glasstech® World

Special Edition

Solar Cells, Inc.

This Glasstech-related company's major accomplishments include:

- **Evaluated semiconductor materials.** Analyzed amorphous silicon and cadmium telluride and selected cadmium telluride as the semiconductor material.
- **Created deposition and production systems.** Designed a continuous deposition and encapsulation line and built a prototype. Also constructed a full-scale deposition line in Perrysburg, Ohio. This was the initial **First Solar, Inc.,** production line.
- **Increased conversion efficiency of cells.** In the late 1990s, a **Solar Cells'** unit with cadmium telluride achieved a then world's record for the highest efficiency for a thin-film photovoltaic module at 13.2 percent.

Solar Energy: Glasstech Builds On Its Pioneering Ideas

Company and founders played major role in development of photovoltaic modules. Impact continues to be felt in the recently announced Solar Products Business Unit.

Today, the world is going "green."

The green movement is toward natural products and processes that do not harm the environment, yet still provide for progress and mankind's comfort. One of the best examples of this movement is solar energy development. Today, companies are forming or expanding at a rapid pace to provide energy from the sun's rays.

Many may think solar energy is a 21st century development. To the contrary, there has been experimentation with solar energy devices going back many decades. **Glasstech Inc.'s** founders, Harold A. McMaster and Norman C. Nitschke, first began investigating solar energy during the energy crisis of 1973 – 1974, just three years after Glasstech was formed and eventually settled in Perrysburg, Ohio.

What McMaster, Nitschke and their employees learned, and what they and the company accomplished, are a rich heritage upon which the recently formed Glasstech **Solar Products Business Unit** now is based. The unit currently markets five specially modified Glasstech systems for the mass production of shaped and flat glass substrates for solar energy collectors.

Mark D. Christman, Glasstech President and CEO and Norman C. Nitschke, Glasstech's Co-founder

In a recent series of interviews, Nitschke, a true pioneer in the glass processing field and now a senior spokesman, talked about his and Glasstech's involvement in solar energy development, primarily from the mid-1970s through the mid-1990s. He also talked about his and McMaster's continued activity in the field after they officially retired from Glasstech. Mark D. Christman, Glasstech President and CEO also participated in the interviews.

But why did Nitschke and McMaster, two "glass men," become so deeply involved in the early development of solar energy technology? What did they and Glasstech develop? What giant of the photovoltaic industry is the direct descendant of the work of these glass men and their company?

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An Idea for the Good of the Country and the Company

Primarily, Glasstech was interested in solar energy to ensure a potential market for its glass processing systems. Additionally, McMaster, the inventor and entrepreneur, was interested in solar energy as a way of relieving the world's reliance on fossil fuels.

"We got interested in photovoltaics [a form of solar energy collection] because it was another outlet for glass from our end. If you look at the fields of solar panels that are beginning to dot the landscape worldwide, that's a lot of glass," Nitschke said.

Throughout Glasstech's first decade plus, Nitschke said he and McMaster would discuss solar energy and how glass could play a role in this inevitable development.

In 1984, Nitschke and McMaster, along with Glasstech, created **Glasstech Solar, Inc.,** and located it in Wheat Ridge, Colorado, to be near the National Renewable Energy Laboratory in Golden, a part of the U.S. Department of Energy.

"When we founded Glasstech Solar, we actually set two goals for it," Nitschke said. "First, the company was to research ways of increasing the conversion efficiency of photovoltaic modules made from amorphous silicon and to identify ways to use the modules. Second, it was to create systems for the production of large-sized photovoltaic modules on a continuous basis."

He explained the idea was that glass panels, processed on Glasstech systems, would serve as substrates for the resulting photovoltaic modules.

According to Nitschke: "We started seriously looking at producing amorphous silicon panels of substantial size that would serve as a way of generating electricity on a good-sized scale. We didn't think as much about putting it on a house or anything like that as much as building a field of row after row of panels tied together to feed into the electric grid or supply power to a free-standing installation.

"At the same time, we knew we had to have what we called the balance of systems," he said. "This included a way to convert DC power to AC, build up the voltage to tie it to the grid and mount the panels solidly enough so they would withstand hail tests and wind tests. The John Hancock Tower in Boston was falling apart about that time."

