McMaster University | Engineering

28TH McMASTER UNIVERSITY

BLAST FURNACE IRONMAKING COURSE

May 10-15, 2026
Hamilton, Ontario, Canada

BOOK OF ABSTRACTS

Blast Furnace Control Measurement Data and Strategy

Bob Nightingale, University of Wollongong/Retired from Bluescope Steel

The competitive realities of modern blast furnace practice necessitate high standards of product delivery, quality, safety, environmental compliance and extended asset life. All need to be achieved consistently at an acceptable cost. The development of sound operating control strategies is a basic necessity.

Near term control of production rate and quality are strongly dependent on strategies to control thermal balance and gas distribution. These are increasingly based on complex models founded in basics of thermodynamics and fluid flow. Data from sophisticated sensors and probes is required for successful application. Proper calibration and maintenance standards are essential to operator confidence and interpretation.

In the longer term, decisions about raw materials sourcing and preparation set the foundations for process capability. Decision makers must be able to respond to variations in market pricing while respecting guidelines that define the boundaries for adequate operation.

In both the shortest and longest terms, diligent monitoring of asset status provides the key to maximising process safety and value extraction from any furnace asset. These data also provide the best basis for improvement decisions at reline time.

This paper will also discuss hearth dynamics and explain the formation, behaviour and influence of the deadman coke bed. The interpretation of hearth thermocouple data in relation to both refractory wear and liquid flow regimes will also be discussed.

Blast Furnace Design I

Brian Black, SMS group Americas

Today's efficient blast furnace (BF) operations have evolved through developments in raw materials preparation and quality; blast furnace design, including profile, cooling system, refractory configuration; cast house layout and operations; improvements in equipment; the application of automation and control technology.

This paper, which is complementary to others presented in this course, reviews the following components and sub-systems, which form the blast furnace iron making plant.

- BF iron making materials flow sheet
- Stockhouse
- BF charging equipment
- BF proper; design for efficient operation and long campaign life
- Cast house; hot metal and slag handling with associated equipment

Blast Furnace Design II

Guilherme Guidugli, Primetals Technologies

This lecture examines modern blast furnace air and gas system design with emphasis on hot blast generation, stove technology, and energy recovery. It reviews advances driven by higher blast temperatures and pressures, including regenerative stove operation, blast control strategies, gas cleaning systems, and top-pressure energy recovery. Key operating parameters, design trade-offs, and concepts such as oxygen enrichment, waste heat recovery, and flue gas recycle are discussed with the aim of improving furnace efficiency, stability, and overall energy utilization in ironmaking operations.

Blast Furnace Design III, Campaign Extension

Salustiano Martins Pinto Junior, Consultant

Before a Blast Furnace reaches the end of its lifespan, it is advisable to implement a campaign extension plan to postpone the reline. This approach follows the example of industry benchmarks that have achieved campaigns exceeding 25 years with high productivity and lower costs. Furthermore, extending a campaign provides more time to study CO2 emission reduction solutions currently under development. This is crucial as the steel industry faces increasing pressure to address climate change by significantly reducing emissions.

This presentation will detail best practices for Blast Furnace Campaign Extension, including:

1. A dedicated work team;
2. A separate and specific budget;
3. Continuous assessment of hearth and tap hole residual thickness;
4. Shotcreting every 2 to 4 years to protect aging refractory lining and cooling elements;
5. Continuous monitoring of stave wear;
6. Constant shell temperature control;
7. Immediate elimination of any water leaks in the cooling system;
8. Maintaining cooling system water quality to prevent fouling and clogging;
9. Early procurement of long-lead items (e.g., hearth refractories, staves, top charging systems);
10. Benchmarking and synergy programs.

Finally, experiences regarding Blast Furnace Campaign Extensions and Relines will be shared, followed by a Q&A session.

