



**INDUCTOTHERM**

*An Inductotherm Group Company*

# **The Induction Foundry Safety Fundamentals Guide That Might Save Your Life**





	<b>! DANGER</b>
	Molten metal is inherently dangerous. The information provided in this guide must be followed. Failure to do so could result in injury or death.

	<b>! WARNING</b>
	Equipment must only be operated by a trained, qualified and authorized person who has read and understood all equipment manuals.

	<b>! DANGER</b>
	Personnel working in proximity to molten metal must wear appropriate Personal Protective Equipment (PPE).

	<b>! WARNING</b>
	Always read and understand the equipment instruction manuals before operating or maintaining the equipment.

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# Foreword

## About This Guide

This guide describes general safety information. Some, but not all, parts of this guide will apply to your equipment. All information contained in this guide is the latest information available at the time of printing. Inductotherm Corp. reserves the right to make changes at any time without notice.

Inductotherm Corp. makes no warranty of any kind with regard to this material and assumes no responsibility for any errors that may occur in this guide.

## Equipment Manuals Must Be Your Primary Safety Source

We really care about you and your workers. This is why we have taken the time to compile this Induction Foundry Safety Fundamentals Guide to bring to your attention some major safety hazards.

This guide provides safety information of a general nature and is not intended to be a substitute for the more detailed and specific operational and safety information provided in equipment manuals. These equipment manuals must always be your primary source of information on the proper and safe operation of all equipment.

## Safety Must Be a Key Corporate Value

Please read this guide thoroughly and have all appropriate personnel in your organization read and follow the instructions carefully. It is our firm belief that management, owners and supervisors play a key role in assuring safe operation of melting, holding, pouring and heating equipment.

In most foundries, they bear frontline responsibility for implementing and monitoring established safety procedures and new worker training, as well as equipment inspection and maintenance.

While it is impossible to remove the risk from melting metal, it is possible to make the melt shop an accident-free workplace. Accomplishing this goal requires a true partnership between foundry managers, the suppliers who equip the melt shop and the foundry workers who operate their equipment.

It requires management to make safety a key corporate value and then to communicate that to the foundry workers both by selecting the safest available equipment and by extending every possible effort to assure that personnel are instructed in its proper use.

## Hazard Intensity Levels

At all times you must refer to your equipment manual for comprehensive information and definitions. You must follow these warnings carefully to avoid injury and possible death.

Throughout this Induction Foundry Safety Fundamentals Guide you will see both safety and operational warnings set apart from the regular informative text. These special boxes have been inserted to call your attention to matters that you cannot afford to overlook. They are often referring to incidents that if ignored or overlooked can lead to serious injury or death.

There are three generally accepted signal words defining three levels of hazard intensity, and a fourth that should also be read carefully. The types of warnings, what they look like and how they are used in this Induction Foundry Safety Fundamentals Guide are described here for you to familiarize yourself with and to use to educate other personnel in your melt shop.

	<p><b>DANGER</b></p> <p>Danger tags advise of a hazardous situation which, if not avoided, will result in death or serious injury.</p>
	<p><b>WARNING</b></p> <p>Warning tags advise of a hazardous situation which, if not avoided, could result in death or serious injury.</p>
	<p><b>CAUTION</b></p> <p>Caution tags advise of a hazardous situation which, if not avoided could result in minor or moderate injury.</p>
	<p><b>NOTICE</b></p> <p>Notice tags advise of equipment damage or practices not related to personal injury.</p>

### Consult Your Governing Agencies & Industry Organizations

While we at Inductotherm are aware of many safety hazards and want to help create a safer melt shop, we cannot be your sole source of safety information.

Please consult with both your national and local governing agencies and industry organizations for additional safety information and refer to national and local safety codes.

*Occupational Safety & Health Administration (OSHA)*

www.osha.gov

*National Fire Protection Agency (NFPA)*

www.nfpa.org

*American Foundry Society (AFS)*

www.afsinc.org

*American National Standards Institute (ANSI)*

www.ansi.org

*ASTM International*

www.astm.org

### The Induction Foundry Safety Training Kit

Working with molten metal always has been a dangerous job. In the past, the heat, noise and fumes produced by combustion furnaces constantly reminded foundry workers of melt shop hazards. But today's high-efficiency induction furnaces have improved working conditions by making foundries cooler, cleaner and generally less hostile workplaces. They have not, however, eliminated the dangers inherent in working close to molten metal.

The goal of this guide and the Induction Foundry Safety Training Kit described below is to make all foundry workers aware of the lifesaving precautions that must always be taken whenever metal is melted.

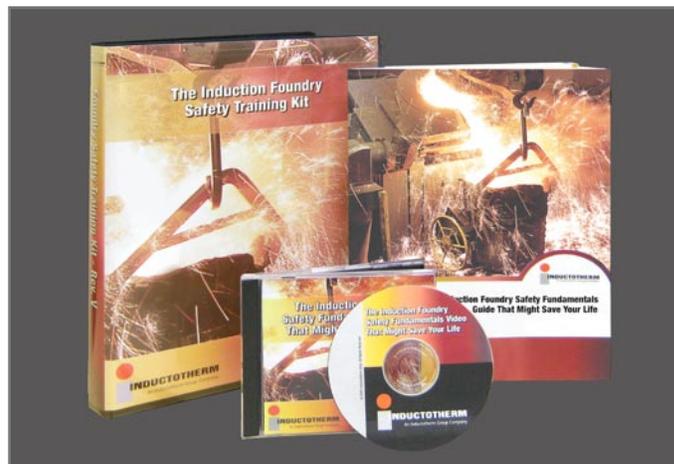
Induction furnaces make today's foundries safer and more productive than at any time in history. Sadly, many of the deaths and injuries that have occurred could have been prevented by observing common-sense safety precautions.

For this reason, we have created the Induction Foundry Safety Training Kit and have made it available for free to all foundries, whether they have Inductotherm equipment or not.

The Induction Foundry Safety Training Kit consists of the following parts:

- This [Induction Foundry Safety Fundamentals Guide](#)
- The [Induction Foundry Safety Fundamentals Video](#)
- Safety related bulletins and articles

At Inductotherm, we want every foundry employee, owner and supervisor to become knowledgeable about the safety hazards associated with melting metal. This Induction Foundry Safety Training Kit is one way we are working to achieve this goal.



*The Induction Foundry Safety Training Kit*

	 <b>DANGER</b>
	<p>OSHA's Personal Protective Equipment Part 29 CFR (1910.132) states, "The employer shall assess the workplace to determine if hazards are likely to be present, which necessitate the use of Personal Protective Equipment (PPE)."</p>

	 <b>CAUTION</b>
	<p>This safety training guide provides safety information of a general nature. It is not intended to be a substitute for the more detailed and specific operational and safety information provided in equipment manuals.</p>

	 <b>CAUTION</b>
	<p>According to OSHA Publication 2056, "All employers must establish or update operating procedures and communicate them so that employees follow safety and health requirements."</p>

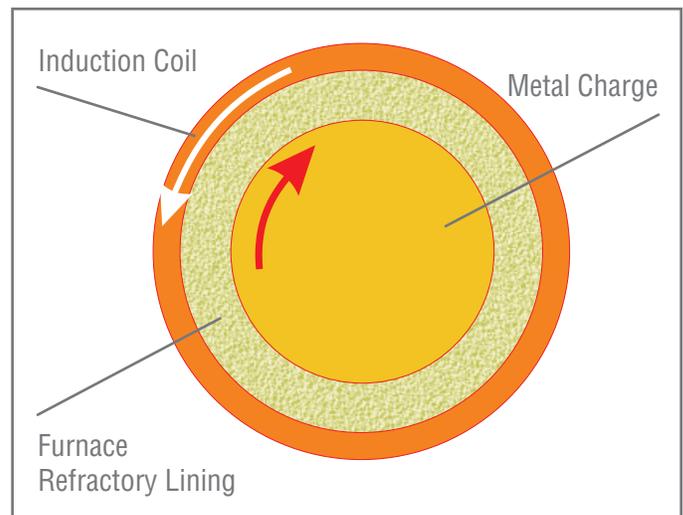
## Induction Melting

Combustion furnaces and induction furnaces produce heat in two entirely different ways.

In a combustion furnace, heat is created by burning a fuel such as coke, oil or natural gas. The burning fuel brings the interior temperature of the furnace above the melting point of the charge material placed inside. This heats the surface of the charge material, causing it to melt.

Induction furnaces produce their heat cleanly, without burning fuel. Alternating electric current from an induction power unit flows into a furnace and through a coil made of hollow copper tubing. Electrical current flowing in one direction in the induction coil creates an electromagnetic field that induces an electrical current flow in the opposite direction in the metal charge inside the furnace, producing heat that rapidly causes the metal to melt.

With induction, you heat the charge directly, not the furnace, although some furnace surfaces may become hot enough to present a burn hazard.



*Current flowing in one direction in the induction coil induces a current flow in the opposite direction in the metal charge. This current heats the metal and causes it to melt.*

## Induction Electrical System Configurations

Induction furnaces require two separate electrical systems: one for the cooling system, furnace tilting and instrumentation, and the other for the induction coil power.

A line to the plant's power distribution panel typically furnishes power for the pumps in the induction coil cooling system, the hydraulic furnace tilting mechanism, and instrumentation and control systems.

Electricity for the induction coils is furnished from a three-phase, high voltage, high amperage utility line. The complexity of the power supply connected to the induction coils varies with the type of furnace and its use.

A channel furnace that holds and pours liquefied metal can operate efficiently using mains frequency provided by the local utility. By contrast, most coreless furnaces for melting require a medium- to high-frequency power supply.

Raising the frequency of the alternating current flowing through the induction coils increases the amount of power that can be applied to a given size furnace. This, in turn, means faster melting.

A 10 ton coreless furnace operating at 60 Hz can melt its capacity in two hours. At 275 Hz, the same furnace can melt the full 10 ton charge in 26 minutes, or four times faster.

An added advantage of higher frequency operation is that furnaces can be started using less bulky scrap and can be emptied completely between heats.

The transformers, inverters and capacitors needed to "tune" the frequency required for high-efficiency induction furnaces can pose a serious electrical hazard. For this reason, furnace power supplies are housed in key-locked steel enclosures, equipped with safety interlocks.

### **Safety Implications**

Typically, the induction coil power supply and the other furnace systems are energized from multiple electric services. This means that foundry workers cannot assume that the power to the furnace coil has stopped because service has been interrupted to the furnace's cooling system or hydraulic pumps. Review the lockout/tagout section provided in this safety guide.

## Induction Furnaces Come In Many Varieties

### Coreless Furnaces

A coreless furnace has no inductor or core, unlike the channel furnace described below. Instead, the entire bath functions as the induction heating area. Copper coils encircle a layer of refractory material surrounding the entire length of the furnace interior.

Running a powerful electric current through the coils creates a magnetic field that penetrates the refractory and quickly melts the metal charge material inside the furnace.

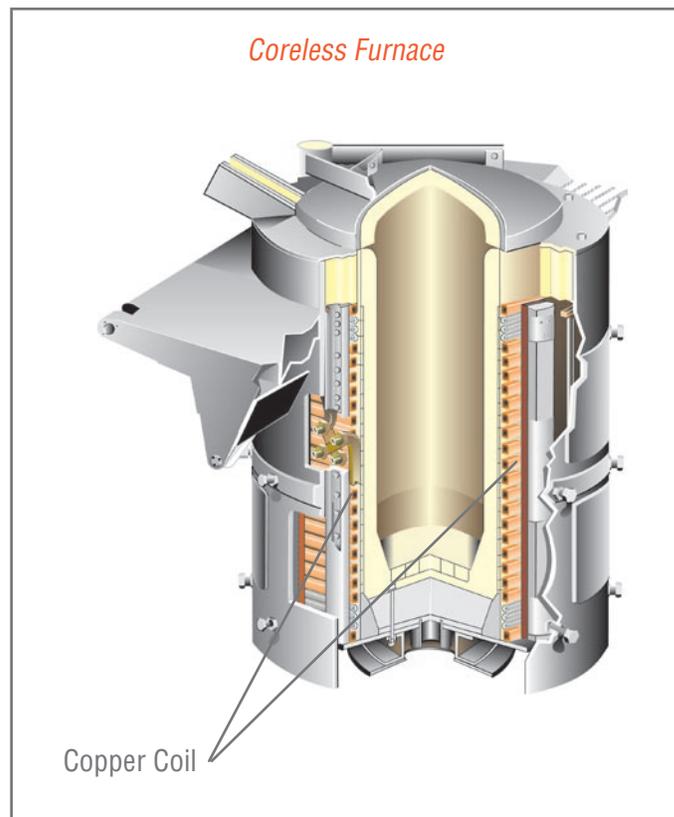
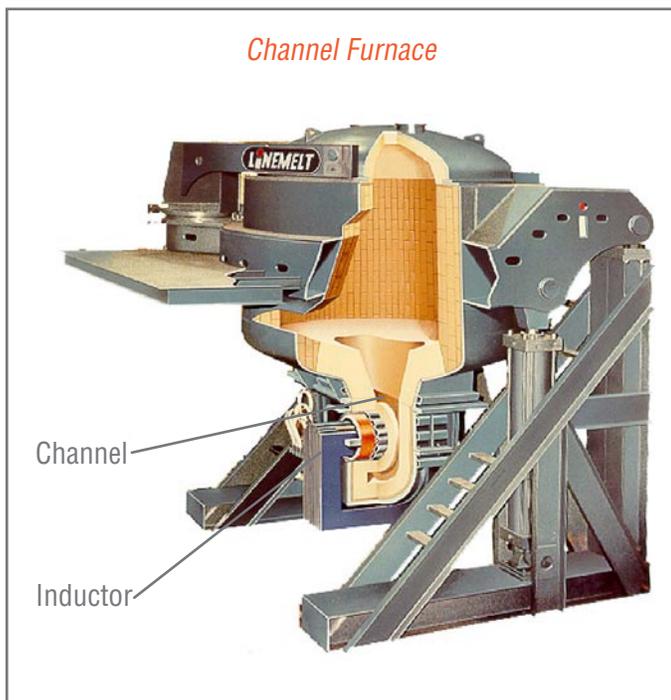
The copper coil is kept from melting by cooling water flowing through it. Coreless furnaces range in size from just a few ounces to 100 tons of metal and more.

A direct electric heat furnace is a unique type of highly efficient air-cooled coreless furnace that uses induction to heat a crucible rather than the metal itself. This furnace is used to melt most nonferrous metals, including aluminum.

### Channel Furnaces

In a channel furnace, induction heating takes place in the “channel,” a relatively small and narrow area at the bottom of the main bath.