Glasstech Solar produced laboratory-sized coating lines that coated small pieces of glass up to a foot square. It also conducted research into other uses for amorphous silicon-based photovoltaic modules, including thin-film transistors.

Glasstech Solar received a contract to build a much larger, continuous coating line and moved from Wheat Ridge to larger space in Arvada, Colorado. Concurrently, what had been a theoretical concern became much more realistic.

> Solar Cells was to use Glasstech Solar systems to produce panels and build generating fields, thus commercializing solar energy.

"It was at this time," Nitschke explained, "we found we'd not been able to pass all the weathering tests – the impact tests, hail tests – with amorphous silicon. On a small scale, amorphous silicon worked pretty well, at first; but, then, we found it didn't retain its efficiency. It would drop 20 percent in the first weathering test. And, it appeared it would be more difficult to make large panels."

It was this troubling news that led Nitschke and McMaster to look in another direction.

A goal: Create systems for continuous production of large-sized PV modules.

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The Second Half of the Idea

In May 1987, Nitschke and McMaster formed **Solar Cells, Inc.** Later that year, other investors were added, primarily from the Toledo, Ohio, area.

"You'll remember, our goal was for Glasstech Solar to develop systems that would generate solar energy," Nitschke said, "so that it [the electric power] could be fed into the commercial electric grid or be used to power free-standing installations. This meant producing actual photovoltaic modules on large glass substrates up to four-by-eight feet.

"To move this goal forward, we began Solar Cells, Inc., in May 1987, to use systems created by Glasstech Solar to produce the panels and build the generating fields, thus commercializing solar-energy generation," he said.

In conjunction with Solar Cells' development, Nitschke and McMaster heard about and began to look into cadmium telluride as a possible semiconductor material for the collection of solar energy.

Solar Cells eventually hired Peter Meyers, an early cadmium telluride researcher, to develop a system to deposit cadmium telluride on large glass substrates that had been processed on Glasstech equipment.

According to Nitschke, "Cadmium telluride is a material that never goes through a liquid phase; it sublimes from a solid to a gas, just as dry ice does. One of the things we did at the beginning was to make little platinum boats and fill them with powdered cadmium telluride. We'd heat the boats to a very high temperature so that a vapor appeared, which would condense on whatever's somewhat colder. It doesn't take much difference in temperature to do that."

> Solar Cells' Vapor Transport Deposition technology was key to thin-film, flat plate, photovoltaic modules for direct sunlight to electricity production.

Initially, this method was used to coat the bottom of the glass part. However, depositing the coating on the top of the piece of glass presented greater problems.

"A real breakthrough," Nitschke said, "came when we tried transporting cadmium telluride powdered particles in a stream of gas from outside the chamber to a vaporizing station above the glass, where the particles were vaporized at temperatures considerably above 1100 degrees centigrade. This vapor then condensed on the top surface of the glass. The development of this deposition system eventually resulted in a successful cadmium telluride film."

In 1990, Solar Cells decided to make a process change and go away from amorphous silicon and concentrate on cadmium telluride.

Solar Cells leased laboratory space from The University of Toledo, and the solar operations moved from Glasstech to UT in early 1991.

Nitschke retired from active management at Glasstech in 1989, but he continued to work with Solar Cells as a board member. In 1993, McMaster also retired from Glasstech. However, he continued at the helm of Solar Cells for several years.

In the mid-1990s, Solar Cells made progress and outdoor testing showed photovoltaic modules made from cadmium telluride deposited on glass substrates did not lose efficiency.

The eventual, successful development of the patented Vapor Transport Deposition technology by Solar Cells (depositing cadmium telluride on large glass substrates, up to four-by-eight feet) was the key breakthrough that led to the burgeoning development of thin-film, flat plate, photovoltaic modules, which produce electricity directly from sunlight.

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Solar Energy:
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Bringing the Idea to Commercialization

As often happens with high technology start-up businesses, it took a long time and sizeable financial commitment to commercialize Solar Cells' technology. Despite some financial softness, the company built a full-scale deposition line.

