduction of the two-part...
glass mold, which made it easy for glassmakers to mass produce identical glass objects. These two developments made glass products affordable, and for the first time they were available to the average citizen.

The Romans revolutionized glassmaking in the first century A.D. by using a variety of manufacturing processes—including free blowing, mold blowing, and mold pressing—to produce a wide range of ornately shaped glass products. Flat window glass was produced by pouring molten glass onto an iron table and stretching it—which changed the face of architecture. The Roman Empire also produced flat glass by blowing huge glass bubbles or cylinders, which were then opened and flattened. They also began to manufacture mirrors by applying a silver amalgam to their flat glass. These Roman innovations soon began to spread throughout Europe.

With the fall of the Roman Empire, however, much of the fine art of glassmaking was lost. In Western Europe, glass again became a product reserved for the wealthy, and flat glass was used to produce stained glass windows for medieval churches. However, the Byzantine glass industry continued to produce some innovations. Around 650 A.D., Syrian glassmakers developed a revolutionary new manufacturing method for producing “crown” glass. Crown glass was made by making a hole in a molten glass bubble, then spinning the soft glass to produce a thin, circular piece of glass with a distinctive “bulls-eye” pattern at its center. Because it was relatively inexpensive to produce, crown glass would be used in windows until the late 19th century.

The Venetians, who had been importing Byzantine glassware, began their own thriving glass industry in the late 13th century. In order to protect “trade secrets,” all Venetian glasshouses were moved to the island of Murano, where the Italian glassmaking Renaissance continued for the next several centuries. The Venetians perfected a manufacturing process for plate glass, which involved casting colorless glass on an iron table, and then polishing the sheet of glass until no distortions remained. The Venetians also developed a mercury foiling process that produced mirrors renowned throughout Europe. While many people involved in this process died of mercury poisoning at a young age, these mirrors could be sold at an enormous profit—and the city fathers instituted a death penalty for anyone who revealed the secret of the manufacturing process.

But, despite Italy’s best efforts, Venetian glassmaking expertise spread throughout Europe. Soon French glassmakers had improved upon Italian processes by using larger tables to make more sizable pieces of flat glass, and creating annealing ovens which cooled glass sheets over the course of several days. Glassmaking was also being perfected in Germany, Northern Bohemia, and England, where lead glass was invented by George Ravenscroft in the 1670s. Around this same time, plate glass was first produced in France through the cylinder process. Improving on a process developed by the ancient Romans, French glassmakers blew a long glass cylinder, cracked it open, and flattened it with a block of wood to form a rectangle.

With the founding of the British Plate Glass Company in 1773, England became the world’s center for quality plate glass for windows. This period marked the first time in the history of glassmaking that glazed window glass was widely available and affordable for most homeowners.

England first sought to make its American colonies a glassmaking center then, fearing competition for its domestic glass houses, outlawed glassmaking in America. With the American Revolution, however, came an influx of European glass manufacturing expertise that led to a burgeoning glass industry in the United States. The first American glassmaking innovation was a glass pressing machine that was patented in 1825. In the pressing process, molten glass was poured into a mold, and pressed into the desired shape by a plunger.

The Industrial Revolution brought a number of innovations to glassmaking, beginning with the development of an air-pressure pump in England in 1859. This pump automated the process of glassblowing, reducing the need for skilled craftsmen. Advances in chemistry also impacted glassmaking, by enabling manufacturers to alter the composition of glass products—making them stronger and more heat-resistant. In 1871, William Pilkington invented a machine which automated the production of plate glass made using the cylinder process.
method; this mechanized process was improved by J.H. Lubber in America in 1903.

Around the turn of the century, glassmakers discovered that plate glass could be “tempered” by reheating it and then cooling it again quickly. The resulting compression of the glass material would increase its strength by as much as 400 percent. This would prove especially important in the automobile industry, which was still in its infancy.

The cylinder process was made virtually obsolete when the American Irving Colburn and the Belgian Emile Fourcault simultaneously developed a new automated glassmaking process which drew molten glass from the furnace in a thin stream, then flattened and cooled it by pulling it between asbestos rollers. Though glass produced by the “draw” process was still not distortion-free, it was the highest-quality flat glass ever produced—and it helped to drive down prices across the industry. In fact, between 1920 and 1930, as the “draw” process began to dominate glassmaking, the price of flat glass dropped by more than 60 percent.