The channel passes through a laminated steel core and around the coil assembly. The electric circuit formed by the core and coil is completed when the channel is filled with molten metal.



Once the channel is filled with molten metal, power can be applied to the furnace coil. This produces an intense electromagnetic field which causes electric current to flow through and further heat the molten metal in the channel.

Hotter metal leaving the channel circulates upward, raising the temperature of the entire bath.

Foundries typically use channel furnaces to hold and dispense molten metal whenever it is needed. Channel furnaces are emptied only for relining.

A pressure pour is, in essence, a channel furnace, as described above, that is carefully sealed so that the metal can be moved out of the furnace by way of pressurizing the chamber above the molten metal bath in the furnace.

The recharge and pouring spouts reach below metal level and ensure that clean metal is raised out of the furnace and into a pouring launder.

A high-speed digital camera sights on the mold pouring cup, controlling the stroke of a stopper rod to precisely control the flow of molten metal into the mold. This allows as many as 400 molds or more per hour to be poured precisely with no operator intervention required.

## Be Aware of Induction Hazards

	 <b>DANGER</b>
	<p>Personnel with artificial organs, joints, plates, or similar objects must keep away from any induction equipment. The magnetic fields from the equipment may induce currents causing heating of metallic implants. Personnel with cardiac pacemakers are particularly at risk and must stay well away from any induction equipment.</p>

	 <b>DANGER</b>
	<p>Do not operate the equipment if any safety devices are jumpered, bypassed, or non-operational.</p>

	 <b>WARNING</b>
	<p>Do not attempt to use the equipment for anything other than its intended purpose.</p>

A review of foundry accident records reveals that, in almost every case, observing basic safety precautions could have prevented injury and damage.

Most melt shop precautions, such as wearing eye protection and nonflammable clothing, are simple common sense.

Other safety measures, such as knowing how to handle a bridging emergency, require specific knowledge of the induction melting process.

This guide will help you better understand and deal with both day-to-day hazards present in all foundries and many of the emergency situations you may one day encounter.

Accident investigation reports indicate that most foundry accidents happen due to one of the following reasons:

- The introduction of wet or damp metal into the melt, causing a water/molten metal explosion
- Lack of operator skill during temperature taking, sampling or the addition of alloying compounds, causing metal splash
- Dropping large pieces of charge material into a molten bath, causing metal splash
- Improper attention to charging, causing a bridging condition



*Working with molten metal always has been and always will be a dangerous occupation. Responsible foundry workers acknowledge the risks and responsible managers minimize the risks by instilling among foundry workers the importance of training and accident prevention.*

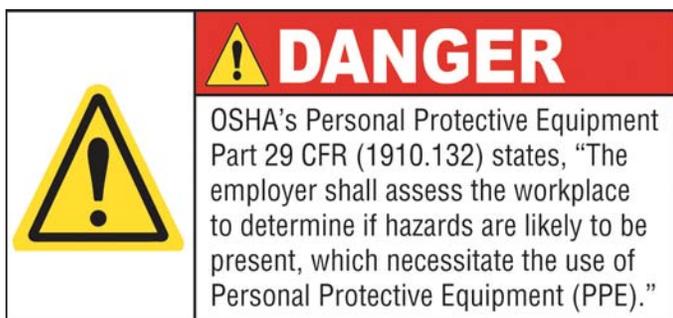
- Failure to stand behind safety lines, causing a trapping situation
- Coming into contact with electrical conductors, overriding safety interlock switches or coming into contact with incompletely discharged capacitors, causing electric shock or electrocution
- Lack of operator training

This guide will focus on what you can do to protect yourself and your co-workers from these hazards and others.

However, this is not a substitute for the more detailed information found in your equipment manuals.

The equipment manuals must be your primary source of information.

## Personal Protective Equipment (PPE) Can Save Your Life



If a foundry worker's first line of defense against injury or death is safe equipment and training that enables proper operation under both routine and emergency conditions, the final line of defense is the worker's Personal Protective Equipment (PPE).

Wearing the appropriate Personal Protective Equipment (PPE) can mean the difference between walking away from a foundry catastrophe or being injured or killed.



*Appropriate Personal Protective Equipment (PPE) helps protect this worker from a molten metal splash during charging.*



*Appropriate Personal Protective Equipment (PPE) protects melt shop workers from both metal splash and radiant heat.*

Various organizations that set national standards have established broad guidelines for the use of protective equipment in the metal casting industry. These organizations tend to agree on the basic types of personal equipment which provide workers with meaningful protection from molten metal exposure.

Many protective equipment manufacturers and distributors refine industry guidelines. Armed with knowledge of the latest technological advances in protective materials and products, they can tailor safety equipment programs to specific foundry needs.

There are two types of protective equipment worn in a foundry: primary and secondary protective equipment.

### **Primary Protective Equipment**

Primary protective equipment is the gear which you wear over your secondary protective equipment when there is significant exposure to radiant heat, molten metal splash and flame. It is designed to give you the greatest protection.

Primary protective gear should be worn during work activities like charging, sampling, temperature measuring, slagging, tapping, pouring and casting operations, or whenever there is close proximity to molten metal.

Primary protective equipment includes safety glasses, a face shield, hard hat, hearing protection, jacket, apron, gloves, leggings, spats, cape and sleeves, and must be made of aluminized glass fabrics.

For eye/face protection, safety glasses with side shields are the minimum requirement. For molten metal exposure, a face shield is needed in addition to safety glasses. Your eyes are extremely susceptible to injury, and protection is so easy to provide.

For head protection from flying/falling objects, shocks, splashes, etc., a hard hat must be worn.

Proper hearing protection must be used.

Working near places where there is heat, heat resistant/flame retardant gloves should be worn. In working near molten metal, foundry gloves which extend above the wrists must be worn.



The American Foundry Society (AFS) publishes a [Guide for Selection and Use of Personal Protective Equipment \(PPE\) and Special Clothing for Foundry Operations](#). This guide can be obtained by contacting AFS at:

American Foundry Society  
1695 North Penny Lane  
Schaumburg, IL 60173-4555 USA

Toll Free: 800/537-4237

Fax: 847/824-7848

Phone: 847/824-0181

Website: [www.afsinc.org](http://www.afsinc.org)

For protection of the body, arms and legs, aluminized glass outerwear has been recommended by the American Foundry Society (AFS) for protection against radiant heat and molten metal splash.

Aluminized glass outerwear, similar to that pictured here, will deflect about 90% of the radiant heat away from the body, while shedding molten metal splash and sparks. Use leggings to cover your legs.

Pourer's or laceless safety boots are required for foot protection from molten substance exposure. They can be removed quickly in case metal gets inside.

Metatarsal-guard shoes protect the top of the foot. If laced boots are worn, they must be covered with spats, especially near the top where there is danger of the molten metal entering.

AFS classifies protective garments according to metal types. When melting ferrous and other metals at high temperatures, they advise clothing which has undergone phosphorous-base treatment.

However, for resistance to the clinging of molten splash from lower temperature melts, such as aluminum, Galvalume<sup>®</sup>, zinc, etc., vendors recommend apparel of a non-phosphorous treatment.

Visitors must also be made to wear appropriate Personal Protective Equipment (PPE) at all times, irrespective of their duration of stay.

	
	OSHA's Personal Protective Equipment Part 29 CFR (1910.132) states, "The employer shall assess the workplace to determine if hazards are likely to be present, which necessitate the use of Personal Protective Equipment (PPE)."

### Secondary Protective Equipment

Secondary protective equipment is worn in areas where there is less hazard and is used to prevent ordinary clothing from igniting and burning.

Flame resistant coveralls would be an example of secondary protective clothing. Secondary protective clothing will help to reduce burns significantly.

In many cases, serious burns and fatalities have occurred because ordinary clothing caught fire from a small spark or splash, not from burns caused directly by molten metal.

Along with secondary protective equipment, you also must wear natural fiber outer clothing, undergarments and socks.

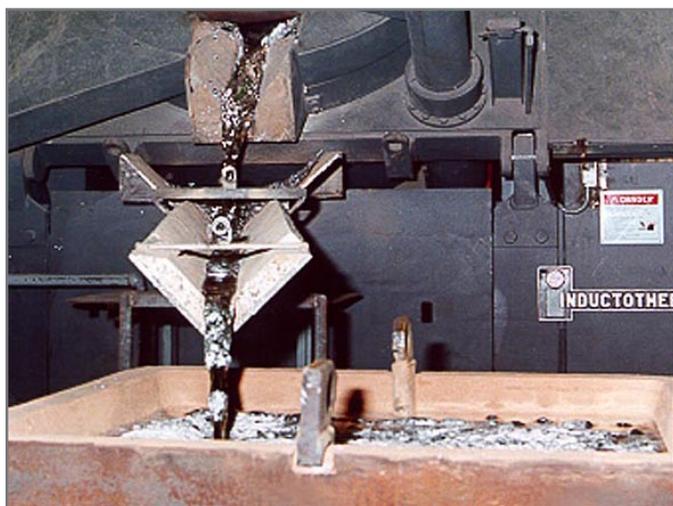
Some synthetic fabrics melt or catch fire and this can increase the burn hazard. AFS recommends the use of washable, fire resistant undergarments.

Certainly, foundries are hot places to work and Personal Protective Equipment (PPE) adds to the problem of heat-related stress, but it can save your life.

### Lower Temperature, Higher Risk

While some metals melt at a lower temperature than ferrous metals, they, in some respects, present a greater metal splash hazard to the foundry worker.

Low temperature metals and their alloys, such as aluminum, Galvalume<sup>®</sup>, tin, lead, Galfan<sup>®</sup>, zinc, copper and



*Although molten aluminum looks less threatening, in some respects it is even more dangerous than higher temperature metals and must be treated as such.*

copper alloys, etc., stick to bare skin, producing severe and possibly disfiguring burns. If larger amounts of metal are involved, the burns can be fatal.

Wearing appropriate Personal Protective Equipment (PPE), including safety glasses, hearing protection, face shield, head and body protection and foot and hand protection is crucial to safety when working in proximity to molten metals, regardless of the melting temperature.

Safety professionals advise that not all protective clothing provides the same protection against all metals. For example, they report that molten aluminum sticks to some fabrics and not others.

Also, some types of aluminized fabrics ignite when splashed with molten aluminum while others do not. They specify that splash tests be conducted to evaluate new protective equipment before it is put into use.



*When these ordinary work clothes were ignited by molten aluminum, the worker suffered fatal burns. Flame resistant clothing might have saved his life.*

Galvalume is a trademark of BIEC International, Inc. Galfan is a trademark of International Lead Zinc Research Organization, Inc.

### Masks & Respirators

	<p><b>! DANGER</b></p>
<p>Wear appropriate respirators when working with dry powders and installing or removing refractories. Respirators must fit properly.</p>	

Where airborne hazards and noise pollution pose a threat, safety professionals also specify the use of respirators and hearing protection devices. Silica dust particles are considered a health hazard when inhaled over time.

Inhalation without protection may cause severe irritation of the respiratory system, leading to silicosis or cancer. Please refer to the manufacturer’s warning.

When insulating the coil terminations or pass thrus inside a vacuum chamber, the materials used release fumes which are considered to be hazardous.

Be sure to use the appropriate mask for a given situation. Most masks protect against only certain types of dust and vapor. For example, respirators designed to filter out sulfur dioxide gas are required when cleaning the nitrogen lines on pressure pour furnaces used to hold ductile iron.

Working with molten metal in a foundry is serious business and involves many hazards. Injuries ranging from minor to fatal can occur, but by being aware of the dangers and taking the appropriate steps to safeguard ourselves, we can reduce the day-to-day risks associated with our work.

Appropriate respirators must be worn when removing and installing furnace linings or where dust is prevalent. Check with your refractory supplier to determine the respirators needed for your application.



### Three Keys to Personal Safety

There are three primary ways to help protect people from the dangers of molten metal. These are distance, protective barriers and appropriate Personal Protective Equipment (PPE).

**Distance** - Distance is a very straightforward form of protection. The further you are away from metal splash, the safer you are. That’s why manufacturers promote features such as automatic charging systems and computer controls. These systems enable people working with the furnace to stay further away and still do their jobs.

In all situations, people not directly involved in working with the furnace must stay out of the immediate area of the furnace during charging, melting and pouring operations.

**Protective Barriers** - Protective barriers can provide protection against heat and splash when distance isn’t practical. An example of a barrier would be a screen around a pouring control station on the melt deck.

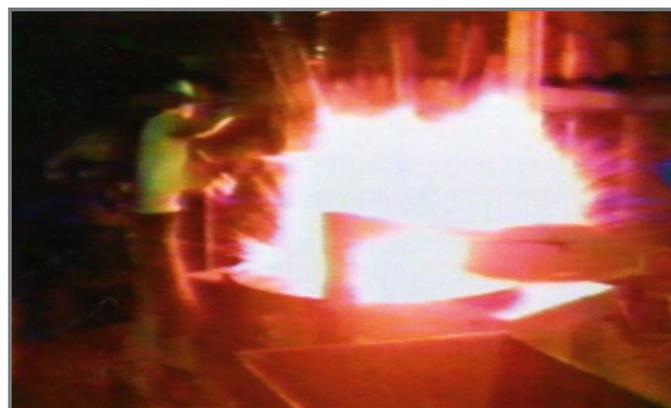
**Appropriate Personal Protective Equipment (PPE)** - Wearing appropriate Personal Protective Equipment (PPE), however, is the most important step you can take as an individual to protect yourself from metal splash. Appropriate Personal Protective Equipment (PPE) has to be your last line of defense.



*This melt deck worker is protected by all three keys: distance, a barrier and Personal Protective Equipment (PPE).*

## Molten Metal Splash: The Most Visible Foundry Hazard

	 <b>DANGER</b>
	<p>Personnel working in proximity to molten metal must wear appropriate Personal Protective Equipment (PPE).</p>



*This image was taken from a video of a real furnace eruption, probably caused by wet scrap dropped into the furnace.*

Wet charge materials are a serious safety hazard in all foundries. When molten metal comes in contact with any water, moisture or liquid-bearing material, the water instantaneously turns to steam, expanding to 1600 times its original volume and producing a violent explosion. This occurs without warning and throws molten metal and possibly high-temperature solids out of the furnace and puts workers, the plant, furnace and related equipment at risk.

A water/molten metal explosion can occur in any type of furnace. For an induction furnace, the aftereffects may be more serious and include the possibility of additional explosions caused by liquid in ruptured cooling system lines coming in contact with molten metal. Molten metal need not be present in the furnace for an explosion to occur. Explosions also can occur if sealed drums or containers are charged into an empty but hot furnace. In this case, the force of the explosion can eject the newly charged material and quite likely damage the refractory lining as well.

