# Metalcasting Industry Research

AFS directly funds research projects from allocation of a portion of the annual dues paid by AFS Corporate Membership. In addition, AFS is involved in several research partnerships funded through government funding, industry contributions and other means. Support of research is critical for North America to maintain a strong, vibrant, healthy, and continually advancing metalcasting industry. AFS participates in these projects by securing industry partners and providing technical management and oversight. AFS is currently active in two metalcasting research funding partnerships.

## American Metalcasting Consortium/Defense Logistics Agency-Funded Projects

AFS is a partner in the American Metalcasting Consortium (AMC). AMC is funded through the U.S. Department of Defense (DOD), Defense Logistics Agency (DLA). The American Metalcasting Consortium provides direct support to the DLA through new technology, improved processes, and technical expertise in the procurement of metalcastings to ensure warfighter readiness. AFS is managing two projects under the current AMC program, Innovative Casting Technology.

### Casting Alloy Data Search (CADS)

AFS through AMC/DLA has developed a very effective web-based tool called Casting Alloy Data Search (CADS) for design engineers and ICME professionals. It has been used for over five years by the foundry industry and is accessible through the AFS website. CADS needs to further expand to accommodate more ICME relevant data generation for optimization and more accurate predictions, such as thermo-physical and thermo-mechanical properties required for process simulation beyond casting alloys. The goal of this research project is to enhance the current CADS and create an additional module of CADS for nonmetallics, such as molding and core materials being used in the sand casting process, populated by generating and validating data useful to ICME professionals. CADS is developed in partnership with Product Development & Analysis (PDA).

### Integration of ICME Tools in Casting Design and Process Optimization for Intelligent Manufacturing

The project will develop an effective and integrated ICME framework as an approach to make more efficient casting designs and improved manufacturing approaches. Current physics-based simulation tools are limited to simulate for a few, finite, known process variabilities, but do not account for many more process variables, including dimensional, compositional and section thickness variability inherent to the metal casting process. A comprehensive approach of physics-based simulation with probabilistic metamodeling using historic data is unique and will allow for rapid and more accurate predictions.

## Advanced Casting Research Center (ACRC)

The Advanced Casting Research Center (ACRC) is a collaboration of companies to fund and promote research addressing the global foundry industry. ACRC brings fundamental understanding to existing processes, develops new methods, and addresses management–technology interface issues with industrial partners. ACRC helps the industry resolve technical issues by bringing members, WPI faculty, and staff together to discuss and brainstorm solutions.

**About the ACRC**: The ACRC, founded in 1985, is an academic–industry partnership headquartered on the campus of Worcester Polytechnic Institute in Worcester, Mass. Built on the university's strengths and focused on helping industry solve technical issues, the center provides a collaborative environment in which members, faculty, and students discuss challenges in the metalcasting industry, specifically in the areas of light metals, nonferrous alloys, and semi-solid processing.