The “draw” process also made it possible to produce patterned glass, by pulling the glass through imprinted asbestos rollers. Architects and builders quickly embraced patterned glass for a number of uses in which privacy was a concern.

In the years following World War I, the flat glass industry saw phenomenal growth, thanks to a worldwide housing boom and the growth of the automobile industry. By 1929, 70 percent of all flat glass produced in the U.S. was sold to the automotive industry. Much of this was “safety glass,” produced by bonding two sheets of glass to a center layer of cellulose acetate.

However, despite improved processes used to make flat glass, the polishing process needed to produce high-quality plate glass continued to be time-consuming and expensive. As early as 1848, glassmakers around the world were searching for a way to make high-quality, polished sheets of glass without adding a separate production step.

Glass manufacturing was changed forever when Alastair Pilkington developed the modern float glass process in the 1950s, eliminating the distinction between flat glass and polished plate glass. In Pilkington’s process, molten glass was poured in a continuous stream into a shallow pool of molten metal, typically tin. The molten glass would spread onto the surface of the metal, producing a high-quality, consistently level sheet of glass that was polished by heat.

Pilkington’s process revolutionized the worldwide flat glass industry in a number of ways. It drove down the cost of plate glass dramatically, and created new applications for flat glass products, such as the exterior of high-rise office buildings. This new high-quality glass began to dominate the construction, automotive, and mirror industries, because it was a superior product at a lower price. Today, 90 percent of the world’s flat glass is still made using Pilkington’s float process.

3. MODERN DEVELOPMENTS IN THE FLAT GLASS INDUSTRY

In the 1960s, companies that were licensing Pilkington’s float process were increasing their capacity, while lowering the price of flat glass—leading to difficulties for smaller firms who didn’t yet have float capabilities. By 1975, float plants would account for 97 percent of all plate glass plants worldwide—making Pilkington’s float process one of the greatest innovations in the history of the glass industry.

The float process, in turn, enabled a number of new technologies and product developments in flat glass manufacturing. For the first time, uniform, high-quality sheet glass could be made in a variety of thicknesses, ranging from .5 millimeters to 19 millimeters or even thicker. Glass could be made thicker to address safety, security, or noise reduction concerns, while still meeting the highest aesthetic standards. In addition, the float process made it easy for glass manufacturers to vary the composition of the glass.
molten glass to make plate products for special applications—including tinted glass.

As insulating glass units and storm windows grew in popularity during the 1960s, the recently introduced float process enabled the flat glass industry to keep up with the demand for attractive, efficient, and cost-effective window glass.

With the worldwide energy crisis in the early 1970s, the demand for flat glass declined—and the entire industry suffered. Because of energy-efficiency concerns, glass was used less often in high-rise buildings. The housing industry saw a steep decline, thanks to a severe economic recession. Compact cars were using less glass and, to make matters worse, the Ford Motor Company began to produce its float glass in-house, greatly reducing sales to the auto industry. In fact, in 1970 Ford’s Nashville facility was the largest glass manufacturing plant in the world.

The glass industry responded with new technologies that answered consumers’ growing concerns about energy efficiency—and addressed new performance concerns. For example, with expanded awareness of solar energy, glassmakers developed new coatings that would help flat glass to retain passive solar and radiant heat more efficiently, as well as solar control coatings that would help to block the sun’s heat in warmer climates—while still allowing visible light transmittance. The 1970s also saw the introduction of low-iron glasses for photo-voltaic applications. These products increase solar transmittance and help convert the sun’s energy to electricity.

In addition, glass manufacturers began to introduce new high- and medium-performance reflective coatings that would enable builders and architects to achieve specific performance characteristics in terms of visible light transmittance, solar reflectance, and shading coefficient. These new high-performance products, applied through off-line vacuum deposition processes, and medium-perform-ance on-line pyrolytic coatings helped to revolutionize the architectural industry in the late 1970s and early 1980s—making possible the wide range of attractive, energy-efficient buildings we see around us today.

