The heat losses in bare vs. insulated water-cooled skid pipes are dramatic. Payback to insulate skid pipes can be realized within three weeks of operation. An effective preventive maintenance program for skid pipe insulation is a key component to reducing overall energy consumption in reheat furnaces.

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Implications of skid pipe insulation

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ALMOST everyone involved in some capacity with reheat furnaces has heard the statement, “Light it up, the furnace will run without insulation!” While that statement is true, would you consider heating your home during the winter with the doors and windows open?

Statistics point to a reduction in total U.S. steel industry energy consumption of roughly 20% from 1980 to 1991[1]; this trend must continue into the future to maintain global competitiveness.

A key component in reducing overall energy consumption in reheat furnaces is an effective skid pipe insulation preventive maintenance program to maintain the highest percentage possible of insulation coverage on your water-cooled support pipe.

Heat transfer rate

The difference in heat transfer rates to cooling water at elevated temperatures for bare pipe vs. insulated pipe is astronomical (Fig. 1). For example, if a furnace is operating at 2400°F, the theoretical heat loss to water for bare pipe is approximately 95,000 Btu/ft^2/hr. The theoretical heat loss to water for a pipe insulated with a 2-in. thick, high-strength monolithic refractory insulation is approximately 11,000 Btu/ft^2/hr, a reduction of approximately 90%.

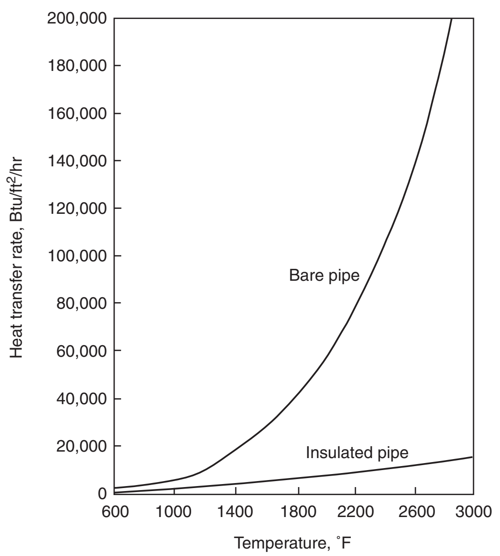

Fig. 1 — Heat transfer rate for insulated vs. bare skid pipe.

In a typical Generation II 5-zone pusher reheat furnace with insulation coverage at 90% effectiveness, the heat loss to cooling water would decrease by approximately 67%, while the heat transferred to steel would increase by approximately 36% (Fig. 2).

As can be seen in Fig. 3, the relationship between heat losses to cooling water vs. percentage of skid pipe insulation coverage is linear. The curves presented here are at an operating temperature of 2400°F. This analysis does not take into account the quality of the insulation, but rather emphasizes the effect of pipe coverage. In essence, a high-quality refractory material that quickly exposes bare skid pipe is not as effective at reducing heat losses as a good-quality refractory that provides full skid pipe coverage.

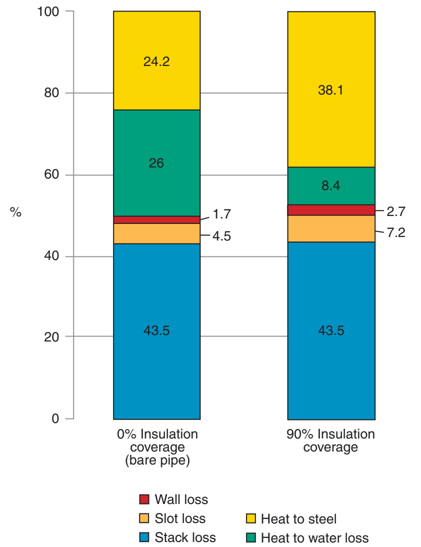

Fig. 2 — Heat output of a typical Generation II 5-zone pusher furnace.

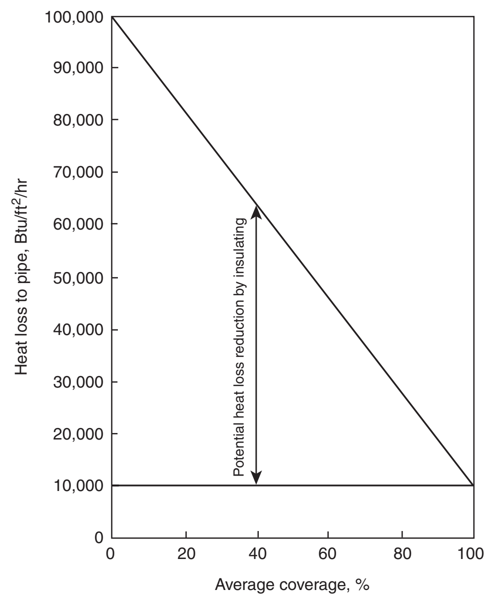

Fig. 3 — Heat losses to cooling water vs. percentage of insulation coverage at 2400°F.