	 <b>DANGER</b>
	<p>All material charged into the furnace must be completely dry. Bundled or baled scrap must be dried to eliminate trapped moisture before adding it to the melt.</p>

	 <b>DANGER</b>
	<p>The violent and unpredictable nature of a water/molten metal explosion makes the wearing of appropriate Personal Protective Equipment (PPE) by melt shop workers absolutely imperative. Such clothing may help prevent disfiguring and incapacitating burns as well as fatal burns.</p>

Remote charging systems permit the operator to be away from the furnace or behind protective screens during charging. Dryers and preheaters maximize the removal of water and moisture before the scrap enters the bath.

### Sealed Containers

An easily overlooked danger is posed by sealed containers and sections of tubing or piping that are sheared, closing the ends. Containers holding combustible liquids or their fumes will explode long before the scrap itself melts. Preheating sealed materials will not prevent this hazard. Aerosol cans, oxygen cylinders, propane tanks, acetylene tanks and shock absorbers must never be used as charge material.

In fact, there is a risk that a sealed container will explode inside the preheating systems. Operator vigilance is the only preventive measure.

### Eliminating Wet Scrap

In foundries where most of the charge originates as scrap, wet charge materials pose the greatest cause for concern.

Some foundries reduce the possibility of water/molten metal explosions by storing scrap under cover for at least one day and then carefully inspecting the charge for any residual moisture. A more reliable solution being used by an increasing number of foundries today is to use remote charging systems with charge dryers or preheaters.

	 <b>DANGER</b>
	<p>Sealed material must never be permitted into the furnace or preheater.</p>

Sealed material must never be permitted into the furnace or preheater. Sheared sections of scrap tube and pipe and apparently empty sealed containers may seem less dangerous but can be equally hazardous.

Even though they do not contain combustible liquids, the air inside them can rapidly expand in the heat. In extreme cases, the pressure buildup will be sufficient to breach the container wall or escape through a sheared-closed end. If this occurs, the forceful expulsion of gas can propel the hot scrap out of the furnace or smash it into the furnace lining, causing damage.

#### **Other Hazards**

Cold charges, tools, cold aluminum “sow” molds and easily fragmented materials pose a special hazard for induction furnaces and their operating personnel because they may contain a thin layer of surface or absorbed moisture. On contact with the bath, the moisture turns to steam, causing spitting or splashing.

Appropriate protective clothing and face and eye protection normally will protect the operator. Preheating the charge and tools helps prevent many splashing injuries.

In ferrous metal foundries the greatest splashing risk occurs toward the end of the melt, when a foundry worker adds ferro-alloys or introduces tools into the melt. Ferro-alloy materials can absorb moisture from their surround-



*During normal pours, sparks can ignite flammable clothing causing serious injury if workers are not properly protected.*

#### **Primary Causes of Metal Splash & Furnace Eruptions**

1. Wet or damp charge material
2. Dropping heavy charge into a molten bath
3. Wet or damp tools or additives
4. Sealed scrap or centrifugally-cast scrap rolls

#### **Primary Protection from Splash & Furnace Eruptions**

1. Scrap drying and preheating systems
2. Remote charging systems
3. Appropriate Personal Protective Equipment (PPE)
4. Barriers

ings. Sampling spoons and slag rakes collect moisture as a thin film of condensation. Following manufacturers’ instructions for storing alloying materials and preheating tools minimizes moisture accumulation, reducing the risk of splashing.

In a nonferrous foundry, spitting or splashing can accompany the introduction of ingots into the melt, as surface condensation comes in contact with molten metal. Items such as ingots, pigs, sows, etc., must be placed in an empty furnace or on top of foundry returns. When added to an already molten pool, they must be preheated first.

Since it is impossible to wring every bit of humidity from the open air, there is always a potential for moisture condensation and splashing. Moisture condensation and absorption tend to increase with time between melts. Therefore, the greatest splashing hazards are likely to occur at the beginning of the work week or workday, or after a furnace has been taken out of service for maintenance.

Allowing more time for the initial melt during these start-up periods can help to reduce the potential for splashing hazards. During normal pours, sparks can ignite flammable clothing, causing serious injury if workers are not properly protected.

#### **Centrifugally Cast Scrap Rolls**

Special steps need to be taken when charging a furnace with centrifugally cast scrap rolls. This type of scrap should not be melted in an induction furnace. The hazard stems from the possibility a roll may contain a ductile inner core surrounded by a brittle outer layer.

The different rates of expansion can cause the surface material to explosively separate from the roll, damaging equipment and injuring personnel. If scrap rolls are to be melted, the fragmenting hazard can be minimized by breaking up the scrap before charging.

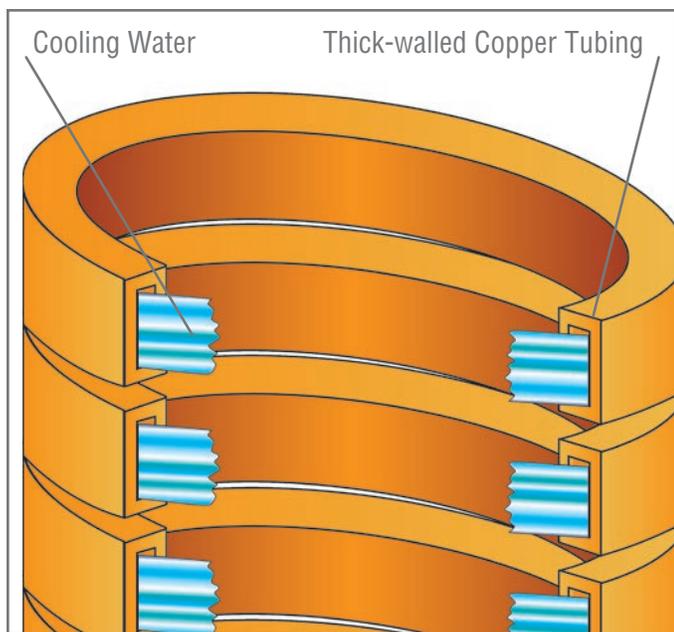
## Furnace Cooling

For those unfamiliar with induction melting, it may seem unusual for a high-temperature furnace to be equipped with a cooling system that operates by circulating water inside electrical conductors carrying thousands of amps of electric current. Yet without continuous cooling, induction furnaces cannot operate.

The furnace coil, which produces the electromagnetic field, is not designed to get hot. Although some heat is conducted from the molten bath through the lining to the coil, most of the heat load on the coil is caused by current flowing through it. This requires that it be continually cooled, not only to increase its electrical efficiency but to prevent it from melting.

Typically, the cooling system is built into the coil itself which is made of hollow copper tubing in which the cooling water flows. The water picks up the heat caused by the current as well as heat conducted from the metal through the refractory and carries it to a heat exchanger for removal.

If an electrical or mechanical failure damages the pump that circulates the water, a dangerous heat buildup could lead to coil insulation damage, coil arcing, steam buildup and water leaks. These could then lead to a major explosion that could occur within minutes.



*Induction furnaces must have a water cooling system built into the coil itself. The water picks up the heat caused by the current as well as heat conducted from the metal through the refractory and carries it to a heat exchanger for removal.*

Therefore, induction furnaces must have a backup cooling system, such as a battery-powered or engine-powered water pump or a city water connection that can be engaged if normal pump operation fails.

	<b>! DANGER</b>
	<p>Any event that interferes with normal furnace cooling can quickly lead to coil damage and may lead to a catastrophic explosion that can cause injury or death.</p>

## Open Water Systems Require Careful Maintenance

Modern induction systems are typically equipped with closed water cooling systems. Totally closed systems offer the best protection against low water flow caused by scaling or the accumulation of contaminants in the water passages. Open water systems, however, were common in systems built before 1980.

For safe operation, open water systems require frequent cleaning, treatment and maintenance as specified in their operating manuals. Without careful maintenance, an accumulation of minerals, dirt, scale and other contaminants will block the cooling water passages, causing components within the power supply and/or furnace to overheat.

In the power supply, this overheating could cause the decomposition of insulating materials and produce flammable hydrogen, methane or propane gases. This could produce an explosion resulting in injury or death.

In the furnace, loss or restricted flow of cooling water could lead to overheating the copper coil resulting in failure of the tubing. This could produce water leaks leading to a water/molten metal explosion causing injury or death.

Because water cooling is crucial to the safe operation of induction furnaces and power supplies, no induction system should be operated without functioning water temperature and flow interlocks. These interlocks must not be bypassed.

	<b>! DANGER</b>
	<p>Never clean out water lines with compressed air while the power is on. The air will displace the cooling water and the system will overheat rapidly, and may result in a catastrophic explosion that can cause injury or death.</p>

## Bridging Situations Require Immediate Emergency Action



It is important that care be taken when charging the furnace so that charge continues to feed into the molten pool properly. If it hangs up due to interlocking or bridging, superheating below can erode the refractory, causing molten metal to penetrate to the coil.

This results in loss of the melt and loss of the lining, and represents a very dangerous condition. Should the molten metal burn through the coil, the water in the coil can cause an explosion, causing serious injury or death.

When material charged into the top portion of the furnace is not in contact with the molten metal in the bottom of the furnace, the condition known as “bridging” exists.

When bridging occurs, unmelted charge material is no longer serving to moderate the temperature of the bath during the melting cycle. Also, the air gap between the molten metal and the bridge acts as an insulator. The molten metal in the bottom of the furnace, under the impact of melting power, will superheat.

This superheating in an induction furnace will occur very rapidly and will soon raise the temperature of the bath above the maximum temperature rating of the refractory.

Also, excessive stirring in the bottom of the furnace, due to the small metal mass and high power density, will combine with the high metal temperature to cause rapid lining erosion or possibly complete refractory failure.

Without immediate attention to a “bridging” condition, a runout or explosion will occur. If the runout is through the bottom of the furnace, it can cause a fire under the furnace and in the pit area with loss of hydraulics and water cooling.

If the molten metal melts through the furnace coil and water comes in contact with the molten metal, the water instantaneously turns into steam with an expansion rate of 1600 to 1.

If the water gets under the molten metal, this instantaneous expansion will produce an explosion which could cause injury or death and extensive damage to equipment.

Be sure to keep the furnace pit area clean and dry because it is designed to hold molten metal in case of an emergency.

Bridging can occur in any induction furnace and all furnace operators must be trained to be able to recognize bridging and its dangers. All operators must be trained how to solve a bridging problem.

### Warning Signs of Bridging

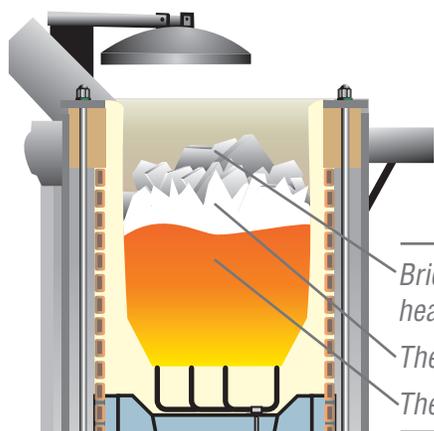
Bridging may reveal itself with one of several warning signs. The clearest warning sign that bridging has occurred is that the melt is taking longer than expected. Rather than increase the power, the operator must switch off power and evacuate all personnel from the area immediately. Under no circumstances should the operator increase power.

If ferrous metal is being melted, the chemical reaction which it creates on contact with the furnace lining will, under superheated conditions, produce carbon monoxide.

This gas may reveal itself as small blue flames on or in the bridge. The appearance of these flames indicates the bridge may be pressurized, and it must not be breached. In the case of a nonferrous charge, gas production will also occur, but there are no flames or other visible indications.

### In The Event of a Bridge

Bridging can be minimized by using proper charge material and by making sure the different sizes of charge material are added correctly. If a bridge occurs, power must be turned off immediately. All personnel must be evacuated from the furnace area until enough time has elapsed to allow the molten metal to solidify.



*Bridging occurs when a “cap” forms over the top of the furnace, allowing a buildup of superheated gases in the void below. If a bridge develops, power must be turned off immediately.*

*The void separating molten metal from the bridge of solid charge material acts as an insulator.*

*The molten metal will superheat and the temperature will rise rapidly.*

## Spill Pits May Keep You from Being Knee-Deep in Molten Metal



Induction melting furnaces must only be operated with adequate, carefully maintained and dry spill pits. These pits, often called runout pits, are located under and in front of induction furnaces. They serve to contain any molten metal spilled as a result of accident, runout or dumping of the furnace in an emergency.

Without adequate pits, free-flowing spilled molten metal would flow across the foundry floor, endangering workers, damaging equipment and structures and could also produce devastating fires and explosions.

To accomplish the job for which they are intended, spill pits need to meet the following standards:

**Adequate Capacity** - There must be a pit for each furnace large enough to hold 150% of its furnace's capacity. This size allows room in the pit for the almost inevitable accumulation of metal spilled during routine pouring.

**Proper Construction** - Spill pits must be designed and built by qualified professionals who are experienced in foundry design and knowledgeable about your installation. Pits must be constructed of concrete and lined with firebrick.

The area immediately under the furnace must be sloped to carry spilled metal away from the furnace and into a deeper holding pit. The area directly in front of the furnace must be covered with a steel grating.

Inverted steel drums set to their full depths in foundry sand in the bottom of the pit aid in containment and later removal of spilled metal. With these drums, the molten metal flows across the sand, melts through the bottoms of the inverted drums and fills them. These can later be removed.

Very small furnaces such as Mini-Melt™ furnaces, rollover furnaces and smaller Dura-Line® furnaces also require spill pits, but because of the small quantity of molten metal in the furnaces, these 'pits' can be surface-mounted structures that will fully contain 150% of the furnace capacity in the event of a runout.

**Absolutely Dry** - Spill pits must be kept completely dry at all times. This requires careful vigilance since these pits are low points and can catch water from leaks, cleaning operations or ground seepage.

