Technical & Commercial Advantages of Accelerated Heatup of Coke Ovens

Irwin C Cobane

Hotwork - USA

Abstract

In the late 1980's, Hotwork-USA developed, patented the technology and began offering services utilizing high velocity combustion equipment to accelerate the heating of repaired throughwalls and endwalls on conventional coke ovens. The shorter heating time utilized by Hotwork permits new or repaired ovens to go back into operation weeks ahead of those heated using conventional methods.

While the time savings offered as a result of an accelerated heatup can easily be converted to financial gain as a result of the earlier production of coke, the technical benefit as a result of controlled uniform heating is not necessarily so apparent in the overall evaluation associated with the Hotwork-USA process. This paper discusses both the financial and technical benefits of the accelerated heatup of conventional slot oven coke batteries and the newer technologies utilizing both non-recovery and heat recovery batteries.

Hotwork-USA has heated in excess of 2500 conventional coke oven walls and 6 new heat recovery coke batteries. This service has been provided for over 30 years to clients worldwide.

With over 20,000 successful refractory dryout / heatup projects completed since its inception in the mid 1960's Hotwork-USA is considered the World leader in the provision of this highly specialized service.

Key Words

Heatup, Slot Oven, Non-Recovery, Heat Recovery, By Products, Thermal Expansion, Silica, Regenerators, Throughwall, Endwall, Fluewall, Thermomechanical, Patent, UV Flame Scanner, Conventional Heatup, Burner, Convective Flame.

Introduction

For many years, coke ovens have been built in large batteries of, for example 25 - 80 plus, immediately adjacent oven chambers varying in height from 3 - 7 meters and up to or exceeding 15 meters deep. The throughwalls separating adjacent ovens burn coke oven gas (generated by the coking process) to heat the ovens to the coking temperature. This type of coke battery is typically referred to as a "By Products Coke Plant" (or "Slot Oven Coke Battery") as the by products are recovered and are typically used in other processes or in the production of other products.

As with most industrial processes, recent technological advances have drastically reduced the environmental impact of coke production. The most recent advance in coke production technology is that of the "Heat Recovery Coke Battery" (as the technology is referred to most commonly in the Western Hemisphere) or "Non-Recovery Coke Battery" as it is referred to in other areas of the world. Rather than collecting the by-products of coke production as in the conventional slot oven design, heat recovery ovens incinerate the by products, and may (or may not) utilize the waste heat to generate steam which is then used, in many cases, to drive turbines and produce electricity. This type of coke battery typically consist of 20 - 80 immediately adjacent oven chambers having dimensions up to 4 meters wide x 15 meters deep x 3.5 - 4 meters high and having sprung arch silica brick crowns.

In the case of both technologies described above, silica refractory brick and special preformed silica shapes are the product of choice for construction of the batteries. However, the use thereof, due to its thermal expansion characteristics, requires careful consideration and attention during both the initial heating of a new battery and/or following repairs to existing batteries. Subsequently, conventional heating methods have resulted in typical heating times of 2 - 3 months to heat an entire new coke battery or new installed through walls on existing by product coke oven batteries, in order to avoid thermal and/or mechanical spalling of the silica brick during commissioning.

In the very early 1960's a British Gas Board Combustion Engineer was charged with the task of developing a burner to effectively and efficiently burn natural gas in industrial applications, as an abundance of this fuel had recently been discovered in the North Sea. From that development work, emerged the World's first high velocity burner, which was shortly thereafter patented, both in the UK and USA in the mid 1960's. A short time later Hotwork Ltd. was established in the UK and the first application for the use of the new developed burner was identified and applied to the heating up of newly constructed industrial glass melting furnaces, which previously, had been heated with wood fires, gas lances and other flammable materials over periods exceeding several weeks. Ironically, and as is the case in the coke industry, silica brick sprung arch crowns were, and for the most part remain, the product of choice for roof construction of these furnaces. Following the initial entry into the glass industry it was not long before these furnaces were being heated in 3 - 5 days, which continues to be the case to this day. Hotwork Ltd ultimately established franchisees in several parts of the world, with Hotwork-USA being the first of these in 1965, and this company has operated continuously up to the present day. Having eventually acquired the assets of the original Hotwork Ltd in 1998, Hotwork-USA has expanded its services worldwide and has strategically position personnel and equipment in most all Industrialized regions of the world including Asia, the Pacific rim and Australia.

