A History of Shotcrete in Refractory

By Ted W. Sofis

THE EARLY YEARS OF REFRACTORY GUNNING

It wasn't long after Carl Akeley developed the dry-mix process (originally trademarked by the Cement Gun Company as "gunite") in the early 1900s that dry-mix started to be used for the fireproofing of mines. The earliest refractory gun mixtures were proportioned and mixed in the field. Mixtures such as the 1-2-4 mixture were widely used for industrial ductwork and petrochemical applications. The 1-2-4 mixture consisted of one part lumnite, or calcium aluminate cement; two parts haydite, an expanded shale; and four parts vermiculite. These early refractory mixtures were mixed on the ground or with paddle mixers—on jobsites—and they provided a low-density insulating refractory that could be gunned in place and handle the high temperatures.

DRY-MIX GUNNING MATERIALS

Manufactured refractory mixtures date back to the 1930s, but they were generally mixtures made for cast-in-place applications. In those days, gunning castables usually involved pre-dampening and aging the material for a period of time prior to gunning to get a successful result. In the 1960s, ball clays and chemical additives were incorporated into the refractory mixtures to help the material hang better and stay in place. The ball clays gave the mixture a sticky quality and chemical additives aided set times. A good gun mixture needed to have enough sharp aggregate to keep the gunning hoses clean from buildup and enough clay to help hold the material in place until it began to set. In the 1970s, gun mixtures were refined further to widen the water threshold and rebound was greatly reduced. Gunning products quickly gained acceptance in the steel industry for addressing refractory wear areas in steel ladles, soaking pits, and furnaces.

The speed of installation soon led to the use of monolithic gunned refractory materials in blast-furnace troughs, blast furnaces, and many other applications.

STEEL MILL AND INDUSTRIAL APPLICATIONS

I personally began working in the shotcrete industry gunning refractory in steel teeming ladles. After a teeming ladle finished emptying its steel into molds, the empty ladle would be laid on its side and a thin layer of clay-based refractory would be gunned on red glowing ladle brick. This thin refractory coating would instantly dry on contact. When a ladle went off for repairs, we would take advantage of the opportunity to gun the ladle with a thicker application. The refractory coatings would extend the life of the ladle brick from 17 heats per ladle to 50 or 60 heats. In 1975, we worked with the first spinner prototype for gunning ladles. The spinner gun was a rotating nozzle system that was lowered into

A 9 in. (225 mm) thick dry-mix process installation of high-strength 2600°F (1400°C) refractory in a power plant ash hopper

Gunning a high-temperature refractory with the dry-mix process in the burners of a coal-fired power plant. The refractory material did not use portland cement

the upright ladle to enable the operator to shoot ladles by remote control.

In blast-furnace departments, we would routinely gun refractory materials to reline the blast-furnace troughs. Because the refractory gunning could be performed quickly, blast-furnace down time was greatly reduced. This enabled the blast furnace to get back on line quicker and possibly get an additional cast in that day. In steel making, lost production time is expensive and can often be costlier than the repair work.

In the power industry, gunned monolithic refractories began to replace fire brick in power plant ash hoppers. Large boiler design and engineering companies such as Babcock & Wilcox and Combustion Engineering developed their own refractory gun mixtures, including a prepackaged version of the old 1-2-4 mixture.

A variety of specialty gunned refractory materials, including high-strength refractories for ash hoppers; chrome alumina, for cyclones; and medium-density and lightweight insulating gunning mixtures, are currently used in power generation facilities.

"Hot gunning," common in the steel industry, is where gunning repairs are made to vessels, soaking pits, or coke ovens while the units are still hot. These gunning repairs can be done with a handheld lance or with a remotely operated nozzle.

ADVANCES IN DRY-MIX GUNNING EQUIPMENT

Initially, most of the refractory maintenance gunning was done with single-chamber, batch-type guns, where the gun was loaded with material, pressurized, and then the material discharged. The development of the continuous-feed rotary gun (National Foundry's Jet-Creter, a straight drop rotary gun with a rotating air lock) opened refractory shotcrete to greater use in the steel industry.

The Reed Gun that followed was the first bowl-type continuous-feed rotary gun to be widely used for refractory gunning. The Reed Gun gained popularity in the mid-1970s because it was easy to use and small enough to be stationed at various steel mill locations where maintenance gunning was done on steel ladles, blast-furnace departments, and soaking pits. Pre-dampening of the prepackaged refractory materials was initially accomplished with paddle mixers. This required adding a premeasured amount of water, mixing for a few minutes, dumping the mixture out of the mixer, and hand shoveling the dampened material into the gun. Allentown developed a gunning system with a mixer, conveyor, and hopper, and provided a method to pre-dampen without having to double-handle the material. In the 1970s, auger-type pre-dampeners emerged, most notably the Reed-Mate and the B & B Pre-dampener. They provided a more efficient means of pre-dampening dry packaged refractory material.

In my time in the business, I worked through the early years using paddle mixers, then the conveyor hopper rigs, and on to the auger type pre-dampeners that we still use today.