**Current ACRC-Funded Projects**

- **Al-Based High-Entropy Alloys (ACRC)**
  This is an exploratory project to investigate the Al-based HEAs. The aim is to develop a new set of alloys with either high stiffness, both good ductility and strength, or excellent creep resistance at high temperatures (> 300 °C).
- **Big Data for Assessment and Enhancement of Casting Processes (ACRC)**
  Modern foundries have the capability to capture a vast amount of process data on a daily basis. However, the data from various sources throughout the operation are often kept in silos where their value might have limited utility. This is especially true when there are no significant quality issues arising to motivate a holistic interrogation of these data. It is a lost opportunity for the foundry if there is no way to compile, fuse, and analyze these data to better understand the process factors influencing the quality of castings.
- **Heat Treatment (ACRC)—**Still under development
- **Castable High-Strength Al–Mg–Zn Alloys Development (ACRC)**
  This project aims to develop a castable high-strength and high-ductility aluminum alloy, which has:
  - Good castability. Hot tearing and fluidity indices to be significantly better than A206 alloy.
  - 40 Ksi (276 MPa) yield strength at room temperature.
  - 60 Ksi (414) ultimate tensile strength at room temperature.
  - 10% elongation at room temperature.
- **Multi-material Metal Casting (ACRC)**
  The scope of this project is to develop a ferrous insert that promotes the growth of a strong metallurgical bond with the aluminum during the casting process.
- **Residual Stress in Al Castings (ACRC)**
  The goal of this study is to measure and predict residual stresses in aluminum cast parts. It is important to understand the factors that affect the stresses in aluminum casting and to develop data that can be used in simulation technologies.
- **Magnesium LPSO Cerium Alloy Development (ACRC)**
  This project will provide a new high-performance magnesium LPSO cerium alloy via the ICME approach:
  - The adoption of the ICME approach will greatly speed up the evaluation of new alloy chemistries.
  - A new magnesium LPSO cerium alloy with high yield strength/elongation and wide operation temperature range will be developed.
- **Green & Clean Al–Cu Alloys (ACRC)**
  This is a fundamental project to establish the root cause of the problem and to recommend a green and clean method to process Cu-containing Al alloys during molten stage.
- **Projects Leveraged With Funding From Federal Agencies and Industry**
  - DOD Mobile Foundry: Agile Production (SERDP)
  - Cold Spray R&D-with UCI (ARL)
  - Semi-Solid Metal Additive Manufacturing (ARL)
  - In-Situ Manufacturing Techniques For Aluminum Matrix Nano-Composites (LIFT)
  - Thin-Wall Aluminum Die Casting—Optimized Heat Treatment (LIFT)
  - Rapid Creation of Tooling with Conformal Cooling (ATI)
  - Knowledge Creation via Data Analytics in a High-Pressure Die-Casting Operation (Mercury Marine)
  - Numerical Modeling of Segregation and Shrinkage Porosity Formation in Multicomponent Al alloys (Montupet)

For more information visit: https://wp.wpi.edu/acrc/

# AFS Funded and Monitored Research

AFS directly funds research projects from allocation of a portion of the annual dues paid by AFS Corporate Membership. The current AFS-funded research projects are described below.

**Effects of Metallurgical Factors on Micro-porosity in Ductile Iron Castings**

**Principal Investigator(s):** Dr. Simon Lekakh, Research Professor, Department of Materials Science and Engineering, Missouri University of Science and Technology

Cast iron with spherical graphite (SGI) has a unique combination of high strength with good melt fluidity, allowing the metalcasting industry to produce complicated geometry castings. There are many successful examples of when integrated SGI castings have been substituted for steel stampings or forgings. SGI has less solidification shrinkage than steel;

however, it is significantly higher than gray iron. Currently, foundries use effective techniques to prevent formation of macro-shrinkage defects in hot spots; however, increasing complexity of ductile iron castings makes it difficult to produce sound castings without more widely distributed micro-porosity. Intensive risering helps with the elimination of large shrinkage pores but does not always guarantee the absence of micro-porosity. Elimination of micro-porosity will improve casting integrity and increase such important whole casting properties as fatigue life and low-temperature toughness.

The objective of this project is to study metallurgical factors affecting micro-porosity formation in SGI castings using novel experimental and simulation methods. The research will experimentally determine the mutual effects of SGI liquid metal processing on micro-porosity, link solidification kinetics to micro-porosity, suggest methods for controlling micro-porosity in SGI castings, and improve SGI casting soundness.

The work is being monitored by the AFS Cast Iron Division. Those interested in more information about the project or how to participate should contact AFS Senior Technical Associate Bo Wallace (bwallace@afsinc.org).

**LFC Aluminum Molds Produced Using Additive Manufacturing**

**Coordinator:** Marshall Miller, Flowserve Inc, Flowserve Corporation

Currently, lost foam tooling is, in general, prohibitively expensive with long lead times associated with complexity of the tool designs and typically restricted to high-volume production. Significant market share is available if the cost of tools and the lead time is brought in line with conventional casting processes. In order to expand the marketability and viability of the lost foam casting process, this project will demonstrate the production of tools for high-mix, low-volume to high-production level tools using 3D-printed aluminum. The project will take into account material durability, material costs, cycle time, equipment costs, and skill level required for production as compared to conventional methods. Aluminum will be tested to find acceptable parameters for cost, delivery, and performance. This will provide insight into the utilization of printed aluminum as a tool material.

