

# Melting and Holding Furnaces for Die Casting

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Recent increases in energy costs have prompted renewed interest in what can be done to minimize energy usage in die casting plants. Since more than 50 percent of the energy used in a plant can be required for metal melting and holding, this area of the die casting plant is being examined once again.

A recent report sponsored by the U.S. Department of Energy\* (DOE) showed that the seemingly simple process of melting metal – heating metals to turn them into liquids for pouring – is actually very complex, involving a series of steps that incur material and energy losses. The losses are due to several factors, including undesired conduction, radiation and convection losses, stack loss (flue gases), and metal loss. The extent of the losses depends on the furnace design, the fuel used, and the method of imparting heat to the metals. The study reported that typical metal melting furnaces range in thermal efficiency from 7 percent to 76 percent, and they range in melt loss from 0.75 percent to 6 percent.

The DOE study also reported that there is little potential for a single melting technology to provide a “one-size-fits-all” solution because casting plants vary from each other in many respects, such as the metals being melted, the alloying requirements, product specifications, furnace capacity requirements, and the various casting processes that are utilized. It was therefore recommended that each casting plant should implement energy efficient technologies that are best suited for that individual facility.

This article provides information on the various melting and holding technologies that are being utilized in the die casting industry today, and compares the advantages and disadvantages of those technologies. This information will help die casting personnel to quantify the potential for reduced energy consumption in their operation. Also, several R&D activities which may lead to improved metal melting and holding energy efficiency are discussed. In the last section, the metal melting and holding equipment that is provided by NADCA Corporate Member suppliers is presented. Information was provided for the article by Lindberg/MPH, MELTEC, Modern Equipment Company, New Century Heaters, Schaefer, and Thermtronix.

## Types of Furnaces

The first question usually asked by someone evaluating melting and holding furnaces is whether there is a difference between electric or gas furnaces. The inherent advantages and disadvantages of gas fired furnaces are provided in the next column.

- **Advantages of gas fired furnaces.**
  - Least cost per BTU of fuel.
  - High power for fast melting capability.
  - Very large melting and holding furnaces are practical.
  - Suitable for stack melting for improved efficiency and convenience.
  - Reliability of power source over electric power outages.
  - Lower initial cost.
  
- **Disadvantages of gas fired furnaces.**
  - Least efficient use of available BTUs.
  - Ventilation required.
  - Highest melt loss as a result of the products of combustion.
  - Highest melt contamination as a result of the products of combustion.
  - High surface temperatures of the layered melt encourage the absorption of hydrogen.
  - If circulating pumps are used, additional contamination occurs from oxides that would normally settle out but are kept in suspension in the melt.
  - Highest insulation and refractory degradation in the roof, sidewalls, and the exposed hot-face lining above the metal level from roof heating.
  - Difficult to clean.
  - Not portable because of piping and ventilation.
  - Inefficient heat transfer through surface oxides in melting and holding furnaces when attempting to hold temperature in dip-wells.
  - Furnaces must be shallow with a high surface area ratio that invites oxides and hydrogen contamination.

For many years, the question of whether to use gas or electric was answered quite commonly by the following response, “Use gas for melting and electricity for holding.” The reason for this was the high energy intensity from gas permitted a higher melt rate and electricity provided a lower melt loss and a controllable energy source for holding metal at temperature. Unfortunately, many die casters adopted this philosophy, but were very inefficient in the operation and maintenance of both their gas melting furnaces and their electric holding furnaces.

In reality, the decision about melting and holding furnaces, and whether they should be gas or electric, depends on the specifics of the operation. For example, when making a decision about the holding furnaces for aluminum in a die casting facility, several things must be considered.

1. How often will metal be delivered to the holding furnaces each hour?
2. What is the temperature of the metal being delivered? Is it consistent?
3. What is the cleanliness of the metal being delivered?
4. Are there floor space or ceiling height constraints?

By answering these basic questions, you can begin to eliminate one energy source or the other for holding aluminum. If you are considering radiant roof electric holders and plan to deliver metal less often than once an hour and the draw down between deliveries is greater than 5 inches, then you should specify gas fired furnaces instead. The electric elements will not keep the temperature up because the metal gets too far away from the heat source and the electric elements cannot go on “high fire” like gas burners can.

On the other hand, if you plan to have filtered and degassed metal delivered to the holding furnace, and the metal will be at or above the holding furnace temperature, then electric powered furnaces may be the right choice since there is no further contamination of the metal using electric elements. Some gas fired furnaces that use burners whose flame comes in contact with the metal will contaminate the previously clean metal. Other gas fired holding furnaces that use flat flame roof burners, in which the flame pattern never touches the metal, minimize this contamination. It is also true that gas fired furnaces are generally slightly smaller than equivalent capacity electric units.

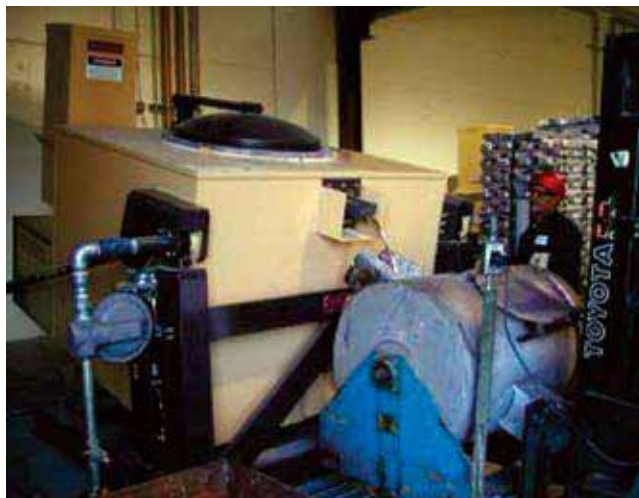
There are several types of furnaces that are used for melting and holding in the die casting industry. These include:

- Crucible Furnaces
- Dosing Furnaces
- Immersion Furnaces
- Induction Furnaces
- Reverberatory Furnaces
- Stack Furnaces

Each of these furnaces has advantages and disadvantages, which will be presented in the next section.

