Entry for the 2006 Governor's Award for Energy Efficiency

Improving the System Life of
Basic Oxygen and Electric Arc Furnace Hoods, Roofs and Side Vents

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Project Name: Improving the System Life of Basic Oxygen and Electric Arc Furnace Hoods, Roofs and Side Vents

Implementation Date: October 2004

Project Summary: Energy Industries of Ohio (EIO) submitted a successful proposal to the US Department of Energy entitled "Improving the System Life of Basic Oxygen and Electric Arc Furnace Hoods, Roofs and Side Vents" to initiate research on alternatives alloys for use in Basic Oxygen and Electric Arc Furnace applications. EIO served as project manager on this effort with work beginning in mid-2002.

As a part of this program, Republic Engineered Products Inc. (Republic), one of the industry partners on this project, agreed to install what is believed to be the first equipment fabricated from aluminum bronze in a Basic Oxygen Process Furnace application. This installation in the skirt portion of the furnace was undertaken to evaluate the performance of the material in an attempt to reduce the maintenance downtime and attendant energy losses that were the result of the need for continual maintenance to repair leaks on the traditional carbon steel skirts used in this service.

As of the end of May 2006, this skirt has produced 3470 "heats" of alloyed steel without requiring a single repair for leaks in the system. A traditional carbon steel skirt would have already been replaced by this time due to corrosion during operation. Estimates on the remaining life of the aluminum bronze skirt suggest that it should be in service for at least 6 years.

This installation has been so successful that Republic has decided to replace their flux chutes in both their furnaces with aluminum bronze alloy to remove another source of continual maintenance, unit downtime and energy losses. Calculations performed at Oak Ridge National Laboratory, another project partner, indicate that the energy savings attributable to the skirts improved performance is 5.3 billion btu/year with another 4 million btu/year saving anticipated once the new flux chutes are received and installed. This savings is the equivalent of 9.3 million cubic feet of natural gas.

Additional benefits have also been documented. Since the aluminum bronze does not allow "skull formations" to stick to the skirt, environmental incidents related to this cause have been eliminated. In addition, maintenance free operation of the skirt has allowed Republic to process 6 additional heats per month or an additional 1,200 tons of steel. The yearly value of this additional production is approximately $12.0 million.

Narrative:

Background

Steelmaking productivity in basic oxygen process (BOP) and electric arc (EAF) furnaces is hampered by the life span of hoods, roofs, and sidewall systems. These systems are constructed from a series of tubes welded together and cooled by pumping water through them. This arrangement protects the equipment from the extreme heat generated during the steelmaking process (≥ 3000°F. See Figure 1 and 2) The hoods, roof and side wall systems are intended to capture the gasses generated during the steelmaking process and transport them to environmental control equipment that cools the gas and removes particulates prior to discharge.

These systems are exposed to extremely harsh conditions. Aside from the extreme heat, the materials used to construct the hoods and roofs are also exposed to corrosive components of the exhaust gas and are also abraded by slag particulates that are entrained in the high speed exhaust stream. As a result of the corrosion, erosion and thermal stresses experienced, these systems may only last 1 to 2 years in service before they need to be replaced. Replacement comes only after continual maintenance on this equipment that eliminates any water leakage into the furnace. Water leaks into steelmaking equipment have the potential of causing an explosion that can endanger the equipment itself and all those working near the furnace. Traditionally hoods and roofs have been considered standard repair and replace items in these operations. As a result they have traditionally been fabricated from carbon steel, the cheapest material that would withstand the service.

In response to a US Department of Energy solicitation, Energy Industries of Ohio (EIO) assembled a project team and submitted a proposal to investigate alternative materials that could in improve the system life of these components. This project, entitled "Improving the System Life of Basic Oxygen and Electric Arc Furnace Hoods, Roofs and Side Vents" involved EIO, Oak Ridge National Laboratory, most of the major steel makers in Ohio, and a number of service suppliers to the steel makers one of which was AmeriFab, Inc. The target for this project was to extend the life by a factor of two and to reduce maintenance-related downtime by up to 95%.

Various alternate materials were evaluated by Oak Ridge National Laboratories through various thermal and corrosion modeling techniques. One material, aluminum bronze was considered to be a possible candidate for this service. A copper alloy, aluminum bronze exhibited superior resistance to thermal stresses as a result of the much higher heat conductivity exhibited by copper as compared to steel. Furthermore, copper is a much less reactive metal than iron which would tend to reduce the damage to the material from corrosive exhaust gas components.