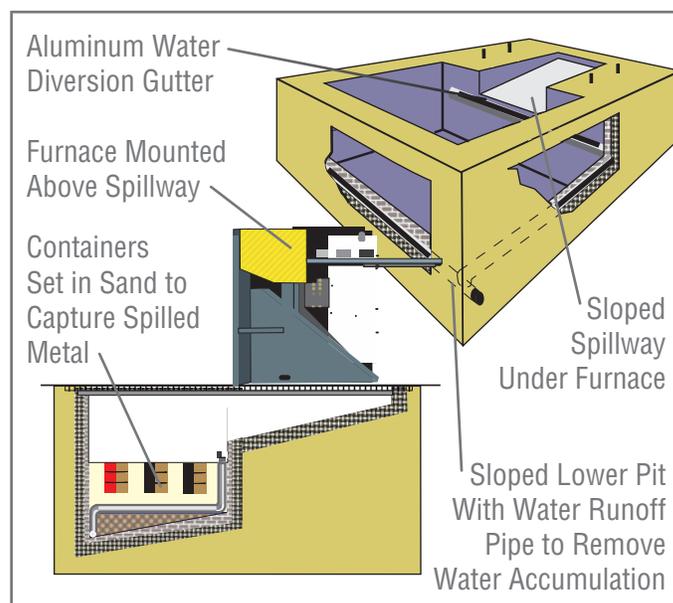
Wet pits are bombs waiting to explode! Only dry spill pits can safely contain a runout or emergency furnace dumping. Furnaces must not be operated if their spill pits are wet!

**Water Diversion System** - A water diversion system, built into your pit during construction or added later, may aid in keeping your pit dry. With this system, an aluminum channel or gutter is placed at the top of the spill pit directly beneath the slope running underneath the furnace. This channel collects any water or liquid running down the slope before it falls into the pit and diverts the water away from the pit to a drain or sump.

**Attentive Maintenance** - As with any key safety system, spill pits must be checked daily. They must be kept clear of debris and flammable materials.

Pit covers must be kept clear of slag and other blocking materials that would interfere with the passage of molten metal. Metal from any minor spills must be regularly removed from the spill pits to ensure that adequate capacity is maintained.

If you know your spill pit is properly sized, dry and clear of debris, you can operate your furnace with the confidence of knowing that if an emergency occurs, you can dump any molten metal from the furnace into the spill pit.



## Ground & Leak Detection Systems



The ground detector is a primary safety device. Never operate the unit with a faulty ground detection system. Many factors (lining condition, etc.) influence the operation and speed of operation of the ground leak detector. If a leak is suspected at any time, cease operation, clear the melt deck area of all personnel and empty the furnace.



*Fins of molten metal can penetrate worn or damaged refractory and come into contact with the coil.*

The ground and leak detector system for use with most coreless induction furnaces and power supply units is crucial to safe melting and holding operations. The system, which includes both a ground detector module associated with the power supply and a ground leak probe, located in the furnace (except in removable crucible furnaces), is designed to provide important protection against electrical shock and warning of metal-to-coil penetration, a highly dangerous condition that could lead to a furnace eruption or explosion.

### Ground Leak Probe Key to Protection

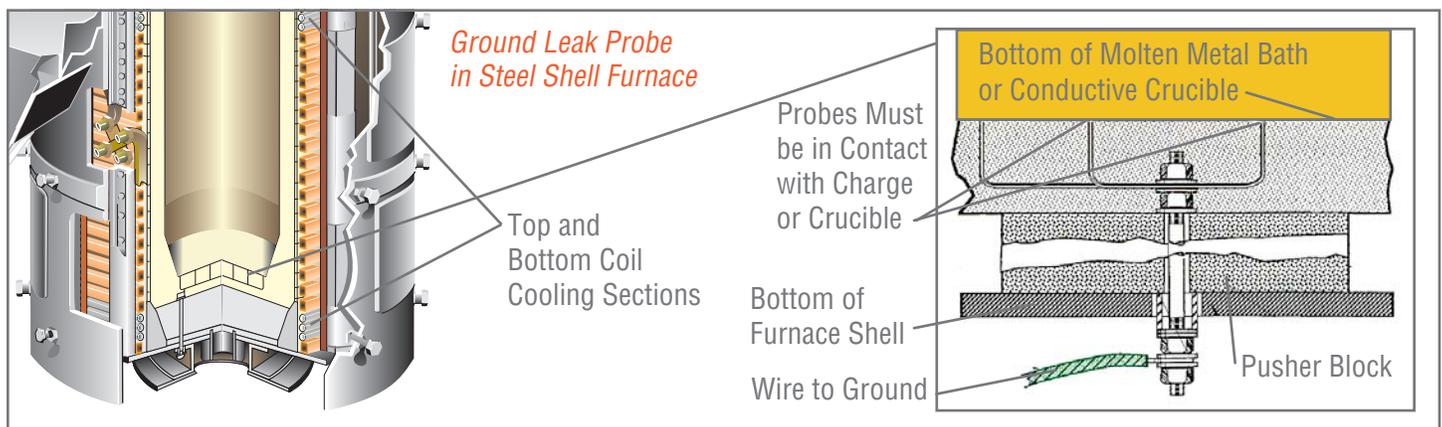
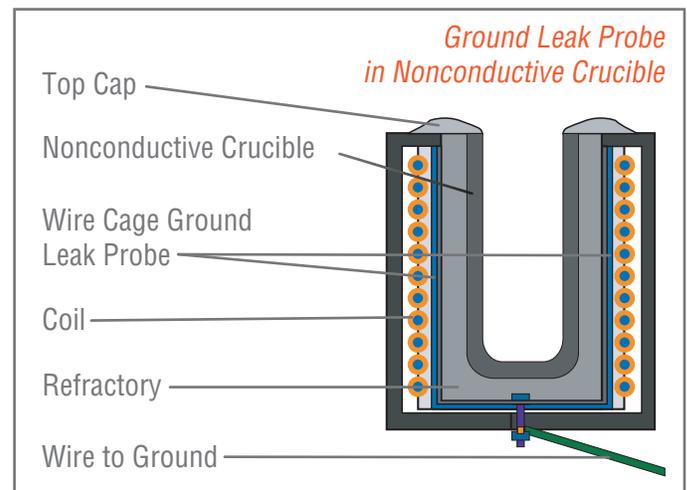
Key to this protection in furnaces with rammed linings or conductive crucibles is the ground leak probe in the bottom of the furnace. This probe is composed of an electrical

ground connected to several wires extending through the refractory and in contact with the molten bath or conductive crucible. This system serves to electrically ground the molten bath.

In some small furnaces with nonconductive, nonremovable crucibles, where the bath cannot be practically grounded, the ground leak probe takes the form of a wire cage located between the crucible and coil. This wire cage serves to ground the bath if metal penetrates through the crucible.

Both of these probe configurations are designed to provide shock protection to melt deck workers by helping to ensure that there is no voltage potential in the molten bath. If molten metal were to touch the coil, the ground leak probe would conduct current from the coil to ground.

This would be detected by the ground detector module and the power would be shut off to stop any coil arcing. This also would prevent high voltage from being carried by the molten metal or furnace charge.



Such high voltage could cause serious or even fatal electrical shock to the operator if he/she were to come into conductive contact with the bath.

Coil cooling sections in the top and bottom of a steel shell furnace serve to maintain uniform refractory temperatures throughout the furnace to maximize lining life.

In Inductotherm steel shell furnaces, these cooling sections are electrically isolated from the active coil, principally to insulate the active coil from ground leakage at the top and bottom of the furnace. If a fin of metal reaches the cooling coil, the metal simply freezes.

The ground and leak detector system can sense metal penetration to the cooling sections while maintaining AC isolation of these cooling sections from the active coil. This improved arrangement is accomplished by incorporating a simple device in all new steel shell furnaces to put low-level DC voltage on the top and bottom cooling coils.

With this voltage, a metal fin touching a cooling section will trip the ground leak detector, turning off the power to the furnace and alerting the operator to the problem. And since the voltage on the cooling coil is low, the fault will generate only extremely low current, up to 150 milliamperes.

Unlike systems which directly connect their cooling coil sections to the active coil to provide ground fault detector protection, this low current poses no risk to the coil. It avoids the danger of a large fault blowing a hole in the tubing used for cooling coils.

Your coreless furnace must not be operated without a functioning ground detector and ground leak probe. The ground leak probe may not be required in removable crucibles and some special vacuum furnaces.

As a normal safety precaution, power to the furnace must always be turned off during slagging, sampling and temperature measuring.

### **Ground Detector Module Turns Off Power**

The ground leak probes work in conjunction with the ground detector module mounted inside or external to the power supply. The electrical circuitry in the ground detector module continually monitors the electrical integrity of the systems. This module turns off power to the furnace if any improper ground is detected in the power supply, bus or induction coil. This is crucial to furnace safety.

If the furnace refractory lining or crucible cracks or otherwise fails and a portion of the metal bath touches the energized furnace coil, the coil could arc and rupture. This could allow water to get into the bath, causing metal erup-



*A handheld ground leak detector probe test device verifies the integrity of the furnace's ground probe system. Note the use of appropriate Personal Protective Equipment (PPE).*

tion or explosion. Both parts of the system, the ground leak probe and the ground detector, must function properly for safe melting operations.

### **System Maintenance**

To keep the ground leak probes working properly in a rammed lining furnace, care must be taken when installing the lining to ensure that the ground leak probe wires come into contact with the lining form.

It is essential that the ground leak probe wires remain exposed, permitting contact with the furnace charge. If the wires are too short, extra lengths of 304 stainless steel wire must be welded to the existing wires to extend the wires into the charge material or into contact with a conductive crucible.

It is important to check your furnace's ground leak probes daily, especially in rammed lining furnaces and furnaces with conductive crucibles. The probes can be covered during improper furnace relining, can burn off, can be isolated by slag, or otherwise be prevented from providing a solid electrical ground.

This check can be done with Inductotherm’s ground leak probe testing device, an easy-to-use, handheld tool for verifying your furnace’s ground connection. It can be used with any system equipped with ground leak probes.

Failure to ensure that the ground leak probe wires are providing a solid ground will result in the loss of protection for the operator and furnace provided by the ground and leak detector system.

Your melting system’s ground detector circuit must also be checked daily. In a typical system, this is done by pushing the test button on the detector, which briefly simulates an actual ground fault. Refer to your power supply users manual for proper usage of the test button.

Because of the crucial safety functions ground and leak detection systems have in coreless induction melting and holding furnaces, your furnace must not be operated without a fully functional ground and leak detection system.

	 <b>WARNING</b>
	In case of a ground fault trip, the melt deck around the furnace must be cleared of all personnel immediately.

In case of a ground fault trip, the melt deck around the furnace must be cleared of all personnel immediately. This is to reduce the risk of injury to personnel should there be an eruption of molten metal.

If after a reasonable period of time there are no indications of an imminent eruption, such as rumbling sounds, vibrations, etc., only qualified maintenance personnel wearing the appropriate Personal Protective Equipment (PPE) may then cautiously proceed to troubleshoot the cause of the ground fault trip.

Furnace capacity must be taken into consideration when determining what a reasonable period of time is. If in doubt, keep all personnel safely away from the furnace until the metal charge has solidified.

	 <b>WARNING</b>	
	The integrity of the probes or the wire cage must be checked frequently.	

Testing the integrity of the probes requires the foundry worker to take measurements using a special instrument.

In rammed lining furnaces and furnaces with conductive crucibles, the frequent checking of probe wires is especially critical. Located at the bottom of the furnace, they can be easily buried during relining, covered with slag, burnt off or otherwise damaged.

**Independent Molten Metal Leak Detector**

An independent molten metal leak detector can be used in certain applications to detect the presence of molten metal close to the coil. The system includes a series of mesh panels that are placed on the coil grout covering the inner diameter (I.D.) of the furnace coil. A similar method is also used to extend the molten metal leak detection to include the bottom of the furnace. In the event that molten metal reaches the panel, an alarm will sound. An independent molten metal leak detector system is not a substitute for the ground and leak detector system.

In compliance with NEC 2002 requirements (665.5), all power supplies shipped after January 1, 2002, will incorporate ground leak detector (GLD) units that will not be equipped with probe disconnect buttons in the GLD circuit. Furnace earth leak detector probes will be hard wired to the furnace ground closest to the probes.

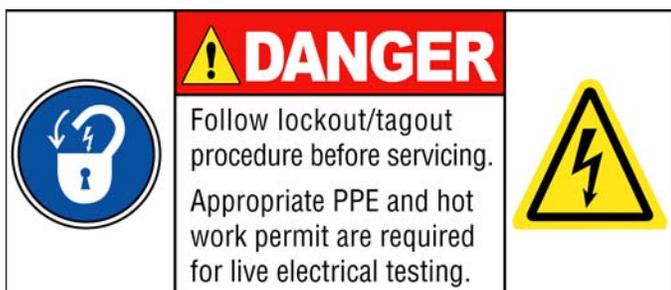
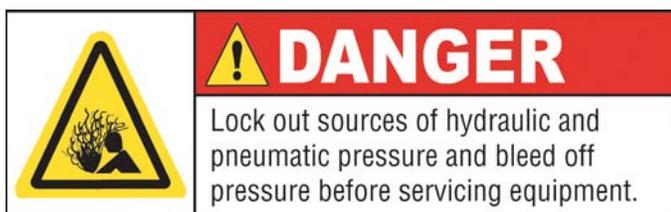
It is the user’s responsibility to ensure that the furnace ground is securely bonded to the approved system ground and the metal bath is grounded through the furnace ground probes at all times.

	 <b>DANGER</b>	
	Do not operate the furnace with the furnace ground probes disconnected from the furnace ground.	

Do not operate the equipment if the metal charge or molten bath in the furnace is not grounded through ground probe wires. Failure to ensure that ground probe wires are in contact with the charge or molten bath could lead to high voltage on the bath during operation. This could cause serious injury or death from electrical shock or molten metal eruption.

	 <b>DANGER</b>	
	A wire cage ground leak probe must be used with nonconductive crucibles.	

## Mechanical Component Inspection



Unless specifically called for, do not troubleshoot the equipment with electrical power applied.

The following components must be inspected during each furnace reline or every two years, whichever comes first. Some components may require more frequent inspections and these items are addressed in the specific equipment manuals. Under no circumstances should the following inspections be performed if the equipment contains molten metal.

**Structure & Welds** - The structure of the furnace and ancillary equipment such as conveyors, charge buckets, lining pushout mechanisms, etc., must be inspected for any signs of damage. This includes deformations, cracking, excessive corrosion, and damage from excessive heating. All welds must be visually inspected for signs of failure. The equipment must not be used if any of the structural components or welds are damaged.

**Hardware** - All fasteners must be checked for tightness according to torque specifications outlined in the equipment manuals. The fasteners must also be inspected for any signs of failure, including excessive corrosion.

Replace all fasteners and washers showing any signs of failure, including excessive corrosion, before restarting the equipment. Fasteners must only be replaced with fasteners of an equivalent grade and material.