### **Crucible Furnaces**

Crucible furnaces are small capacity furnaces used for small melting applications or exclusively as holding furnaces. The metal is placed or poured into a ceramic crucible which is contained in a circular furnace that is fired by a gas burner or heated by electric elements. Gas fired crucible style furnaces, shown in Figure 1, offer the advantage of a high volume melt capacity per square foot of floor space required. They are perhaps the most flexible of all furnace styles. Less affected by frequent cycling, they offer faster start-ups and temperature recovery. In fact, with the current trend of rising natural gas prices, large capacity (1.0 to 1.5 metric ton) modern tilt/pour furnaces have become very cost effective for melting systems. It has become increasingly difficult to justify holding 15 metric tons of metal when only 1.5 tons per hour are required.



*Figure 1 — Gas-fired crucible furnace.*

Electric resistance crucible furnaces are clean, quiet (virtually silent) and environmentally friendly. Producing no stack or flue emissions from their energy source, the electric resistance furnace is as pollution free as the charge material being placed into the furnace. It is generally best suited to continuous 24 hour per day, seven day per week operations. In fact, with a melting efficiency as high as 0.385/Kg of aluminum to 700°C and a holding energy requirement as low as 8 kWh/metric ton, it is often less expensive to operate the furnaces 24/7 even with a single shift operation. However, electric resistance furnaces are not generally thought of as high production melters. While ideally suited for holding furnaces, care must be taken

that the electric resistance furnace is properly sized if both melting and holding is required from a single furnace at the die casting machine.

## Dosing Furnaces

Dosing furnaces are closed holding furnaces with a spout for direct metal delivery. They are used to dispense an accurate amount of molten metal to the die casting machine. The advantage of a dosing furnace is that because it is closed, it minimizes heat loss and protects the molten metal from excessive oxidation.

Dosing furnaces require about 20 percent of the energy to hold 2,000 pounds of aluminum in comparison to an open crucible furnace. Also, the operating costs are about one-third the cost of a comparable holding furnace. Dosing furnaces are very popular in Europe, and are replacing holding furnaces and ladles because of their ability to pour accurate amounts of molten metal at the proper temperature.

The disadvantages of dosing furnaces are their higher initial cost and their uniqueness. The combination of holding molten metal and ladling the molten metal each cycle of the die casting machine from a closed vessel does result in a furnace that is significantly more expensive to purchase. In addition, the successful operation of a dosing furnace requires that the personnel in the facility embrace the capabilities of the equipment as a part of their normal production environment.

## Immersion Furnaces

Immersion furnaces are commonly used for lower melting temperature alloys such as zinc. The heat is generated by combustion or electrical resistance inside a tube which is submerged in the molten metal. The heat is transmitted to the molten material through the wall of the tube by conduction. An advantage of immersion furnaces is that the combustion gases are never exposed to the molten metal, reducing oxidation losses and enhancing heat transfer to the molten metal. An electric immersion holding furnace is shown in Figure 2.

The heat tubes used in immersion furnaces are typically made of metallic materials that have a high thermal conductivity, which are also coated with ceramic or cement materials to resist corrosive attack by the molten metal. In the past, when melting aluminum, or other metals



Figure 2 — Electric immersion holding furnace.

with higher melting points, heavier ceramic coatings were applied because these molten metals attack the tubes more aggressively. The ceramic coatings, however, act as a thermal barrier and lower the productivity of the immersion heater. These tubes must also be structurally strong to survive an industrial environment and to operate under frequent thermal cycling. A small crack in the coating can lead to destruction of the tube.

Recently, electric immersion furnaces are making a strong comeback thanks to a new design that puts the element through the side of the furnace in the middle of the bath. This keeps thermal head temperatures lower and reduces dross formation. Also, the development of new electric elements and protection tubes are providing increased life and higher efficiencies for electric immersion furnaces. There is a significant amount of research and development in these technologies, as found in the DOE report mentioned previously.\* These developments are presented in the R&D Section of this article.

## Electric Induction Furnaces

Induction furnaces are sometimes used for melting die casting alloys. There are two general types of induction furnaces: channel induction furnaces and coreless induction furnaces. Channel induction furnaces are used almost exclusively as holding furnaces. Channel induction furnaces operate at 60 Hz, where the electromagnetic field heats the metal between two coils and induces a flowing pattern of the molten metal, which serves to maintain uniform temperatures without requiring mechanical stirring.

Coreless induction furnaces heat the metal via an external primary coil. Coreless induction furnaces are slightly less efficient than channel induction furnaces, but the melt capacity per unit floor area is much higher. Coreless induction furnaces are used mainly for melting finely shredded scrap, in which case they are very competitive with gas-fired furnaces.

Induction furnaces have high melting efficiencies from 50 percent to 70 percent. They also have low emissions and low metal oxidation losses. The alloy from induction furnaces is very uniform due to the mixing created by the induction fields. The disadvantages of induction furnaces are the high investment cost and high operating and maintenance costs.

## Reverberatory Furnaces

Reverberatory furnaces are commonly used to melt aluminum with heat that radiates from the hot refractory heated by burners or electric rods mounted in the roof or in a sidewall of the furnace. The molten metal is held inside the furnace at the required temperature before it is tapped out for pouring or transferred to a holding furnace.

Gas reverberatory furnaces are used in large aluminum die casting plants because they provide a large reservoir of molten metal, ensuring a steady and reliable supply of molten metal to the plant. For this reason, many medium-to-large plants use them as central melters to supply multiple operations location within the plant. Typical capacity of gas reverberatory furnaces can range from 1 to 150 tons of molten metal. The advantages of reverberatory furnaces are their high volume processing rates and low maintenance





Figure 3 — Gas reverberatory furnace.

costs. A gas reverberatory furnace is shown in Figure 3.