In order to understand and appreciate the ability to heat not just coke oven batteries much faster than by conventional methods, but any type of refractory lined structure, than is possible by "conventional methods", one must first understand the benefits of high velocity combustion and how convective heating (Fig. 1) it differs from radiant heating (Fig. 2), in regards to providing uniform heating and precise temperature control in order to impart the most beneficial treatment of a refractory lining so that it may provide maximum service life.

The Hotwork high velocity combustion process provides the following advantages over conventional methods:

- Precise temperature control via a burner turndown ratio of 100:1. The burner has an operating range of 100,000 - 10,000,000 BTUs / hr.
- High volume excess air - the burner will maintain flame at minimum (energy) output with 100% combustion air and subsequently is very effective at distributing the heat uniformly across the refractory surface from the onset of the heating process.
- An outlet nozzle (150mm diameter) with a product discharge velocity of 450 ft. per second - hence creating turbulence, which dramatically improves the film coefficient of heat transfer and subsequently the rate at which heat is transmitted into the lining.
- Ability to operate under positive pressure - enhances uniformity of temperature within the structure being heated.
- Flame safety supervision via UV flame scanning.
- Internal spark plug ignition.
- Ability to burn various fuels including natural gas, LPG or 100% fuel oil.

Fig.1: Convective Flame Burner

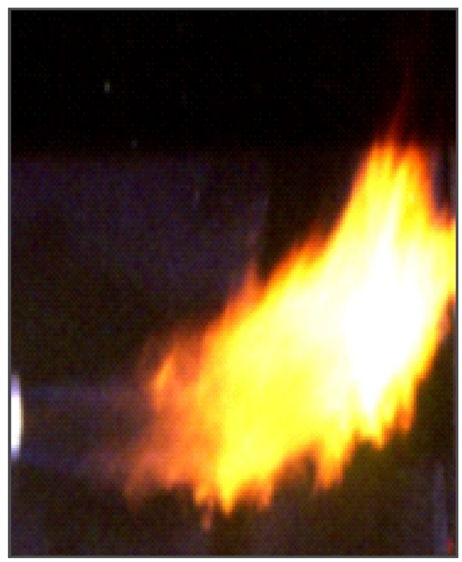


Fig. 2: Radiant Flame Burner

Fig. 3: Standard Combustion Set (Gas fired)

Discussion

The primary objective when considering the heatup of any coke oven battery or repairs thereof, is the ability to heat the structure in a manner conducive to maintaining the integrity of the silica brick, without subjecting the fluewalls to such mechanical stress that the end result is either refractory spalling and/or distortion of the throughwalls. The ability to effect a positive outcome lays in the ability to achieve precise temperature control and uniform heating.

In 1990, following extensive trials and development work, Hotwork-USA applied for and was granted US Patent No. 4,921,597 covering the accelerated convective heating method utilising portable combustion equipment (Fig. 3) for commissioning of repaired coke oven walls after repairs.

Initially the technology was applied to multiple endflue repairs (3 - 4 flues deep into the battery) and which over time evolved into the simultaneous heating of up to 8 - 10 immediately adjacent throughwalls on operating batteries.

In 1991 an extensive Thermal Mechanical study, sponsored by the Coke and By Products Producing Division of AISE (Association of Iron & Steel Engineers - USA) was undertaken on a 6 meter coke oven endflue repair at US Steel's Gary Indiana coke facility.

