Metallurgical Gas Cleaning System Design for Emissions Control and Energy Efficiency

Paykan Safe and Matt Russell
WorleyParsons GCT
111 Ferguson Court Suite 103
Irving, TX, USA 75062

ABSTRACT

Metallurgical smelting furnaces are highly energy intensive operations which generate significant gaseous and particulate emissions. This paper will demonstrate that proper gas cleaning system design will not only provide effective emissions control but can also improve furnace operation and energy optimization.

Two case studies of recent gas cleaning projects in the metallurgical industry will be used to illustrate this concept. Both projects started with a conceptual engineering phase and were taken through basic and detail engineering and system commissioning. Brief details of the case study projects follow.

Nucor Steel installed a new electric arc furnace meltshop with a production rate of 1.2 million ton per year in Jewett, Texas. A meltshop air pollution control system was installed to capture and clean primary and secondary off-gases from the EAF, LMF, and caster. Computational fluid dynamic (CFD) modeling was used to optimize the meltshop configuration as well as the canopy hood design.

PT Inco is a ferronickel smelter in Sulawesi, Indonesia, which operates four electric smelting furnaces. A new off-gas cleaning system was installed and commissioned on Furnace #3 in 2005. Upon successful completion of the gas cleaning system, similar systems were designed for the other three furnaces. The Furnace #4 system was commissioned in 2006. The other two furnace systems are expected to be commissioned later this year.

Introduction

Metallurgical smelting furnaces are highly energy intensive operations which generate significant gaseous and particulate emissions. It is important that the design of an air pollution control system optimize both the fume capture efficiency of the system and energy optimization of the process. The design should consider not only process fume capture but also secondary and fugitive fume capture, building ventilation, and worker conditions.

Proper gas cleaning system design should begin with an initial conceptual or preliminary engineering phase to assess equipment and hood options, to perform preliminary system design, and to establish exhaust rate requirements. This phase can often utilize advanced engineering tools such as computational fluid dynamic (CFD) modeling and thorough process and off-gas mass and energy balances to optimize the system design and performance.

A basic engineering phase generally follows in which the system capacity and equipment sizing is finalized, general arrangement drawings are developed to define the overall layout, and a definitive capital cost and operating cost estimate is prepared. The definitive cost estimate is typically used in requests for capital approval to proceed. Finally, a detailed engineering phase is completed to develop all general arrangement and detail drawings, to procure the equipment, and to guide the construction of the system. Upon completion of construction, the system is commissioned to ensure proper operation and to optimize system performance.

WorleyParsons GCT (WPGCT) has engineered two recent gas cleaning projects in the metallurgical industry which illustrate this approach. Both projects started with a conceptual engineering phase and were taken through basic and detail engineering and system commissioning.

Case Study 1 - Nucor Steel Texas – Jewett, Texas USA

Nucor Steel Texas produces carbon steel bars and high strength, low-alloy structural steel shapes at its facility in Jewett, Texas. In 2003, Nucor asked WorleyParsons GCT to evaluate the air pollution control requirements for a new meltshop and caster building that would be integrated with the existing reheating, rolling and shipping facilities. The new facility was to be equipped with a single Electric Arc Furnace (EAF), a twin station, single power Ladle Metallurgy Furnace (LMF) and a casting machine. The new meltshop and caster building would be constructed adjacent to the existing Texas I Melt Shop building.

The meltshop for the new facility was designed as a ‘closed shop’. All the heat and particulate emissions that are generated as a result of the activities within the meltshop enclosure are captured by the EAF canopy hood and directed to the EAF baghouse. The EAF meltshop is separated from the LMF/Caster area by a wall. Ladle cars pass through an opening in this wall to transfer ladles from the EAF to the LMF stations.

The emission control system for the new furnace consists of a fourth hole direct shell evacuation (DSE) system and roof canopy system. These two systems are used together to capture the emissions during the various phases of the EAF heat. The primary function of the DSE system is to capture the EAF process off-gas during the melting and refining phases of the heat when the furnace roof is in place over the furnace. The primary function of the EAF canopy system is to capture the large plume created during the charging phase when the furnace roof is swung open and the DSE system is off. The EAF canopy system also serves to capture any fugitive emissions from the furnace during the melting, refining, slag skimming and metal tapping phases of a heat. Gases from the DSE and the EAF canopy are combined and sent to the EAF Baghouse to control the particulate emissions.

Computational Fluid Dynamic (CFD) analysis of the melt shop was used extensively to design the meltshop ventilation systems such that air will flow into the building at all door openings that are provided for access and all louver openings that are provided for shop cooling. Based on the CFD analysis, the louver openings were located to ensure that temperatures at all working areas inside the shop are acceptable for the shop personnel. The CFD analysis was also used to optimize the canopy hood geometry and the required canopy hood exhaust flow rate.

WPGCT considered several key design parameters in sizing and laying out the off-gas system. These included:

- Furnace draft,
- Gas velocities,
- Combustion gap sizing and combustion efficiency,
- Water-cooled duct surface area,
- Evaporative spray requirements for gas conditioning,
- Canopy hood storage volume and face velocity,
- Building updraft velocity,
- Temperatures at working decks and the crane rail, and
- Baghouse dust handling and conveying.

In addition to the EAF DSE and canopy hoods, the system also provides exhaust for the two LMF direct capture hoods, the caster canopy hood, and the alloy handling system dust collection. The positive-pressure reverse air baghouse has a total design capacity of 1,680,000 ACFM with seven main ID fans.