New mileage requirements imposed in the 1970s also presented the automobile industry with a number of challenges—and the flat glass industry developed new products and processes to help address them. For instance, glassmakers developed new laminations that made it easier to bend flat glass, accommodating the auto industry’s more aerodynamic designs. In addition, safety glass—first manufactured for cars during the 1920s—became lighter and thinner, with better shaping capabilities that helped to eliminate distortion.

As the worldwide economy improved in the early 1980s, concerns about energy efficiency remained—and glass manufacturers continued their efforts to develop innovative new technologies and processes that would maximize window performance.

Without a doubt, low-emissivity coatings were one of the biggest developments in the flat glass industry during the last decade. These coatings enable homeowners and commercial architects to take advantage of passive solar heat during the winter months, while reflecting radiant furnace heat back into the building’s interior. In addition, these new coatings reduce condensation levels by increasing the glass temperature. These revolu- tionary products are still gaining ground in the marketplace, as builders and consumers learn about the advantages of “low-E” coatings. In fact, sales of low-emissivity coated flat glass products have grown 13 percent each year since 1990.

In addition to developing its own energy-efficiency technologies, the glass industry has had to respond to new developments in the window fabrication industry. The continuing growth of vinyl windows and argon fillings, for example, has placed new demands on glass-makers who sell to window fabricators.

Another far-reaching innovation was the introduction in the late 1980s of “warm-edge” technologies, or spacer systems which reduce
heat transfer between interior and exterior lites in a sealed insulating unit. These design improvements are aimed at meeting consumers’ increasing demands for year-round comfort, greater energy efficiency, and reduced condensation levels.

We’ve also seen product and design innovations in the area of security and noise-abatement windows. The flat glass industry has developed a number of innovative tempering and laminating processes which make glass stronger to address security concerns. And, worldwide, window fabricators have created new window designs for homes and buildings in noisy areas. For example, some European manufacturers have combined different thicknesses of glass to filter various sound ranges, while others have added laminated glass to reduce noise pollution.

Since a double-digit decline in demand in the North American market in 1991, the flat glass industry has seen steady growth in the 1990s, responding to growth in both the automotive and housing industries. Glass use in the auto industry continues to grow each year, due in part to the increasing popularity of sport utility vehicles and minivans, which require more glass than traditional cars. Newer housing designs are also using more flat glass than ever before. And, while we’ve seen the construction of high-rise buildings slow a bit in recent years, that decline has been matched by a growth in the construction of three-and four-story suburban office complexes.

Table 1. These figures show 30-year growth trends in the United States flat glass market.

<table>
<thead>
<tr>
<th>Year</th>
<th>U.S. Residential Demand</th>
<th>U.S. Automotive Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1965</td>
<td>570</td>
<td>540</td>
</tr>
<tr>
<td>1995</td>
<td>2,000</td>
<td>1,300</td>
</tr>
</tbody>
</table>

Unit: Millions of square feet
Source: AFG Industries

The table above shows some interesting statistics on the growth of market demand in the flat glass industry in the past 30 years. In 1965, there were 570 million square feet of flat glass products sold to the U.S. residential construction industry. Today, that demand has risen to nearly 2 billion square feet—increasing more than 300 percent in 30 years. Similarly, U.S. sales of flat glass for automotive applications have increased from 540 million square feet to 1.3 billion square feet in that same period.

I believe these sales increases reflect, at least in part, our recent efforts as an industry to improve our products and processes to better meet customer demands. They also reflect the fact that flat glass is a product which continues to be valued in both form and function—2000 years after it was first produced by the Romans.

In the 1990s, glassmakers have continued to improve the energy-efficient low-emissivity coatings developed in the 1980s, as well as focusing on other technology and process improvements. Flat glass manufacturers are also continuing to target improvements in laminations, forming technologies, and tempering or heat strengthening processes. Recently, we’ve seen the introduction of conductive tempering, a process that uses both hot air and electrical elements to heat-strengthen flat glass products—which has given manufacturers added flexibility in this area of production.

In the lighting marketplace, glass manufacturers are focusing on improvements which will ensure that our products remain competitive with plastic alternatives, which have been growing in popularity for more than a decade.