There are two types of reverberatory furnaces, based on whether the sows, ingots, and scrap materials are preheated before melting or not. A dry hearth reverberatory furnace charges and preheats the sows, ingots, and scrap materials on a slope between the charging door and the molten metal bath, removing any contamination or water residue prior to melting, preventing splashing and explosions. A wet bath reverberatory furnace directly dumps the sows, ingots, and scrap materials into the molten metal bath. Pre-heat hearths are available on these furnaces for pre-heating the ingots or sows to a safe temperature using the flue gases of the furnace. The wet bath system is beneficial for melting scrap types with large surface to volume ratios, which may oxidize excessively unless melted quickly.

Another type of reverberatory furnace is a side-well furnace that consists of a number of burners firing inside the hearth, against the furnace's hot wall or door. A charging well and a pump well are attached to the furnace's hot wall on the outside of the furnace. Both wells are connected to each other and with the furnace hearth by arches, which permit metal circulation between the furnace chambers. During the charging period of the furnace cycle, molten aluminum circulates through the charge well where it melts the scrap, then circulates back into the hearth for reheating. Charging continues until the molten bath reaches the desired level. Subsequent steps in the process may include degassing and alloying.

Although reverberatory furnaces have the advantage of a large supply of molten metal, they have low energy efficiency, high oxidation rates, and large floor space requirements. The energy efficiency of reverberatory furnaces ranges from 15 to 40 percent. Recuperation can improve the efficiency of gas reverberatory furnaces by anywhere from 10 to 15 percent, but also significantly adds to maintenance and capital outlay costs. In addition, for gas reverberatory furnaces, as the molten metal comes in contact with the furnace gases, it forms slag/dross. The melt loss rate for gas reverberatory furnaces is 3 percent to 9 percent when melting aluminum and the fuel required to melt one pound of aluminum typically ranges from 1850 BTU to more than 2000 BTU. Improvements in burner technology, fuel/air ratio control, insulating refractories, and temperature control have contributed to a slow but steady improvement in the efficiency of reverberatory furnaces to as low as 1250 to 1500 BTU per pound of aluminum, including pre-heating and circulation.

Electric reverberatory furnaces are used primarily as holding furnaces but are sometimes used as aluminum melters. These furnaces are typically refractory lined vessels using resistance heating elements mounted in the furnace roof above the hearth. These furnaces are used for smaller melting applications where limitations on emissions, product quality requirements, and yield are of high priority. The advantages of electric reverberatory furnaces are low emissions, low metal oxidation, and reduced furnace cleaning requirements. The disadvantages are higher installation and operating costs, lower production rates, and frequent replacement of heating elements.

For smaller reverberatory furnaces, electric wet bath reverberatory melting furnaces can be operated nearly twice as efficiently as a gas reverberatory furnace due to the fact that there is no flue. These electric reverberatory furnaces also have lower melt loss rates since there are no products of combustion entering the melt chamber to facilitate hydrogen pickup and oxide (dross) formation. Depending on the relative costs of gas and electricity, this can be a viable option for melt rates of less than 2000 pounds per hour. Since the bath to melt rate ratio is 10:1, for a 2000 pounds per hour melt rate, the bath requirement would be 20,000 pounds. With the glow bars suspended above the bath, the bath cannot be much larger than this and still be able to clean the furnace without damaging the glow bars. At melt rates above 2000 pounds per hour in a reverberatory furnace, generally gas is preferred.

## Stack Furnaces

Stack furnaces have received more attention in recent years due to their higher energy efficiency than that of reverberatory furnaces. A stack furnace uses the flue gases to preheat the charge materials. The charge materials slide down a shaft and reach the melting zone where they are melted by the burners, and the molten metal flows down to the holding area. The hot exhaust gases from the melting zone flow through the shaft to preheat the incoming charge, improving the energy efficiency of the stack furnace by 40 to 50 percent compared to a reverb. A schematic of a stack furnace is shown in Figure 4.

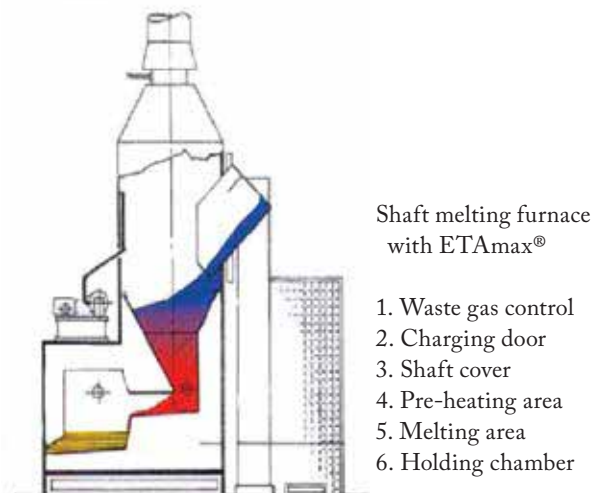


Figure 4 — Schematic of a stack furnace. Courtesy of Case Western University.

The molten bath area of the stack furnace has another independently controlled burner system solely for holding and maintaining temperature. Bath sizes for stack furnaces are significantly lower than for other high productivity furnaces. The bath to melt ratio for stack furnaces is 2.5:1, whereas the typical ratio for other furnaces is 10:1. This makes cleaning and skimming less time consuming and holding costs are significantly lower. Stack furnace performance varies by manufacturer, but efficiencies range from 40 to 77 percent and the fuel required for melting one pound of aluminum ranges from less than 1000 BTU per pound to 1400 BTU per pound. Melt loss for stack furnaces varies from less than 1 to 3 percent, depending on the design and plant operating procedures.

