AN ENGINEERED METHOD FOR INSTALLING REFRACTORY IN CORELESS FURNACES

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Abstract

Silica based refractory continues to be the refractory of choice for lining coreless induction furnaces in about 75 percent of North American foundries. In late 2013, Occupational Safety and Health Administration (OSHA) introduced a proposal to reduce the Permissible Exposure Level for Crystalline Silica by 50% in US workplaces.

In 1994, a refractory installation system was introduced to resolve hazardous health and safety concerns associated with relining large furnaces manually. Recently, the same technology has been adapted to line furnaces as small as 2 tons capacity.

Air samples taken show this technology reduces overexposure as low as four to ten times below OSHA's current PEL and in most cases will meet the proposed requirement.

The equipment permanently eliminated the laborious tasks associated with lining a furnace that can lead to compensable injury such as carpel tunnel syndrome and back injury.

In addition, significant and sustained production improvements have been realized at foundries using the system. Lining life improvements as high as 50 percent and higher tonnage per campaign were reported. Labor savings are realized because only two workers operate the equipment regardless of the furnace size.

The refractory installation system has provided a permanent engineered solution to significantly reducing airborne silica, resolving safety hazards and improving production efficiency when relining a coreless furnace with dry, vibratable refractory.

Keywords: refractory, furnace repair,

Introduction

When a coreless induction furnace needs to be relined, it is vital that it be done in a way that capitalizes on efficiencies, optimum lining life, longer production campaigns and ultimately higher tonnage through put. Since metals were first melted, a container has been required to hold the metal long enough to be melted and transferred to its final destination. This container must be adequate to withstand repeated cycles of physical shock, rapid temperature changes, and chemical attack during the production cycle. The furnace crucible, spout and cover form the container within which it becomes possible to change the physical state, chemistry and temperature of the metal. To form this container a good refractory is required. Installing it should be easy, reliable and predictable from one campaign to the next and uniform in wear, among other qualities.

The aim of this work is to compare the traditional methods of relining a coreless induction furnace with silica-based refractory with an engineered method of refractory installation and examine the differences.

Crystalline Silica Use

Silica has long been the refractory of choice because it "combines the properties of relatively good refractoriness (pure silica melts at 1723ºC) with very good thermal shock resistance and relatively low thermal conductivity."(1) In addition, the silica refractory is low in cost. Despite seemingly ideal properties of silica refractory, many complexities and uncertainties exist in the conventional installation process contributing to inconsistent formation of the container and unpredictable life of the refractory lining from batch to batch. In addition, respirable crystalline silica is considered carcinogenic to humans making the installation process hazardous. (2)

Silica or silicon dioxide (SiO^2), can be crystalline or amphorous. Crystalline silica is the most dangerous to employees in a workplace and most commonly found in quartz or silica-based refractory. Data from a refractory manufacturer's Material Safety Data Sheets shows that the weight percentage of silica in refractory used to line a coreless furnace (to melt ferrous metals) ranges between 80 - 100% quartz silica. Refractory ingredients may also contain small amounts of boron oxide or boric acid (0-5%) binders, depending on the needs of the customer. That means, the silica furnace operators are exposed to may be nearly 99+ percent pure quartz, the respirable fraction of crystalline silica, the most hazardous component. Refractory (used to melt nonferrous metals) is generally comprised predominantly aluminum and magnesium oxide and between 0-5% of cristobalite and quartz silica. (3)

Prolonged inhalation of dust containing free crystalline silica can result in a disease known as silicosis. It is characterized by progressive fibrosis of the lungs, marked by shortness of breath and impaired lung function. Complications can result in death. In 1997, The International Agency for Research on Cancer (IARC) classified crystalline silica as carcinogenic to humans, an upgrade from Group 2A as probably carcinogenic in humans

Foundry workers are among the one million workers exposed to crystalline silica annually, as estimated by the National Institute for Occupational Safety and Health (NIOSH). Foundry employees, primarily in iron and steel foundries are often exposed to crystalline silica throughout various metal casting processes such as sand blasting molds and cores, shakeout and knockout, finishing operations and furnace lining operations. The exposure time required to develop chronic silicosis in foundry workers can be between fifteen and as long as forty years after initial exposure, with a tendency to progress even after exposure has ceased. (4)

In 1997, Rosenman et al., reported the results of a ten year study (1985-1995) in Michigan and found that nearly 80 percent of the 577 confirmed cases of silicosis occurred in foundries with the Standard Industrial Classification (SIC) 3300, [gray, ductile, steel, aluminum, copper and other non-ferrous metals]. That particular study was conducted at a mid-western gray iron foundry and results were tabulated using medical records of 1,072 current and retired employees all of whom had at least 5 years of employment. (5) .

