Vibration Improves Refractory Installation for Channel Furnace Inductors

By William M. Opatt and David C. Williams

The expanded use of channel induction furnaces has highlighted some problems for refractory installation — and led to the development of a new approach for that process.

Dry vibratable refractories are widely used as working linings for melting and holding furnaces, for ferrous and nonferrous metals. Foundries' expanded use of channel induction furnaces has called attention to some problems for refractory installation, and helped to develop a new approach for that process.

Installing dry vibratable refractory to the optimal rammed density involves applying the material to a prescribed thickness, de-airing it, compacting (tamping) and scratching (redistribution of compacted surface) it, and then repeating these steps. Frequently compaction is done via a manual electric vibration tamper or pneumatic vibrator.

The Electric Vibration System is shown with a channel form and bushing mounted to the inductor. A temporary metal retainer is shown, as well.

One commonly used technique involves an electric tamper to compact each 75-100 mm (3-4 in.) layer of refractory, whether a vertical or side-ram installation. This is labor-intensive and prone to human error and inconsistencies.

As inductor designs changed and furnace sizes increased, the process of installing the inductor refractory became simpler by using form vibration of the inductor casings with an air-driven vibrator that attaches directly to the inductor case. Some labor and time savings were realized as a result.

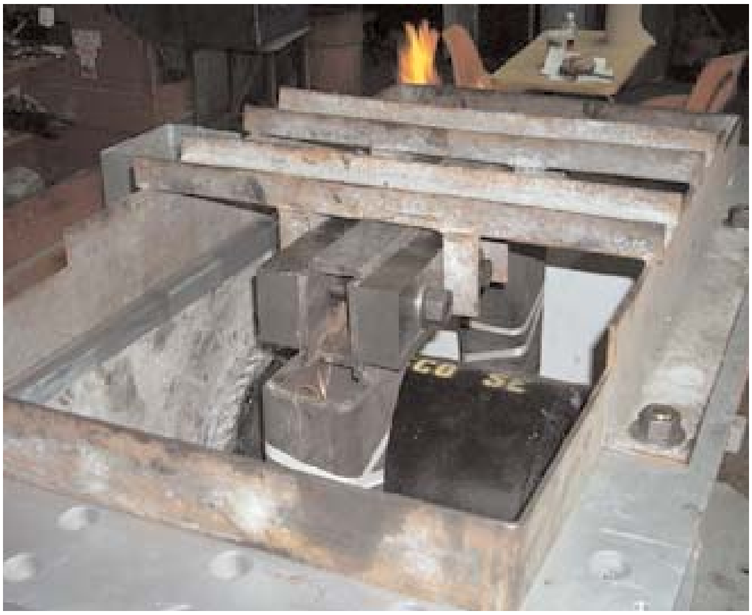
But, optimal installation relies on a consistent, clean-air source to power the pneumatic vibrator. This compressed air must be "moisture free" to ensure maximum vibration, as any moisture in the air will dampen the vibration output. Dry compressed air is not always available.

This is one of the problems solved by the Allied Mineral Products Electric Vibration System (EVS), a patented system developed to offer lower labor costs, consistent vibration, less installation variability, and time savings — with no negative effects from any of the available compressed-air sources. Instead of air, this new vibration system required electrical power.

Powered by electricity, the EVS is thus a stronger and more durable method for installing dry vibratable refractories in channel furnace inductors.

Installation with EVS

The EVS was developed by Allied Mineral Products (www.alliedmin.com)



Another view of the EVS with a channel form and bushing fixed to the inductor.

in order to eliminate air-pressure and air-quality problems during refractory installation in coreless induction furnaces. The primary benefit is the ability to install refractory into the sidewalls of coreless induction furnaces and channel furnace inductors, without manually de-airing or "forking" the refractory material.

The EVS consists of an electric vibrator and vibrator control panel. A vibrator bracket can be welded directly to the inductor case, or a bolt-on bracket attachment can be used to attach the vibrator to the inductor case or loop-form assembly.

The main component of the control panel is a variable-frequency drive (VFD). The VFD controls the output to the electric vibrator, which can be programmed to operate at various frequencies for selected amounts of time. The VFD includes a digital display to indicate vibrator operating status and drive output information. The VFD is available for low-voltage (200-240 V) and high-voltage (380-480 V) applications.