Blast Furnace Energy Balance and Recovery: Rules of Thumb, Game

John Busser and Mitren Sukhram, Hatch

Simplified mass and energy balances are outlined for the purpose of optimising blast furnace operations. A summary of useful blast furnace related data from numerous sources is presented. Tuyere zone, stack and general blast furnace reactions are reviewed from an energy standpoint. The importance of chemical reaction equilibria with respect to temperature are discussed. The impact of variability in blast furnace input parameters is discussed. ***'Rules of Thumb'*** relating furnace raw material and practice changes to energy consumption are reviewed. These principles are demonstrated through a computer simulation model ***"The Blast Furnace Game"*** that uses mass, energy, chemical and cost balances to assess means of improving the blast furnace process.

Blast Furnace Reactions

Leili Tafaghodi, McMaster University

The blast furnace is a counter-current shaft reactor used for primary ironmaking in the integrated BF–BOF route. Agglomerated iron ore (sinter/pellets), metallurgical coke, and fluxes are charged from the top, while a preheated and oxygen-enriched hot blast is injected through tuyeres at the bottom. The process produces liquid hot metal, molten slag, and a CO-rich top gas.

Iron oxides are reduced progressively, primarily by indirect reduction with CO in the upper shaft, while the remaining FeO is reduced at higher temperatures in the bosh by a combination of direct reduction with solid carbon and CO generated in situ. Coke provides mechanical support, heat via combustion in the raceway, and the primary source of CO. Fluxes react with gangue oxides to form a slag, enabling separation from molten iron in the hearth.

High-temperature reactions in the lower furnace govern carbon dissolution and partial reduction of Si, Mn, P, and S, with partitioning between slag and metal controlled by thermodynamics and kinetics. The blast furnace achieves very high productivity (5,000–15,000 tonne hot metal per day) but is intrinsically carbon-intensive, making it a major contributor to CO_2 emissions in steelmaking. Direct reduction processes using natural gas, when paired with electric arc furnaces (EAF), represent the dominant low-CO_2 steelmaking pathway. Compared to traditional blast furnace routes, this approach achieves significantly lower emissions while enabling high levels of scrap recycling.

Burden Distribution and Aerodynamics

Joseph J. Poveromo, Raw Materials & Ironmaking Global Consulting
Presented by Joseph Morey, Consultant

The manner of charging raw materials to the blast furnace affects the distribution of gases that reduce and heat the descending burden materials. The distribution of burden and gases in the stack has a strong effect on the efficiency of gas-solid reactions and on shaft permeability. These in turn have a large influence on furnace performance as measured by fuel rate and productivity. In addition, burden and gas distribution have an effect on furnace lining life and hot metal chemistry.

In this lecture the effects of raw material characteristics, charging practices, charging equipment and furnace geometry on burden and gas distribution and furnace performance are presented. Fundamental concepts and techniques used to physically and mathematically model burden and gas distribution are reviewed. Practical applications of instrumentation to measure and control burden distribution are presented. Some examples are given concerning the use of various types of charging equipment to improve burden and gas distribution and furnace performance. Finally, some principles are outlined for the optimization of burden and gas distribution with respect to furnace fuel efficiency, productivity and lining wear.

Challenging Blast Furnace Operations

Frederick Rorick, Rorick Inc.

Day-to-day blast furnace operations have improved as the process has become more thoroughly investigated and understood, and as standardized practices and techniques have been rigorously implemented. There is a substantial body of opinion, however, which tends to believe that those standardized practices do not and cannot apply to the more challenging operations, such as blowdown, blow-in, and especially chilled hearth recovery, because those circumstances are always uniquely different from furnace to furnace, and even for the same furnace at different times. That opinion is wrong. It turns out that standardized approaches to the more challenging operation circumstances are both available and proven This paper will be specifically address some general rules to avoid getting into blast furnace difficulty in the first place, followed by more detailed explanation of four elements of furnace shutdown (bank, gravel bank for reline, salamander tap, and empty furnace blowdown), two types of restart (from bank and from empty furnace condition), and an additional segment on recovery from a cold furnace or chilled hearth condition. In each case, fundamental principles, and their application, will be explained.