0SHA Rulemaking on Silica

Reducing and ultimately eliminating the workplace incidence of silicosis has been a primary goal of the US Department of Labor-Occupational Safety and Health Administration (OSHA) since its inception. In the early 1980's OSHA began its special emphasis on the prevention of silicosis in foundry personnel.

In 1996, OSHA established a Special Emphasis Program (SEP) for Silicosis which provided guidance for targeting inspections of worksites with employees at risk of developing silicosis.

In January 2008, OSHA launched a National Emphasis Program – Crystalline Silica. The purpose of the program was to implement rigid policies and procedures aimed at reducing or eliminating heath hazards associated with occupational exposure to crystalline silica. This national program built on the 1996, Special Emphasis Program (SEP) for Silicosis which provided guidance for targeting inspection of worksites. The NEP focus shifted from exposure measurement to compliance. (6)

In the fall of 2013, OSHA issued its most comprehensive rulemaking proposal to date. The proposal would reduce the Permissible Exposure Level (PEL) from 100 µg/m³ (currently measured 0.10 mg /m³) to 50 µg/m³ (.05 mg /m³ equivalent). (7)

The proposal also creates an Action Level of 25 µg/m³, half of the proposed PEL, triggers air sampling analysis, training and medical monitoring. In addition, the use of respirators would be prohibited and engineering controls, even if ineffective would be required. If adopted, the industry would have one year to implement the controls. (8)

The magnitude of the challenge to reduce silica exposure of workers to 50 µg/m³ or less in foundry operations is enormous. The industry as a whole has a great deal of experience with every control available including ventilation, enclosure, vacuuming, non-silica alternatives etc.

Slavin, in his presentation at the 118th Metal Casting Congress in Schaumburg, IL in April 2014, expressed the view that "exposures above the PEL are due to infeasibility, not lack of information or effort." (9)

Many departments within a foundry expose workers to silica dust in processes such as brass grinding, ladle and furnace relining, pressure pour operation and core making. For each department or process using silica, an engineered compliant solution would be required by OSHA, even if ineffective, under the latest proposal.

Slavin's comment in his Casting Congress presentation on April 10, 2014, "despite extensive, expensive and sincere efforts, many foundries find it difficult to reliably meet the current PEL for certain operations and will not be able to meet the proposed PEL``, is shared by many in the industry. (10)

Since the focus of this work is coreless induction furnaces, what are some of the implications for foundries using silica to reline coreless induction furnaces? Silica substitutes continue to be largely impractical for the reasons discussed in the introduction of this paper. Silica remains the best choice. This is precisely what is required to form a reliable crucible in which to make molten metals. Silica cannot be wet down to control the dust at the point of generation. Refractory must remain dry to vibrate or compact for a denser lining that is integral to the process of forming a reliable, long lasting crucible.

Engineering controls such as local exhaust ventilation are seen in some melting shop areas to help reduce airborne dust when lining a coreless furnace. Health and safety departments employ and train workers in safe work practices. Unfortunately, when the atmosphere becomes thick with free floating silica dust, the urgency to complete the job as quickly as possible often outweighs the principles of improved work practices. Personal protective equipment, (respirators) are widely used in foundries as the most common form of worker protection, however, if the new OSHA regulations are passed, PPE respirators will not be an acceptable control.

Common Injuries When Relining a Coreless Furnace

Repetitive Strain and Back Injury: Repetitive strain injury is another area where workers are at risk when relining a coreless furnace manually. Repetitive-trauma injury or strain to the wrist, arm or shoulder from repeated forking or de-airing the material when filling the furnace side walls can occur. Workers often de-air in shifts during the lengthy process to reduce strain. However, fatigue quickly sets in when the lining process takes between 5 - 8 hours or longer for larger furnaces.