The results of that study were later presented in a technical paper at an AIST convention. (Copies are available by contacting the author of this paper). The results of that study demonstrated more uniform temperatures and silica brick expansion using the Hotwork accelerated heating process vs much longer conventional heating methods.

In addition to the previously indicated Thermal Mechanical study, an additional thermal study was carried out more recently on a 6 meter high x 16 meter wide by products coke battery to evaluate temperature uniformity across the width and height of each throughwall as well as between each of the 3 throughwalls. The results of this study are detailed further in addendum 1 attached to this paper.

Complete throughwall repairs were initially heated by Hotwork in seven (7) days. As the technology evolved and coke manufacturers and engineering companies became more confident and accepting of the accelerated heatup process, the seven (7) day heatup was eventually reduced to five (5) and which has now been the standard practice for in excess of twenty (20) years. Hotwork has heated in excess of 2,500 throughwalls during this time and has done so in various areas of the world, including India.

The following graphics (Fig. 4) illustrates the typical burner setup for heatup of a new installed by products coke oven throughwall repair. A single Hotwork burner is indicated in this graphic for demonstration purposes. However, for a single throughwall heatup a total of 4 burners are required with 2 push (Ram) side and 2 coke side positioned in the oven chambers on each side of the new throughwall:

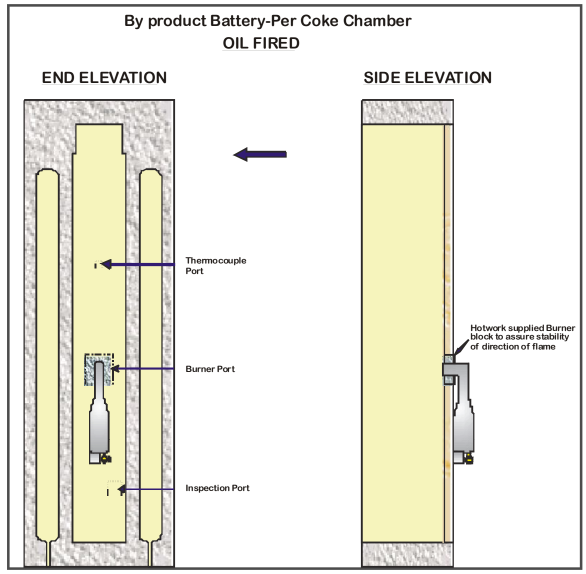


Fig. 4: Burner arrangement (Oil fired)

In addition to heating new installed throughwalls, Hotwork is often called upon to provide hold hot of the regenerators during multiple throughwall repairs in order to maintain the oven floor at elevation while demolition and re-installation of the new throughwalls take place on Batteries that remain in operation while this work is being carried out. The following graphics (Fig. 5 & 6) illustrates the typical arrangement for such an undertaking and in this instance involves the pinion wall and replacement of the immediately adjacent first three (3) throughwalls for a battery having an inner regenerator chamber:

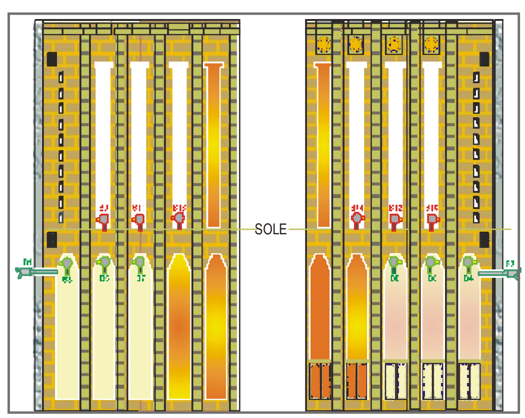


Fig. 5: Regenerator Hold Hot & Fluewall Heatup

In the above instance, the object vens are being heated, using high velocity burners, after repair, and burner positions are shown for both operations.