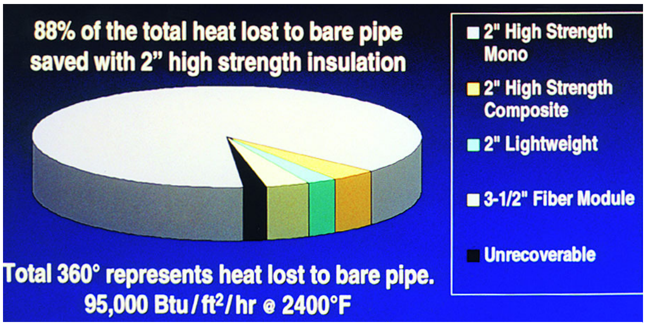

Fig. 4 — Insulation effectiveness by type of refractory material.

Fig. 4 presents the issue of insulation effectiveness by refractory type. The full 360° pie chart represents the heat loss to bare pipe, 95,000 Btu/ft^2/hr, at 2400°F. The various slices of the pie show the reduction in heat loss when the pipe is insulated with different forms of insulation. For example, 2-in. thick, high-strength monolithic insulation reduces the heat loss to bare pipe by a full 88%.

Potential savings

An average size reheat furnace, in terms of square feet of surface area of water-cooled support pipe, is approximately 2500 ft^2. Today, large walking beam reheat furnaces can contain up to 7000 ft^2 of pipe surface (Fig. 5), while the average size bar mill reheat furnace may contain 1000 to 1200 ft^2 of water-cooled support pipe surface area.

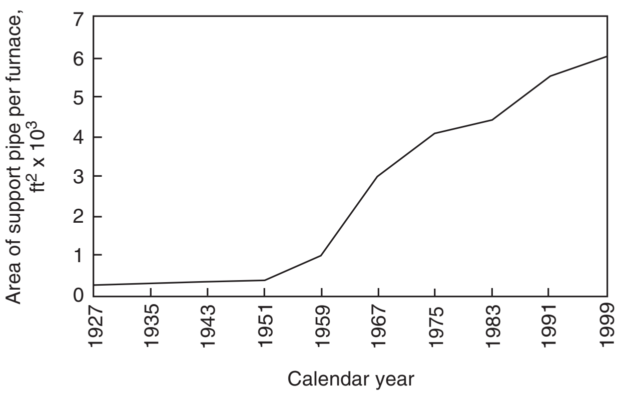

Fig. 5 — Development of the underfired reheat furnace from 1927–1999 as measured by its total area of support pipe.

Consider an average size reheat furnace with 2500 ft^2 of water-cooled support pipe operating with 10% bare pipe. For this calculation it will be assumed that the furnace operates with 10% excess air, heating efficiency of 60%, combustion air temperature in the range 800 to 900°F, and that waste gas leaves the furnace and enters the recuperator at 1900 to 2000°F. This furnace operates at the rate of 15 turns per week, 50 weeks per year. The fuel cost for this furnace is \$3/MM Btu. Given that the heat loss to bare pipe at 2400°F is approximately 95,000 Btu/ft^2/hr, the gross heat loss to 10% bare pipe would be 39.6 MM Btu/hr vs. 4.6 MM Btu/hr for 100% insulated pipe.

The fuel cost savings achieved in this example by operating with all skid pipes fully insulated would be \$105/hr or \$630,000/year. The estimated labor and material to insulate the 10% bare pipe, 250 ft^2, would be approximately \$160/ft^2 installed or \$40,000. The costs of insulating would clearly be recovered within four weeks of installation.

Operating conditions and insulation longevity

To achieve maximum insulation effectiveness, an insulation system must be designed to survive severe operating conditions in a reheat furnace environment, while at the same time, providing low heat loss to water.

An insulation system must withstand:

- Furnace cycling.
- Water-induced cooldowns.
- Temperatures in excess of 2400°F.
- Flame impingement.
- Vibration from steel pushing through furnace.
- Contact with steel product.
- Excessive scale.
- Molten slag.

Any of these conditions, alone or in combination, can be detrimental to the service life of refractory material, which in turn can result in premature failure of the system.