And, while this work moved forward, Nitschke, McMaster and Solar Cells' other investors were searching for a partner who would help them move their company and its technology to the next level.

"We came to an arrangement in 1999 with True North Partners [Phoenix, Arizona] to create a new entity," Nitschke said. "Solar Cells contributed its technology, and True North Partners contributed the financing to move the project toward on-line production. So, our technology had reached a value in the range of eight figures. Finally, there was a tangible value to our work.

"This was the beginning of what has become First Solar."

In 2003, Solar Cell's interests were purchased by First Solar.

As Nitschke notes: "It is fair to say that the company that grew to be one of the original and the world's largest manufacturers of photovoltaic cells was built on technology developed by Solar Cells and commercialized by First Solar."

Both Nitschke and McMaster continued their interest in solar. At the time of his death in late summer 2003, McMaster was still working and experimenting with solar energy and related fields.

Nitschke remains an active investor in the solar energy industry.

Building Upon the Idea

Thanks to the groundbreaking work done by Nitschke and McMaster in both solar energy and glass processing in general, Glasstech's Solar Products Business Unit has a superior and very firm foundation.

The business unit's lengthy roots include an insider's understanding of the solar industry and one-of-a-kind experience combined with Glasstech's acknowledged leadership in the development of bending and tempering systems for the processing of glass for the automotive and architectural markets.

Glasstech President and CEO Mark Christman, also a participant in the series of interviews, stressed how insightful Nitschke and McMaster were back in the early 1970s.

"What we've seen so far in the market is that Harold and Norm's vision has been correct," Christman said.

Mark Christman, Glasstech President and CEO

"I mean, their initial strategy was that if you can create the photovoltaic cell, it would utilize glass as a substrate. Therefore, Glasstech would have the opportunity to provide equipment that would process that glass.

"Currently, we're selling equipment to glass fabricators," Christman said, "who are, in turn, supplying glass substrates to solar panel manufacturers. For example, First Solar is producing solar cells with glass that's coming off of Glasstech equipment. So, it was a perfect circle, even though Harold and Norm eventually withdrew from the First Solar joint venture. Glasstech ultimately is selling equipment that is producing the tempered substrates used by First Solar."

Christman predicted Glasstech sales to the solar products market one day in the near future will exceed its sales to the automotive market. "And, it's not because automotive sales are declining; our automotive sales are still very strong. We see a rapidly developing and incredibly strong

Companies are moving at a rapid pace to provide energy from the sun's rays.

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market for future equipment sales to the solar industry," he said.

"We're positioning ourselves as a total solar provider. Complementing our photovoltaic legacy," Christman said, "the company's Solar Cylindrical Radius Bender, the CRB-S, produces parabolic trough reflectors four-to-five times stronger and at higher speeds than current methods."

The CRB-S™ is one of five systems currently offered by Glasstech's Solar Products Business Unit, which produce precisely bent or curved glass parts ideal for the concentrating solar power (CSP) and concentrating photovoltaic (CPV) markets and the extremely flat glass parts required by the PV markets.