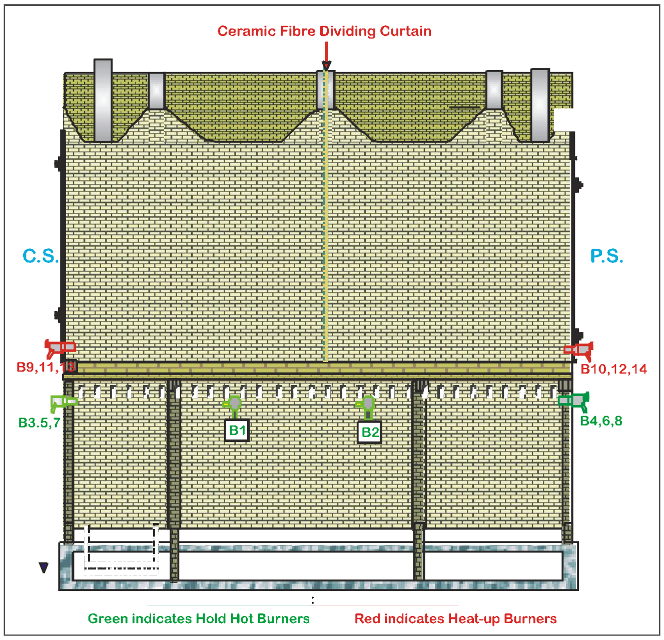


Fig. 6: Face Elevation for Hold Hot & Heatup

The following photo (Fig. 7) shows the heatup of a 6 throughwall repair with 7 oil fired heatup burners on the coke side and 7 on the push (Ram) side of a by products coke battery:

Fig. 7: Throughwall (6) Heatup on Fuel Oil

The next photo (Fig. 8) shows the simultaneous heatup of 48 endwalls following repairs on one side of an entire by product coke battery. In this instance the Hotwork combustion equipment was positioned on flatbed trucks and, because of the the small area of the oven chamber being heated, 1 combustion air fan was used to provide the air to burners positioned in each of 2 immediately adjacent ovens:

Fig. 8: Heatup of 48 Endwall repairs (1 side)

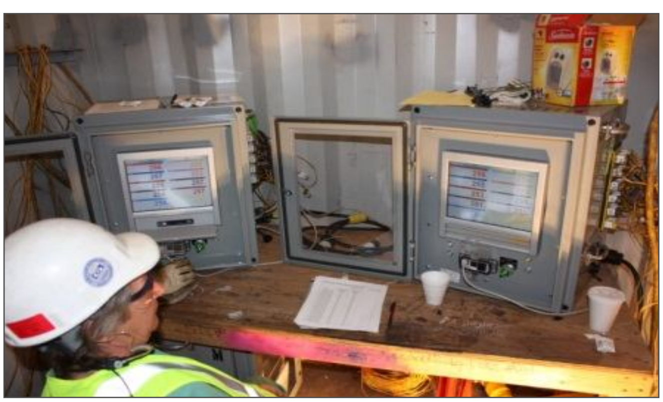
In 1998 the first large scale heat recovery coke oven battery with a design capacity of 1.5 million tons (short) per year came on stream in the USA and presented Hotwork with its first opportunity to participate in, what was at that time, the single largest heatup ever undertaken using portable combustion equipment on such a battery of ovens. All 67 ovens in each battery were heated simultaneously with a single Hotwork high velocity burner positioned in the door on one side of each oven (Fig. 9). Each 67 oven battery was heated to in excess of 1200°C over approx. 2 weeks using natural gas:

Fig. 9: New 67 Oven Heat Recovery Battery

Since that time additional heat recovery coke ovens have come on stream and has resulted in Hotwork performing the simultaneous heatup of as many as 80 ovens (Fig. 10) in a single firing. The execution of such a project requires considerable advance planning and coordination of activities with battery design personnel, engineering companies, construction companies, the plant owner(s) as well as trades and craft personnel at site:

Fig. 10: Elevated view of Heat Recovery Battery

In this instance 80 burners are firing simultaneously and in excess of 250 thermocouples were being monitored continuously for adherence to the prescribed heatup curve and permanent record of the heatup process (Fig. 11 & 12).