As plans were being made to test small sections of aluminum bronze in steel furnaces, Republic, in Lorain OH volunteered to conduct a full-scale evaluation by installing an aluminum bronze skirt on one of their BOP vessels. Since the skirt is the section of the hood system that is closest to the furnace (See figure on page 8), it experiences the most severe conditions in the system and would provide the toughest test possible for this material. It was agreed to proceed with this test and a full size unit was fabricated for installation at Republic by AmeriFab, Inc. of Indianapolis, IN. The skirt was delivered and installed in October, 2004 and is believed to be the first such installation in this service.

Operating Experience

Without any real operating experience to use as a guide, Republic first used this furnace in back-up service (used only when the primary furnace was down for maintenance). This service is extremely hard on the equipment. Normal operations keep the furnace and the attendant equipment fairly hot at all times, minimizing the thermal stresses and corrosion potential. Back-up service, on the other hand, is such that the furnace is allowed to cool to room temperature while to primary furnace is in operation and then is heated to over 3000^{o}F once it is needed for production. The aluminum bronze experienced over 250 heats in this mode, approximately 10 heats per run over the next 10 months, at which time the primary vessel was taken down for major repairs and the furnace with the aluminum bronze skirt was placed in primary service. This occurred in August, 2005. Since that time, the aluminum bronze skirt has processed an additional 3220 heats (a heat is a 200 ton batch of steel) for a total exposure of 3470 heats as of the end of May 2006.

Performance

The performance of the aluminum bronze skirt has exceeded all expectations. After nearly 20 months of service, the skirt has not developed a single leak, eliminating all maintenance shutdowns for skirt repair over that period of time. In addition, it has been found that slag from the steelmaking process does not adhere to the aluminum bronze alloy. This has eliminated all cleaning time, equipment damage and operational difficulties associated with the accumulation of a slag "skull" on the skirt. The overall result has been the benefits outlined below.

> **Energy Efficiency –** Based on their experience with carbon steel, personnel at Republic estimate that a carbon steel skirt would have already required nearly 50 maintenance shutdowns for leak repair and would have already been replaced by a new skirt. Each maintenance shutdown wastes energy since the furnace cools during the shutdown and must be reheated after it is placed back in service. Additional energy is consumed by having to replace the skirt – new steel must be used, additional welding must be done, additional shipping performed.
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> A thorough analysis of the energy performance of the skirt was conducted by Oak Ridge National Laboratory as part of the DOE funded project. Their analysis indicates that the reduction in maintenance on the skirt has saved Republic 5.3 billion btu/year, the equivalent of 5.3 million cubic feet per year of natural gas. As a result of this performance, Republic has purchased and is awaiting the delivery of two new flux chutes for their

furnaces. The flux chutes (the side arm shown in the figure on page 8) represent another high maintenance portion of the furnace installation nearly rivaling the skirt in the number of shutdowns necessary to repair leaks. Once these units are installed, Republic expects to save an additional 4 billion btu/year bringing the overall energy savings for this project to 9.3 billion btu/yr or 9.3 million cubic feet of natural gas..

Environmental Improvements – Optimal operation of the environmental capture and control system for the BOP starts with the condition and function of the skirt. The position of the skirt during operation governs the collection of the vessel's emissions into the primary capture system. If the skirt is too high, vessel emissions bypass the primary system and must then be "captured" by the building's secondary capture system. As a result, the condition and position of the skirt is paramount to operating in an "environmentally friendly" manner.

Standard practice within the industry is to increase the service life of the refractory within the furnace by a practice known as "slag splashing". Once the finished steel is removed from the furnace, the oxygen lance is lowered into the remaining slag and splashed around the vessel to build up a protective layer on the vessel walls which dramatically increased the life of the lining. During the splashing process, gobs of slag invariably are splashed onto the skirt. When operating with a carbon steel skirt, the slag builds up until the next scheduled shutdown at which time it is removed. However, before then slag buildup on the carbon steel skirt can become so great that it is no longer possible to position the skirt to optimize primary capture of the vessel emissions. Furthermore, severe slag accumulations can result in damage to the hydraulic systems used to raise and lower the skirt resulting in additional maintenance downtime.

As mentioned earlier, slag does not adhere to the aluminum bronze in the same way as it does to carbon steel. Any slag that has been splashed onto the aluminum bronze skirt simply falls off as soon as the skirt is moved to begin the next heat. As a result, there have been no occasions that have occurred over the past 19 months on the furnace with the aluminum bronze skirt where the furnace had to be operated without the skirt being in the proper position.

Productivity – While the operation of the aluminum bronze skirt has benefited both energy efficiency and environmental compliance, the impact on productivity has been even more impressive. The reduction maintenance downtime has allowed Republic to product an estimated 6 additional heats per month. This may not seem to be too large an increase until one places a value on the additional steel that is produced. Those 6 additional heats represent an additional 1,200 tons of steel per month valued at over $1,000,000 at current market prices. This is particularly important for industries, such as steel, which face ever increasing international competition and must attempt to squeeze every possible ton of steel from their facilities. An additional $12,000,000 per year of revenue is a great return on a piece of equipment that costs less than $100,000 to purchase.