In addition, constant lifting of bags of refractory, combined with twisting and bending when lining a furnace often results in compensable injury, in particular the lower back

Refractory Installation System to Install Refractory in Coreless Furnaces-An Engineered Control

Technology to effectively balance worker health and safety with achieving predictability and longer lining life when lining a coreless furnace, has existed for twenty (20) years. An innovative Refractory Installation and Vibration System (RIVS) was introduced to the industry in 1994 for furnaces ranging in size from ten (10) ton capacity to the largest induction melting furnace of seventy (70) ton capacity. The system was specifically designed to redress health and safety concerns inherent in lining a coreless furnace with silica and other dry, vibratable refractories.

More recently, the technology was expanded to provide the same installation control for foundries with small furnaces ranging from approximately two (2) tons capacity to nine (9) tons capacity or with former diameters as small as 20 inches (51cm).

The system, regardless of the furnace size, comprises four components: a bottom vibrator plate to compact the furnace bottom material in one operation from the furnace deck; a furnace form centering tool to quickly and accurately center the form; the Refractory Installation System (RIS) to install and simultaneously de-air sidewall material; and finally the three-legged electric Refractory Vibration System that vibrates the internal form, creating a denser lining.

Conventional Lining of a Coreless Furnace

Installing the Furnace Bottom: Typically, 55 pound bags (25 kg) of dry-vibratable refractory are opened then poured over the furnace edge to be compacted. The most common method used to compact the bottom material is a hand-held tamping vibrator. The worker enters the confined space of the furnace to ram loose silica until the surface is solidly knit. Depending on the size of the furnace, this activity can be lengthy, exceeding one hour, exposing workers to airborne dust and repetitive-strain injury.

Setting the Form: The form supports the refractory until the lining has attained enough strength during the sintering process to be self-supporting. Afterwards, the form is normally expended as part of the first melt of metal. Once the bottom is compacted, the steel “liner” or form is set into place and centered. It is important that the form be centrally positioned so that the annular space between the form and outer cylindrical wall is uniform about its circumference for the entire length of the furnace. A form not centered at both the top and bottom creates irregular wall thickness and uneven wear during the melting cycle. This can lead to premature lining failure, taking the furnace off-line unexpectedly and requiring the lining process to be repeated.

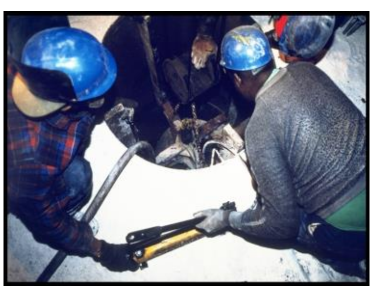
The form is suspended by a hoist and lowered into the furnace. Workers are positioned around the form to guide it as it is lowered and attempt to place it concentrically within the furnace. Some use the assistance of a vertical plumb-bob to find the furnace center. Wedges and hold-down devices may be added for stabilization once the form is lowered. Usually, several trial-and-error attempts are made before pinpointing the correct position, consuming valuable time and effort.

Installing and Vibrating the Furnace Sidewall Material: A variety of methods are available to install and vibrate sidewall material, the objective being achieving optimal material density.

Typically, layers of material are added to the furnace either by dumping individual bags of material or by pouring sacks of material directly into the sidewall. This is followed by a manual de-airing process and repeating additional layers of material and de-airing until the annular space is filled.

The process is competed by applying one of several types of vibration directly to the internal form causing the material to compact once installed in the annular area.

One application uses a quadrant bolted to tabs at upper and lower positions of the form. A single vibrator is moved around the frame for four periods of vibration. Workers enter the confined space of the form to attach the quadrant at various levels and again to move the single vibrator to each of the four quadrant locations. A second application uses a single vibrator attached to an expanding cross system attached to wooden battens. Depending on the size of the furnace, vibration occurs at one or two points of the length of the furnace form. A third type of vibration system vibrates the internal form with a single vibrator bolted to tabs welded to the former at two locations. Variable frequency action is applied to compact the material.



In all of the above methods, workers are exposed throughout the process to free floating silica dust. In most applications, workers enter the confined space of the form to relocate the vibrator to continue the process.

Common Problems with Conventional Installation Methods

- Silica dust exposure to workers is very difficult to control. Concentration of hazardous material seldom registers at or below OSHA's PEL. Controlling silica dust from spreading into adjacent work areas where unprotected workers (not assigned to furnace lining) is virtually impossible.