**Hydraulics & Pneumatics** - The hydraulic and pneumatic components, including interconnecting piping, must be inspected for damage and leaks. Repair all leaks before restarting the equipment. The hydraulic and pneumatic hoses

must be checked for wear, cracking, and damage. Replace all worn, cracked or damaged hoses before restarting the equipment. Leaking hydraulic fluid can create both a fire and slip hazard.

**Water Hoses** - Water hoses must be checked for wear, cracking, and damage. Replace all worn, cracked or damaged hoses and clamps before restarting the equipment.

**Bearings** - Bearings and pivot joints must be inspected for excessive wear. Worn bearings can result in misalignment of mating structures, resulting in binding and structural loads in excess of what the equipment was designed for. Failure to replace worn bearings in a timely fashion may result in unsafe operation and much costlier repairs due to wearing of the bearing bores.

**Water Cooled Power Cables** - Water cooled power cables must be inspected for damage and leaks. The hose must be inspected for cracking due to age and heat related deterioration. Replace all damaged or leaking water cooled power cables before restarting the equipment. The guards or insulation used to protect personnel from the exposed lead ends must be in place and in good condition.

**Protective Barriers** - All protective barriers such as melt operator heat shields, bus bar covers, hydraulic cylinder splash shields, etc., must be inspected on a regular basis to make sure that they have not been damaged or their function compromised in any way through use. Repair or replace as necessary.



## Hydraulic System Safety

The furnace hydraulic system provides motive power to perform a number of functions including opening/closing the furnace cover, tilting the furnace and pushing out the lining.

General cleanliness at the hydraulic connections is critical. There is a hazard wherever heat, molten metal or flame is near hydraulic equipment.

If a line or fitting ruptures, it can send a combustible spray of oil into the heat source causing injury or death.

Therefore, the hydraulic system must be inspected daily and any leaking components repaired or replaced.

Also, fire-resistant fluids must be used with induction furnace hydraulic systems to minimize the danger of fire.



## VITON Seal Safety Advisory



	<b>DANGER</b>
Hydrofluoric acid is extremely corrosive and almost impossible to remove, particularly from human tissue.	

Operators and maintenance staff working with Inductotherm equipment must take careful note of an urgent safety hazard associated with oil seals and “O” rings made of a substance called VITON.

VITON seals are used in Inductotherm equipment and we want you to be aware of a potential problem which has been brought to our attention.

While safe under designed operating conditions, VITON

has been found to decompose into dangerous hydrofluoric acid if exposed to high temperatures.

When inspecting equipment which has been exposed to a high temperature, check if any gaskets, seals or “O” rings have suffered from decomposition. These will appear as a charred or black sticky mess.

You must not, under any circumstances, touch either the seal or the equipment until a substantial cooling period has been allowed and the equipment has been decontaminated.

Disposable, heavy-duty chemical gloves approved to withstand contact with hydrofluoric acid, safety glasses and a face shield must be worn and the affected area must be cleaned using wire wool and a detergent solution.

The gloves must be safely discarded after use.

## Do Not Use “Substitute/Unauthorized” Parts



	<b>WARNING</b>
Do not use “substitute/unauthorized” parts in your melting or heating system.	

Maintain your melting system’s high level of quality, reliability, safety and performance by using only recommended and authorized OEM replacement parts.

Failure to comply will void equipment warranty and can cause equipment malfunction, resulting in equipment and/or property damage including injury risk to personnel.

## Personal Safety for Automatic Pouring Systems



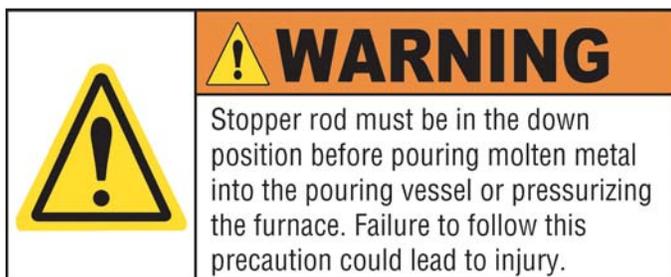
Because they hold and dispense molten metal, automatic pouring systems expose workers to most or all of the same hazards as melting and holding furnaces.

Depending on the type of automatic pouring system, these hazards may include burns from metal splash, from contact with hot surfaces, from metal runouts and from water/molten metal explosions.

But automatic pouring systems also present their own hazards not normally associated with melt shop operations.

The three major types of systems are: unheated tundish systems, heated pressure vessel systems and coreless pouring systems. Again, depending on the type of system and the metal being poured, these may include dangers such as magnesium flashes in pressure vessels and mold failures with resulting metal runouts.

### *Hazards Common to All Types of Automatic Pouring Systems*



Burns from contact with hot surfaces and materials and burns caused by molten metal splash are hazards associated with all types of automatic pouring systems. These burns can result in serious injury or death.

Do not pour molten metal into molds that may contain water or other fluids. Molds should not be of a type that may react with the chemical composition of the melt. Do not overflow molds.

Automatic pouring systems have numerous moving parts, including covers, positioning frames and stopper-rod mechanisms. These create trapping hazards if all or part of a worker's body becomes caught between moving or moving and stationary machinery.

Such entrapment can cause serious injury or death. Workers must be alert to the location and movement path of operating mechanisms and stay out of that path during the operating cycles of these mechanisms.

Hydraulic systems also create hazards in automatic pouring systems. Therefore, hydraulic systems must be inspected daily and any leaking components must be repaired.

### *Safe Operation of Automatic Pouring Systems*



The safe operation of automatic pouring systems requires that operators and maintenance personnel follow safe practices as specified in their system manuals. Here is a review of some of those key practices:

- In all types of systems, do not overflow the furnace or tundish. Molten metal may run over the pour spout or receiver and cause personnel injury or equipment damage.
- In all types of systems, do not use an oxygen lance inside the furnace or tundish as this may cause metal runouts, possible explosions and serious injury.
- Failure to follow rigorous pressure line cleaning procedures on pressure pour systems used to hold and pour ductile iron can result in magnesium buildup in the lines. Magnesium, once exposed to oxygen (air), burns and can cause serious injury or death. Review the daily cleaning requirement in the "Daily Maintenance" section of the Operation and Maintenance Manual for Pressure Pour Furnaces.
- In a pressure pour furnace, do not pressurize the furnace when the metal held in the furnace is below the minimum level. Such pressurization could cause molten metal to

erupt from the furnace siphons. This could cause severe burns or death to personnel in proximity to the siphon.

- In a pressure pour furnace, if it is necessary to reheat the furnace internally, make certain that all pneumatic lines have been thoroughly cleaned and checked and that all water, water vapor or moisture have been removed from the piping.

Remember, water vapor is one of the byproducts of oil or gas flames. Failure to properly inspect these lines can cause water, water vapor or moist air to enter the furnace and trigger a severe metal eruption from the furnace and/or furnace explosion, injuring or killing those working in proximity to the furnace vessel.

- In a pressure pour furnace, do not increase the coil power to levels above the holding power (energy required to maintain the desired metal temperature) of the vessel without proper supervision. If energy that exceeds holding power is applied to the furnace, refractory lining failure resulting in metal penetrating the lining and breaching the steel furnace case could occur.

A metal run out can present a deadly hazard to workers in the vicinity of the furnace or can result in a water/molten metal explosion that could cause injury or death over a wide area of the foundry.

- In a pressure pour furnace, do not remove water flow to the inductor or coil while liquid metal is present in the furnace or while the power is on. Shutting off the cooling water will quickly cause a failure of the power coil and may cause a water leak.

Metal runout can also occur with the possibility of liquid metal trapping water. This is a very serious condition and can cause explosion, injury and death.

**Ductile Iron Pressure Vessels Present Special Hazards**

	 <b>DANGER</b>
	Pressure lines and filters must be cleaned out properly and frequently as specified in the equipment manuals.

Too much accumulation of magnesium in the pressure lines and filters, resulting from too long an interval between cleanings, may cause the magnesium to burn when exposed to air during the cleaning process and could result in serious injury or death.

Since built-up magnesium can burn when exposed to oxygen, never use air to blow out the furnace pressure lines

	 <b>DANGER</b>
	Do not use air to blow out the furnace pressure lines and filters. Magnesium can burn when exposed to oxygen.

and filters. Use only dry nitrogen to blow out the furnace pressure lines and filters.

In ductile iron automatic pouring applications, magnesium buildup in a pressure vessel's nitrogen lines creates a hazardous condition unless these lines are cleaned daily. Never allow these lines to operate longer than 24 hours between cleaning operations. This daily cleaning requirement is specified in the "Daily Maintenance" section of the Operation and Maintenance Manual for Pressure Pour Furnaces.

You must use only dry nitrogen, an inert gas, to blow out the furnace's pressure lines and clean the filter if used. Inevitably, however, when the furnace's pressure lines are opened for cleaning, some air will enter the lines and any magnesium buildup in the lines can burn, producing a flare.

Therefore, full body appropriate Personal Protective Equipment (PPE), including a full-facepiece chemical cartridge respirator approved for exposure to sulfur dioxide gas, must be worn when opening or cleaning nitrogen pressure lines and filters.

	 <b>DANGER</b>
	A respirator designed to filter out sulfur dioxide gas must be worn when cleaning pressure lines.

Sulfur dioxide gas may be created when air mixes with slag that may be present in the pressure lines. This gas will form a dangerous sulfur-based acid when exposed to moisture in the air, eyes and breathing passages. This extremely corrosive acid can cause injury or death. A respirator designed to filter out sulfur dioxide gas must be worn.



## Charging & Preheating Systems Help Fight Molten Metal Splash



Explosions in a furnace containing molten metal may result in serious fires, damage to property and/or serious injury or death to personnel.

Explosions have been caused by wet scrap, fluid trapped in closed or partially closed containers, ice accumulations in scrap charged into the furnace and even by supposedly defused shell cases which actually have live primers. Use extreme care to ensure that the material charged is safe and will not explode.

All material charged into the furnace must be completely dry. Bundled or baled scrap and soft drink cans must be dried thoroughly to eliminate trapped moisture before adding to the melt.



The use of drying and preheating systems and remote charging systems can significantly reduce accidents related to furnace charging operations. However, it does not eliminate the need for appropriate Personal Protective Equipment (PPE).

Many serious foundry accidents occur during furnace charging when foundry workers come in close proximity to the molten bath.

Splashes caused by dropping large pieces of scrap and water/molten metal explosions caused by wet or damp scrap can be reduced through the use of drying and preheating systems and remotely controlled charging systems.

These systems, however, cannot remove trapped liquids, such as oil in cans. Such materials must be shredded and dried before they are used.



*Gas or oil fired charge dryers and preheating systems dry surface moisture on the charge before it enters the furnace.*

### Drying & Preheating Systems

Drying & preheating systems pass scrap through an oil or gas fueled flame tunnel, heating the scrap and minimizing the moisture that could cause a water/molten metal explosion. Always follow local and national safety requirements when working with or servicing fuel-fired equipment.

These systems also burn off oil, producing a cleaner charge and reducing the energy required in the furnace to melt the scrap. Scrap dryers must be used with any heel melting furnace and any application when scrap is introduced into a pool of molten metal.



### Charging Systems

Charging systems include belt and vibratory conveyors, charge buckets and chutes. They significantly enhance safety by permitting furnaces to be charged remotely, keeping the foundry worker at a distance or behind protective barriers.

Care should be taken so that the charge continues to feed into the molten pool properly. If it hangs up due to interlocking or bridging, superheating below can erode the refractory, causing molten metal to penetrate to the coil.



*When a pivoting conveyor or other automated system is used to charge a furnace, the operator can stay safely back or behind a protective barrier.*

This results in loss of the lining and represents a very dangerous condition. Should the molten metal burn through the coil, the water in the coil can cause an explosion, causing possibly fatal injuries.

All charging systems involve moving equipment that can cause injury or death. This equipment may include charge cars that pivot and/or travel across the melt deck, magnets and charge buckets carried by overhead cranes and operating belt conveyors.

You must be alert to the path moving equipment follows and stay out of that path during operation. Being struck by moving equipment can cause injury or death.

When a pivoting conveyor or other automated system is used to charge a furnace, the operator can stay safely back or behind a protective barrier.

## Moving Equipment Presents Trapping Hazard

	<b>WARNING</b>
	<p>Always watch for moving equipment. No one should be on or near the furnaces or charging equipment when they are in motion. The lift, tilt, indexing and swing movements could injure bystanders.</p>

In foundries, as in many manufacturing operations, moving equipment poses a trapping hazard to the unwary. “Trapping” is the term for the situation where part or all of a worker’s body becomes caught between moving equipment and another object or structure. Trapping also includes situations where a worker’s limbs or clothing get caught in or on moving equipment.

Trapping can result in injury or death. The loss of a limb or limbs is a common injury in trapping accidents. Trapping hazards on the melt deck may include moving charge buckets carried by overhead cranes, traversing or pivoting charge conveyors, belt conveyors, moving ladles, tilting furnaces and moving automatic pouring vessels.

Induction furnaces tilt forward to pour and then return to the upright position for charging and melting. While in motion, they can pose special hazards for foundry workers. One preventable accident occurs if a foundry worker’s

foot becomes trapped between a descending furnace back platform and the working deck.

OSHA Standard 29 CFR 1910.23 (a) (8), “Guarding Floor and Wall Openings and Holes,” states, “Every floor hole into which persons can accidentally walk shall be guarded by either:

- A standard railing with standard toeboard on all exposed sides, or
- A floor hole cover of standard strength and construction.

While the cover is not in place, the floor hole shall be constantly attended by someone or shall be protected by a removable standard railing.”

	<b>WARNING</b>
	<p>All uncovered floor holes must be properly guarded.</p>

A foundry worker must know the path a furnace or other piece of mobile equipment will travel when it is set into motion and remain behind designated safety barriers until the machine completes its duty cycle and returns to its normal resting position.

Trapping also is a hazard during maintenance operations, when workers must be within a piece of equipment’s

motion path. That’s why special steps must be taken to lockout/tagout all sources of energy and secure the equipment mechanically before maintenance work begins. In a foundry, this is particularly true of melting, holding and pouring furnaces.

If work is to be performed on tilted equipment, the tilted equipment must be secured in the tilted position with a mechanical support. Reliance on hydraulics alone could lead to the furnace dropping without warning, causing injury or death to anyone trapped underneath.

A furnace or a close capture hood which suddenly and unexpectedly swings down from a tilted position will cause injury or death.



Charge conveyors and buckets can traverse across the melt deck and index forward to the furnaces. Workers must be alert and remain clear of all moving equipment.

Whenever you are working on a furnace or close capture hood when it is in the tilted position, support it in that position with a structural brace that is strong enough to keep it from dropping if hydraulic pressure is lost.