The control panel presents various features that allow for automatic or manual control of the vibrator, including frequency control and vibrator motor direction. A safety lock prevents anyone from opening the control panel while the unit is operating, and overload protection is included to protect the vibrator. Also, the panel is dust-tight (NEMA 12), which means the unit can be mounted near the furnace or designated installation area.

The electric vibrator is operated from the control panel, and it can be wired for low or high voltages, and to operate at variable frequencies (0-6,500 rpm). The unit's eccentric weight settings can be changed during operation to optimize refractory installations.

For the de-airing phase of installation, the vibrator is operated in the high-weight setting at a lower frequency (3,000-3,600 rpm) for maximum flow and de-airing of material. Once the de-airing phase is complete, the vibrator rotation is reversed and operated in the low-weight setting at high frequency (4,600-6,500 rpm). This completes the final compaction of the refractory.

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Problem solving

The EVS resolves many standard problems of installing dry vibratables.

Consistent refractory installations are achieved because there is no concern that the compressor is supplying enough air pressure, because the system is powered by electricity. Fluctuating air pressures may result in less-than-optimal refractory density, which can shorten campaign life. Dirty or moist compressed air will degrade the internal components of pneumatic vibration equipment, which also can result in inferior refractory density.

The supply of electricity to the EVS is constant. The variable-frequency drive is accurate to 0.01 Hz, so the output of the vibrator will be exactly what is programmed into the unit.

The crew installing the refractory is a critical part of a successful installation, but training and maintaining a talented crew is difficult. Inexperience, fatigue, availability, and worker turnover also effect the process.

Using the EVS minimizes the workers' physical involvement. The refractory can be installed using bulk packaging lifted by cranes. Refractory can be added to fill completely a large inductor case in under 10 minutes. The need for workers to de-air the refractory with a forking/de-airing tool is eliminated, reducing worker fatigue. The EVS performs the de-airing function as part of the vibration process, so by using bulk packaging and eliminating forking the refractory can be installed two to three times faster than traditional installation techniques. And, the system can be programmed to automatically de-air and compact the refractory, so every

EVS installations demonstrate convenience, performance

Installing inductors using the EVS is a relatively new but proven installation technique. Many installations are currently online or have recently finished their campaigns. Typically, inductor campaigns are measured in months or years, whereas most coreless induction furnace campaigns are measured in weeks or perhaps months. The applications described here were conducted in Asia, Europe, and the U.S.

Ferrous installations

Foundry A — A magnesia-based refractory was installed into a 500-kW, single-loop Whiting inductor for a 15-mt gray iron pouring furnace. The inductor was removed after 18 months, considered a normal campaign. A total of 1,900 kg (4,200 lb) was installed using two vibrator locations. The amount of refractory installed equaled the amount installed using a pneumatic vibrator with manual de-airing of 3 in. (75 mm) refractory layers. Total installation time was less than one hour.

Foundry B — This foundry has a 3,000 kW, single-loop DUCA inductor attached to a 30-mt uppercase for melting iron. Over 3,500 kg (7,700 lb) of magnesia-based refractory was installed. Multiple vibrator locations were used, including the loop form assembly. The previous installation method was a manual vibrating tamper. This inductor achieved a normal campaign of 18 months.

Foundry C — A mangesite refractory was installed into a single loop ABB inductor for a 10-mt pouring furnace for ductile iron. Approximately 1,225 kg (2,700 lb) of refractory was installed into this inductor, which is comparable to previous installations with a vibrating tamper. This inductor lasted a normal campaign of one year. A second inductor installed with the EVS was recently put online.

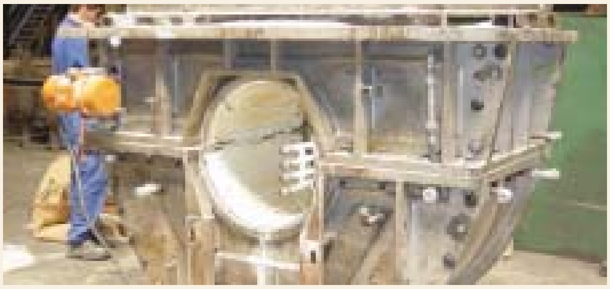
Foundry D — This automotive foundry has a 300-kW, single-loop Georg Fischer inductor attached to a 10 mt pouring furnace for ductile iron. The previous installation method was a vibrating tamper. This installation required 700 kg (1,550 lb) of magnesite refractory and ran a successful 10-month campaign. Inductors are typically removed due to excessive buildup in the inductor and throat. These inductors continue to be installed with the EVS.