- Installing material in the furnace bottom and sidewalls is strenuous and labor intensive, exposing workers to high levels of respirable silica dust.

- Workers' are at risk of compensable injury when physically lifting and dumping many bags of material. Repetitive strain injury is a complication that may arise from manual de-airing material.

- Worker fatigue, hazardous working conditions and inexperience contribute to inconsistencies in even distribution and uniform density of material. Human variables' leads to unpredictable lining life from one rebuild to the next.

- Workers' are reluctant to work in hazardous, laborious conditions. Some foundries are experiencing difficulty finding replacements as the workforce ages and retire.

- Conventional external form vibration methods inadequately vibrate material in the tapered section. This can contribute to premature wear and lining failure.

With escalating pressures from OSHA to eliminate airborne silica dust, most foundries recognize they must adopt a method of installing refractory designed to bring the permissible exposure level of silica in compliance. Over-exposing a worker to the risk of silicosis and other diseases must be redressed. In addition, foundries demand efficiencies such as longer lining life, increased tonnage and fewer annual relines to remain competitive in world markets.

Lining a Coreless Induction Furnace using a Refractory Installation and Vibration System (RIVS) - An Engineered Control

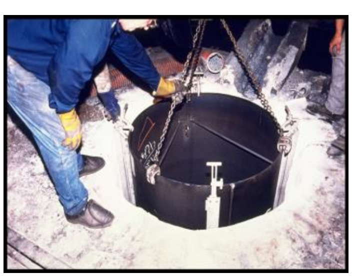
Installing the Furnace Bottom Material: The automated method of lining a coreless induction furnace is a series of processes that begins with adding material to the furnace bottom. Bulk bags of refractory are lowered by hoist**,** onto the furnace floor. Very little dust is emitted from the bulk bag using this method provide d the sleeve of the bag remains submerged in the material while the bag is being emptied. Workers are relieved from the laborious task of opening and dumping multiple bags of material onto the furnace bottom. Once the material is in place and evenly distributed, the bottom is ready for vibrating.

Furnace Bottom Vibration: The entire bottom of the furnace is compacted in one operation using a vibrator plate, equipped with two electric vibrators. The plate is lowered by hoist, on top of the material and vibrated for approximately twelve to sixteen minutes depending on the size of the furnace size, producing a solidly knit base. Vibration is performed by the furnace operator using a control stand, from the furnace deck. Entering the confined space of the furnace to hand tamp the bottom material has been eliminated.

The plate is removed and the material is checked for level. A worker enters the furnace only long enough to check that the floor material is level.

Setting the Form Using Form Centering Tools

. Each tool is suspended between the form and furnace at equal, circumferentially spaced locations. The tools are individually adjusted and locked in place at equal amounts to set the spacing between the form and furnace sidewall. Once all tools are set at equal distance, the form is centered for its entire length and is lowered to the furnace floor. When resting in place, the tools are unlocked, removed and stored until next use.



Lining Furnace Sidewalls Using the Refractory Installation System (RIS): For purposes of clarification, the Refractory Installation System (RIS) serves two functions. It dispenses dry refractory into the annular space between the furnace wall and form and simultaneously and automatically performs the de-airing function.

When the furnace form is placed and centered, the RIS is set on top of the form using an overhead hoist. After positioning, hydro is connected to operate the machine. Individual bags of material have been replaced with specially designed “super sacks” of dry refractory designed according to the amount of material required.

The sack is positioned over the hopper of the RIS and emptied. The sack is removed, the lid closed and locked into position containing silica refractory within the hopper during the filling of the furnace sidewalls.

The machine is engaged and rotates around the form at a rate of 360º every two minutes and distributes approximately 250 pounds of material, creating layers 2 inches (5 cm) deep. Material is laid in the annular area, not dumped as when manually lining the furnace. As a result, very little dust is raised during the filling of the sidewalls. When a rotation is completed, the telescopic feeder tube raises 1/2 inch (2.5 cm) and continues to lay additional layers of material until the sidewalls are filled.

Simultaneously, each layer of silica is de-aired at the rate of 450/600 strokes per revolution using dual forks. Fork tines penetrate the material 4 inches (10 cm). As a result, each layer is penetrated at least twice, effectively mixing the layers of material and providing optimum de-airing.