The disadvantage of the stack furnace is that due to the charging mechanism, a stack furnace is usually very tall, often more than 20 feet for higher melting rates. However, stack furnaces are made in smaller capacities as well. Some manufacturers make a compact model that is specifically designed for cell manufacturing arrangements. These compact versions can be placed in between die casting machines and allow more flexibility in alloy changes than their larger counterparts. Also, stack furnaces are a continuous melting operation, and are not conducive to alloying directly in the stack melter.

## R&D Activities for Furnaces

The increase in energy costs throughout the world over the past few years has stimulated new interest in the research and development of more energy efficient processes for melting and holding metals. The U.S. Department of Energy study discussed earlier provided insight into several technologies that could improve the energy efficiency of die casting. The study identified six experimental melting technologies that are being developed. They are:

1. Electron Beam Melting
2. High-Temperature Immersion Heater Melting
3. Infrared Heating
4. Microwave Heating
5. Plasma Heating
6. Solar Furnace

Of the above technologies, Electron Beam Melting is directed at melting cast ingots of titanium, zirconium, and molybdenum. Microwave Heating is being used for melting uranium and research is directed at alloys for investment casting. The Solar Furnace is an ideal melting system, but requires acres of land to place reflective mirrors and is used mainly for scientific experiments. It does not offer the practicality to be applied to die casting operations in the near future. However, High-Temperature Immersion Heater Melting, Infrared Heating, and Plasma Heating do have the potential to find applications in the die casting industry. Each of these is summarized below from material contained in the DOE report.

### Immersion Heaters

There are four ongoing projects related to improving the capability of immersion heating for melting metals. First, work has been done to optimize the nitride-bonded,

silicon-carbide-fiber-reinforced Continuous Fiber Ceramic Composite (CFCC) immersion tube burners for application in aluminum and other light metal melting. When tested at an industrial site, the immersion tube survived over 1,000 hours and 31 cycles in an aluminum casting furnace. In another test, the immersion tube successfully survived for 1,752 hours in the furnace.

A second research activity involves the development of intermetallic alloys that possess improved resistance for use as heater tubes. Researchers have developed a Ni3Al alloy that can withstand service temperatures more than 200°F higher than commercial Ni3Al alloys. These kinds of intermetallic alloys can be applied in immersion heater tubes to withstand any wear from chemical reactions.

The third project called "Isothermal Melting (ITM)" shows promise for developing new materials and construction techniques that will allow immersion heaters to be built with higher heat flux capabilities and external coatings that provide mechanical and chemical protection. These high heat flux heaters are practical for large-scale applications.

The fourth research area is the development of integrated retrofit technologies for clean aluminum melting systems by focusing on immersion heating coupled with metal circulation systems. This is being achieved through substitution of conventional radiant burner methods with immersion heating in reverberatory furnaces. The program will enable cost-effective retrofits to a range of existing furnace sizes, reducing the economic barrier to implementing new applications.

## Infrared Heating

Infrared Heating is being developed for use in die heating and heat treatment in the metalcasting industry. It offers a method for reducing the time and the energy costs of die preheating. A study conducted at Oak Ridge National Lab indicated that the surface of the die can be heated to 300°C (572°F) in less than 20 minutes. Recently, the DOE funded a study on surface treatments on refractories used in aluminum processing. High-density infrared processing can be used to apply corrosion-resistant, high emissivity coatings on refractories so as to reduce its porosity.

## Plasma Heating

Plasmas are gaseous collections of electrically charged particles such as electrons and protons. These charged particles carry energy, and as the ionized plasma flow hits the metal surface, it releases its energy, melting the metal.

Plasma aluminum melting furnaces are reported to impart heat 60 percent quicker than conventional high rate melters. The plasma melting process also minimizes metal loss due to oxidation and contamination. The plasma keeps a thin oxide film on the molten metal intact, protecting the molten metal from absorbing gases. The dross rate of melting aluminum by plasma heating is less than 1 percent and plasma heating also reduces the cost of fuel.

## Furnace Supplier Information

NADCA Corporate Members who supply furnaces to the die casting industry were asked to provide input for this article. Much of their input is included in the discussions provided previously concerning the various types of melting and holding furnaces. In this section, information on each supplier is provided. In addition, contact information is provided for those who may want to have additional discussions about specific products or applications. Information is provided on the following six suppliers:

1. Lindberg/MPH
2. MELTEC, a Subsidiary of FRECH
3. New Century Heaters Ltd.
4. Modern Equipment Company, Inc.
5. The Schaefer Group, Inc.
6. Thermtronix® Corporation

## Lindberg/MPH

Lindberg/MPH provides melting and holding furnaces to all segments of the die casting industry. Recently, they supplied two furnaces to Ryobi Die Casting in Shelbyville, Indiana, equipped with regenerative combustion technology as supplied by Bloom Engineering. The first was a retrofit of a 140,000 pound furnace. During a three month period from December 2004 to February 2005, the aluminum melted and the gas consumption were metered, and provided in Table 1. After the retrofit, gas consumption decreased by over 50 percent.

The regenerative combustion technology that was implemented, shown in Figure 5, uses a pair of burners which cycle to alternately heat the combustion air and recover and store heat from the furnace exhaust gases. When one burner

Table 1

	12/ 2004	1/ 2005	2/ 2005	Average
Pounds Melted	3,389,580	4,821,041	4,639,227	4,283,282
BTU/lb. – Production & Non-Pro- duction Days	1468	1251	1139	1286
BTU/lb. – Production Days Only	1142	1052	974	1056



Figure 5 — Lindberg/MPH reverberatory with regenerative combustion.

is firing, the other is exhausting the furnace gases. Exhaust gases pass through the burner body and into a media case which contains refractory material. The refractory media is heated by the exhaust gases, thus recovering and storing energy from the flue products. When the media bed is fully heated, the burner currently firing is turned off and begins to exhaust the flue products. The burner with the hot media bed begins firing. Combustion air passes through the media bed and is heated by the hot refractory. Air preheat temperatures within 300°F - 500°F of the furnace are achieved, resulting in exceptionally high thermal efficiency.