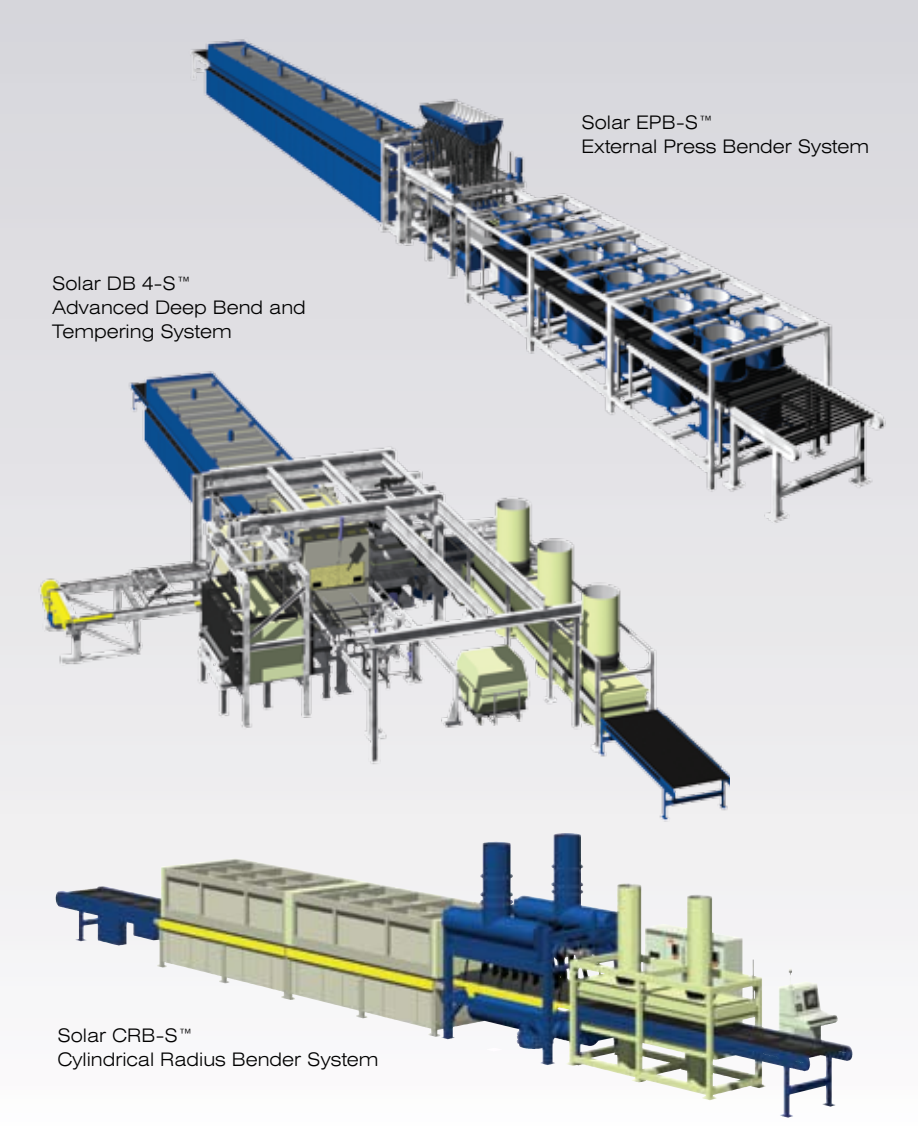
Glasstech-processed parts meet the solar industry's requirement for reliability, repeatability, tight specifications and cost effectiveness.

CSP and CPV Systems

Glasstech's **Solar Cylindrical Radius Bender** is the world's most efficient and precise system, processing tempered and heat-strengthened, parabolic trough reflector glass shapes for concentrating solar power. The system processes glass from 1.6mm up to 5.0mm into specified shapes without dedicated tooling. Shape changes take minutes and energy savings are significant, since no molds are heated.

The **Solar External Press Bender System (EPB-S™)** for tempering and heat-strengthening produces high-quality, economical, accurate bent parts with minimum tooling and fast cycle times. The EPB-S is ideal for smaller, high-volume spherical and parabolic shapes.

The **Solar Advanced Deep Bend and Tempering System (DB 4-S™)** for tempering and heat-strengthening produces complex parts for dish segments and smaller, high-volume spherical and parabolic solar collector deep-bend shapes.



Solar EPB-S™
External Press Bender System

Solar DB 4-S™
Advanced Deep Bend and
Tempering System

Solar CRB-S™
Cylindrical Radius Bender System

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PV Systems

The **Solar Electric Radiant Heater Flat Glass Tempering System (ERH-S™)** is a continuous, flat glass tempering system for fabricating glass specified for silicon wafer-based photovoltaic panels or thin-film photovoltaic solar panels. The system is ideal for heat treating active (coated superstrate) glass, high light transmission (low-iron) smooth or textured cover panels, rigid back panels and clear glass for PV panels.

The **Solar Forced Convection Heater Flat Glass Tempering System (FCH-S™)** is Glasstech's gas-fired convection heater system alternative. The FCH-S also is a continuous, flat-tempering system. It normally requires less floor space and potentially can offer significant energy savings compared to an electrically heated system.

Both PV-targeted systems offer high productivity and meet the solar industry's very precise flatness specifications.