Nonferrous installations

Foundry E — A silica-based refractory was installed into a 400-kW, single-loop JAVA inductor for melting copper. The loop form was solid copper. 600 kg (1,320 lb) of refractory was installed. One vibrator location was used. Previous installations used a vibrating tamper, which was difficult when trying to compact the area between the loop and bushing. This inductor achieved a normal campaign of over 12 months.

Foundry F — This foundry uses a silica-based refractory for a 150-kW, single-loop Inductotherm inductor for melting copper. 900 kg (1,980 lb) of refractory was installed. One vibrator location was used. Previous installations used a vibrating tamper, which was difficult when trying to compact the area between the loop and bushing. This loop form was solid copper. This inductor has been online for over 12 months.

Foundry G — This foundry has a 450-kW, double-loop Toshiba inductor for melting brass. Previous installations were completed with castables and wet ramming refractories. A silica-based dry vibratable was introduced to eliminate the long dryout necessary with previous refractories. Over 1,200 kg (2,640 lb) of silica-based dry vibratable is installed in addition to a solid copper loop form. Numerous installations have been done with typical lining life averaging 9-12 months, which is comparable to campaigns using castable and wet ramming refractories.



Foundry H — An alumina-based refractory was installed into an 800-kW double loop Calamari inductor for melting copper. Two installations have been completed, resulting in the same campaign life as with installation by vibrating tamper. This inductor requires more than 3,500 kg (7,700 lb) of refractory. A solid copper loop form was used.

The EVS vibrator unit is seen here mounted to the inductor channel loop form.

installation will be completed in the same way every time.

In terms of worker health and safety, the EVS offers ergonomic advantages over other methods. Installing material in bulk packaging and eliminating the need to de-air the refractory minimizes worker fatigue.

Plus, the noise level of the electric vibrator (rated at 60-70 dB) is lower than that of pneumatic vibrators (rated at 95 dB or more). Air-driven vibration systems generate a lot of dust during operation due to air leaks, exhaust, and release of compressed air — all of which are minimized because electricity is used instead of compressed air.

In-plant operation of the EVS has shown it to be an highly versatile system. It has been proven successful in large single- and double-loop inductors containing up to 3,500 kg (7,700 lb) of high-alumina or magnesia-based refractory, to small single-loop inductors containing 500 kg (1,100 lb). The operating procedure is no different even as inductor sizes vary, though the number of vibrator mounting locations will depend upon the size and geometry of the inductor case.

Foundries operating both coreless and channel induction furnaces will find that a single EVS will install refractory effectively in both designs, and it can be used to install various refractory compositions.

With respect to cost, the initial investment in EVS is higher than vibrating tampers or pneumatic vibrators, though the return on investment for the system is accelerated by the reduced manpower and refractory installation times, and increased furnace productivity. In addition, the EVS has a lower operating cost than standard refractory installation systems.

Operating procedure

Installation using the EVS differs from the process involving a vibrating tamper or pneumatic vibrator, and it involves several steps:

Inductor casing and bushing assembly — When using the EVS, there is more preparation before installing refractory. It is imperative that the channel form is attached and secured/bolted to the inductor case. Also, the bushing(s) must be secured, and the gap between the bushing and inductor case must be sealed. Ceramic fiber rope soaked in a sodium-silicate/water mixture is the industry's preferred and standard method. Any movement of the bushing(s) or loop form during vibration will abort the installation.

Adding refractory to the inductor — Once the inductor channel form and bushings are secured and the gaps are adequately sealed, the refractory can be added to the inductor case. The quickest method involves the use of bulk packaging, which can be completed in several minutes. Refractory is added to the inductor in one continuous step until the case is completely full. Special attention should be taken to add the refractory in even layers, ensuring that the material fills the complete volume.