*A charge bucket carried by an overhead crane drops its charge materials into a charge car.*

## Melt Shop “Confined Spaces”

**Furnace Spill Pits** - These fit OSHA’s definition of a “confined space” under 29 CFR 1910.146(b). They also may be “permit required confined spaces” under 29 CFR 1910.146(b).

**Furnaces** - The internal working volume of a furnace large enough for a person to work inside fits OSHA’s definition of a “confined space.”

When a lining is being removed or installed in such a furnace, “permit required confined space” procedures and appropriate Personal Protective Equipment (PPE) are required.

**Vacuum Chambers** - Vacuum chambers clearly are “confined spaces” under OSHA’s regulations. They may also be considered “permit required confined spaces.”

When insulating the coil terminations or pass thrus inside the chamber, the materials used (resins and hardeners) release fumes which are considered to be hazardous.



## Maintaining Your Refractory Lining



Proper and well-maintained refractory linings are important for the safe operation of all metal melting furnaces. In induction furnaces, they are absolutely critical.

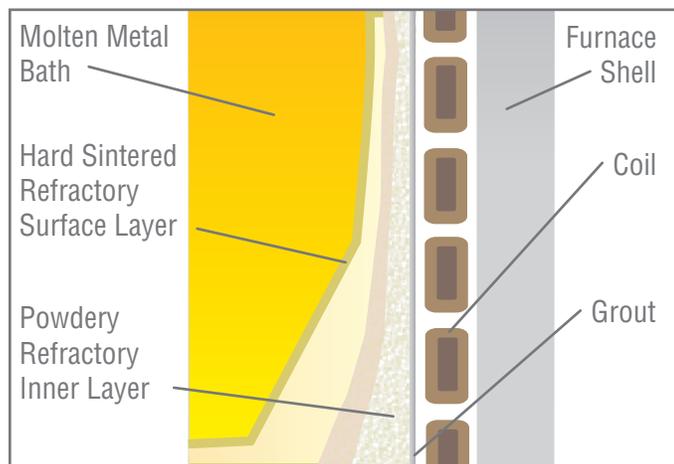
The physics of electrical induction demand that the refractory lining between the induction coils and the bath be as thin as possible. At the same time it must be thick enough to fully protect the coils and prevent metal runout in the face of attacks by molten metal, chemical agents and mechanical shocks.

Assuring that the furnace lining remains within manufacturer-specified limits requires careful treatment of the lining during all furnace operations as well as comprehensive inspection and monitoring procedures.

Without question, metal runout ranks among the most severe accidents that can occur during melting and holding operations. Runouts occur when molten metal breaks through the furnace lining. If cooling, electrical, hydraulic or control lines become damaged, there is an imminent danger of a fire or water/molten metal explosion.

The integrity of the furnace lining can be compromised by:

- Installation of the wrong refractory material for a particular application.
- Inadequate/improper installation of refractory material.



- Inadequate/improper sintering of refractory material.
- Inadequate/improper preheating of a used lining from cold.
- Failure to monitor/record normal lining wear and allowing the lining to become too thin.
- Failure to properly maintain the furnace.
- The sudden or cumulative effects of physical shocks or mechanical stress.
- The sudden or cumulative effects of the excessive temperatures or improper thermal cycling of a lining.
- Excessive slag or dross buildup.

Any of these situations can lead to a metal runout from an induction furnace. Therefore, careful attention to a furnace's lining is absolutely critical to safe melting and holding.

### Choosing the Right Refractory

Refractory material consists of several chemical compounds. The bulk of any lining material consists of a class of compounds called oxides. Refractory linings used in induction furnaces are commonly made of alumina, silica, magnesia, or zirconia plus smaller amounts of binding materials.

Choosing the right refractory material for your specific melting or holding application is crucial. You must take into account the specific metal you will be melting, the temperatures you will be reaching, the length of your melt, how long you will be holding metal in the furnace, how much inductive stirring will take place, what additives or alloying agents you will be using and your furnace relining practices.

The best way to select the right refractory is through close consultation with your refractory vendor. They will have the most current information on the specifications and performance characteristics of a traditional and new refractory material. Your refractory vendor should be your source for instructions and training for the installation and sintering of the chosen refractory material.

### Proper Installation of a Furnace Lining

Proper installation is as important to the safe operation of the furnaces as the selection of the right material for your application. If the refractory material is inadequately compacted during installation, voids or areas of low density may create weak spots easily attacked by the molten metal. If the crucible is created with a form that is improperly

centered, or one that has been somehow distorted during storage or shipment, lining thickness will be uneven. As a result, the lining may fail before the end of its expected service life.

	<b>! DANGER</b>
	Wear appropriate respirators when working with dry powders and installing or removing refractories. Respirators must fit properly.

Wear appropriate respirators when mixing dry powders. Inhalation without protection may cause severe irritation of the respiratory system, leading to silicosis or cancer. Please refer to the powder manufacturer's warning and follow all instructions.

	<b>! CAUTION</b>
	It is mandatory that the refractory manufacturer's instructions for installation, curing, day-to-day maintenance and start-up procedure of the initial lining are followed. Refractory temperature must be properly controlled by using thermocouples during the sintering process.

It is especially critical that the refractory manufacturer's procedures for drying and sintering be followed and never hurried. If sufficient time is not allowed for the refractory materials to bond, the lining will be more prone to attack by molten metal and slag. The sintering schedule must not be interrupted for any reason once it has begun.

Coreless furnaces sometime use preformed crucibles for nonferrous melting in place of rammed linings. One advantage of crucibles is that they can be manufactured with a protective glaze. In addition to minimizing oxidation of the refractory material, the glaze can seal-over any small cracks that develop during routine foundry operation.

The protective effect of the glaze lasts only as long as the coating remains undamaged. Should it become chipped or otherwise compromised during installation or subsequent operations, a small crack will, rather than "self-heal," begin to spread. Metal runout may occur.

#### **Automated Sintering Control Systems**

Computerized control of melting operations represents one of the most technologically advanced forms of melt

	<b>! DANGER</b>
	Failure to ensure that ground probe wires are in contact with the lining form or crucible could result in high voltage on the molten bath during operation and could render the molten leak detection system inoperable. This could cause serious injury or death.

shop automation. The most advanced foundry melting automation systems provide fully programmable control of sintering, the ability to schedule and control furnace cold-start procedures, and computerized control of the melting process. With furnace thermocouple feedback, computerized control of sintering can be more accurate and reliable than manual control.

Automated control systems are designed to assist a fully trained and qualified operator in running the furnace and power supply. They are not a substitute for the direct, careful and continuous attention that an operator must give to the furnace and power supply whenever they are operating.

#### **Monitoring Normal Lining Wear**

Induction furnace refractory linings and crucibles are subject to normal wear as a result of the scraping action of metal on the furnace walls. This is largely due to the inductive stirring action caused by the induction furnace's electromagnetic field.

In theory, refractory wear should be uniform; in practice this never occurs. The most intense wear occurs:

- At the slag/metal interface
- Where sidewalls join the floor
- On less dense areas caused by poor lining installation

The emptied furnace must be visually inspected. Special attention must be paid to high-wear areas described above. Observations must be accurately logged.

Although useful, visual inspections are not always possible. Nor can visual inspection alone reveal all potential wear problems. Some critical wear areas, such as the inductor molten metal loop of a channel furnace or pressure pour, remain covered with molten metal between relinings. The presence of a low density refractory area can likewise escape notice during visual inspections. These limitations make lining-wear monitoring programs essential. Directly measuring the interior diameter of the furnace provides excellent information about the condition of the lining.

A base-line plot must be made after each relining. Subsequent measurements will show a precise rate of lining wear or slag buildup. Determining the rate at which the refractory material erodes will make it possible to schedule relining before the refractory material becomes dangerously worn.

Some warning signs of lining wear are:

- In a fixed frequency power supply, an increase in the number of capacitors needed to be switched into the circuit to maintain unity power factor could be an indication of lining wear.
- In a variable frequency power supply, running at frequency limit could be an indication of lining wear.

Useful though they may be, changes in electrical characteristics must never be used as a substitute for physical measurement and observation of the lining itself.

A state-of-the-art automatic lining wear detection system which graphically displays the lining condition (i.e., Save-way or equivalent) can be used.

Two commercially available instruments can be used to provide localized temperature readings. A magnetic contact thermometer attached to the steel shell of a channel furnace will indicate lining wear by revealing the position of a hot spot. Infrared thermometers make it possible to remotely measure temperature by looking at a furnace through the eyepiece of a device resembling a hand-held video camera.

Regardless of the instrument used to monitor lining wear, it is essential to develop and adhere to a standard procedure. Consult your refractory vendor for information and training for how to monitor the condition of your lining.

Accurate data recording and plotting will help to assure maximum furnace utilization between relinings, while minimizing the risk of using a furnace with a dangerously thin lining.



### **Physical Shock & Mechanical Stress**

The sudden or cumulative effects of physical shocks and mechanical stress can lead to a failure of refractory material. Most refractory materials tend to be relatively brittle and very weak in tension. Bulky charge materials must always

be lowered into the furnace. If it must be “dump charged,” be sure there is adequate material beneath the charge to cushion its impact. The charge must also be properly centered to avoid damaging contact with the sidewall.

Mechanical stress caused by the different thermal expansion rates of the charge and refractory material can be avoided by assuring metal does not become jammed within the furnace. Except when it is done for safety reasons, dealing with a bridge for example, the melt must never be allowed to solidify in the furnace. In the event of a prolonged failure, a loss of coolant event, or other prolonged furnace shutdown, the furnace must be emptied.

### **Excessive Temperatures & Thermal Shock**

Refractory manufacturers take furnace temperature extremes into account in formulating their products. For this reason it is important that refractory materials be used only in applications that match a product’s specified temperature ranges. Should actual furnace conditions heat or cool the lining beyond its specified range, the resulting thermal shock can damage the integrity of the lining. Cracking and spalling can be early warning signs of thermal shock and a potentially serious metal runout.

Thermal shock can also be caused by excessive heating or improper cooling. The best way to avoid overheating is to monitor the bath and take a temperature reading when the charge liquefies. Excessive overheating of the bath must be avoided. Careful monitoring is essential. Temperatures exceeding the refractory’s rating can soften its surface and cause rapid erosion, leading to catastrophic failure.

The high heating rates of medium frequency coreless furnaces enable them to quickly overheat. Channel-type holding furnaces have low heating rates and thicker linings in the upper case. However, temperature control is also necessary because the inductor linings tend to be thinner. In all types of induction furnaces, kilowatt-hour counters, timing devices and computerized control systems can help prevent accidental overheating.

When working with a cold holding furnace, be sure it is properly preheated to the refractory manufacturer’s specifications before filling it with molten metal. In the case of melting cold charge material, slowing up the rate of the initial heat until the lining is completely expanded will minimize the risk of thermal shock to a cold furnace. The gradual heating of the charge allows cracks in the refractory to seal over before molten metal can penetrate. When cooling a furnace following a melt campaign, follow the refractory manufacturer’s recommendations.

Thermal damage to the refractory can also result from overfilling a coreless furnace. If the level of molten metal in the furnace is higher than the top cooling turn on the coil, the refractory material in the top of the furnace is not being cooled and is exposed to thermal stresses that could lead to its failure. Overfilling may also cause metal penetration between the working refractory lining and the top cap refractory material. Either situation may lead to metal runout and possibly a water/molten metal explosion. Serious injury or death could result.

### **Managing Slag or Dross**

Slag or dross is an unavoidable by-product of melting metal. Slag forms when rust, dirt and sand from the charge and refractory material erode from the furnace lining and rise to the top of the bath.

Dross is created when oxides form during the melting of nonferrous metals such as aluminum, zinc, Galvalume, etc. Chemical reactions between the slag or dross and the lining increase the rate at which the lining erodes.

A highly abrasive material, slag or dross will erode refractory material near the top of the molten metal. In extreme circumstances, this erosion may expose the induction coils, creating the risk of a water/molten metal explosion. Careful monitoring of the refractory thickness is necessary so it can be replaced before the coils are exposed.

### **Slag Removal Automation**

The manual process of removing slag from very large furnaces is a time consuming and labor intensive operation.

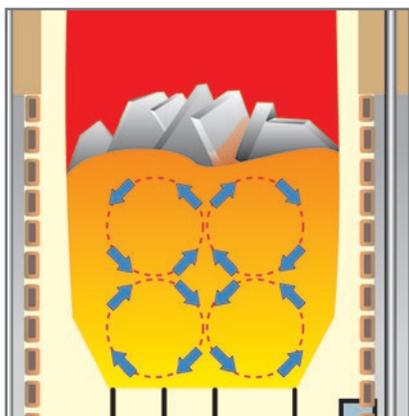
It also exposes furnace operators to high levels of radiant heat and physical exertion.

Where overhead clearances permit, slag removal can be accomplished using a clamshell type slag scoop operated from an overhead or jib crane.



*These photos show three different slagging methods that foundries can choose from to remove slag: a trained and qualified foundry worker wearing appropriate Personal Protective Equipment (PPE), an automated ARMST<sup>™</sup> System or an automated clamshell type slag scoop.*

## **Inductive Stirring**



In a coreless or channel induction furnace, the metal charge material is melted or heated by current generated by an electromagnetic field. When the metal becomes molten, this field also causes the bath to move in a “figure eight” pattern as illustrated. This is called inductive stirring. It also serves the important purpose of mixing the metal, producing a more homogeneous alloy. The amount of stirring is determined by the size of the furnace, the power put into the metal, the frequency of the electromagnetic field and the type and amount of metal in the furnace.

Inductive stirring circulates high-temperature metal away from the furnace walls, preventing overheating of the refractory surface, but also causes the refractory lining of the furnace to gradually wear away through the action of the moving metal on the furnace walls. This gradual wear requires that furnaces be relined periodically. It is vital that linings be replaced promptly when they wear down to their minimum thickness to prevent failure.

## Melt Automation Technology Helps The Operator To Prevent Accidental Superheating & Lining Damage

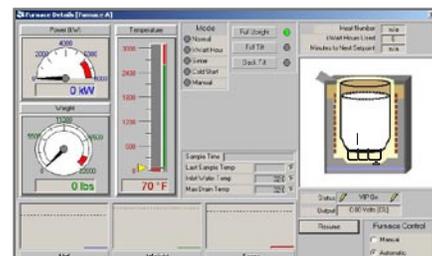
Modern induction melting systems are often high powered and melt the charge very rapidly. This has spurred the development of computerized melting systems designed to provide the furnace operator with the ability to precisely control the melting process and reduce the risk of accidental superheating. Some of these systems operate on special computers, some are PC based and some are built into the melting equipment itself. Induction melting operations lend themselves to computerized control.

