



# Fiber Reinforced Plastics Shop Implements Light RTM to Produce Parts

Minnesota Technical Assistance Program ■ CASE STUDY

<b>Company</b>	Phoenix Industries Crookston, MN
<b>Change</b>	Converted 60 percent of molded part production to closed molding. Light RTM is used for a quarter of that (15 percent).
<b>Cost</b>	\$10,000 for new equipment. Cost per part reduced by ten percent. Payback was less than two years.
<b>Benefits</b>	Reduced 80,000 pounds of styrene emissions over two years. 20,000 of this was due to Light RTM. Cleaner production. Better material efficiency.

## Closed Molding Replaces Open Molding

Converting from open-mold to closed-mold processes reduces emissions and optimizes the glass-resin ratio, producing a higher quality laminate, and allowing both sides of the part to have a finished appearance. With advances in FRP materials, closed molding has become a viable technology, finding renewed interest as it demonstrates success. Vacuum molding is one relatively simple and affordable means for open molders to move to closed molding.

In two years, Phoenix Industries converted 60 percent of its open molded parts production to closed molding. The company selected Resin Transfer Molding (RTM) and Light RTM technology as its vacuum molding systems. The conversion reduced 80,000 pounds of styrene emissions during 2000 and 2001. Light RTM is used for a quarter of the closed molding (15 percent overall). Phoenix uses Light RTM when a part is produced less frequently because it is less costly to use on a smaller scale than RTM. The company plans to continue the conversion to closed molding, anticipating additional significant bottom line benefits.

## Light RTM

Light RTM is a vacuum-assisted, low-pressure, resin injection system. The vacuum draws the resin through the mold, limiting the pressure needed for injecting the resin. Because limited pressure is used, the molds do not require extra engineering, helping to keep costs down. Light RTM results in lower environmental emissions, improved quality and part-to-part consistency, and reduced per part cost. Light RTM has nearly universal application. If a part can be "pulled"—part configuration allows molds to easily separate—it is a candidate for Light RTM.

Three major components make up this molding system: a two-part mold, a vacuum source and a low-pressure resin injection pump.

Phoenix Industries, in Crookston, Minnesota, produces fiber reinforced plastic (FRP) parts in a 100-person job shop. The parts, produced by open and closed molding techniques, vary in shape, size and end use.

Reducing styrene emissions was a priority at Phoenix Industries for a number of years, primarily driven by worker exposure and air permitting requirements. The U.S. Environmental Protection Agency (EPA) classifies styrene as a hazardous air pollutant. The National Emission Standards for Hazardous Air Pollutants (NESHAP) for the reinforced plastic composites industry became effective August 2001, limiting styrene emissions from FRP shops.

Converting to nonatomized spray resin application equipment and using low styrene resins in its open mold process significantly reduced the company's emissions. Phoenix Industries saw closed molding as an opportunity to further reduce emissions, enhance the efficiency of material use in FRP manufacturing and improve part quality.

The general steps to producing a Light RTM part are:

1. Gelcoat as normal.
2. Manually place the reinforcing media in the mold.
3. Bring together the two halves of the mold and draw a vacuum to seal their contact areas.
4. Inject resin to coat the part's perimeter. Then apply vacuum near the mold's center to draw resin through the glass media towards the vacuum source.
5. Cure, demold and finish the part as usual.

Jeff Burgess, Phoenix Industry's CEO, was brought into the company because of his experience with closed molding. The following information is based on his knowledge and on his experience at Phoenix Industries.

## Equipment Basics

The cost to investigate and use Light RTM on a small scale can be minimal. Small, simple parts currently open molded are ideal candidates for testing closed molding and seeing quicker successes. Starting with smaller parts of a non-technical configuration allows experience to be gained without major risk.

## Molds

If an FRP shop has internal expertise building open mold tooling, it can quickly learn to build Light RTM molds. Having in-house capability to make molds holds down Light RTM mold cost. Most open molds can be modified into Light RTM molds. Among other minor changes, mold flanges need to be widened to six inches so the countermold—the second half or top mate to the mold—can be securely held in place. Light RTM and open molding place a similar level of stress on the mold, unlike conventional RTM which puts the molds under greater pressure when injecting the resin. This means that molds for Light RTM have similar strength requirements as open molds, allowing the same construction materials to be used.

Counter molds can be built using a number of techniques. One technique uses calibrated wax which comes in sheets and rolls to help build the countermold. Two layers of wax are pressed into the mold, matching the part's thickness. The sheets of the bottom layer are spaced with small gaps between them to function as vacuum channels. A second continuous layer of wax is positioned over the first. The original mold is connected to a vacuum source which pulls the two layers of wax together, holding them in place while the countermold is cast over them. Gaskets, gauges, and resin and vacuum ports

are installed to complete the countermold. Because both a mold and countermold are needed, building tools for Light RTM costs about two to two-and-a-half times more than open molding.

FRP material suppliers have videos demonstrating the basic steps of this and other mold building techniques. More extensive formal training for mold building and process training is available. The cost for two operators over five days is around \$10,000.

## Positioning Resin and Vacuum Ports

Injection pushes resin into the mold, but its flow through the media is due mostly to the vacuum's pull. The level of vacuum limits the flow rate. Resin injection ports are positioned on the mold to obtain adequate initial wetting. Good resin flow through the media depends on properly positioning the vacuum ports in relation to the resin injection ports. Computer simulation of resin flow through a mold can help determine where to place vacuum and injection ports. To ensure that the resin travels through the media at a constant rate, vacuum ports should be spaced at an equal distance from the resin injection ports, this distance is measured along the mold's contour. Multiple resin injection and vacuum ports may be necessary to achieve this.