Chinese Blast Furnace Practice

Dennis D. Lu, ArcelorMittal USA

Exponential growth in the Chinese ironmaking industry in the last 2 decades has resulted in over 1,500 blast furnaces, large and small, being built, and now producing about 61% of the world's pig iron. Following in the footsteps of European and Japanese iron makers, the Chinese have pushed the science and art of ironmaking to a new level garnered by vast numbers of trained professionals in ironmaking and steelmaking, supported by many universities and research institutes, and guided by various government agencies. This presentation describes the widely practiced top gas dry dedusting system, highly efficient top fired stoves and many new and innovative waste-reduction and energy-saving technologies such as waste heat recovery and zero blast furnace gas flaring at many blast furnaces in China. Details are given on the record (1315 0C) hot blast temperature achieved at three modern 5,500 m3 blast furnaces at Jingtang Steel and the very high (265 kg/thm) PCI rate once practiced at Baosteel. The largest blast furnace (5,800 m3) ever built at Shagang is briefly described. Recent development and future challenges for the Chinese blast furnaces and practices are also presented.

Coke Production for Blast Furnace Ironmaking

Hardarshan S. Valia, Inland Steel Company Research Laboratories
Presented by Ka Wing Ng, NRCAN

The cokemaker has to understand the definition of coke from consumers' perspective who demands high quality coke with certain specifications that reflect coke behavior both inside and outside the blast furnace. Similarly, the consumer, the ironmaker, has to understand how the coke producer is trying to achieve a balance between the competing sets of requirements such as throughput/high quality/battery life/cost efficiencies. Hence, there needs to be a better understanding on both cokemaker and ironmaker's part as regards to each others' requirements. Keeping this in mind, the lecture is divided into four sections that cover: 1.) Coke Properties and Coke Behavior, 2.) Coke Production, 3.) Factors Affecting Coke Quality, and 4.) Coal Quality Monitoring and Reserve Evaluation. The emphasis is on understanding the needs of both cokemaker and iron maker.

Comprehensive Numerical Modelling of the Blast Furnace Ironmaking Process

Tyamo Okosun and Chenn Zhou, Purdue University Northwest
Presented by Sam Neilsen, Purdue University Northwest

Blast furnaces are counter-current chemical reactors, widely utilized in the ironmaking industry. Hot reduction gases injected from lower regions of the furnace ascend, reacting with the descending burden. Through this reaction process, iron ore is reduced into liquid iron that is tapped from the furnace hearth. Due to the extremely harsh environment inside the blast furnace, it is difficult to measure or observe internal phenomena during operation. Despite the age of the process, the blast furnace remains critical to industrial ironmaking. With advances in analysis technologies and control systems, and pressure from new steelmaking techniques, modern blast furnace operation has become more efficient. Further development requires better understanding of phenomena within the blast furnace, including heat transfer, mass transfer, chemical reactions, and multiphase flow in the three regions of the furnace, the shaft, the raceway, and the hearth. To that end, computational simulation and visualization have been applied to explore blast furnace phenomena. This paper discusses recent current state-of-the-art techniques for simulation and visualization of the blast furnace using Computational Fluid Dynamics (CFD) models developed by the Center for Innovation through Visualization and Simulation (CIVS) at Purdue University Northwest (PNW), as well as an overview of their applications for troubleshooting and optimization of blast furnace operations, and development of a DRI reactor model using similar modeling approaches to the blast furnace models. In addition, PNW is working to expand the application of these models to the development of a combined CFD-machine learning approach to real-time, what-if, and guidance predictions called the Integrated Virtual Blast Furnace (IVBF).