In the mirror market, we’re all watching with interest the recent European development of on-line mirror coatings—silicon coatings which are applied during the float process. While mirror costs continue to be low, this new technology may push them even lower, while making mirror products more durable. Other technologies currently in development include copperless mirrors, and low-lead or lead-free coatings. Glaverbel, a sister company of AFG Industries, is one of the world leaders in copperless mirrors, with its Mirox products.

Glassmakers have also continued to watch and respond to developments in the worldwide automotive market. As freon has been phased out as a coolant, the flat glass industry has introduced new high-iron batch compositions that help auto glass to absorb more energy, reducing the demands placed on air conditioners. Glassmakers are also focusing on even thinner automotive glasses that reduce weight and increase mileage.

One of the most important recent developments has been the effort to perfect on-line reflective coatings which provide “built-in” solar control properties—keeping the interior of the car cooler without the need for tints or other coatings. AFG and other flat glass manufacturers are continuing to work on this technology.

4. THE FUTURE OF THE FLAT GLASS INDUSTRY

As global concerns about energy conservation and the environment continue—and government building regulations get tougher—we’re certain to see a continuing focus on energy-efficient window design. Glass manufacturers will be
investing in ongoing research on energy-efficient coatings and tints, while the entire window industry will be working to improve warm-edge technologies and other window design features.

Today, more than 90 percent of all windows sold in North America are insulating glass units, and we expect that this percentage will only rise in the future. Though many windows currently sold in the Asia-Pacific marketplace are single-glazed units, this market will probably see an increased demand for insulating units as air conditioning becomes standard and building codes become more strict. As an example of the market potential in this area, today only 25 percent of windows produced in Japan are insulating glass units.

We’re also sure to see a continuing rise in the sale of replacement windows, as existing homes age. Already, replacement windows have surpassed new windows in volume. This will most likely mean that vinyl windows will continue to be a growing product category. In fact, it is expected that sales of vinyl windows will exceed sales of wood sash windows in the U.S. by the year 2001.

The trend toward smaller suburban office buildings will probably continue as well, which means that there will be less demand for “curtain wall” windows, and increasing orders of smaller, medium-perform-ance architectural window units. Sales of “storefront” glass should also remain strong, as the retail industry continues to expand around the world.

I noted that the industry will be focusing on energy-efficient coatings and tints—and I believe there will be especially strong growth in sales of window glass with “low-E” coatings. As the chart above demonstrates, AFG’s marketing research indicates that 20 percent of all windows in the U.S. today include low-emissivity glass—and that percentage is expected to grow by more than 50 percent over the next five years. One of the major trends we’ll be seeing in the area of low-emissivity glass is the development of color-neutral products—which, unlike current products, will be colorless in both reflectance and transmittance. AFG is focusing on this area today—and we believe that color-neutral low-E glass will soon be an industry standard.

In order to ensure that our customers are using low-emissivity products most effectively, we need to educate them about energy-efficiency issues. The energy-efficient glass market is currently driven by U-value measures, which reflect heat transfer rates and often are not a true measure of window efficiency.

Low U value is not the only indicator of energy efficiency in much of the world. In fact, in areas where furnaces are used more on an annual basis than air conditioners, products with a lower U value can actually be less energy-efficient if they have a lower shading coefficient, because they block too much natural solar heat—causing furnaces to work longer and harder to achieve a comfortable indoor temperature.

In these cooler climates, pyrolytic low-emissivity products have been shown to block 71 percent of radiant furnace heat from escaping a building in winter, while allowing 72 percent of available solar heat to enter. Low-emissivity glasses with stacked coatings, on the other hand, are better for climates where air conditioning is used more on an annual basis. Stacked coatings block more solar heat than pyrolytic coatings, making these products ideal for areas with warm temperatures year-round.

In order to win consumers’ confidence in low-emissivity glasses, we need to ensure that builders and homeowners understand these energy-efficiency issues—and are installing low-E glasses that are right for their particular heating and cooling needs.

In addition to low-emissivity coatings, I believe we’re going to see significant growth in sales of insulating glass units which use “warm-edge” technologies, as consumers become better educated about energy efficiency. I also think we’re going to see significant improvements in the technology behind warm-edge designs in the next few years.