A typical system takes the weight of the furnace charge, either from load cells or as entered by the operator, and the desired pouring temperature. It then calculates the kilowatt hours needed to complete the melt and then turns off the system or drops to holding power when the melt is complete. Thermocouple readings can be transmitted to the computer to further enhance accuracy.

This precise melting control optimizes power usage by

minimizing temperature overshoot, saves time by reducing frequent temperature checks and enhances safety by reducing the chance of accidental superheating of the bath which can cause excessive erosion, lining failure and the possibility of a furnace explosion.

Automated control systems are designed to assist a fully trained and qualified operator in running the furnace and power supply. They are not a substitute for the direct, careful and continuous attention that an operator must give to the furnace and power supply whenever they are operating.



Screen from Meltminder® 200 melt control computer.

## Electrical Monitoring of Lining Wear

A limited amount of information about the condition of the refractory material can be ascertained from changes in the furnace's electrical characteristics. An important limitation of these measurements is that they reveal average conditions. Electrical measurement will not isolate a localized problem, such as a gouge or a void beneath the lining surface.

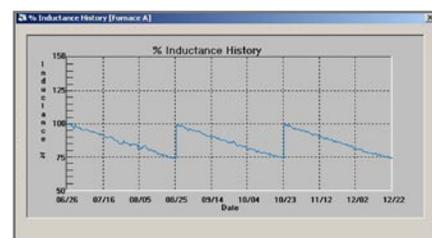
One situation in which electrical measurements are very useful is in estimating wear in the induction loop of channel furnaces. Molten metal is always present in the furnace, making visual inspections between shut-downs impossible.

Lining wear causes changes in furnace voltage, current and power readings. From these values it is possible to calculate resistance, reactance and the power factor of the channel loop. Comparing one or more of these characteristics with values from previous measurements indicates erosion (or buildup) of the refractory in the inductor loop. Always maintain a start-up log and regular meter readings.

This technique provides absolutely no information about the condition of the lining in the main bath. The main bath or upper case refractory can be subject to chemical attack at the slag line. The slag line can be at any level in the furnace depending on how it is operated. The lining must be checked visually and

also the outside shell temperature must be checked. If the refractory lining is thin, this will show as a hot spot on the shell. Once detected, the furnace lining must be carefully inspected. If the lining is severely eroded, the furnace must be removed from service immediately. Normal shell temperatures may be as high as 500°F. If the shell temperature is above 500°F or if localized hot spots are more than 100°F above adjacent areas, the lining must be carefully inspected to determine why.

Similar electrical measurements can be made of coreless furnace linings but, as noted, these measurements reveal average conditions. They will not disclose a localized problem so total reliance on this is not practical. Coreless furnaces are emptied with sufficient frequency to permit visual inspection and physical measurements, which are always more accurate.



This computer control system calculates coil inductance to check average lining wear in a coreless furnace.

## Pouring Cradle Provides Bottom Support for Crucible

Lifting a bilge type crucible with a conventional two-man ring shank provides no support to the bottom of the crucible. Should a crack in the crucible occur below the bottom ring support, the bottom of the crucible can drop and molten metal will spill and splash, possibly causing serious injury or death.

To reduce this danger, a pouring cradle that provides bottom support for the crucible must be used. This not only reduces the chance of a crack allowing the bottom to drop from the crucible, it also increases crucible life by reducing stress on the sidewall.

A crucible must never be subjected to physical damage or thermal shock and must never hold metal exceeding the crucible's maximum rated temperature. It is important to check a crucible's condition every time it is used and to replace it if it is worn, cracked or damaged.



## Push-out Systems Minimize Refractory Dust During Lining Removal

All workers in the general area of the lining push-out operation must wear appropriate respirators or masks for protection from the dust that is going to be created when the old lining crumbles. Appropriate respirators must be worn when removing and installing furnace linings or anywhere dust is prevalent.

	<b>DANGER</b>
	Wear appropriate respirators when working with dry powders and installing or removing refractories. Respirators must fit properly.

Whenever you are working on your furnace when it is in a tilted position, support it in that position with a structural brace strong enough to keep the furnace from dropping if hydraulic pressure is lost. A furnace which suddenly and unexpectedly swings down from a tilted position can cause injury or death.

	<b>DANGER</b>
	Secure a tilted furnace or a close capture hood before servicing.

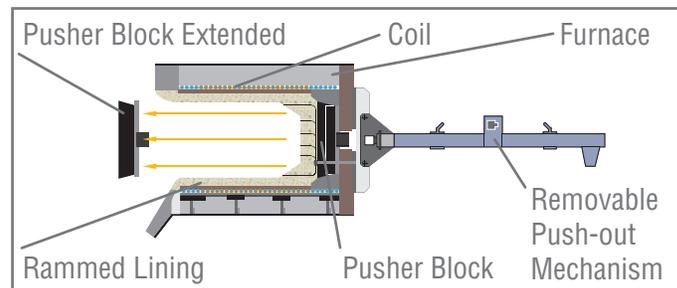
Before automated lining removal systems were developed, removing a furnace lining was a labor-intensive, time-

consuming process. Today, however, coreless induction furnaces equipped with lining push-out systems speed the lining removal process, lessen the risk of damage to the coil and reduce worker exposure to refractory dust.

These systems can be supplied with new furnaces or retrofitted to existing furnaces. They consist of a hydraulic ram and a pusher-block in the bottom of the furnace. These work together to remove the bottom and side refractory material.



*Make sure no one is standing directly in front of the furnace where they could be hit by lining material as it is pushed out.*



## Induction Electrical System Safety

When melt shops relied on fuel-fired furnaces, the electrical hazards in foundries were similar to those in any other industry. Electrical motors, lift-truck battery chargers, heaters, lights and office equipment operated at standard voltages. The switches, connectors and circuit interrupters encountered at work were simply larger versions of those found at home.

Like all industrial workers, foundry workers realized the need to treat electricity as a force to be respected. But at the same time, their years of experience in living with electrical devices taught them electrical hazards could be easily avoided.

The introduction of induction furnaces made it necessary for foundry workers to work in close proximity to high voltage power supplies and open air-cooled bus bars, apparatus commonly associated with dangerous power company substations.

Foundry workers also had to learn that a certain amount of sparking and arcing between the metal pieces in a cold charge is normal in an induction melting furnace and not necessarily a sign of an imminent catastrophe.

	 <b>DANGER</b>
	<p>Power to the furnace must be turned off whenever any process involving contact with the metal bath, such as taking samples, checking metal temperature or slagging is taking place. This is to prevent electrocution if safety systems should fail and the bath is in conductive contact with the induction coil.</p>

While induction systems present more exposed conductive surfaces than other industrial equipment, they are designed with a variety of safety systems to deal with these hazards. For example, current handling bus bars and components are surrounded by enclosures.

Safety interlocks turn off power if power supply access panels (except bolted-on panels) or doors are opened while the unit is running. They are also designed to prevent accidental starting if access panels or doors are open.

	 <b>WARNING</b>
	<p>Induction melting equipment must not be run if any safety systems are inoperable or bypassed.</p>

*High-current bus bar is encased in clear plastic to prevent accidental contact.*



*This power cabinet door latching bar provides both a mechanical barrier to door opening and an electrical interlock.*

The following are basic rules for electrical safety on the melt deck:

- Only trained and qualified personnel who have read and understood the equipment manuals are to be permitted to run induction melting equipment. A trained operator must be fully knowledgeable about the system's controls, alarms and limits, diagnostic functions and safety features, and must be fully versed in the rules and procedures related to the system's operation.
- Induction melting equipment must not be run if any safety systems are inoperable or bypassed.
- Unless a system operator is also a trained and qualified electrical service technician, he must never open the power supply cabinet doors or gain access to any secured high voltage area.
- Power to the furnace must be turned off whenever any process involving contact with the metal bath is taking place, such as taking samples, checking metal temperature or slagging. This is to prevent electrocution if safety systems should fail and the bath is in conductive contact with the induction coil.
- Keep cabinet doors and access panels locked and bolted-on panels in place at all times.

 	 <b>WARNING</b>
	<p>Only trained and qualified personnel who have read and understood the equipment manuals are to be permitted to run induction melting equipment. These personnel must be fully knowledgeable about the system's controls, alarms, limits, diagnostic functions, and safety features.</p>

 	 <b>WARNING</b>
	<p>Unless a system operator is also a trained and qualified electrical service technician, he must never open the power supply cabinet doors or gain access to any secured high voltage area.</p>

If your power unit does not have safety locks and interlocks on all doors and access panels, it should be modified to add these devices.

Your equipment manufacturer should be able to assist you in adding these important safety devices. Cabinet door locks are the most important barrier to unauthorized access to the dangerous electrical elements inside the power cabinets. These doors and access panels must be kept locked at all times.

**Safety Recommendations for Supervisors & Managers**

Supervisors need to be especially aware of electrical safety. Increased use of induction furnace technology has made it necessary for a growing number of maintenance and repair workers to come into close proximity to high current conductors.

Many maintenance technicians, particularly those who work with low-voltage devices, such as control systems, do not fully appreciate the risk posed by the high levels of voltage and current used in induction melting.

It is imperative these individuals be impressed with the fact that shortcuts, such as overriding safety interlocks during troubleshooting, are absolutely unacceptable when working with even the smallest induction furnaces and power supplies.

Only trained and qualified personnel are to have access to high-risk areas. A safety lockout system is another effective measure to prevent electrical shock.

The following procedures can help minimize the risk of electrical accidents while servicing induction furnace coils, power supplies and conductors:

- Post warning notices for all systems operating at high voltages as required by OSHA and local codes.
- Allow only trained and qualified personnel to perform maintenance or repair.
- Disconnect and lockout/tagout the power supply during maintenance.
- Forbid entry into any enclosures until the main circuit interrupter is locked in the OFF position and circuit interrupter poles are confirmed to be open.
- Wait 5 minutes after opening a circuit interrupter before opening cabinet doors. This allows capacitors time to discharge.
- Test all bus bars for residual voltage before touching.
- If the power supply energizes more than one furnace, leads to the furnace undergoing maintenance or repair must be disconnected from the power supply and the furnace induction coil grounded.

	 <b>DANGER</b>
	<p>If the power supply energizes more than one furnace, leads to the furnace undergoing maintenance or repair must be disconnected from the power supply and the furnace induction coil grounded.</p>

	 <b>DANGER</b>
	<p>Wait 5 minutes after opening a circuit interrupter before opening cabinet doors. Capacitors require time to discharge.</p>

	 <b>WARNING</b>
	<p>Test the measurement equipment for proper operation and measurement settings.</p>

## Safety Lockouts are Key Systems

 	 <b>DANGER</b>
	<p>The lockout/tagout procedure must be followed before entering any remote and/or main control cabinet or enclosure or working on any equipment or system which has exposed or enclosed electrical motors or any electrically controlled solenoids.</p>

To prevent power from being turned on accidentally while equipment is being serviced, a safety lockout/tagout system is required.

Lockout/Tagout (LOTO) refers to established practices and procedures to safeguard employees from the unexpected startup of equipment, or the release of hazardous energy during service or maintenance activities.

With this system, the individual performing the service work uses a lock to secure the circuit interrupter in the OFF position.



The same individual keeps the only key until the service work is complete and the equipment is ready to be restored to operation.

At that time, the same individual who put on the lock removes it, allowing the circuit interrupter to be closed and power to be turned on.

	 <b>DANGER</b>	
	<p>Follow lockout/tagout procedure before servicing. Appropriate PPE and hot work permit are required for live electrical testing.</p>	

	 <b>DANGER</b>
	<p>It is important that the molded case circuit interrupters (breakers, switches, etc.) be immediately taken out of service if the molded case is cracked, has burn marks on the case or the operating handle is damaged.</p>



	 <b>DANGER</b>
	<p>All capacitors must be checked for residual charge before doing any work inside the cabinet.</p>

	 <b>DANGER</b>
	<p>All bolted-on panels must be on before the power supply is energized.</p>

## Induction Power Units Include Some or All of These Safety Systems

**Safety Interlocks** - Safety Interlocks are designed to turn off power automatically when power cabinet service access doors are opened. Equipment must not be operated unless all interlocks are in proper working order.



**System Self Diagnostics** - System Self Diagnostics in many advanced induction power systems prevent the unit from operating when a fault is detected and identify the location of the fault.

**Ground and Leak Detector Systems** - These systems are crucial. They turn off power if metal in the furnace comes close to or touches the induction coil or if inverter output is otherwise grounded.

**Battery-Operated DC Pump** - A battery-operated DC pump provides emergency cooling water to your furnace if normal power is interrupted.

**Ultra-Fast-Acting AC Interrupter Module** - This serves as a solid-state circuit interrupter and expedites the system's response to emergency conditions.

 	! DANGER
	The ACI is not a disconnect. Always ensure that the circuit interrupter is off and locked out, that control voltage is off and the key removed, and that all capacitors are discharged before performing maintenance on the furnace or power supply.

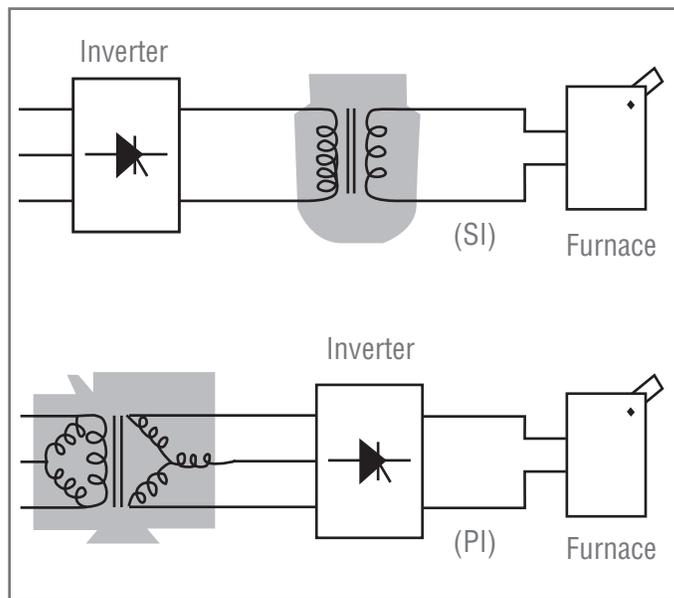
	! DANGER
	Wait 5 minutes after opening a circuit interrupter before opening cabinet doors. Capacitors require time to discharge.