Day-to-Day Blast Furnace Operation

Arthur Cheng, National Steel Corp.
Presented by Jason Entwistle, U.S. Steel Corporation

This presentation provides a comprehensive overview of day-to-day blast furnace operations, emphasizing the foundational principles required to maintain furnace stability, optimize hot metal quality, and ensure safe, efficient production. It explores key operational domains—including raw material control, thermal and chemical balance, burden distribution, pressure management, casting practices, and water-leak prevention—while highlighting how these interconnected factors influence furnace performance, productivity, and campaign life. Through practical guidelines, operational rules of thumb, and examples drawn from industrial practice, the presentation equips operators and engineers with the knowledge needed to make informed decisions, respond effectively to process deviations, and support reliable, cost-efficient ironmaking.

Fuel Injection in the Blast Furnace

Frederick W. Hyle, Manager Ironmaking Technology
Presented by Donald Zuke, Cleveland-Cliffs

This module provides an in-depth examination of fuel injection technologies and their influence on modern blast furnace operation. Beginning with a historical overview of thermal and chemical blast modification—from early steam and natural gas trials to today's widespread use of pulverized coal, hydrocarbons, and alternative injectants—the course outlines how injection practices have evolved to improve furnace efficiency, stability, and cost performance.

Core technical themes include combustion and raceway phenomena, indirect and direct reduction reactions, and the role of Raceway Adiabatic Flame Temperature (RAFT) in assessing thermal conditions. The presentation explains how different fuels affect gas composition, hydrogen levels, fluid dynamics, and reaction kinetics throughout the furnace. Students learn how injectants influence burden distribution, tuyere zone energy balance, coke replacement ratios, and overall furnace productivity.

Practical operating data from North American and international furnaces are used to illustrate performance trends, injection limits, and optimization strategies for natural gas, pulverized coal, oil, tar, coke oven gas, and plastics. The module concludes with a comparative assessment of injectants and the key practices required to maximize efficiency and maintain stable, high productivity blast furnace operation.

Fundamental Principles Applied to Blast Furnace Safety

Shawn C. Tilbury, ArcelorMittal Dofasco

The Ironmaking Blast Furnace can be a very dangerous machine. However, much has been done to manage the hazards associated with making iron. Although there are countless hazards associated with this heavy industrial process, three hazards unique to the process will be discussed specifically. These include heat (Hot Metal and Gases), Carbon Monoxide and water. Specific events and corrective actions associated with these hazards will be reviewed. The stress response will also be introduced as a potential cause and will be reviewed. Through continuous improvement and advancements in technology and legislation, the three conditions have been controlled to reduce the risk to humans working in Ironmaking. Although in many advanced blast furnaces, human interaction has been minimized or eliminated from day-to-day operations, extreme injuries are still a risk. Today, the biggest hazard to human safety is humans themselves in the form of poor behaviours. Today, each accident in the blast furnace is a repeat of a historical event. The next quantum leap forward in safety will be from instilling good behaviour and reducing risk tolerance in the workforces.

Future Trends in Ironmaking

Ian Cameron and Mitren Sukhram, Hatch

Steel produced from iron ore will continue as the main global production route over the next 25 years due to limitations in scrap availability needed for electric arc steelmaking. Ironmaking technologies will embrace innovations that reduce fossil fuel use to decrease conversion costs and greenhouse gas (GHG) emissions in tandem.

Fossil fuel usage will be reduced in stages, first with the optimization of blast furnace ironmaking to world-class performance followed by transformative changes including the use of pre-reduced iron products such as hot briquetted iron, higher injection rates, artificial intelligence, greater hydrogen usage, electrification and aspects of top gas recycling technologies. New ironmaking processes including electric smelting of DRI, smelting reduction and iron ore electrolysis technologies will grow in importance as the steel industry innovates to reduce coal consumption and meet its aspirations for carbon neutrality by 2050. This paper describes the expected ironmaking technology changes and their related challenges as the industry innovates over the coming years.