The thermographs on the next page illustrate the ongoing progress in energy efficiency we’ve seen as a result of warm-edge technology improvements. Introduced in the late 1980s, first-generation warm-edge technologies focused on two design innovations: replacing traditional aluminum spacers with less heat-conductive materials, and changing the shape of the spacer.
to provide a "thermal break" that would help reduce heat transfer. These first-generation warm-edge technologies provided marginal improvements in both sill temperature and condensation threshold, while in some cases costing less than traditional spacers.

The second generation of warm-edge innovations, introduced in the 1990s, eliminated metal components entirely, replacing them with such man-made materials as rubber and extruded plastics. Though more expensive than first-generation spacer designs, these innovations brought about significant improvements in both sill temperature and condensation threshold. However, because of their higher price, these spacer designs have not won universal consumer acceptance—and much of the industry has continued to focus on first-generation technologies, even today.

I believe we’re about to see a new third generation of warm-edge technologies that combine first-generation cost benefits with second-generation performance. Flat glass manufacturers need to monitor ongoing improvements in warm-edge technologies—and ensure that our window products are compatible with these warm-edge systems. We also need to actively support the development of even more energy-efficient window designs to help satisfy consumers around the world.

Another major area of focus in the industry in the next decade will be electrochromics and photochromics. “Smart window” technologies have already been developed that allow flat glass to sense changes in light and adjust accordingly—for example, to block out sunlight during the brightest parts of the day, or to capitalize on available light during overcast days. These glasses are coated with special materials which change as different voltages are applied across their surfaces. This technology, which has the potential to make shutters, blinds, and draperies obsolete, could become affordable within the next three to five years—and may signal the next revolution in the window industry. Flat glass manufacturers are already preparing to enter this promising new marketplace.

Today, 28 percent of all flat glass is used in the automotive industry—and, as sport utility vehicles and minivans continue to grow in popularity, that percentage will only increase. For that reason, the flat glass industry continues to focus much of its attention on innovations for this market. As concerns about performance and air conditioning use continue, flat glass manufacturers will continue to focus their efforts on developing thinner, lighter, stronger glass products which also control solar energy.

An important development for the automotive market is the continuing work on flat glass products which will accommodate “heads-up” displays, which reflect dashboard readings onto a car’s windshield, where they can be more easily read. This new technology, which is made possible with specialty coatings, has the potential to spread across the automotive industry, as well as the commercial airline industry. It is certainly an area of development that deserves our attention.

Another innovation that will impact the auto industry is the development of “switchable” mirrors that respond to changes in light, reducing glare during night driving. In addition to improving safety, these new mirrors are more durable than existing automotive mirrors. As these mirror products decrease in cost, they will quickly become a standard feature in every new car—and flat glass manufacturers need to prepare for this market shift.

Another standard feature will be metallic-coated windshield glass, which acts as an antenna and eliminates the need for a traditional radio antenna. This technology has already been introduced in many new cars, and is expected to spread across the industry—increasing the demand for these conductive glass products.

The display market is changing radically as we approach the 21st century—and new technology developments are certain to have a huge impact on the flat glass industry. New display technologies use special coatings to generate electrical impulses across flat glass, making televisions much more precise, as well as much flatter.
As flat-panel displays become a reality—displacing standard cathode ray tube displays—an enormous new market opportunity is on the horizon for glass manufacturers. We need to be ready to supply this new market with high-precision specialty coatings that help to make this new technology cost-effective as demand for high-definition, flat-panel televisions increases. Much industry effort right now is focused on trying to improve low-emissivity and other coatings for this application.

Other opportunities in the display market include improved glass for computer monitors, as well as more sophisticated liquid crystal display technologies. Again, flat glass manufacturers are investing in research and development work in these areas. Just as the invention of the automobile impacted the flat glass industry nearly a century ago, the new era of display technology is sure to bring changes for all of us.

Now I’d like to turn to the increasing globalization of the flat glass industry. As I demonstrated in the first part of this article, the glass industry had traditionally been centered in Europe and, later, North America. But, as the patents for Pilkington’s float process have expired, the cost of entering the flat glass business has decreased—and float lines have been springing up in many new areas. As we approach the turn of the century, any new market demands will be met by glassmakers around the world. As the chart below demonstrates, we are truly becoming a global industry.