The main component to longevity with any system is the method of attachment to the skid pipe. The design must be properly mated, then mechanically locked, pinned, bolted or welded to the pipe. The amount of time a furnace must be taken out of production for maintenance must be minimized. At the same time, maintenance crews must be able to complete the maximum number of repairs in a minimum amount of time. Outages and repairs require extensive preplanning, scheduling and selection of the proper insulating materials.

An insulation system must pass all of the following criteria:

- Must be economical.
- Must reduce heat losses to cooling water.
- Must be quick and easy to install.
- Must not add additional downtime for setup and dry-out.
- Must provide long lasting service life.

The design that is chosen must pass all of these tests. To obtain any one of these benefits without the others would be unacceptable.

Two of the most common and widely accepted methods of insulating water-cooled support pipe are: preformed refractory shapes; and field-installed cast-in-place. Each will be reviewed.

Preformed refractory shapes

A survey was conducted by Bloom Engineering of the water-cooled skid systems in the underfired reheat furnaces in the U.S. and Canada in March 1998. Survey results show that 70% of the surface area of water-cooled support pipe was insulated with preformed refractory shapes (Fig. 6), 27% of the surface area of water-cooled support pipe was insulated with cast-in-place, and 3% of the surface area of water-cooled support pipe was insulated by other methods.

The 27% cast-in-place represents almost all new, first-time insulated walking beam reheat furnaces. Most of these installations have chosen to repair the cast-in-place with preformed shapes exclusively or with a combination of the two systems.

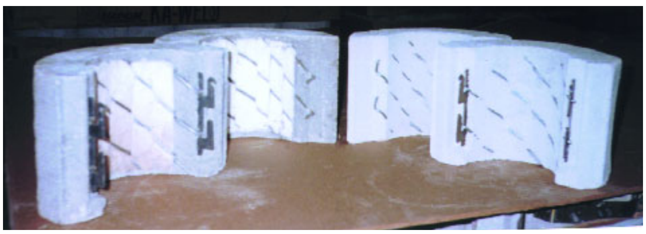

Fig. 6 — Preformed refractory shapes.

Preformed shapes have evolved into an insulation system that can provide low heat losses to water and long-lasting service life through extensive engineering, research and over 50 years of learned experience from operating successes and failures.

Preformed shapes offer the following advantages:

- Consistent quality because they are manufactured under controlled shop environments.
- Quick and easy to install.
- Lower NOx emissions in proportion to reduced fuel usage.
- Allow high level of coverage to be maintained.
- Require no added downtime to an outage for dry-out.
- Provide long-lasting service life.
- Reduce and/or eliminate welding in most applications.
- Protect water-cooled support structure such as buttons and hot riders.
- Improved furnace temperature uniformity.
- Quality of heating improved with better insulation coverage.
- Can be designed for most pipe sizes and configurations.
- Do not require welding of numerous pipe anchors, reducing heat losses of bare pipe when exposed.
- Can be installed on water-cooled pipes outside of furnace.

Hard refractory shapes provide excellent service life, even in severe service conditions, such as slagging, while greatly reducing heat loss to water. Hard shapes are generally manufactured with 50 to 60% Al_2O_3 refractory plastic. In severe conditions, refractory raw material can be upgraded to a higher Al_2O_3 content (Fig. 7). Hard shapes, as well as any preformed shapes, must contain an effective method of attachment to the pipe, such as bolt-on or pinned designs, hook and loop, strap or conventional welded designs.

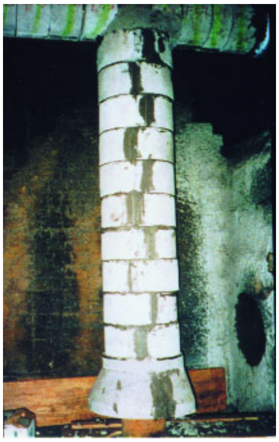

Fig. 7 — Hard refractory preformed shapes.

Composite and lightweight designs — Insulation designs can also be composite designs—those with a ceramic fiber layer next to the water-cooled pipe and with a hard refractory outer shell (Fig. 8)—and/or a monolithic lightweight refractory shape. Both designs provide low heat losses to water and excellent service life. However, in general, as insulating properties are increased a corresponding performance decrease occurs in strength and slag resistance.

Recently, a few steel mill operators have installed preformed composite hard shapes and then applied a 1/8 to 1/4-in. thick layer of gunnite refractory over the hard shapes. The pneumatic gunning technique points and seals all small voids or gaps. One Midwest plant has extended the service campaign of their preformed hard shapes with this "composite-composite" system.