Applicant

Energy Industries of Ohio (EIO) is a 501.c.3 non-profit organization that was established to facilitate technology research, development and deployment in Ohio's energy power generation and energy intensive user industries. EIO accomplishes this mission by fostering collaborations between among private industry, universities and national laboratories in response to targeted federal and state funding opportunities. EIO was established in 2000 and since that time has initiated over $40 million in projects.

The subject project is a perfect example of the type of project EIO undertakes. The initial project concept resulted from meetings with the steel producers within the state. EIO was able to successfully package that concept in response to a US Department of Energy solicitation. However, none of this activity would have been successful without the willing cooperation of Republic Engineered Products, Inc. and AmeriFab, Inc. in making the aluminum bronze skirt installation at Republic's Lorain Plant a reality. The next phase of this effort will be to transfer the knowledge learned to other steel makers across Ohio.

Key Project Personnel

From Energy Industries of Ohio

Robert Purgert, President
Lawrence Boyd, Director, Core Programs

From Republic Engineered Products, Inc.

James Vogt – Vessel Manager Lorain Plant
Troy Gorrell – Process Engineer, BOP and Steel Operations
Eric Flynn – Department Coordinator, BOP Maintenance

From Oak Ridge National Laboratory

Dr. Vinod Sikka, Corporate Fellow

From AmeriFab, Inc.