**Current Limiting Reactors and Quick-Acting Circuit Interrupter** - These provide protection against component failure and major line disturbances on smaller systems.

**Capacitor Pressure Switches** - These help prevent pressure buildup inside the capacitor case by shutting down the power supply if pressure builds up due to capacitor malfunctions. If this pressure buildup is undetected and power remains on, the capacitor will explode.

**Line Isolation** - All induction furnaces need to be designed so that the current flow from the output circuit, or from output components external to the converting device, to ground under operating and ground fault conditions shall be limited to a value that does not cause 50 volts or more to ground to appear on any accessible part of the heating equipment and its load.

This protection may be provided through an isolation transformer located either between the inverter and the furnace (secondary isolation) or between the incoming power line and the inverter (primary isolation).



## For Trained Electrical Technicians Only

	<b>! DANGER</b>	
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	<p>Wait 5 minutes after opening a circuit interrupter before opening cabinet doors. Capacitors require time to discharge.</p>

	<b>! DANGER</b>
	<p>All capacitors must be checked for residual charge before doing any work inside the cabinet.</p>

Obviously there will be times when electrical measurements need to be taken from energized circuits. This work must only be done by trained and qualified electricians. Any manufacturer’s manuals, circuit diagrams or drawings that are used to guide the work must be double-checked to be sure they are complete and up to date.

Before performing a test on an energized circuit, the technician must verify that he has selected the appropriate measuring instruments rated for the proper voltage and current and fully understands the manufacturer’s directions. Power cords and test leads must be inspected and, if necessary, replaced with parts recommended by the instrument supplier. The rating of the measuring instruments must be higher than the electrical parameters of the electrical equipment. Power supply settings must never be set to exceed the capacity of the instruments or the test leads. Test instruments must be properly fused and grounded. The measuring instrument must be tested for proper operation prior to use in measuring energized circuits.

Before the technician enters the energized areas, power sources and current paths should be clearly identified. The circuit must be turned off and locked out until test instruments are properly set and leads connected. Technicians

must never touch leads, instruments, or settings while the circuit is energized. Power must be turned off and capacitors fully discharged before changing instrument settings or disconnecting leads from the system. If resistance measurements are part of the test program, power must be disconnected and all capacitors fully discharged before tests are performed.

Technicians conducting tests near energized circuits must be dressed in appropriate Personal Protective Equipment (PPE), including dry, insulated gloves as required by governing codes (i.e., NFPA 70E). They must stand on a dry, insulated surface capable of withstanding the voltages that may be encountered. The floor beneath the insulated surface must be dry, as must the technicians’ hands and shoes.

A supervisor must not allow technicians performing tests to work alone. If the supervisor cannot be personally present during the test, the supervisor must alert nearby personnel to the nature of the work taking place and instruct them how to react in an emergency.

After the job is complete, temporary grounds and bypass connections are removed and covers, guards and fuses replaced. Supervisors must verify that all safety devices and interlocks are fully operational. If modifications have been made to the equipment, the appropriate changes immediately must be made to equipment manuals, diagrams and drawings. The reason for the alteration, person making the changes and the person under whose authority they were acting should be noted, along with the time and date the modifications were completed. Everyone, including subcontractors and other off-site personnel, having copies of the original equipment manuals or drawings must be promptly provided with copies of the updated documentation and the old drawings discarded.

### **Common Electrical Regulatory Notices & Requirements**

**NFPA 70E 110.3** - “The safety related work practices shall be implemented by employees. The employer shall provide safety related work practices and shall train the employee who shall then implement the training.”

**OSHA 1910.303 (g) (2), NEC 110.27 (A)** - “Live parts of electric equipment operating at 50 volts or more shall be guarded against accidental contact by approved cabinets or other forms of approved enclosures, or by any of the following means: ...”

**OSHA 1910.333 (a) (1)** - “Live parts to which an employee may be exposed shall be de-energized before the employee works on or near them, unless the employer can demonstrate that de-energizing introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. Live parts that operate at less than 50 volts to ground need not be de-energized if there will be no increased exposure to electrical burns or to explosion due to electric arcs.”

**OSHA 1910.333 (6) (2) (ii) ©** - “Stored electric energy which might endanger personnel shall be released. Capacitors shall be discharged and high capacitance elements shall be short-circuited and grounded, if the stored electric energy might endanger personnel.”

**OSHA 1910.333 (2) (IV) (B)** - “A qualified person shall use test equipment to test the circuit elements and electrical parts of equipment to which employees will be exposed and shall verify that the circuit elements and equipment parts are de-energized. The test shall also determine if any energized condition exists as a result of inadvertently induced voltage or unrelated voltage back-feed even though

specific parts of the circuit have been de-energized and presumed to be safe. If the circuit to be tested is over 600 volts, nominal, the test equipment shall be checked for proper operation immediately before and immediately after this test.”

**OSHA 1910.334 © (3)** - “Test instruments and equipment and their accessories shall be rated for the circuits and equipment to which they will be connected and shall be designed for the environment in which they will be used.”

**OSHA 1910.306 (g) (2) (iii)** - “Where doors are used for access to voltages from 500 to 1000 volts AC or DC, either door locks or interlocks shall be provided. Where doors are used for access to voltages of over 1000 volts AC or DC, either mechanical lockouts with a disconnecting means to prevent access until voltage is removed from the crucible, or both interlocking and mechanical door locks shall be provided.

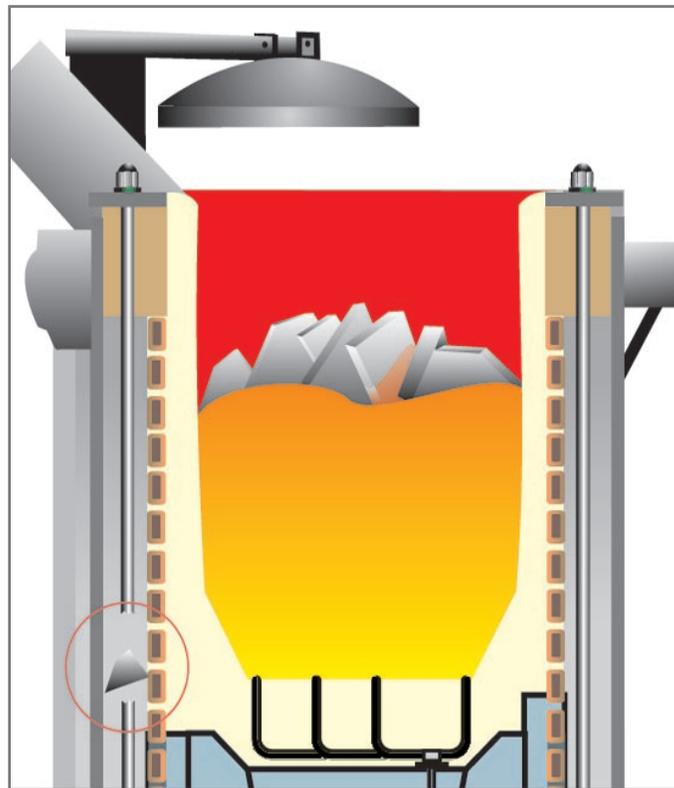
**OSHA 1910.306 (g) (2) (iv)** - “‘Danger’ labels shall be attached on the equipment and shall be plainly visible even when doors are open or panels are removed from compartments containing voltages over 250 volts AC or DC.”

## Furnace Arcing



The sparking and arcing of the charge materials in the furnace are characteristic of induction melting and not particularly hazardous. Induction furnaces melt metal by creating a flow of heat-generating electric current within the charge materials.

Although rare, a fault may develop between the coil and the furnace structure, generally resulting in coil damage and power failure. It is typically caused by loose metallic chips that work their way between the coil and furnace structure, underscoring the importance of good foundry housekeeping practices. Furnace controls also can fail due to poor foundry housekeeping practices.



## Making Foundry Safety a Shared Value

Working with molten metal always has been, and always will be, a dangerous occupation. Responsible foundry workers acknowledge the risks and the possibility of serious accidents. Responsible managers can minimize the risks by instilling among foundry workers the importance of accident prevention.

While it is impossible to remove the risk from melting metal, it is possible to make the melt shop an accident-free workplace. To accomplish this goal requires a true partnership between foundry managers, the suppliers who equip the melt shop, and the foundry workers who operate their equipment.

It requires management to make safety a key corporate value, then to communicate that to the foundry workers both by selecting the safest available equipment and by expending every possible effort to assure that workers are instructed in its proper use.

### **Who Needs Foundry Safety Training?**

Safety training needs to extend beyond melt shop workers. Maintenance crews, laborers, crane and lift-truck operators and outside contractors whose work occasionally takes them into the melt shop all need to understand basic foundry safety measures. Obviously, the amount of foundry safety training required by any one individual depends on how closely he or she works with melting, holding, pouring and charging equipment.



*Automated pouring systems distance the foundry worker from the molten metal.*

Training for office workers and visitors must include making them aware of the importance of remaining behind “do not enter” areas and wearing appropriate Personal Protective Equipment (PPE).

Melting system operators must know how to safely operate their equipment and must also know the warning signs of a potentially dangerous situation and how to react to prevent or control uncommon problems such as bridging or runoff situations.

### **Safety Starts on Day One**

A foundry’s personnel department and staff must play an active role in supporting foundry safety efforts. Personnel typically has the first contact with a newly hired employee and they can ensure that new employees are given full information on the safety procedures appropriate to their jobs and that they further understand that wearing appropriate Personal Protective Equipment (PPE) on the job is a condition of employment. Both of these requirements should be clearly stated in the employee’s job description or work rules.

Personnel managers are also in a position to identify employees who serve on local volunteer fire departments and emergency medical teams. If these individuals work outside production areas, time spent familiarizing them with the melt shop layout and the nature of foundry emergencies could make a life or death difference during an emergency. Finally, the personnel manager is often best able to coordinate the scheduling of refresher and new equipment training.

### **Melt Shop Supervisors Play Key Role**

Melt shop supervisors play a key role in assuring safe operation of melting, holding and pouring equipment. In most foundries, they bear frontline responsibility for implementing and monitoring established safety procedures and new worker training, as well as equipment inspection and maintenance. In the event of an emergency, workers often will look to the supervisor for instructions.

The only way to assure that no one is ever injured in the melt shop is to keep all personnel away from molten metal, furnaces and holding and pouring equipment. While this may seem like a farfetched solution, leading furnace manufacturers have actually made considerable progress in designing remote furnace charging, operating and pouring systems. Until these technologies are in common use, there are several steps foundry supervisors can take to

minimize worker contact with high risk areas.

Perhaps the single most effective step a foundry supervisor can take is to limit routine equipment maintenance activities to periods when furnaces are not operating. Production downtime can be predicted more accurately with the help of detailed record keeping. Although production supervisors are usually responsible for keeping equipment operating logs, it is the maintenance supervisor who is likely to be most knowledgeable about the type of information that needs to be entered. In foundries where melting operations carry over from shift to shift, the use of forms and checklists will aid in assuring uniform data collection.

Insisting the log book be neatly maintained not only makes data readily available, but also reinforces the importance of good equipment monitoring practices. One of the shift supervisor's first tasks of the day must be a careful inspection of log entries made during his absence.

In smaller foundries, the production supervisor may also have responsibilities for overseeing maintenance work and equipment troubleshooting. In these situations there is sometimes the temptation to perform maintenance as rapidly as possible to quickly bring the furnace back into production. Production supervisors who find themselves responsible for equipment maintenance must continually remind themselves that induction furnaces can be very unforgiving. Accidents caused by improper or rushed maintenance may be serious and sometimes catastrophic.

Production supervisors must never be pressured into bringing a furnace or other foundry equipment into production until they are ensured that it is safe. They must also keep equipment out of production when relining or other scheduled maintenance work is due.

### **Preparing For Accidents**

No matter how carefully equipment is manufactured, workers trained or procedures followed, the possibility of an accident is always present wherever molten metal is present. For this reason, melt shop supervisors must always be prepared to deal with the unexpected.

A careful supervisor anticipates the types of emergencies that can arise at different stages in the melting process. He has, both in his mind and on paper, an action plan that gives first priority to minimizing injury to his workers and assisting those already injured.

Although all accident plans must address issues such as evacuating personnel, providing emergency first aid treatment and notifying emergency squads and fire departments, each foundry's plan must also be unique. The plan

must take into account not only the type and capacity of the melting equipment but also the training and experience level of equipment operators. A newly hired furnace operator cannot be expected to react as confidently to a runout accident as an experienced and fully trained foundry hand.

The potentially catastrophic nature of water/molten metal explosions makes it crucial that accident plans be written and that they be understood by everyone in the melt shop and adjacent plant areas. Local fire departments and emergency medical squads must be included in planning efforts, familiarized with molten metal hazards and the melt shop layout, and encouraged to participate in drills. Everyone who might be expected to become involved in rescue or first aid activities must be trained on how to safely isolate furnace power supplies.

Written accident plans must clearly establish:

- Who will decide the extent of an emergency situation and the criteria for making that decision
- Who will be in overall command
- Each person's responsibilities during the emergency

### **Specify Safer Equipment**

Furnace manufacturers and other foundry equipment suppliers are continually attempting to make the melt shop the safest possible work environment. That's why virtually all induction melting systems today include safety features such as ground leak detectors and backup cooling systems.

In the past, specifying new foundry equipment typically has been the responsibility of senior level management. Production and maintenance supervisors simply had to learn to work with the equipment on the floor. But as companies around the world work to make their operations more competitive, they are increasingly turning to frontline supervisors for equipment recommendations.

Selecting the proper furnace, power supply or preheating and charging system is, of course, a complex technical task. Frontline supervisors who become involved in equipment selection, however, are in a good position to also evaluate a system's safety features, safety certifications, overall quality and operational efficiencies.

An induction furnace is a place where three ingredients that are not otherwise brought together – water, molten metal and electric current – are in close proximity to each other.

The quality of the components that make up an induction furnace system and the care that goes into its assembly and maintenance are the foundry worker's first line of defense against accidents.

## Induction Foundry Safety Fundamentals

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*Automated systems, like the ARMS™ (Automated Robotic Melt Shop) System, shown here, distance the foundry worker from the furnace and allow you to protect your most valuable asset on the melt deck - your employees.*

For more information call, 1.888.INDUCTO [1.888.463.8286] or visit [www.inductotherm.com](http://www.inductotherm.com)  
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Leading Manufacturers of Melting, Thermal Processing & Production Systems for the Metals & Materials Industry Worldwide.

Important: Appropriate Personal Protective Equipment (PPE) must be worn by anyone in proximity to molten metal.