Table 2. Shown here are statistics on float lines worldwide, as reported by Glass International in March 1997. Only the highest-producing countries are represented.

<table>
<thead>
<tr>
<th>Country</th>
<th>Float Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>47</td>
</tr>
<tr>
<td>U.S.</td>
<td>38</td>
</tr>
<tr>
<td>Japan</td>
<td>14</td>
</tr>
<tr>
<td>Germany</td>
<td>11</td>
</tr>
<tr>
<td>Russia</td>
<td>10</td>
</tr>
<tr>
<td>Indonesia</td>
<td>8</td>
</tr>
<tr>
<td>South Korea</td>
<td>7</td>
</tr>
<tr>
<td>Italy</td>
<td>7</td>
</tr>
<tr>
<td>France</td>
<td>7</td>
</tr>
</tbody>
</table>

Source: Glass International

Just how will future flat glass demand be met? The chart below looks ahead to the year 2000 and projects future glass demand and production capacities for the entire world, excluding Russia. As our industry expands, production capacity is outpacing growth in global demand levels by about 1 percent per year.

Table 3. This chart demonstrates projected growth in global flat glass demand through 2000.

<table>
<thead>
<tr>
<th>Total World (excluding Russia)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand</td>
</tr>
<tr>
<td>Capacity</td>
</tr>
</tbody>
</table>

Unit: Thousands of short tons
Source: AFG Industries

The table below breaks those world numbers down into three different regions. The Asia-Pacific region is projected to continue its strong growth—accounting for more than 50 percent of global flat glass capacity by the year 2000. This capacity increase is, however, significantly outpacing demand in this region. Europe and the Americas will also have enough production capacity in place to meet their own glass needs. As regional demand has increased, it has been matched by the construction of new float lines in every geographic market.

Table 4. This chart illustrates the projected demand and capacity in three global regions for the year 2000.

<table>
<thead>
<tr>
<th>Region</th>
<th>Projected 2000 Demand</th>
<th>Projected 2000 Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia, Pacific</td>
<td>15,217</td>
<td>17,174</td>
</tr>
<tr>
<td>Africa, Middle East (except Russia)</td>
<td>7,555</td>
<td>8,706</td>
</tr>
<tr>
<td>North, Central, South America</td>
<td>7,169</td>
<td>7,857</td>
</tr>
</tbody>
</table>

Unit: Thousands of short tons
Source: AFG Industries

While we can always hope to win a certain percentage of new business by improving our service levels and our product quality, we still need to keep a close eye on worldwide supply and demand ratios, and ensure that we are remaining competitive with the rest of the global industry.

Obviously, in this kind of global marketplace, the supply and demand ratio will be a key factor for flat glass manufacturers around the world. Profit margins in China have all but disappeared, with the selling price about equal to the cost of production.

Glassmakers who want to compete in the new global marketplace of the future will need to cut their costs by developing new, more efficient ways to produce, process, and deliver their glass.
to customers around the world. For example, in the past year, cargo shipping rates have dropped by 10 percent, and that trend is expected to continue. Historically, glass has been expensive to transport. But, as the global industry base evolves, we will find ourselves in more direct competition. Cost-cutting, balanced by new product development and superior customer service, will be essential to our survival.

The real key to success in the flat glass industry lies in looking at the past of our industry. I believe it is innovation that will determine the course of the next 10 or 20 years in our industry, just as it has for the past 3500 years. From the early development of glassmaking in the Roman Empire to the invention of the float process, our industry has always been characterized by revolution and innovation—by the ability of glassmakers to look ahead to the future.

I believe that this pattern of innovation will continue to lead our industry to new heights — and help glass manufacturers around the world to achieve success, even in today’s increasingly competitive marketplace. It is this challenge that all of us must answer if we hope to live up to our industry’s past.

As glass manufacturers and processors, we are in a unique business, with a long tradition of providing products that customers find attractive in both form and function. After all, how many modern industries are 3500 years old? To continue our tradition of continuous product improvement, we need to remember that it is customers who drive our industry. We need to be aware of the needs and expectations of our customers around the world, and answer those needs with product innovations that they truly value. If we can do that, then we can not fail to achieve continued success as an industry.

REFERENCES