The work is being monitored by the AFS Lost Foam Division and the Additive Manufacturing Division. Those interested in more information about the project or how to participate should contact AFS Senior Technical Associate Bo Wallace (bwallace@afsinc.org).

**Lost Foam Process Stainless Steel ASTM A351 CF8M**

**Coordinator:** Marshall Miller, Flowserve Inc, Flowserve Corporation

This project goal is to produce low-carbon (0.08% C maximum) stainless steel in the lost foam process. This steel casting market is primarily ruled by the sand and investment casting processes. Sand, while reasonably fast for delivery, especially in 3D-printed core and tool applications, is relatively imprecise compared to lost foam and investment, requiring extensive machining of the casting and more weight for draft, stock, and molding dimensional issues. Investment casting, while precise, has size and cost limitations. While there have been examples of success producing ASTM A351 CF8M grade of stainless steel (0.08% C maximum), a sponsored study to develop the necessary parameters for producing stainless steels in the lost foam process has not been performed so that the process can be refined and deployed. Defining the base chemistry metal parameters to accommodate carbon pickup, pattern bead type and density are not tested and defined aside from tolerable pattern density levels. Coating type and permeability are not yet established nor molding media parameters, although they are basically understood. This project will produce ASTM A351 CF8M stainless steel with 0.08% maximum carbon level in the lost foam process by understanding and implementing practices of bead selection, bead expansion, expanded bead density, permeability and fusion, coatings and their permeability, carbon-consuming additives, metal pouring rates and base composition, and molding media refractoriness and permeability.

The work is being monitored by AFS Lost Foam Division. Those interested in more information about the project or how to participate should contact AFS Senior Technical Associate Bo Wallace (bwallace@afsinc.org).

**Development of Improved Repair Welding Alloy and Process for Al–Cu Sand Castings**

**Principal Investigator(s):** David Weiss, Eck Industries; Thomas Wood, Michigan Technological University

Current practices to weld 206 alloy castings, particularly for repair of through-wall defects or defect depths of greater than 0.25 in., result in unsatisfactory welds. Both 206 and 2319 weld rods are typically used for repair welding of 206 castings. A recent project to determine the effect of weld repair on the static and dynamic properties of A206 sand castings did not successfully produce welds of the desired quality. The work determined that the major problem is the chemistry of the weld wire used to make the welds. The two alloys currently used by AFS foundries (A206 and 2319) either produce inconsistent weld quality (A206) or low ultimate tensile strength (2319).

To mitigate the effects of weld wire chemistry and other variables on weld repair quality, this project will utilize a set of statistically designed experiments to optimize a weld alloy chemistry and the welding parameters necessary for the

successful weld repair of A206 sand castings. The key objectives are:

- Develop new weld wire alloy.
- Develop improved repair welding practices.
- Establish effect of welding parameters on weld quality.
- Determine the effects of homogenizing post-weld heat treats.
- Determine effect of weld repair on tensile properties of A206 sand castings.

The work is being monitored by the AFS Aluminum and Light Metals Division. Those interested in more information about the project or how to participate should contact AFS Senior Technical Associate Bo Wallace (bwallace@afsinc.org).

**Effect of Filling Conditions on Steel Casting Quality**

**Principal Investigator(s):** Dr. Laura Bartlett, Dr. Mingzhi Xu, Missouri University of Science and Technology

Recent understanding on the effect of filling conditions on casting surface and performance of aluminum castings has resulted in the design of new gating systems that eliminate damaged metal, greatly increasing casting quality and yield. It has been proposed by recent researchers that nearly all surface and internal defects in steel castings result from air entrainment during turbulent filling conditions causing unnecessary weld repair, low mechanical properties, and customer rejections. Novel gating systems have been boasted by some to greatly reduce oxide and gas defects and completely eliminate the need for post-welding of steel castings. However, there has never been a quantitative study to determine the effectiveness of these gating systems for steel castings and the impact of filling conditions on actual steel quality is currently unknown.