Fig. 8 — View of a composite shape before installation, showing the fiber layer adjacent to the pipe being surrounded by a hard refractory outer shell.

Fiber modules — The preformed assembly that provides the lowest heat losses to water while surviving the rugged reheat furnace atmosphere is ceramic fiber. Ceramic fiber is the lowest heat loss refractory material that will withstand reasonable furnace temperatures.

Preformed ceramic fiber assemblies are compressed to form modules to counter shrinkage and are supported on an alloy steel frame. After the modules are installed, a special refractory spray is applied over the fiber to make the surface rigid and seal any small voids (Fig. 9). This ceramic spray provides protection to the fiber from high-temperature waste gas erosion and attack by slag. When furnace temperatures exceed 2400°F, a special refractory patching material is veneered onto the outer surface of the fiber.

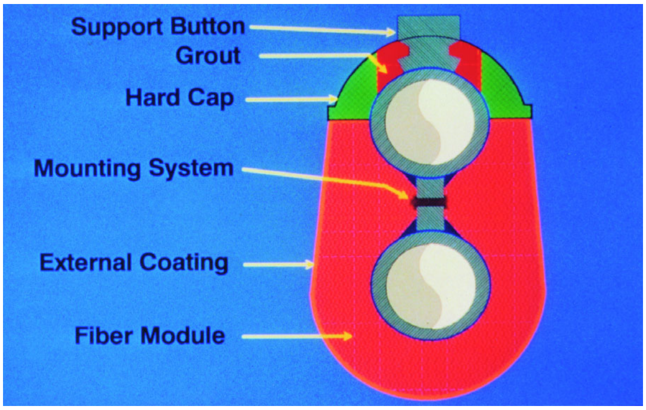

Fig. 9 — Preformed ceramic fiber assemblies.

Advantages of fiber modules include:

- Fuel savings, resulting from the lowest energy consumption.
- Ease of installation and replacement.
- Installed cost similar to other systems.
- Resistance to vibration and cracking.
- Less affected by mechanical contact from slab ends than hard shapes.
- Reduction of flue emissions due to reduced fuel usage.
- Easy to form and provides full insulation coverage at junctions where verticals, crossovers and/or horizontal supports meet.

Extreme care must be exercised during installation and removal of ceramic fiber. Also, experience has shown that in a walking beam furnace a hard refractory cap is necessary to resist the crushing action of the scale on the cap as the slabs are walked through the furnace (Fig. 10).

Fig. 10 — Fiber module assembly with hard refractory cap.

Cast-in-place

The second common method to insulate water-cooled support pipe is field-installed cast-in-place (Fig. 11). Field-installed cast-in-place can be applied either monolithic or composite (two components).

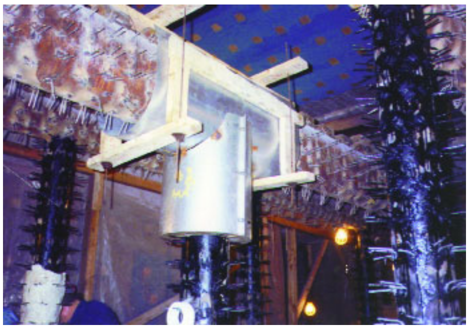

Fig. 11 — Field installed cast-in-place.

Field-installed cast-in-place composite (two component lining) insulation designs can provide lower heat losses to water than monolithic cast-in-place designs. Both types can provide competitive service life. Composite and monolithic designs require extensive labor for installation and can add downtime to the furnace outage. Cast-in-place insulation might provide good service life with the original installation (not in all cases), but is extremely difficult and time-consuming to repair and/or replace. It is difficult to maintain refractory patches with cast-in-place designs. Once the insulation is gone, the exposed welded anchors behave like finned tubes in a boiler, and can actually increase the heat losses from bare pipe by as much as 25%.

Hidden costs — Perceived lower initial installed costs of cast-in-place insulation can be misleading. Often times, part of the total installed costs are hidden. For example, the purchase and installation of tens of thousands of stainless steel V-anchors is often hidden in the cost of pipe structure fabrication. The purchase and installation of the composite lining may be hidden as in-house material and labor. When analyzing costs, these items must be identified and included.

Tunnel furnace rolls

While this article focuses on skid pipes in underfired reheat furnaces, with the advent of numerous thin slab casting operations using roller hearth furnaces, the subject of tunnel furnace rolls must not be overlooked.

The majority of the water-cooled rolls in a tunnel furnace (approximately 90 rolls per furnace) have four tires upon which the slabs are supported (Fig. 12). To minimize heat losses, the exposed parts of these water-cooled tunnel furnace rolls should be insulated analogous to the need to insulate the water-cooled skid pipes in reheat furnaces.