The Jet-Creter was the first straight-drop rotary gun used for refractory installations in the United States. They typically had gasoline engines to run the rotor and were mounted on wheels with a trailer hitch for towing

An auger-type pre-dampener used in dry-mix process refractory installations

A typical setup used in dry-mix process refractory installations with a rotary gun and an auger-type pre-dampener for gunning dry prepackaged refractory material

WET-MIX PROCESS SHOTCRETE REFRACTORY

The emergence of wet-process shotcrete for refractory installation lagged behind the civil and building industries for a few reasons. First, the technology in refractory shotcrete pump mixtures had not yet been developed. That work

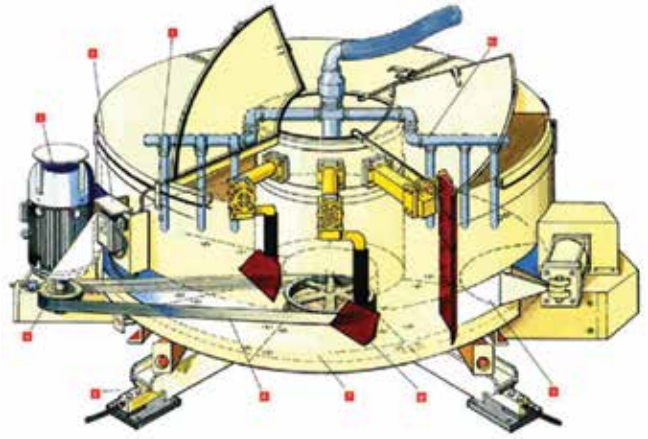

Diagram of a turbine mixer. The wet-mix process didn't become viable for refractory installations until the 1990s, when mixers were developed that could mix quickly enough to keep pace with the higher-volume wet-mix shotcrete pumps

was first undertaken at Harbison Walker in the mid-1990s. The patent was applied for in 1996, by inventors Mark C. Langenohl and Gustav O. Hughes, for "non-slumping, pumpable, castable, and method of applying same" for shotcrete application. Another obstacle was mixing dry, pre-packaged refractory materials quickly enough to keep pace with concrete pumping. The existing refractory mixing equipment, at the time, was not adequate to mix and handle a volume of material that could be pumped. Early installations used continuous mixers or a dedicated concrete truck to mix the refractory materials. This problem was later overcome with the development of turbine-style pan mixers with high-speed mixing blades.

The pan mixers and the new technologies in pumpable shotcrete refractories opened the door to high-volume wet-process shotcrete installations.

Wet-mix shotcrete pump with a pan mixer for handling bulk sacks works well for mixing and placing large volumes of material

ROBOTIC SYSTEMS

The progression to robotic systems for remote manipulation of the nozzle created many innovations. In years past, hot gunning was mainly done with long, handheld lances and protective clothing. The major problems with hot gunning by hand involved contending with the intense heat and the difficult and awkward gunning angles. Today, with the technology available, basic oxygen furnace vessels can be shot with robotic systems. Visibility in hot vessels and the intensity of the high temperatures present major difficulties. However, these issues can be effectively dealt with by using a computer-programmed robotic gunning system. The areas in need of repair are located by a laser that scans the inside of the vessel. The nozzle is then directed to these areas where the refractory material is gunned in place. The refractory material can be efficiently installed without the exposure and difficulties of using a handheld nozzle.

LOOKING FORWARD

Refractory mixtures continue to evolve. In recent years, ultra-low-cement gunning mixtures have become more common. There are ultra-low-cement gun mixtures for the dry-mix process gunning and ultra-low-cement pump mixtures for wet-mix shotcrete. Refractory gun mixtures with no cement, with enhanced refractory properties, have been introduced and are being used effectively in a variety of applications.

Refractory-lined 0.25 mile (0.4 km) long tunnel was placed with shotcrete

In the 42 years that I've been involved in gunning refractory, we've seen substantial advances. I've had the good fortune to work with many talented, dedicated, and innovative people in both the material and equipment sides of refractory applications. When we had problems gunning, they listened and made adjustments with grain sizing and other aspects of their mixtures to make better gunning refractory products. It's remarkable how far we've come and how much progress has been made in such a short time. With the 20th anniversary of the American Shotcrete Association, it is fitting to look back at the progress we've made in the rather specialized refractory shotcrete business and detail the accomplishments we've made along the way.

Acknowledgments

Gus Hughes, President, Mt. Savage Specialty Refractories.

Ted Sofis *and his brother, William J. Sofis Jr., are the Principal Owners of Sofis Company, Inc. After he received his BA in 1975 from Muskingum College, New Concord, OH, Ted began working full time as a shotcrete nozzleman and operator servicing the steel industry. He began managing Sofis Company, Inc., in 1984 and has over 40 years of experience in the shotcrete industry. He is Chair of the ASA Publications Committee, a member of multiple other ASA committees, and an ACI Examiner. Over the years, Sofis Company, Inc., has been involved in bridge, dam, and slope projects using shotcrete and refractory installations in power plants and steel mills. Sofis Company, Inc., is a member of the Pittsburgh Section of the American Society of Highway Engineers (ASHE) and ASA.*