Keeping the Idea Alive

Throughout the interviews, Nitschke and Christman commented on the foresight of Glasstech's founders and the resulting formation of not only an industry segment – photovoltaic modules – but also new uses for the company's highly innovative glass processing systems.

So, what does Glasstech plan in the future for its Solar Products Business Unit?

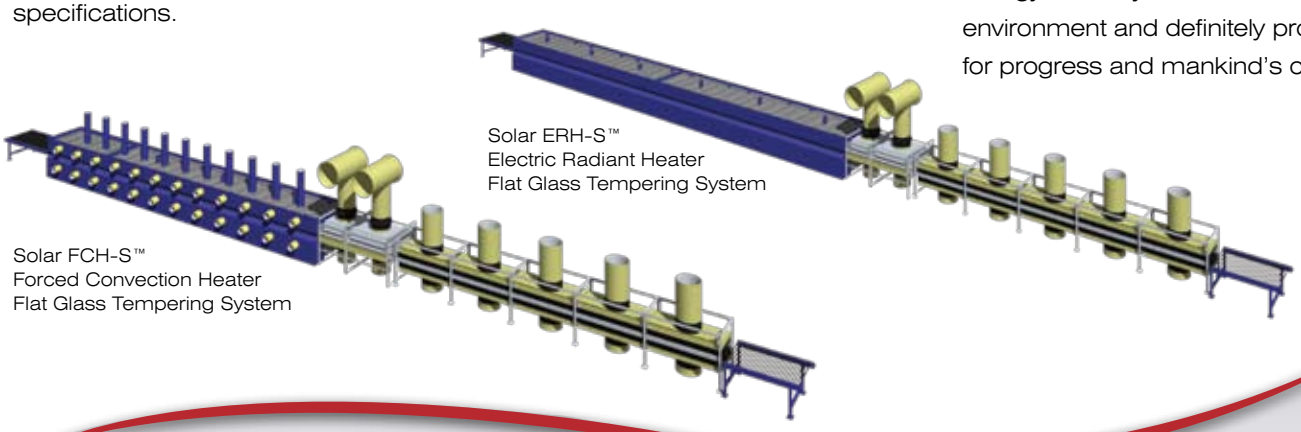
According to Christman: "Our technical development activities are ongoing and will improve the quality of glass used in concentrating solar and solar PV applications. We have robust equipment that's very cost effective and produces very high-quality glass. We're well positioned and will continue to do what Glasstech has done well through the years, which is to listen very closely to our customers' needs and improve our technologies to better meet those needs.

"We want very much," Christman said, "to be the go-to company for anybody in the solar industry that's looking to use glass as a substrate, much in the same way we've done in the automotive and architectural industries through the years."

The solar energy idea Nitschke, McMaster and Glasstech first developed during the 1970s is much like an evergreen tree that remains green throughout the seasons.

> Glasstech offers five systems that produce precisely bent or curved glass parts for CSP and CPV markets and extremely flat glass for PV panels.

Their solar energy idea definitely fits with today's "green" movement and will play a prominent role in the future of the company and the environment. And, like the green movement, solar energy certainly does not harm the environment and definitely provides for progress and mankind's comfort.



Solar ERH-S™
Electric Radiant Heater
Flat Glass Tempering System

Solar FCH-S™
Forced Convection Heater
Flat Glass Tempering System

Glasstech equipment provides reliable, repeatable results at high throughput.

Solar energy technology will play a prominent role in our "green" future.

Timeline: Glasstech's Pioneering Solar Involvement

1971

- Harold McMaster, Norman Nitschke and Frank Larimer form **Glasstech, Inc.,** to temper "safety" glass for patio doors.

1974

- The "energy crisis" gets Harold McMaster thinking seriously about solar energy. Discusses with Norm Nitschke.

1984

- **Glasstech Solar, Inc.,** Wheat Ridge, Colorado, launched by McMaster and Nitschke to research photovoltaics using amorphous silicon and to create production systems.

1987

- **Solar Cells, Inc.,** Toledo, Ohio, formed by McMaster and Nitschke and later joined by other investors to produce commercial-sized installations using equipment developed by Glasstech Solar.