A large furnace equipped with this technology can be as efficient as a much smaller shaft or stack furnace. The initial cost of this technology is high, but as gas prices rise, the time to pay it back gets shorter and the technology becomes more economical even on smaller furnaces.

Lindberg/MPH has also recently installed a stack melter at Michigan Automotive Compressor Incorporated (MACI) in Parma, Michigan. The installation is shown in Figure 6. As natural gas prices have gone up recently, so has the popularity of stack melters. Ever increasing competition has die casting companies looking to reduce operating costs by every means available.

Provided there is the necessary ceiling height and it is practical to run on-spec ingot, a stack melter is a good choice. In addition to efficiency, advantages include a low melt rate to bath capacity ratio and lower metal loss. Lindberg/MPH incorporates a modular concept in this type of design. The stack/melt zone and the hold zone are separate structures interconnected through a launder,





Figure 6 — Stack melter at Michigan Automotive Compressor Plant.

which allows flexibility in designing for cleaning and best fit within the available floor space. Under test conditions, these furnaces have operated at between 983 and 1179 BTU per pound. Variations are dependent upon scrap density and the ratio between scrap and ingot. They can also be designed to melt sows, where fractional savings per pound can buy a lot of gas.

For more information on Lindberg/MPH furnaces, please contact Andrew Paul at (269) 983-5216, or by email at [apaulmph@aol.com](mailto:apaulmph@aol.com).

### MELTEC - Subsidiary of FRECH

Because of the growing number of applications for magnesium in consumer electronics and the automotive industry, magnesium die casting and thus, MELTEC magnesium melting and dosing systems have become an integral part of the process. Apart from the die casting die, the die casting machine, and the related peripheral equipment, it is also the overall melting process that plays an important role in providing the required quality of the casting. A schematic of the MELTEC melting cell is shown in Figure 7.

The MELTEC electric magnesium furnaces for proportioning (dosing) of liquid metal to the cold chamber die casting machine are used for direct melting of the magnesium needed and for holding the metal at the proper temperature. The dosing furnace need not be supplied with liquid metal. Melting the metal and holding it at the proper temperature is performed in a closed metal crucible requiring a special protective atmosphere above the liquid metal level. This

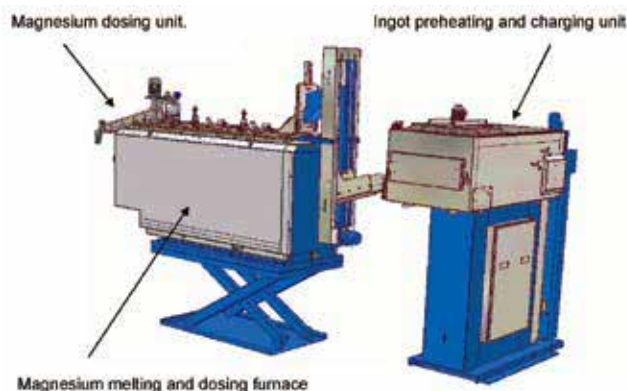


Figure 7 — MELTEC magnesium melting cell.

atmosphere is produced by a gas conditioning unit.

The raw material (ingots) is melted in the dosing furnace arranged immediately upstream of the cold chamber die casting machine. For reasons of safety and of quality it is necessary to heat the furnace charge to a temperature of at least 150°C before charging it to the furnace. This is affected in a preheating furnace arranged upstream of the dosing furnace. Proportioning (dosing) of the magnesium melt is affected via a dosing unit installed in the melting and holding furnace. Therefore, the whole melting process begins with the required preheating of the ingots. It continues via melting and holding the proper temperature in the magnesium furnace under a protective atmosphere and ends with a controlled transfer of the melted material to the shot sleeve of the cold chamber die casting machine. To better explain the purpose and design of each piece of the MELTEC melting cell for magnesium, a brief description of each component is provided. First, the ingot preheating and charging unit heats the ingots to at least 150°C to avoid steam and hydrogen explosions. In addition, heating the ingots to 250°C increases the melting capacity of the melting furnace by 20 percent. Also, since the ingots are preheated, they melt quickly in the melting furnace and eliminate unwanted deposits at the bottom of the crucible caused by alloy segregation. These deposits have a high aluminum content and could reduce the service life of the steel crucible. Automatic proportioning of the ingots helps to keep the liquid metal level within narrow tolerances and largely avoids fluctuations of the melt temperature. These are important prerequisites for a high dosing accuracy. In addition, the automatic charging unit must have a large store of ingots to support the melting capacity of 750 kg per hour.

The magnesium melting and holding furnace is provided with a preheated ingot as required whenever the minimum liquid metal level is no longer achieved. The furnace has a crucible inserted into the specially designed furnace. A tightly welded enclosure is provided with an efficient insulating layer storing little heat, as well as an inner lining which cannot be reduced by magnesium that might leak from a damaged crucible. This also prevents the release of any oxygen to the magnesium, which is a fire danger. Heating is affected in the form of so-called electric radiators that can be easily installed and dismantled. Each radiator is equipped with up to 24 individual heating elements. This kind of heating has the general advantage that there is no major loss of performance in case of the failure of one or more of the electric heating elements, and production need not be interrupted.