## Vacuum Source

Systems capable of attaining a vacuum of around 30 inches of mercury are required for Light RTM. A number of low cost vacuum options are available. If the plant has compressed air, a venturi vacuum generator can meet the requirements of small molds. It costs less than \$100. For larger molds, rotary vane vacuum pumps are available for about \$300. For full-scale production, portable vacuum systems rigged to handle Light RTM are available for \$5,000 and higher.

## Low-pressure Resin Injection Pump

A pumping system is required to feed resin to the mold. With minimal expense, FRP shops may be able to modify existing resin application equipment for use as a pump while they experiment with Light RTM. Equipment specific to Light RTM costs around \$5,000.

## Implementation Issues

### Good Process Control

Process control is absolutely necessary to produce consistent, quality parts. Key factors include:

- Tightly controlling the temperature and viscosity of the resin used because they both affect how the

resin flows through the media. Bad parts can result if these variables fluctuate significantly.

- Thoroughly checking the mold setup for vacuum leaks before injecting resin. Leaks dramatically impact how the resin flows through the media and will cause bad parts.
- Selecting and placing glass reinforcing media. A conformable, advanced reinforcement media may be required for complex parts. Improperly placed media can lead to mischanneling of the resin and poor mating of the mold and countermold. These both result in non-wetted areas and a bad part.

### Reinforcing Media for Complex Parts

Conventional glass reinforcement works fine for parts of simple configuration, especially if mating the mold and countermold requires little effort. Because conventional glass materials do not readily conform to a part's shape, complex parts can be very tedious and challenging to load. Advanced reinforcing medias have a sandwich construction with glass on the outside and a synthetic interior which allows resin to flow easily. Its conformable "memory" helps control placement. Its compressibility makes building variations in part thickness easy. This newer generation of materials reduces the amount of labor involved with media placement, especially in complex parts. But, it costs twice as much as conventional reinforcement media.

### Finishing Work

In Light RTM, pulled parts require trimming of cured flashing material, which can be labor intensive, noisy and dusty. In open molding, although some part designs require cutting of cured material, cutting away excess uncured flashing material is relatively simple. Overspray and trim waste can account for ten percent or more of the materials used in open molding. These waste costs counter the extra post cure finish requirements of Light RTM.

### Styrene Emissions

Because parts are removed from the Light RTM mold as soon as they are structurally sound, some styrene may be released to the environment during final curing of the part. Compared to open molding, Light RTM releases virtually no styrene because the entire system is closed and even the gases evacuated from the mold can be passed through a small carbon adsorption bed to eliminate any release during part processing.

Using the American Composites Manufactures Association (ACMA) Unified Emission Factors, the emission factor for open molding is about 11 percent of the resin's available styrene. The EPA's Compilation of Air Pollutant Emission Factors, commonly referred to as "AP-42," lists the emission factor for closed molding as one to three percent of the styrene available. The AP-42 range is based on semi-closed processes (i.e., marble casting). Because Light RTM is a closed process, its emission factor should fall in the lower end of this range. The table below compares open molding using a low-styrene resin (38 percent) and nonatomized application equipment against closed molding using resin with a slightly higher styrene level (42 percent) to benefit from its lower viscosity. Closed molding shows a ten-fold reduction in styrene emissions over open molding.

Emission factor comparison.

	Open molding*	Closed molding
Resin applied	1,000 lb	1,000 lb
Styrene in resin	38%	42%
Emission factor	11%	1%
Total styrene emissions from resin application	42 lb	4.2 lb

\* Compliant with NESHAP requirements for low styrene resin and nonatomized application.

Note: Light RTM parts are gelcoated in the conventional manner used in open molding. Styrene emissions from gelcoating remain a significant fraction of total styrene emissions.

### Costs and Benefits

The following cost-and-benefit analysis summarizes the success Phoenix Industries had with Light RTM.

- **Lower cost per part.** Per part cost reduced 10 percent. Productivity of the molds increased with shorter cycle times. Material use improved and the bill of materials became more consistent. Part quality was enhanced, while less labor per part was needed.
- **Reasonable capital investment.** Phoenix had a payback of less than two years. One Light RTM station, including a vacuum source and resin injection system, cost under \$10,000, excluding the tooling costs. Closed molding experience can be gained with less than \$1,000 if simple and small parts are addressed first.
- **Quality improvements.** The day-to-day inconsistencies of open mold operators were minimized. Light RTM enhanced part consistency,

gave better control over part thickness improving dimensional tolerance, and offered a two-sided finish.

- **Reduced manufacturing wastes.** Styrene emissions were reduced tenfold. Per part material use was reduced by 10 percent or more because open molding wastes—like overspray—were eliminated. This further reduced styrene emissions.
- **Employee retention.** A much cleaner work setting and a more desirable job reduces worker turnover.

## **For More Information**

Other MnTAP publications for the FRP industry:

- Controlled Spraying and Laser Touch in the Fiber Reinforced Plastics Industry [#89]
- Fiberglass Fabricators Upgrades Open Mold Processing Equipment [#61]
- Fiber Reinforced Plastics Shop Complies with New Air Permit Regulations [#83]
- Reducing Volatile Emissions in the Fiber Reinforced Plastics Industry [#75]

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