Intro to Ironmaking

Marco Lopez, U.S. Steel Corporation

This course serves as a foundational introduction to iron making, providing students with the background knowledge required to understand and engage with modern iron and steel production. The course covers the basic chemistry and principles underlying iron making processes, with particular emphasis on blast furnace iron making. Topics include raw materials and their preparation, key chemical reactions, iron and steel making routes, and the structure and operation of the blast furnace, including its distinct zones and internal processes. Students will also be introduced to ancillary equipment, blast furnace hearth operation, and practical aspects such as tapping, plugging, and cast house layout. By establishing a clear link between fundamental concepts and industrial practice, the course is designed to make subsequent iron making coursework more accessible, meaningful, and technically grounded.

Iron-Bearing Burden Materials

Marcelo Andrade, John Ricketts, Harold Kokal, and Pinakin C. Chaubal, ArcelorMittal
Presented by Renard Chaigneau, Baffinland Iron Mines Corp.

Iron ore is one of the crucial ingredients for iron and steelmaking. The interaction between iron ore and the blast furnace process is especially key to efficient operation. In the presentation we delve deeper into the nature of iron ore, including its origin and the various preprocessing techniques used, such as beneficiation, sintering, pelletizing, and briquetting, to create the optimal ferrous burden for the blast furnace. Additionally, we will cover the characterization of these agglomerates, their quality control, and how their properties affect blast furnace performance.

Ironmaking in Western Europe

Jan van der Stel, Tata Steel

This presentation introduces the evolution of iron making in Western Europe as compared to the development of iron making in other parts of the world. This highlights several aspects of iron making practices, such as: introduction into the development of hot metal production, progress of the structure of reductants and ore burden materials, sintering of iron ores, evaluation of constructional features and equipment of the blast furnace. This also provides an outlook for the current and future European iron making scenario.

The integrated steel works in Western Europe operate modern plants to produce a wide variety of high-grade steel products. Currently, the blast furnace-basic oxygen furnace (BF-BOF) route for steel production is the dominant production route within Europe.

However, this scenario will undergo a transition toward iron making process with the use of “Green and Blue” H_2 in the direct reduction shaft, together with application of electricals furnaces like EAF and REF, or with the integration of deep CO_2 capture, utilisation, and storage (CCUS) to meet the challenges of net-zero emissions steel production by 2050. Thus, the other focus of this paper is to provide an insight to the development of the CO_2 emissions reduction programme based on past and on-going projects, and the impact of the EU emissions trading system together with the introduction of any form of carbon border adjustment mechanisms.

Ironmaking Refractories

Floris van Laar, Allied Mineral Technical Services, Inc.

In an integrated steel mill, the blast furnace is one of the first links in the steel processing chain. The ironmaking process must have reliable refractory systems to sustain its operation.

This paper focuses on refractories that operators are exposed to on a daily basis such as the Blast Furnace hearth, hot blast stoves, and casthouse. The criteria for taking the proper steps when selecting ironmaking refractories and how they are applied will be discussed.

Ironmaking/Steelmaking Interface

M. Price, D. Liao, M. Pomeroy, ArcelorMittal Dofasco
Presented by Mike Pomeroy, ArcelorMittal Dofasco

A healthy customer-supplier relationship between Ironmaking and Steelmaking is vital. Understanding the needs of each department will ensure an optimized solution. Optimization of both Ironmaking and Steelmaking is dependent upon regular and consistent communication, working models, and a fundamental understanding of each other's business.

The production planning process translates market demands into facility deliverables for each operation.

Hot metal specifications generally reflect a balance between the plant infrastructure, process capability, and raw material inputs along with the internal customer requirements (Steelmaking).

Management of hot metal inventory is a primary consideration for operational and process control which supports monthly or annual production and cost targets.

Opportunities to lower costs are available through recycling of by-products and other wastes into the Blast Furnace.