The magnesium dosing unit is the interface between the furnace and the die casting machine. It serves the purpose of a controlled transfer of the melted material to the shot sleeve of the die casting machine. Dosing is started by means of a rotating feed pump. Different feed pumps of various sizes may be used. The liquid metal is fed to the pump from below the liquid metal level. The liquid metal level inside the pump remains constant so that build-up is avoided. From the pump, the liquid metal is forced into the ascending pipe of the dosing chute without turbulence, where protective gas is provided to the system. As soon as the melt reaches the heated dosing chute, it runs off to the shot sleeve of the die

casting machine. The heated dosing chute is rated for 700°C, thus holding the melt temperature up to entry into the shot sleeve. Air is prevented from entering the dosing chute by providing an argon atmosphere.

The prerequisite for consistent dosing is the interplay of all components of a complete melting cell. A constant liquid metal level in the melting furnace can be achieved only by means of automatic charging. This constant metal level, as well as a constant temperature, is the absolute prerequisite of high dosing accuracy. Any deviations from the relevant set points must be input to the dosing control system for automatic correction of the pump setting. The length of the biscuit must also be continuously measured for the dosing unit to avoid producing scrap. It is this interplay that insures the production of high quality castings.

For more information on the MELTEC magnesium melting cell, please contact Robert Tracy at FRECH USA at (219) 874-2812 or visit [www.frechusa.com](http://www.frechusa.com).

### Modern Equipment Company

Modern Equipment Company, located in Port Washington, Wisconsin, has been in business since 1919. The company provides equipment for the die casting, permanent mold casting, sand casting and investment casting industries. In addition to stack melting furnaces, Modern Equipment Company produces ladles, cupolas, molten metal delivery and handling systems, automated charging systems, ingot de-stackers, and complete turn-key systems.

Modern Equipment Company has been producing stack melting machinery since 1982, and has a technology partner (Nippon) who has been making them in Japan since the 1970s. Their experience allows them to put a guarantee of performance results in any formal proposal to a customer. Their Jet Melter® for aluminum, schematically shown in Figure 8, comes in various sizes, from a melt rate of 500 pounds per hour to as much as 20,000 pounds per hour. The holding capacity for the furnace ranges from 1,250 pounds to 50,000 pounds of aluminum. The furnace is a high efficiency melter, with energy consumption that ranges from 750-1000 BTUs per pound depending on the operation, and a melt loss of less than 1 percent. The temperature of the metal can be controlled to  $\pm 18^\circ\text{F}$ . The furnace includes state-of-the-art programmable controls with a graphic display, and includes automated material handling, batching and charging systems.

One feature offered by Modern Equipment Company is an Automatic Bucket Delivery System. This system automatically delivers a full bucket to the charger and into the furnace, maintaining an even furnace level. The system reduces material handling requirements, since buckets can be placed at trim machines for easy collection of trimmings and scrap castings. Manpower requirements are reduced since an hour's production can be staged in a few minutes. The delivery system can also be integrated with an automatic scrap handling system and multiple bucket systems (3 or more) can be custom designed to match a customer's needs.

For more information on the Modern Equipment Company Jet Melter or their other foundry equipment, contact David Magnuson at (262) 284-9431 or visit [www.moderneq.com](http://www.moderneq.com).

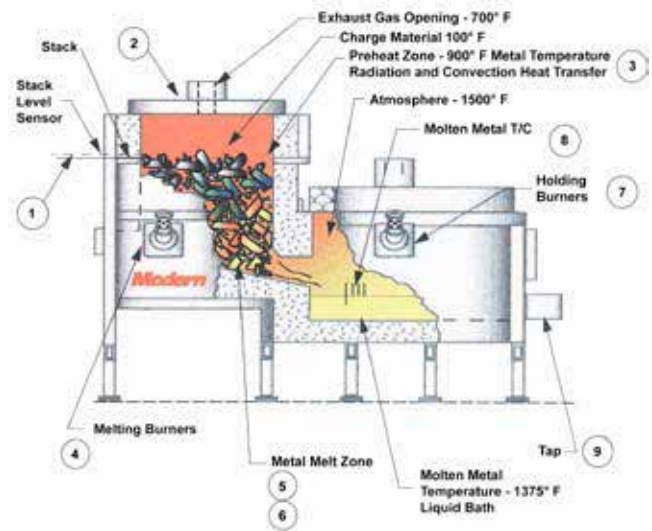


Figure 8 — Schematic of Jet Melter™ above and an actual example of one installed below.

### New Century Heaters Ltd.

New Century Heaters is a provider of electric immersion melting and holding furnaces, and is located in Bay City, Michigan. The company began the development of immersion heaters in 1995. About three years ago, they began to place these furnaces in commercial operation, and there are now about 40 of these furnaces in operation, utilizing the new immersion heaters.

Many die casting companies use silicon glow bar melting and holding furnaces because there is no ventilation required, they are quiet and easy to clean, they can be repositioned and replaced easily, they are moderately priced and electricity is normally available everywhere. The disadvantages of glow bar furnaces are that they provide inefficient heat transfer through surface oxides into the metal, they create dross from overheating the top layer of the melt, there is high insulation and refractory degradation in the roof and sidewalls, the furnaces must be shallow with a high surface area ratio that invites oxides and hydrogen contamination, and they are costly for both power consumption and glow bar replacements.

The New Century Heater furnace utilizes wire wound immersion heating elements in a board or refractory lined furnace. The furnaces range in size from a 25 kilowatt holding furnace to a 360 kilowatt furnace with a continuous aluminum melt rate of 1800 pounds per hour. A diagram of this melting furnace is shown in Figure 9.