The purpose of the research is to quantitatively evaluate the effect of different filling conditions on steel casting quality and mechanical properties. A series of test castings will be produced utilizing different rigging systems commonly used in steel foundries. Filling of gating systems such as direct pour, horizontally gated, and bottom-gated systems will be designed using filling and solidification software. The results of casting trials will be compared to the use of design best-practices involving bottom fill utilizing vortex gating. The objective will be to quantitatively compare casting metal quality and filling simulation results for a variety of filling conditions utilizing a combination of optical metallography, automated nonmetallic inclusion analysis, and evaluation of mechanical properties.

This project is being monitored by the AFS Steel Division. Those wishing more information about the project or how to participate should contact AFS Senior Technical Associate Bo Wallace (bwallace@afsinc.org).

**Quantify Casting Quality Through Filling Conditions**

**Coordinators:** Dan Hoefert, Eck Industries, and AFS Aluminum and Light Metals Division

Today, predicting the actual filling damage that oxides may cause to a casting remains largely based on theory, experience, and speculation. In the past decade, great strides have been made in simulation capabilities. Heat transfer data and computational fluid flow have been combined to do a wonderful job of predicting porosity and mechanical properties. Filling concerns such as excessive filling velocity, eddies, and other turbulent conditions can also be noted with simulation software. However, simulation software does not take the chemical reaction of oxide formation into account. Filling results only offer an indirect indication of the potential oxide damage, with no effect to the predicted porosity or mechanical results. As such, serious pitfalls can exist when it comes to interpreting simulation results.

Without correlating filling concerns related to oxide damage, misleading simulation results can be predicted. If a gating design includes well-placed feeders and chills, but also includes turbulent filling conditions, simulation can falsely predict excellent soundness and mechanical properties, despite the filling damage noted indirectly by viewing the filling results. As foundries look for competitive ways to tool and fill castings, this confusion can tempt a foundry to choose a more turbulent-fill gating design if the simulation results predict quality advantages over a more tranquil-fill gating design. This project is intended to help answer these difficult questions with meaningful data that can be used to quantify these concerns.

The project is being monitored by the AFS Aluminum and Light Metals Division. Those wishing more information about the project can contact the PI Dan Hoefert at Dan.Hoefert@eckindustries.com or AFS Senior Technical Associate Bo Wallace (bwallace@afsinc.org).

**Determining the Effect of Boron in Gray Iron**

**Principal Investigators:** Dr. Laura Bartlett and Dr. Simon Lekakh, Missouri University of Science and Technology

The use of boron-containing ultra-high-strength steel parts has been ever increasing in Europe and North America since 2007. All of that steel is now making its way into the scrap supply with unintended quality control consequences to gray iron foundries. The other source of boron in gray iron melts can come from fresh furnace linings. Although boron is known to be a powerful carbide stabilizer, boron may also counteract the effects of pearlite stabilizing elements like Cu and Mn, resulting in "soft" pearlitic castings. It is debated what is the "safe" level of boron in gray iron castings or what effect boron has on the microstructure and mechanical properties. Conflicting reports exist because the synergistic effects of

boron and pearlite stabilizing elements such as Cu and Sn, and other minor elements, such as N and Ti, have not been considered.

The purpose of this project is to quantitatively evaluate the effect of different boron additions in the range of 8–60 ppm on the microstructure and mechanical properties of Class 30 and Class 40 gray iron. The synergistic effect of boron and other alloying elements such as Cu and Sn trace elements such as nitrogen will be evaluated.

The project is being monitored by the AFS Cast Iron Division. Those wishing more information about the project can contact AFS Senior Technical Associate Bo Wallace (bwallace@afsinc.org).

# AFS Information Services

### Casting Process and Alloy Assistance

The American Foundry Society website provides tools to assist casting design engineers in selecting the best casting process for a potential component and also provides casting alloy property data on many commonly used alloys. The goal is to give casting users, design engineers, and purchasers relevant and accurate information on casting capabilities and properties, providing easily accessible and retrievable information from a single site. The alloy property data can be quickly exported to a spreadsheet or FEA tools. The casting alloy and process selector, *Casting Alloy Data Search (CADS)*, is located on the AFS Web site, www.afsinc.org under the tabs: *Designers and Buyers* tab or can be accessed directly at: www.metalcastingvirtuallibrary.com/cads/cads.aspx. For more information, contact Steve Robison, AFS Chief Technical Services Officer, at 847-824-0181 ext. 227, or srobison@afs inc.org.