It is important to overfill the inductor casing, using either a temporary metal baffle or retainer around the top of the inductor case. This will act as a reservoir for the refractory as it settles/compacts during the de-airing and vibration sequences. The excess material can then be scraped away after vibration,

A view of the installation effort for dry vibratable refractories from bulk packaging.

It may not be necessary to overfill the inductor casing if a wet capping material will be applied. In this case the inductor should be filled to complete volume.

leaving a compact, level surface.

It may not be necessary to overfill the inductor casing if a wet capping material will be applied. In this case the inductor should be filled to complete volume. A layer of refractory will be removed in preparation of the wet capping material.

Mounting EVS vibrator to the inductor casing — Vibrator brackets/clamps that can be bolted or welded to the inductor case are used. Bolt-on brackets are preferred because they are removable and can be mounted to multiple locations. The mounting locations depend upon inductor size, inductor geometry, channel form composition, and refractory density. Other factors, such as water jacket locations and other obstacles, will limit mounting locations.

The EVS vibrator may also be attached to a metal melt-in channel form. This has been done for larger installations to ensure refractory compaction between the channel form and bushing(s).

Vibration sequence

1. Attach the vibrator to the mounting bracket.
2. Operate the vibrator in de-air mode (forward rotation) at 60 Hz (3,600 rpm) for five minutes.
3. Continuously add material during vibration as the refractory settles.
4. Operate in reverse direction at minimum 75 Hz (4,600 rpm) and maximum 108 Hz (6,500 rpm) for five minutes for the compaction sequence. Refractory may be added during the compaction sequence, too.
5. If required, move the vibrator to

In this sequence, the refractory is seen before vibration, during de-airing, and after the vibration process.

The EVS vibrator unit is shown attached to the inductor case.

next mounting location, and repeat steps 2 through and 4.

Prior to beginning the vibration process, the dry vibratable refractory is added in one continuous layer to fill the inductor volume. A temporary baffle may be used to over fill the inductor.

During vibration, the dry vibratable refractory is de-aired first, and then compacted. The de-air function is obtained when operating the vibrator in the high-weight setting at lower frequency. After the de-airing cycle is complete, the compaction cycle begins by operating the vibrator in the reverse direction, which is a lower weight setting and higher frequency. This task can be done by automatic program or by manual operation.

The above photograph illustrates the de-air sequence; compare it with the refractory illustrated "before vibration". During the two-stage vibration sequence, the vibration frequency may also be monitored during each vibration stage through the output of the control panel display, or through the use of the Vibra-Tak vibration tachometer. Readings should be at least 3,000 VPM (50 Hz) in the forward direction and 4,600 VPM (75 Hz) in the reverse direction.

After vibration, the vibrators are removed from the inductor casing along with the temporary inductor alignment rig/metal baffles. The excess dry vibratable refractory is removed and the level of the refractory should match the inductor casing flange, or be below the inductor casing flange in preparation for the wet capping material. Now, the inductor refractory face is ready for surface treatment and attachment to the furnace uppercase.

Inductor applications

The EVS has been used to install dry vibratable refractory for both ferrous and nonferrous applications. In either case, the installation procedure is essentially the same as refractories of similar densities are used for most applications. The only difference concerns silica-based refractories used in some nonferrous applications. The main difference between the refractories used in these applications are bonding agents and other compounds to improve performance.

All ferrous foundry applications, as well as most nonferrous foundry applications, use a metal melt-in channel form. This presents an additional EVS vibrator attachment site for larger inductor cases. Vibration energy is transferred to the areas between the channel form and bushing(s) when attached to the channel form assembly. Excellent results have been obtained for inductors requiring more than 3,500 kg (7,700 lb) of refractory and for inductors requiring as little as 500 kg (1,100 lb).

EVS installations for inductors with wooden channel loop forms have been successful. The primary requirement is ensuring the wooden loop form is securely attached. Wooden loop forms are used for aluminum alloy, zinc alloy and many copper alloy applications.

William M. Opatt is assitant business manager - International with Allied Mineral Products Inc.; contact him at bill.opatt@alliedmin.com.

David C. Williams is vice president - Technology, with ASI International.