The hopper is refilled when empty and the process continues until the material reaches the top of the form. When filled, the machine is removed, cleaned and stored until next use. The system replaces all of the repetitive, labor intensive activities performed by workers manually lining a furnace.

Vibrating the Sidewalls Using the Electric Refractory Vibration System (RVS): The sidewalls are vibrated using a three-legged electric vibration machine, each leg delivering 3600 VPM. Spring-loaded legs are forced by a central cylinder, against the internal form and simultaneously deliver equal distribution of force impact against three points of the form. Furnaces of 20 tons and larger require a 4 legged vibrator.

Operated from the furnace deck, the vibrator unit is lowered to the bottom of the furnace form where vibration begins 1 inch (2.5 cm) above the bottom of the form floor. Vibration time is concentrated in the tapered section of the form where maximum compaction is critical to achieving maximum lining life. The legs are adjusted against the angle of the form taper using an air valve to ensure that contact is controlled and consistent during vibration. The majority of the vibration time is focused in the tapered area to reduce or eliminate the likelihood of "elephant's foot" erosion. The machine is then slowly pulled up the internal form, ensuring equal treatment for the entire length of the form. Total vibrating time ranges from fourteen (14) to sixteen (16) minutes.

Findings: Environmental, Health and Safety Considerations

Statistics gathered for furnaces smaller than nine (9) ton capacity is trending toward similar outcomes as the larger furnaces ranging 10 tons and larger which were collected during the past fifteen years. Results were gathered in both North America and Asia.

1. Silica dust control: Air samples for respirable silica (quartz) conducted while lining a furnace with the RIS produced results between < 0.01 mg/m³ (equivalent to 10 µg/m³ under the proposed OSHA PEL) and 0.026 mg/m³ (equivalent to 26 µg/m³ under the proposed OSHA PEL) at foundries tested; ranging four to ten times below OSHA's permissible exposure level of 0.10 mg/m³. Samples were collected using a cyclone filter and quantified by Fourier Transform-Infrared Spectrophotometer FT-IR, Infrared Spectrophotometer (IR) or X-Ray diffraction Spectrometer (X'D), standard National Institute for Safety and Health (NOSH) fibre counting practices accredited by the American Industrial Hygiene Association (AHA). and analysts have participated in the required. The furnace operator wore the cyclone filter for a total of 6.5 hours during the installation of the furnace bottom material, installation of refractory into the side wall and sidewall vibration processes. Results of the test (using the method described above) measured 0.026 mg/m³, approximately four (4) times below OSHA's Permissible Exposure Levels (PEL). This particular foundry was required by OSHA to employ and engineered control to bring levels into compliance with the PEL for silica. The technology was successful in bringing this foundry into compliance.

No comparative air sample reports were provided by foundries for exposure levels taken during a conventional lining as it is kept confidential. Anecdotally, foundries indicated, where testing had been done, results were significantly above OSHA's PEL during a manual lining, often generating OSHA citations for overexposure to workers.

Reduction in respirable silica dust levels continues to be the most frequently expressed motivator for introducing the technology.

2. Number of workers to reline a furnace: Foundries using the system reported they used between four (4) and twelve (12) workers to line a furnace manually. The number was influenced by the size of the furnace. A foundry with four (4) ton capacity furnaces used five (5) workers while a foundry with sixty (60) ton furnaces used twelve (12). Once the RIVS was introduced, the number dropped an average sixty six (66) percent. Despite the size of the furnace, only two (2) workers are required to be present to operate the equipment. In all cases, workers were no longer required to participate in laborious activity associated with manual furnace lining. Significantly fewer workers were exposed to any level of silica exposure simply by employing the advanced technology. A 2014 survey of 2 foundries with 4 ton furnaces and 1 with 2 ton furnaces showed that the number of workers was reduced by fifty (50) percent.

3. Man hours of labor to reline a furnace: The number of hours required to install material and vibrate a furnace conventionally varied and again related directly to the size of the furnace. Foundries using the system were asked to calculate the number of hours elapsed from the time the furnace bottom material was installed until the completion of sidewall vibration. The RIVS process reduced hours of labor an average seventy six (76) percent. This significant decrease was mainly because fewer workers were used. The length of time taken to line a furnace ranged from no change in elapsed time in one case, but for the balance averaged time savings of thirty seven (37) percent. The foundry with the four (4) ton furnaces reduced total man-hours from thirty (30) to fourteen (14) hours for significant man hour savings.