Figs. 11 & 12: Digital temperature recording

Financial Consideration

As with any commodity, coke prices fluctuate drastically due to changes in supply and demand. During times when coke prices are elevated, returning ovens to service quickly can have significant financial impact for the coke plant owner. The accelerated heating method (5 days) allows clients to return ovens to production sooner, saving them considerable time and expense. The following table (Table 1) indicates nominal production gain on a 24 hour day basis using 18 hours coking time. From this table the reader can make their own assessment of the financial impact of an accelerated heatup vs conventional methods being utilized at present. Obviously the more ovens out of commission as the result of repairs being made, the more beneficial an accelerated heatup becomes:

Oven Height	Production per 24 hr. day
3 M	9.0 Metric tons
4 M	17.0 Metric tons
5 M	22.6 Metric tons
6 M	28.2 Metric tons

Table 1: Battery height v.v. Production

Considerations for carrying out an accelerated heatup and/or a regenerator hold hot

The following must be taken under consideration when deciding to utilize an accelerated heatup and/or perform the hold hot of regenerator chambers vs conventional methods:

- **Utilities** - electrical power requirement, fuel to be used, compressed air requirement for atomization of fuel oil should gaseous fuel not be available.
- **Support for Heatup Contractor** - assistance unloading, placing equipment, connection of utilities to heatup company equipment, disconnect and loadout of heatup equipment at project completion.
- **Oven / Regenerator Preparation** - temporary bulkheads in oven doors for burner placement (openings in bulkheads required) and heat containment, proper oven bracing in place, oven chamber division barrier (ceramic blanket) in place via charging port, exit port to accommodate the exhaust of products of combustion from the oven chamber, access for burner placement in corbel area on top of regenerator chamber to accommodate regenerator hold hot, burner access via sole flues or pinion wall to heat these areas if required and access for positioning of temporary thermocouples for temperature monitoring during the heatup or hold hot.

- **Silica Expansion** - Monitoring and management of silica expansion with appropriate adjustment as required throughout the accelerated heatup process.
- **Health & Safety** - provision for training of heatup contractors personnel to site specific rules and requirements, safety barriers in place to minimize access to areas of the battery where heatup is in process, downstream fuel shutoff valves identified and their proper operation confirmed, electrical power connections safe and secure.
- **Other Considerations** - in the case of new non-recovery or heat recovery batteries, is the coal handling system ready to deliver coal to the heated ovens and are all downstream facilities ready to handle the earlier production of coke? In the case of either type of battery, by-products, heat recovery or non-recovery, is there a plan in place for eventual takeover of the ovens from the heatup contractor so that the ovens can be placed into normal operating conditions at completion of the heatup process?

Contact author at: irish.cobane@hotwork.com

Conclusions

Many major coke producers world wide have adopted the Hotwork accelerated heatup process as their preferred means of handling the heatup or hold hot of regenerator chambers when extensive repairs are being carried out simultaneously on multiple throughwall repairs on operating batteries. In the case of heat recovery batteries, all such batteries constructed in the western Hemisphere since the mid 1990's have been heated using an accelerated heat-up utilizing high velocity portable combustion equipment. The technical advantage over conventional methods has been proven and documented over the past 20 plus years. Those using the technology have also realized the financial gain both in terms of faster return of ovens to service and the benefits associated with a more precisely controlled and uniform heatup process the latter imparts upon the refractories involved, including the opportunity to meet expectations for maximum service life.

References

1. United States Patent No. 4.921.579 (May 1990)
2. Thermomechanical study of a 6 meter coke oven endflue repair (March, 1991)

Addendum 1

Deployment of Thermocouples and plot of Temperature Profiles during a Triple Throughwall Heatup on a 6 meter By Product Coke Oven Battery in U.S.A.

All temperatures (30 Thermocouples - 2 per Oven - 8 per Throughwall)