The advantages of the immersion furnaces are that they are energy efficient, require no ventilation, and are quiet. They also have essentially no melt loss and the melt surface



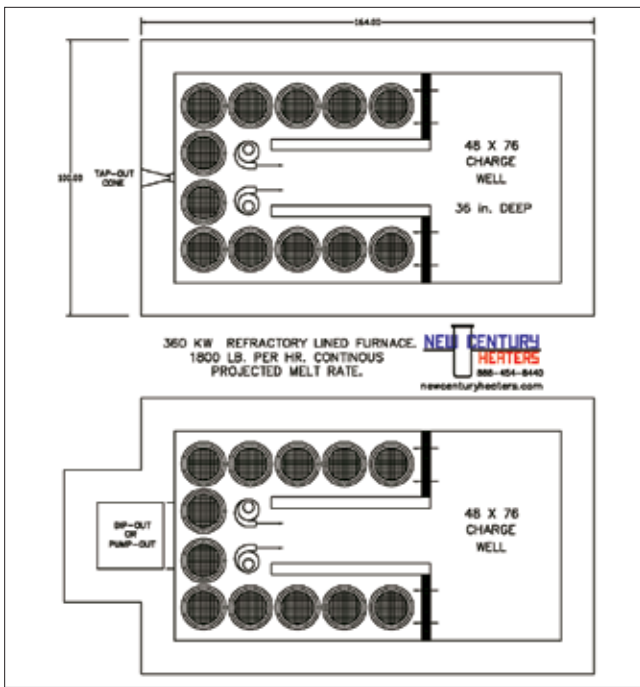


Figure 9 — Schematic of electric immersion furnace.

is not super-heated, thus reducing melt contamination. A circulation pump is not required to maintain the metal temperature in the dip well. Uniform temperature can be maintained with no layering. Adding ingot or cold metal at the supply end of the furnace has little effect on the temperature in the dip well at the far end of the furnace.

High insulating board construction is practical for this type of furnace. Not only does board construction save energy through better insulation, but it also has no moisture in it so a dry-out cycle is not required. These immersion furnaces also require less cleaning than other types of furnaces.

There are a few disadvantages of the immersion furnace. There is a higher initial cost and very large melting furnaces may not be practical. Also, depending on the design, immersion furnaces can be hard to clean. A large heel can be held in the furnace to minimize temperature fluctuation when metal is added to the holding furnace. New Century Heaters is currently converting some shallow glowbar heated furnaces to immersion heat, providing a 30 percent power reduction. Currently, 40 percent of the company's business is providing heaters for horizontal tubes manufactured by Japanese companies. They last up to two years.

For more information on New Century Heaters furnaces contact Dean Vander Jagt at (989) 671-1992, or visit the company online at [www.newcenturyheaters.com](http://www.newcenturyheaters.com).

## The Schaefer Group

The Schaefer Group, Inc. started business as a refractory contractor in 1930, and began designing and manufacturing industrial furnaces in 1945. In the early 1970s, the aluminum furnace business grew to the place that it became necessary to form two divisions within the company: A Refractory Sales and Service Division and an Industrial Furnace Division. In 1998, the Industrial Furnace Division was separated from FWS, Inc. to form a new company, Schaefer Furnaces, Inc. (SFI). A combining of these two related companies took place in late 2002,

forming The Schaefer Group, Inc. The Schaefer Group, Inc. provides turn-key service; from design, to construction and installation, to complete technical support and maintenance for furnaces of all types and sizes.

The Schaefer Group, Inc. is the foremost supplier of aluminum melting systems in the United States. SGI has more working heated launder systems in North America than all the other suppliers combined. They have installed 14 lost foam and/or precision sand casting systems in the last 10 years. SGI is currently completing its seventh large melter system (5,000#/hr -8,000#/hr radiant roof gas fired wet bath furnaces) for one of the largest die casters in North America.

The same engineering and design that goes into large foundry and die cast systems is used in the smaller furnaces as well. Schaefer offers smaller electric reverberatory furnaces, like the one shown in Figure 10, that provide energy efficient melting with a melt loss of less than 1 percent. In fact, the installation of a small electric reverb can often be justified with a payback of less than one year when compared to a gas fired reverb.



Figure 10 — Small electric reverb.

In terms of energy usage, SGI has paid close attention to customers' demands by keeping the cost to hold aluminum at 1250°F in a radiant roof gas fired holding furnace at less than 25 BTU per pound. This means that a 5000-pound gas fired holding furnace will hold the metal for about 125,000 BTUs per hour, which is about \$1.125 per hour based on a natural gas cost of \$9.00 per 1,000 cubic feet of gas. An electric furnace will hold 5,000 pounds of aluminum at 1250°F for about 10.5 kilowatts per hour, which is \$0.84 per hour, based on an electricity cost of \$0.08 per kilowatt-hour. This seems like a straight forward comparison, but this is only under normal conditions. If cold metal is delivered to either of these holding furnaces, the cost per hour goes up. This is also based on air movement around the furnace at 5 feet per second. These costs are also for furnaces that have an open dip well and an open charge well at each end of the furnace. If energy costs change, the respective holding cost will change also.

One thing is for certain, and that is that you cannot make a decision on the correct holding or melting furnace based solely on energy costs. Operational practices, metal quality, and molten metal handling must be taken into consideration before deciding on which energy source to use in a holding furnace.

From a holding and melting standpoint, the easiest and quickest return on investment in radiant roof melters is to

stop as much of the fixed heat loss out of the furnace as possible. Fixed heat loss is what is being lost through the casing, the open wells, and the flue. Properly designed furnaces with the right insulation can reduce the casing temperature over 25 degrees. The difference between older furnaces and the new "super insulated furnaces" can be as much as 100 degrees. That equates to about a 15 percent decrease in energy consumption by using the newer furnace. In addition to this, adding a pre-heat hearth and circulating the metal can save an additional 20 percent in energy usage.

The future of melting metal and holding metal at temperature is changing quickly. Custom designed furnaces to fit a particular facility and their practices make sense in today's economy. You can't afford an off-the-shelf inefficient furnace in the 21<sup>st</sup> century. Energy efficient furnaces that produce high quality metal, that are easy to clean, and fit into your manufacturing cell are the future of die casting.