Gabe Carinci, President

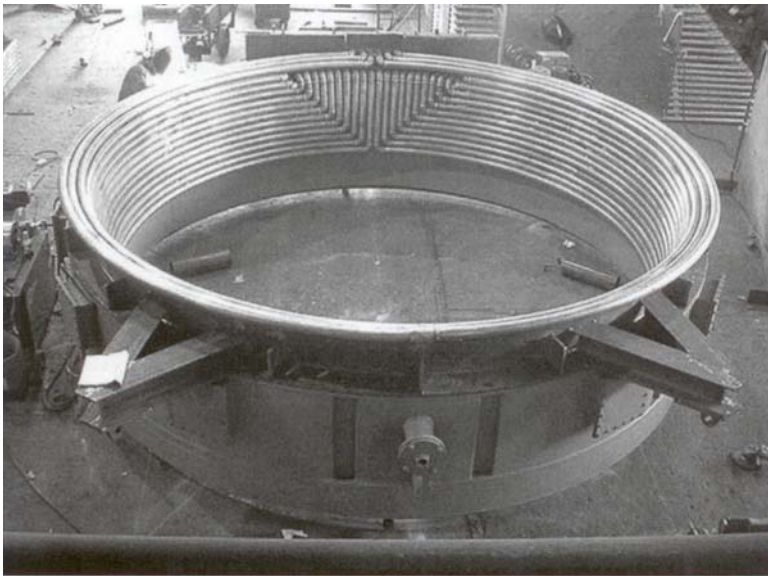


Figure 1. Aluminum Bronze Skirt Prior to Installation

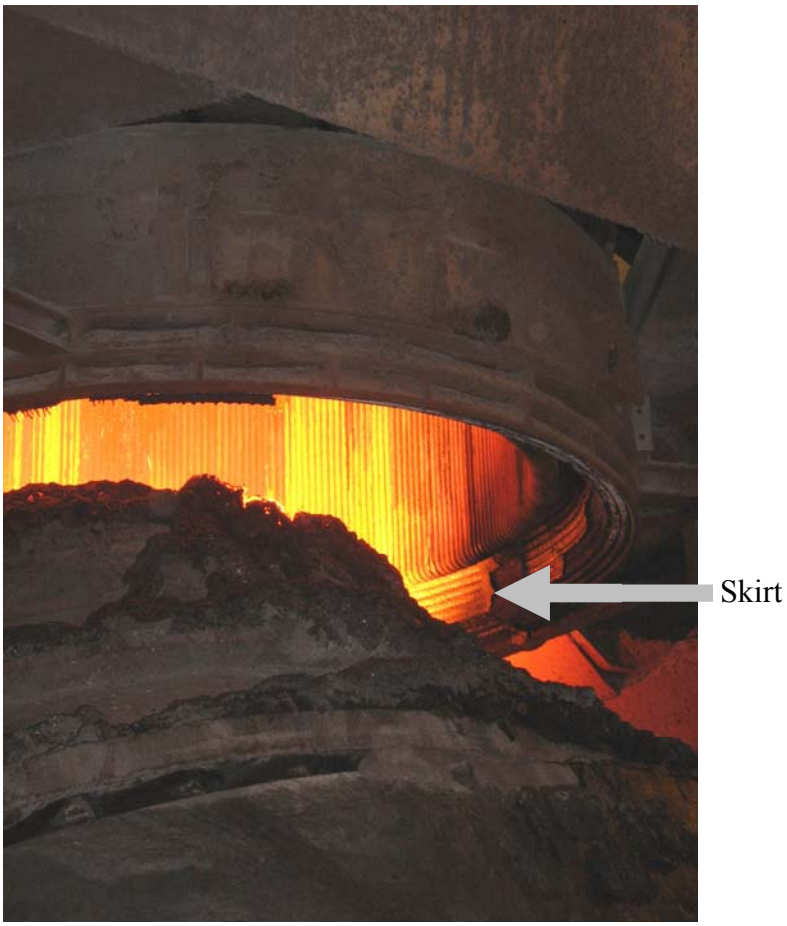
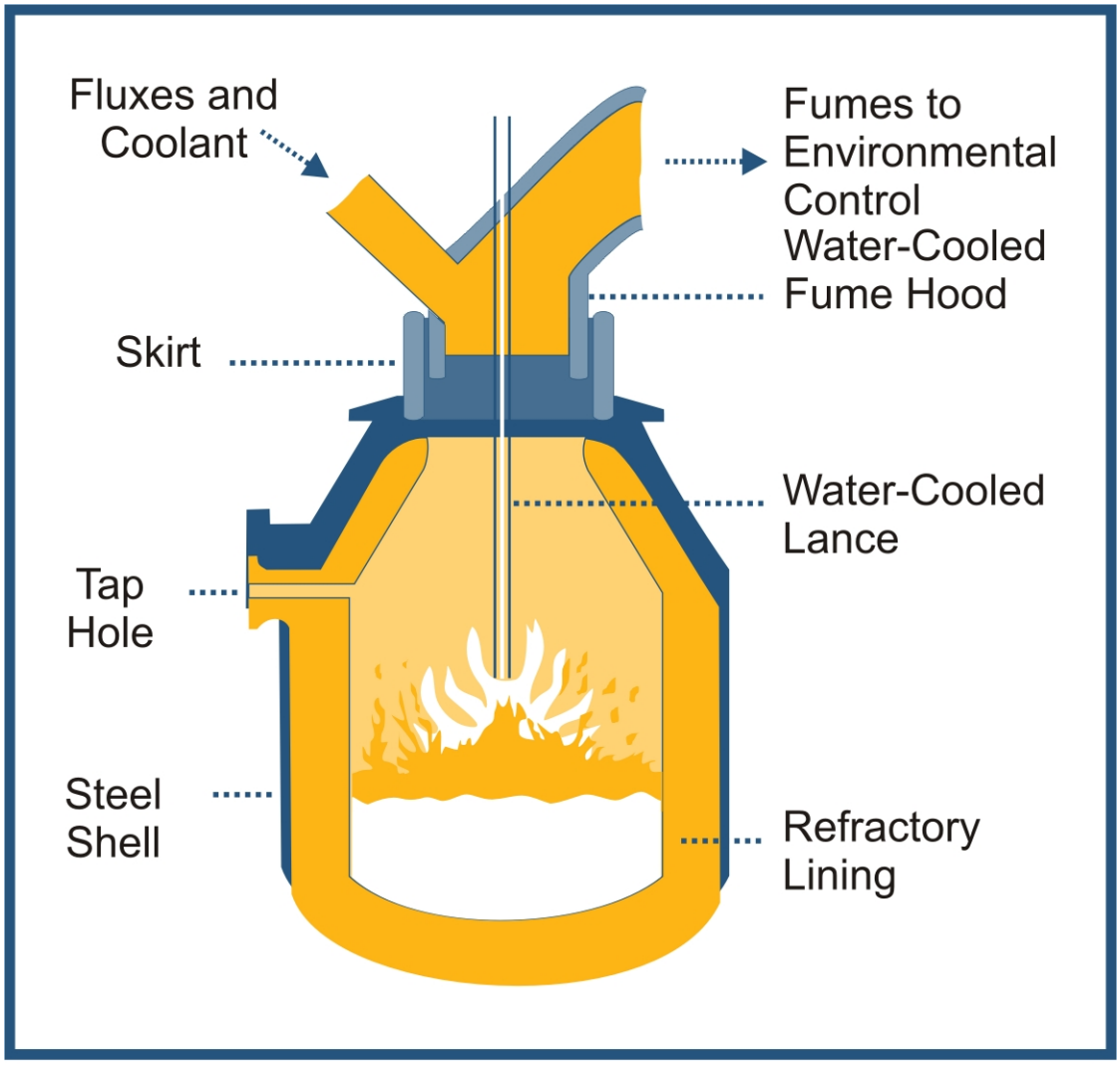


Figure 2. Aluminum Bronze Skirt Installed



Basic Oxygen Furnace (BOF)