Japanese Ironmaking

Kaoru Nakano, Nippon Steel Corporation

This lecture addresses low-carbon technologies in Japanese blast furnace ironmaking, with a focus on the reduction of the fossil-fuel-derived reducing agent rate achieved through the stepwise advancement of process optimization. It provides a systematic review of the technical evolution of these efforts, ranging from operational improvements and auxiliary fuel injection to advanced process control technologies. Furthermore, the lecture presents a detailed scientific and engineering review of the research and development achievements of hydrogen-rich gas injection technologies in the COURSE50 project and outlines the current status and long-term vision of the GREINS project toward carbon neutrality.

Maintenance Reliability Strategies in an Ironmaking Facility

Johan van Ikelen, ret. Tata Steel, consultant Danieli-Corus

In order to establish and maintain maximum output of the blast furnace, equipment reliability is paramount.

On a day to day, week to week and month to month basis the blast furnace is required to operate without interruption to allow downstream processes to function with a consistent supply of hot metal, liquid steel and semi-finished product. Only then can the integrated steel production facility maximize equipment assets to produce a quality product, on schedule and within set budgets.

At the blast furnace, there must be a proper maintenance strategy to ensure reliable, consistent operation, with provision for timely outages and possibilities to use unscheduled outages.

The key word is “installation condition knowhow”. That starts with recognition of the critical installation parts, combined with a simple inspection system, which provides knowhow over the condition and signals future breakdown treats of the working installation.

But remember this saying of Nelson Piquet, former World champion F1 auto racing:

When you measure it, you can control it. When you control it, you can improve it.
But when you want to control everything, you are not driving fast enough!

Which means here: do not overact such measuring and preventive maintenance actions, otherwise your maintenance will be very costly. But do make the right inspections, because for some installation parts the punishment for missing information may be very costly and very dangerous for your staff.
Extra concerns are the essentials for campaign extension and contingency measures which may be prepared. This presentation is intended to explain this program and factors required that influence its success.

Overview of the DRI process

Kevin Persad, Nucor

This presentation introduces Direct Reduced Iron (DRI) ironmaking for iron and steelmaking professionals without extensive exposure to DRI operations. It reviews the fundamentals of shaft-furnace processes, explains the importance of raw-material quality and general utility requirements, and shows how these factors influence safety, yield, and downstream performance.
Using practical examples from operating plants, the session is designed to give course participants a clear starting point for understanding DRI technology and its expanding role in lower-carbon ironmaking pathways.

Recent History of Ironmaking

Maarten Geerdes, Geerdes Advies

The lecture reviews ironmaking since the 1950's. From 1950 to present both world population and per capita steel consumption tripled, and worldwide steel production has increased 10-fold. How did hot metal production follow steel requirements? The focus will be on blast furnace ironmaking: developments in ferrous materials, fuels, blast furnace size and instrumentation, and operation. The challenges facing the operator today will be discussed.

Transitioning The Iron and Steel Industry Towards a Low-Carbon Future: Climate Change Policies and Approaches

Katie Chan, Stelco

In 2021, almost 200 countries around the world made commitments to adopt the Glasgow Climate Pact whi ch includes commitments to reduce greenhouse gas (GHG) emissions to prevent planetary warming from ex ceeding 1.5 degrees above pre-industrial temperatures. While geopolitics have altered since that time, the world at-large continues to seek solutions to address climate change. And the steel sector is recognized as a n essential part of global sustainable development. Meanwhile, it is important to note that the steel industr y is an energy-intensive and trade-exposed sector. According to the International Energy Agency, the global s teel industry is responsible for 2.8 gigatonnes of carbon dioxide emissions per year, or 8% of total energy syst em emissions1. Approximately 70% of CO2 emissions in integrated steel mills comes from blast furnace iron making2. This lecture will provide an overview of climate change policies related to steel industry GHG emiss ions from multiple regions around the world. Further, it will explore some key groupings of iron and steelma king decarbonization pathways.