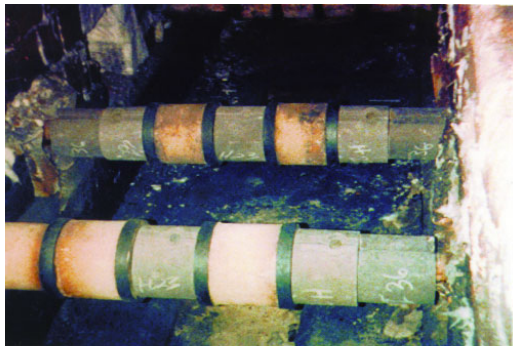

Fig. 12 — Tunnel furnace water-cooled rolls insulated with hard refractory shapes.

The tunnel furnace rolls are usually insulated with field-installed castable by the OEM, while repairs have typically been conducted utilizing preformed shapes (Fig. 13). In general, attrition rates of the refractory insulation are approximately 33% higher on the ends versus the middle of the rolls. Failure mechanisms include centrifugal forces, mechanical damage, slag attack and thermal deterioration.

Fig. 13 — Tunnel furnace rolls re-insulated with preformed shapes.

Other considerations

Scale formation and shadow effect — Insulation designs have negligible effect on scale formation. When insulation system designs are engineered, careful consideration must be given to the thickness and width of the design at or near the furnace product. The design should be the minimum thickness or width tolerable at or near the furnace product to help reduce the shadow effect on the bottom of the furnace product.

Tips to prolong service life of insulation — The following tips can prolong the service life of an insulation system:

- Regular and frequent close-up inspections.
- Seal all voids and cracks using a 3000°F air-setting refractory mortar or refractory patching plastic.
- Replace damaged insulation that may not last to the next outage.
- Wrap and seal vertical posts and crossover pipe with 1-in. thick fiber blanket.

The service life of highly engineered refractory products depends on a high-quality installation. Insulation designs should be installed according to suppliers' specifications, such as:

- Clean scale, slag, rust and debris from area to be re-insulated.
- Observe layout of a particular section of pipe so maximum insulation coverage can be achieved without leaving large gaps.
- Install insulation tight to the pipe so that the insulation can receive the maximum cooling effect from the water-cooled pipe.
- Maintain proper expansion allowance between insulators and pipe structure fixtures.
- Position joints on insulation designs away from flame.
- Properly lock assemblies.
- Weld areas to the pipe should be full penetration welds.
- Weld areas should be covered with high-quality refractory mortar or patching plastic.
- Minimize refractory thickness and width near furnace product to minimize shadowing.
- Study furnace product push patterns or spotting of the slabs prior to outage. Position insulators on skids away from shear drag.

Supplier partnerships — According to Fr. Hogan, "productivity and product quality are served by installing and maintaining the best available refractory products in the least possible amount of time, which in a growing number of instances has come to require a close working relationship between steelmakers and refractory suppliers."[2] The "steel industry" work force, including mill supervision, has experienced severe downsizing. Now, more than ever, mills require more and more of supplier-sponsored service.

Preventive insulation maintenance program — A preventive insulation maintenance program, implemented in conjunction with a supplier, can allow the furnace operator, engineer and maintenance personnel to concentrate on quality heating of steel product and maintenance of the furnace equipment. Such a program should include the following:

- Supplier sales/service be present during furnace repairs.
- Regular inspection and mark-up of the furnace sketch as to insulation condition throughout the furnace.
- Determination of insulation system strengths and weaknesses.
- Record location of insulation replaced during each outage.
- Periodically photograph insulation.
- Keep a list of insulation designs and the quantities of each design required to insulate a full furnace in the event of an emergency or disaster.
- Routinely take inventory of insulation spares to maintain the above.
- Set a minimum inventory/spares level for each design.
- Re-order when inventory/spares go below minimum level.
- Where possible, set up a blanket order program to expedite order processing procedures for stocking programs.
- Color code insulation types for ease of inventory, handling/stocking, installing, etc. (Fig. 14).

Fig. 14 — Color coding of preformed shapes.

Summary

In summary, the first and foremost primary goal of the furnace operation, maintenance, energy and engineering personnel, while working in conjunction with a supplier, must be to maintain the highest level of insulation coverage possible without disrupting the primary purpose of the furnace—to heat steel product. This requires an insulation system that is quick and easy to install, and permits a high degree of skid pipe coverage while providing long-lasting service life and lowering heat losses to water.

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