### Casting Source Directory

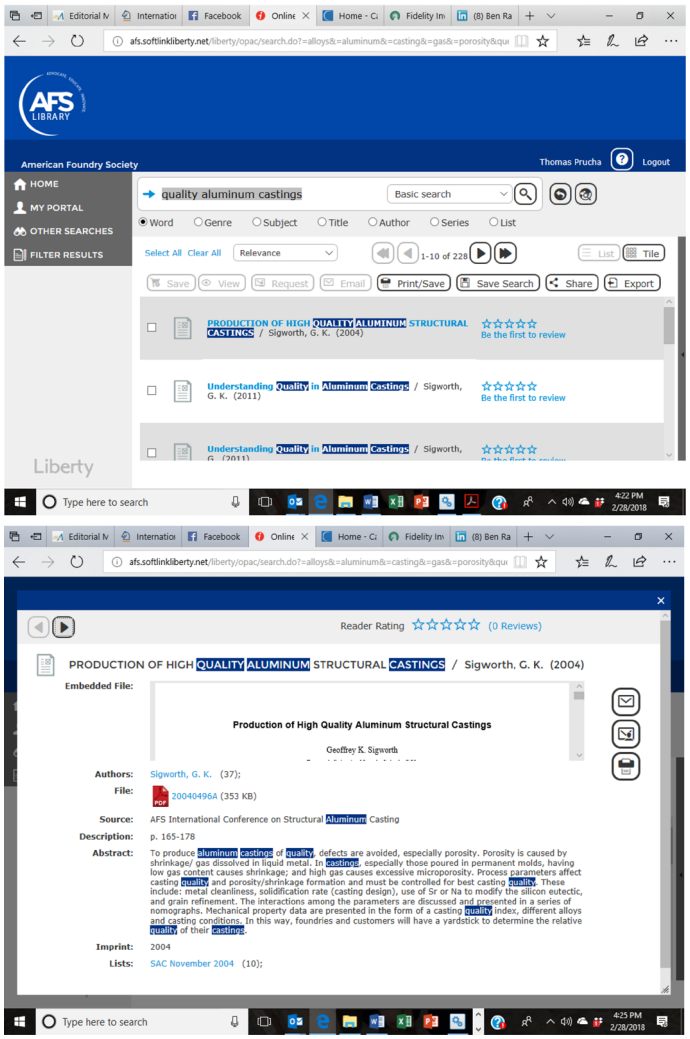
The *Casting Source Directory* is also available to the public on the AFS website. The site provides a directory of North American metalcasters in a single source. Potential casting buyers can search by metal, alloy, casting process, casting size (weight), and U.S. state to locate a casting provider that meets their needs. The *Casting Source Directory* is located on the AFS website under the "*Designers and Buyers*" tab or can be accessed directly at www.afsinc.org/metalcaster-directory. For more information, contact Steve Robison, AFS Chief Techni cal Services Officer, at 847-824-0181 ext. 227, or sro bison@afsinc.org.

### CastingConnection

CastingConnection is a private, professional, social network to connect, engage, and share critical industry information and best practices in real time. Through the Open Forum and sites devoted to our special interest groups, members gather to network via a comprehensive member directory, and participate in focused discussion groups. AFS members access and share useful, informative documents and media in all formats. Visit https://castingconnection.afsinc.org.

### Library

The new AFS online library serves the needs of the metalcasting industry for current and historic information on metallurgy, casting processes, and material property data. The digital library is open to all AFS members. With a simple-to-use search, members have access to relevant technical and research articles and reports from all AFS published sources. Author and summary information is available for viewing, and full articles can be downloaded. All technical and management papers published in *AFS Transactions*, from the very first edition (published in 1896) to the present, are available, as well as technical articles from all AFS magazines. Hundreds of members have already leveraged this resource, conducting thousands of searches that span topics ranging from iron inoculation to silica exposure to gating and riser design. The library is located on the AFS website (www.afsinc.org) under the "Innovation & Management" tab. The library also includes summary information for technical articles published in the International Journal of Metalcasting. For more information, contact the AFS Senior Technical Associate at 847-824-0181 ext. 249, or bwallace@afsinc.org.