Detail engineering was completed in the fall of 2003, and construction was completed in the first half of 2004. WorleyParsons GCT provided commissioning assistance in July 2004 to assess the current performance of the new system and to optimize the system operation. A key focus of the system optimization process was minimizing heat loss to the off-gas system from the furnace. Several recommendations were made to adjust damper positions, the combustion gap size, and control set points to improve performance. Actual performance of the system collected during commissioning was used to validate the CFD model for future design projects.

The system has now been in operation for three years and has provided excellent fume capture performance and has maintained a very clean meltshop environment.

Case Study 2 - PT Inco Nickel Smelter – Soroako, Sulawesi Indonesia

PT Inco operates a rotary dryer / reduction kiln / electric furnace / converter smelter in Soroako, Sulawesi Indonesia to produce nickel matte. Four electric furnaces operate continuously with calcine feed from five rotary kilns. The furnaces are circular with slag and ferronickel matte tapped from side tapholes into slag pots and matte ladles, respectively. The furnace matte is later processed to a nickel matte in Peirce-Smith converters.

The electric furnaces originally operated with two stacks to atmosphere and no off-gas system for gas conditioning or cleaning. WorleyParsons GCT performed a study of the furnace operation in 2003 to develop a conceptual off-gas system design for installation on Electric Furnace #3 (EF3).

A basic engineering phase was then completed in 2003 to determine the overall system design, system capacity, and definitive cost estimate. WPGCT completed a benchmarking study of off-gas systems at similar operations and also performed furnace freeboard composition testing to better define the operating conditions of the furnace and off-gas system.

The system needed to meet several key performance objectives:

- Minimize the explosion risks related to combustibles in the off-gas,
- Reduce emission levels to meet regulatory compliance,
- Minimize maintenance requirements and associated downtime,
- Prevent condensation of the sulfur-containing species in the off-gas stream and the associated corrosion problems,
- Design the system with sufficient capacity for the current, as well as planned, furnace operation and production levels.

The new off-gas system would include a refractory-lined combustion chamber with natural draft combustion gap followed by an evaporative spray chamber and draft control damper. The furnace off-gas would then mix with secondary ventilation from the furnace feed bins, smoke hood, and gap hood. The combined gas would then be directed to a negative pressure, pulse jet baghouse and one ID fan before discharging to a stack. The system was designed for later incorporation of a calcine transfer ventilation system. The system capacity is 375,000 ACFM. The ID fan was specified with a variable speed drive for reduced power consumption at lower production rates.

WPGCT considered several key design parameters in sizing and laying out the off-gas system. These included:

- Furnace draft,
- Gas velocities,

- Combustion gap sizing and combustion efficiency,
- Evaporative spray requirements for gas conditioning,
- Secondary ventilation requirements, and
- Baghouse dust handling and conveying

In ferronickel furnace applications, it is best to maximize the combustion of combustibles inside the furnace freeboard, which requires the furnace to operate under negative pressure. The negative pressure provides stability for the furnace operation by allowing pressure fluctuations from the furnace operation to occur without the furnace pressure going positive and puffing fumes out of the roof openings.

Freeboard combustion of combustibles enables at least some of the combustion heat to be absorbed by the calcine bed for increased furnace energy utilization. Additional heat is picked up by the furnace cooling panels. As a result of the freeboard combustion, the off-gas heat content is reduced and the off-gas system capacity requirements can be reduced.

WPGCT performed detailed engineering of the EF3 off-gas system in 2004, and the new system was installed and started up in April 2005. WPGCT provided commissioning assistance to check system operation and to optimize performance. Key focuses of the commissioning work included optimizing the combustion gap size, damper positions and control set points, and optimizing the dust handling and conveying system operation.

System startup went very well, and the system has now been operating successfully for more than two years. The new off-gas system provides much better control of furnace draft, which has resulted in much more stable and reliable furnace operation.

WPGCT has since provided basic and detail engineering of similar off-gas systems for the other three electric furnaces. The new system on EF4 was completed and successfully commissioned in October 2006 and has been performing very well. The system included the conversion of two old ESPs into the new EF4 baghouse. Engineering for the EF1 and EF2 off-gas systems has also been completed, and commissioning of these systems will occur in the second half of 2007.

In parallel with the off-gas system design, WPGCT completed a study on heat recovery options for the electric furnace off-gas. For the PT Inco operation, a waste heat boiler was found to be the most effective option for recovering heat from the off-gas in terms of total heat recovered, capital and operating cost impact, and precedence. The detail engineering for the EF1, EF2, and EF4 off-gas systems included provision for future installation of a waste heat boiler in parallel with the spray chamber for heat recovery.

WorleyParsons GCT has performed several heat recovery studies for other smelters as well, including extensive benchmarking of existing heat recovery applications. Furnace off-gas heat content often represents up to 40% of the total furnace energy input, so finding ways to recover and use that heat can provide significant improvements in energy utilization and major reductions in operating costs. Smelting furnaces in particular have proven to be good candidates for heat recovery systems due to the stable gas conditions from the continuous furnace operation.

Conclusion

WorleyParsons GCT has completed several successful off-gas cleaning system designs in the ferrous and non-ferrous metals industry. Results from the performance of the Nucor Steel Jewett and PT Inco off-gas system designs have shown that taking a project through the conceptual, basic, and detail engineering phases to completion and commissioning provides the best approach to optimizing the system design, performance, and reliability.

This approach allows thorough process analysis in the early phases of a project to optimize process parameters and equipment sizing. This can include appropriate test work and modeling. The findings from the early phases together with experience from past projects can be incorporated into the later engineering phases to ensure the final design of a system is state of the art and highly reliable.

Finally, the approach shows that systems can be effectively designed for optimum emissions control performance while maximizing energy utilization and potentially providing heat recovery options.