A 2014 survey of 2 foundries with 4 ton furnaces and 1 with 2 ton furnaces showed that the average man hours was reduced from 14.3 hours to 6.3 hours.

4. Working conditions: Working conditions and worker morale improved dramatically at all workplaces using the installation system to line furnaces. Workers in both unionized and non-unionized workplaces expressed that working conditions were significantly improved in two ways:

- Dramatic reduction in free floating silica dust for improved health and safety conditions;
- Dramatic reduction in manual labor with the de-airing task eliminated resolving the potential for repetitive strain injury, and elimination of dumping of multiple bags of material resolving the potential for back injury.

In addition to silica dust control for improved workplace environment, the machinery has been ergonomically designed to relieve workers of the onerous physical labor of lining a furnace. One foundry noted that the air quality was excellent, the difference from day and night.

Findings: Production Improvements

Although the Refractory Installation and Vibration System was introduced to improve health and safety conditions for workers, production benefits continue to be reported at foundries using the system.

1. Refractory utilization/increased lining density: Literature on the subject, previous studies and most foundry melting experts concur that a denser lining (achieved by de-airing and vibration), will promote longer lining life and ultimately higher production per campaign. Foundries using the system provided a record comparison of the number of pounds of material used. In every case, more material was added when installed and vibrated with the RIVS, despite the manual practice or the type of conventional vibration equipment used previously.

Silica added depended on the effectiveness of the manual process and on the size of the furnace and ranged from an additional 100 to more than 1,000 pounds. One of the 4 ton furnaces in the survey added 200 pounds compared to previous lining practices.

Foundries that provided comparative density results of sintered material for each process reported the following:

- manually installed refractory measured between 120 and 130 PCF. In every case tested, RIVS installed refractory evaluated at 136 and 137 PCF, the maximum achievable density for silica.

All participants reported a marked improvement in the lining in the tapered section. Several foundries that previously patched the tapered section mid-cycle, ceased to do so.

2. Lining life per campaign: Length of lining life before the introduction of the equipment related more to the effectiveness of conventional installation and vibration practices rather than furnace size. Some foundries measure increases in days or weeks while others measured in tonnage output per campaign. No correlation between furnace size and lining life was identified.

Foundry participants in the first study comprised of furnaces larger than 10 tons indicated that linings installed manually were lasting between 3.5 and 7 weeks. Foundries lining furnaces with the RIS with dual de-airing forks reported lining life increases averaging 42 percent than when manually lining a furnace. It is generally found that a foundry will extend the length of the campaign slowly as furnace operators learn through examination of the furnace lining and electrical readings how much useful lining life remains and how much longer a furnace can remain on line. A 2014 survey of 2 foundries with 4 ton furnaces and 1 with 2 ton furnaces reported lining life improvement of 20%, 23% and 25% in the 2 ton furnaces.

3. Tonnage per campaign: Participants expressed that a more significant indicator of improved lining life would be the ability to melt more tons of iron per campaign. Foundries using the Installation System melted either gray or ductile iron. Some rotated production between the two types of metals. The four (4) ton furnace, in its early stages of data collection reported an average tonnage of one thousand two hundred (1,200) tons for a manual lining to one thousand four hundred fifty (1,450) tons and climbing when using the installation system, for an early return increase of twenty one (21) percent. Another 4 ton furnace surveyed in 2014 reported that they averaged 1000 – 1100 tons per campaign manually and are now regularly yielding 1300 – 1400 tons using the system.

Foundries reporting on tonnage comparisons all experienced a proportionate increase in production when they introduced the Refractory Installation and Vibration

System. As the lining life per campaign increased, the furnaces stayed on-line longer, producing more tons of molten metal.

4. Annual relines: one outcome of denser linings and longer lining life achieved was fewer annual furnace linings. All foundries reported a reduction in annual relines ranging from a low of fifteen (15) to a high of fifty (50) percent fewer A 2014 survey of 2 foundries with 4 ton furnaces and 1 with 2 ton furnaces showed that the average number of relines was decreased from 30 to 15; 50% fewer. Less forms, refractory, insulating cloth, saving on sintering costs etc., all contributes to cost savings and favorable return on investment.