*For more information on equipment provided by The Schaefer Group, contact Dave White at (937) 253-3342 or visit the company's website at [www.theschaefergroup.com](http://www.theschaefergroup.com).*

### **Thermtronix®**

Thermtronix® Corporation is a specialized industrial technology company. Founded in 1985 as a manufacturer of quality solid state electric resistance and gas fired furnaces for the aluminum foundry and die casting industries, Thermtronix rapidly earned a worldwide reputation for quality, performance and service. Thermtronix is headquartered in the Adelanto Industrial Park in Southern

California with USA sales/service offices in Milwaukee, Cleveland and Nashville. Licensed North American agents are Canadian Thermix, Inc. in Canada and Castmet, S.A. de C.V. in Mexico. In 1997 a joint venture manufacturing facility was established in Chennai, India, and international agents are located in most industrial areas of the world.

Thermtronix furnaces are presently operating in facilities ranging from the smallest job shops to the world's largest automotive manufacturers throughout the U.S. and in 17 countries around the world. Key to the energy efficient operation for any modern aluminum melting or holding furnace today, electric or gas fired, is a solid state furnace power control system. Solid state control technology has experienced a quantum leap during this past decade. With energy costs spiraling out of control, these new technologies have become an indispensable element for improving energy efficiency in the melting department of every modern die casting facility.

Applied to electric melting and holding furnaces, devices such as solid state SCR power control systems eliminate the on-off cycling of maintenance prone magnetic contactors and precisely measure the exact amount of electrical energy necessary to melt and maintain temperature. This helps to reduce or eliminate temperature overshoots and costly electrical demand charges during peak periods. Solid state power control also extends the useful life of electric heating elements by eliminating the saw tooth effect of the on-off cycling of electrical power. Gas fired melting and holding furnaces are able to maximize energy efficiency through



Figure 11 — Small melting-holding furnace.

a wide array of solid state temperature and combustion control technology. Fully proportional, modulating solid state motor controls constantly meter combustion gas flow, replacing outdated energy intensive, high-low burner firing systems. Gas flow and combustion are continuously monitored for maximum operating efficiency.

Solid state microprocessor based temperature and control devices benefit both electric and gas fired furnaces by continuously controlling both metal and chamber temperatures to maximize energy utilization. In addition to direct energy efficiency improvements, modern solid state furnace controls allow one to easily capture and store valuable energy data for benchmarking, cost analysis and maintenance purposes. They are also available with features that allow for automatic pre-programmed temperature adjustments, time of day use schedules, automatic demand limiting and numerous safety features including listing to UL Standards of Safety by Underwriters Laboratories Inc. (UL).

Over the next three years, die casters worldwide can expect to see continuous, incremental improvements in energy efficiency as superior materials and control technology become available and are made practical, in part, through the rising cost of energy. Thermtronix will continue to focus in several areas:

One key area will be ongoing development of compact, energy efficient, non-crucible melt systems that allow for the placement of furnaces at each die casting machine to eliminate the transfer of molten metals, as shown in Figure 11. A dramatic reduction in energy use, not to mention improvements in metal quality and safety, can be achieved by eliminating unnecessary transfers of molten metal. Ladle pre-heating, temperature loss, refractory maintenance, metal reheating and processing can be reduced or eliminated. These energy efficient, compact melting systems allow for the recapture of energy normally vented to the exhaust flue. They also provide a means for degassing and filtering the aluminum in a single unit without additional energy loss and eliminate the danger of placing charge materials directly into a molten aluminum bath.

For more information on Thermtronix® melting and holding systems, contact Vince Danega at (760) 246-4500 or visit [www.thermtronix.com](http://www.thermtronix.com).

The various types of melting and holding systems available for the die casting industry have been presented in this article and the advantages and disadvantages of each have been provided. Several NADCA Corporate Member companies provided information about their equipment and the ongoing efforts they are taking to improve the energy efficiency and reduce the costs of melting and holding metal. If something presented has prompted a question, please contact any of the companies that contributed to this article.

The bottom line to all of this was summarized well in the recently released DOE study. The conclusion to that report included the following:

*“Several advancements in melting technologies have been made over the last few decades, but significant opportunities still exist for the metal casters to improve the melting efficiency and reduce the metal loss. The implementation of the existing best practice technologies in the industry can alone save approximately 1.2 million BTU for melting a ton of iron and 3.0 million BTU for a ton of aluminum (or 1.2 trillion BTU per year for iron and 3.0 trillion BTU per year for aluminum). Considering that iron and aluminum casting tonnages comprise more than 85 percent of the total casting tonnage, the savings potential in melting these metals promises to be substantial.”*

The report goes on to offer the following suggestions about the path to improvement:

*“Further, the research path for advancing melting technologies in the metal casting sector must be guided by pursuing retrofitting technologies that can supplement the existing furnaces, as they provide cost-effective and low-risk methods to improve the melting efficiency – factors that are crucial in decision-making for the metal casters. Due to the industry’s small profit margins, metal casters are reluctant to risk replacing entire melting systems, but will accept retrofit technologies more easily.”*

So there you have it. Improvement is possible and the potential savings are tremendous. Technologies have been developed to improve existing melting and holding systems and new energy efficient systems have been developed and are available when opportunities for new or replacement furnaces present themselves. With the current rise in all types of energy costs, the incentives have never been higher.

*\*“Advanced Melting Technologies: Energy Saving Concepts and Opportunities for the Metal Casting Industry,” by BCS Incorporated, sponsored by the U.S. Department of Energy and the Cast Metals Coalition (CMC).*

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### About the Author/Editor

*Bill Butler retired from General Motors after 35 years in the metal casting industry. He managed the Die Casting Research and Development Center while at GM and also served as Chairman of the NADCA Research and Development Committee for several years. He continues to serve the industry through technical projects for NADCA.*