1989

- Nitschke retires from Glasstech management. Remains on Solar Cells board.

1990

- Solar Cells abandons amorphous silicon and identifies cadmium telluride as a more promising semiconductor material.

1993

- McMaster retires from Glasstech but continues hands-on management of Solar Cells.

1998

- Solar Cells develops the patented Vapor Transport Deposition approach to applying thin films of photovoltaic-sensitive, semiconductor material and metals on glass substrates.

1999

- Solar Cells joins with True North Partners, LLC, Phoenix, Arizona, to form **First Solar LLC**.
- First Solar finishes building production plant in Perrysburg, Ohio, started by Solar Cells.

2003

- Solar Cells, Inc., doing business as McMaster Energy Enterprises, forms a new entity, Solar Fields, Inc. Nitschke invests in Solar Fields.
- Solar Cells' interest in First Solar is purchased by First Solar.
- McMaster dies in August.

2007

- Solar Fields begins merger into Calyxo GmbH, a wholly owned subsidiary of Q-Cells AG of Germany, to build a production facility for commercial photovoltaic modules using a cadmium-telluride technology developed by Solar Fields.

A prolific inventor, Nitschke is named on approximately 40 U.S. patents.

A True Pioneer

Norm Nitschke, Glasstech's Co-founder

Norman C. Nitschke has spent his entire professional life as an innovator in the field of glass processing. A true pioneer in the field, today he is a senior spokesman and active investor in solar energy, an area in which he played a prominent developmental role. For more than 50 years, the professional lives of Nitschke and the late Harold A. McMaster were inseparable.

The two met in 1948 when McMaster, then head of the technical control department for Libbey-Owens-Ford Glass Company, Toledo, Ohio, hired Nitschke to work as a development engineer. At the time, Nitschke was working in Sun Oil Company's exploration department in Beaumont, Texas. He had graduated from The University of Michigan with bachelors' degrees in electrical engineering and engineering physics in the mid-1940s.

By the end of 1948, McMaster had formed his own company, Permaglass, Inc., Genoa, Ohio, near Toledo. Originally, the company processed glass parts for appliances and implosion plates for television sets. Eventually, Permaglass grew to seven plants internationally and pioneered bent and tempered glass for the auto industry.

Nitschke rejoined McMaster in 1951 as vice president of engineering for Permaglass. Together, they recorded many engineering firsts, including the introduction of thinner, tempered automotive glass and the development of the air-float process for bending and tempering automotive glass. In December 1969, Permaglass merged with Guardian Industries, Detroit, Michigan.

Two years later, Nitschke, McMaster and the late Frank A. Larimer, previously Permaglass' vice president and general manager, formed Glasstech, Inc., now of Perrysburg, Ohio. In the ensuing years, Glasstech has developed into the world's leading innovator, designer and producer of processing systems for bending, tempering and heat strengthening glass for the solar, automotive and architectural markets.

In addition to glass processing, Nitschke and McMaster were principals in the development of Glasstech Solar, Inc., Wheat Ridge, Colorado, (1984 – 1990) and Solar Cells, Inc., Toledo (1987 – present), companies that helped develop the thin-film technology used today to collect solar energy by means of photovoltaic modules.

Nitschke retired from Glasstech's active management in 1989, but he continues to be active in the solar field as a shareholder of Solar Cells, Inc., and Solar Fields, Inc., Perrysburg, a successor to his and McMaster's ongoing solar development activities. McMaster, who was inducted into the National Inventors Hall of Fame in 2008, died in August 2003.

Nitschke is a prolific inventor and collaborator and is named on approximately 40 U.S. patents and numerous corresponding international patents.

He played an important role in establishing both the Z-26.1 standard for automotive safety glass and the Z-97.1 standard for architectural safety glass of the American National Standards Institute (ANSI). His involvement included founding and serving as president of the Glass Tempering Association, as an early member of ANSI, and as first president and chairman of the Safety Glazing Certification Council for eight years.

Today, Nitschke continues to be an investor in the solar energy field. He divides his time between Perrysburg, where Glasstech's headquarters are located, and visiting with family and friends. Nitschke says he simply hopes to be remembered as a "significant contributor" in the development of both glass processing and solar energy.

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