Conclusions

Foundries surveyed regardless of the furnace size have reported that the Refractory Installation and Vibration System met or exceeded their expectations in all areas reported. The RIVS reduced airborne silica dust to levels below OSHA’s PEL, and protected workers from exposure to injury, creating a workplace safer and more comfortable than experienced during a conventional lining. Lining a furnace was no longer the least desirable job in the foundry.

Inconsistencies and unreliability of lining life during conventional furnace lining were largely the result of human variables such as fatigue, inexperience and unfavorable working conditions. The system has eliminated human variables that adversely affect consistency and optimum density of lining.

The RIVS produced denser linings and provided the opportunity for higher tonnage output, despite furnace size or the manual installation technique or previous vibration method used. Linings generated by the RIVS were more consistent and reliable, permitting the foundries to more accurately predict production schedules and length of melting campaigns.

The RIVS generated savings by significantly reducing the size of the workforce, working hours and materials used to line a furnace. Foundries in the survey that used alumina-based refractory reported similar results and improvements in all areas.

On the whole, the RIVS was shown to be a highly effective, permanent solution to controlling respirable silica dust when lining coreless furnaces. In addition, significant, cost effective production improvements were experienced in foundries using the advanced technology.

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REPORT OF RESULTS

September 11, 2008

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The samples were received in the laboratory on August 26, 2008 in acceptable condition. They consisted of one PVC filter sample and one blank for analysis of respirable silica (α-quartz). The blank value has been subtracted from the reported results. The analysis was completed on September 4, 2008.

Laboratory Sample No.	*Your Sample Identification*	*Air Volume (l)*	*Respirable Silica (α-quartz)*	
			(mg)	*(mg/m³)*
08080511	G-108 HMACPA-10	612	0.016	0.026
08080512	Blank	-	< 0.005	-

Method: Infrared Spectrophotometry, NIOSH Method 7602 (with modifications)

Detection Limit: 0.005 mg/sample

Analytical Precision: $S_r = 0.20$ @ 0.005 mg quartz per sample

Analyst: Shari-Ann McCollin, B.Sc.
Research Assistant

Reviewed and approved by: Lorraine Shaw, B.Sc., CIH, ROH
Laboratory Manager

The results in this report apply only to the samples received and tested by the Occupational and Environmental Health Laboratory, McMaster University. This report shall not be reproduced, except in full.
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Bibliography

1. Newsome, D.R., Ogden, G. "Induction Furnace Refractories, State of the Art and Future Trends", Casting Technology International, Paper 18, page 3. (September, 1993).

2. "Crystalline Silica-Health and Safety Information". The Refractories Institute, Pittsburgh, PA, 04/96.

3. Material Safety Data Sheet, Data Sheet ID# DS033 and ID#DS003, Allied Mineral Products, Inc., Columbus, OH, June, 1996.

4. Weill, H., Jones, R.N. Parks, W.R. "Silicosis and Related Diseases", in Occupational Lung Disorders, 3rd ed. Butterworth-Heinemann Ltd., Oxford, England, 1994.

5. Rosenman, K.D., Reilly, M.J., Watt, F.C. "Silicosis in the 1990's", Chest 111 (3):779-782, 1997.

6. "OSHA Instruction" U.S. Department of Labor, Occupational Health and Safety Administration; Directive Number CPL 03-00-007, National Emphasis Program, January 24, 2008.

7 & 8. Slavin, Thomas, Slavin OHS Group, LLC,``OSHA`s Silica Proposal-What It Will Mean For Foundries``, AFS Metal Casting Congress, Schaumburg, IL, USA, April 10, 2014. (Slide No. 4)

9. Slavin, Thomas, Slavin OHS Group, LLC,``OSHA`s Silica Proposal-What It Will Mean For Foundries``, AFS Metal Casting Congress, Schaumburg, IL, USA, April 10, 2014. (Slide No. 18)

10. Slavin, Thomas, Slavin OHS Group, LLC,``OSHA`s Silica Proposal-What It Will Mean For Foundries``, AFS Metal Casting Congress, Schaumburg, IL, USA, April 10, 2014. (Slide No.26)