## e-Learning

AFS offers a program that provides industry-specific training, information, and education for metalcasters in a web-based format for a single access fee. The e-Learning program gives subscribing organizations full access to online modules for formal staff training on a wide variety of metalcasting topics. Individual e-Learning modules also are available a la carte. More information and a video demonstration are available at www.afsinc.org/e-learning.

## Casting Design Training

The Institute of the American Foundry Society is partnering with the company *NoRedesign.com* to offer online education to support original equipment manufacturers and their design engineers. The partnership is formed expressly to support training for OEMs that will greatly enhance the design of components for the casting process. The training offers a suite of 32 instructional videos walking the listener through each step of casting design and engineering, assisting design engineers to reduce final assembled component costs through effective design principles. With this methodology and training, users will avoid product launch delays, costly overruns, suboptimal components, and failed prototypes. For more information, contact the AFS Institute (847-824-0181) or Clarence Trowbridge, AFS Vice President of Education and Workforce Development, at ctrowbridge@afsinc.org.

# AFS Technology Transfer

### 123rd AFS Metalcasting Congress

Plan to attend next year's AFS Metalcasting Congress at Huntington Convention Center, in Cleveland, OH, April 21–23, 2020. Metalcasting Congress is AFS's annual meeting and industry showcase. One of the largest metalcasting trade events in North America, it includes exhibits from foundries and industry suppliers, technical presentations and educational courses, keynote speeches, and awards for leaders and innovators in metalcasting. More than 2200 people are expected to attend Metalcasting Congress 2020, with about 225 exhibitors anticipated. Exhibitor registration will open in Fall 2019. For information on exhibits, please contact Deana Barrueta at exhibits@metalcastingcongress.org or 847-824-0181 x238. For information on sponsorship opportunities, please contact Ben Yates at 847-824-0181 x205, or byates@afsinc.org. For information on presentations and papers, please contact Kim Perna at 847-824-0181 x246, or kperna@afsinc.org.

### Conferences and Workshops

AFS offers members and industry personnel an extensive program of professional development and learning opportunities in 2019 on a wide variety of topics covering all aspects of metalcasting, including casting alloys and technologies, as well as events targeting EHS, management, and marketing professionals. In addition, AFS sponsors several workshops and conferences focused on best practices and the latest metalcasting technical developments, metallurgy, production, and safety.

- **Future Directions in Steel Casting (July 10, 2019):** The 1-day class focused on the future of steel castings. The American Foundry Society assembled senior steel foundry executives and steel casting academic leaders from around the country to provide a look into the future of steel castings. This interactive seminar covered new innovations, ground-breaking research and featured an economic forecast for steel castings.
- **Hit a Home Run Managing Your All-Star Team (July 23, 2019):** Metalcasting professionals discussed topics that impact your organization: assessing talent, facilitating interviewing, effective training and tracking systems, safety, performance reviews, handling office gossip and terminations. These were just some of the topics that were discussed at the roundtable.
- **Copper Alloy Workshop (Sept 18–19, 2019):** This AFS workshop on casting copper alloys provided details on commonly poured alloys and metallurgy, with emphasis on best practices for melt cleanliness, pouring, and casting process control. Presentations included information on melting and pouring non-leaded alloys, new alloy developments relevant to copper alloy casting.
- **2019 Foundry Leadership Summit (September 22–24, 2019):** Join us for North America's premier event for leaders from foundries and supplier companies at the Grand Traverse Resort and Spa in Traverse City, Michigan. The Foundry Leadership Summit features high-level speakers, industry roundtables, and presentations about issues important to metalcasting leaders, including industry innovation, public policies, and economic forecasts.
- **2nd Carl Loper Cast Iron Symposium (Sept 30–Oct 1, 2019):** This symposium is co-sponsored by AFS, honoring the late Dr. Carl R. Loper Jr., with the focus to review the fundamentals of cast iron solidification and highlight the latest research, technology and developments in metallurgy, production and applications of the material. Taking advantage of the 10th anniversary of the 1st Carl Loper Symposium held in Madison, Wisconsin (USA), the 2nd Carl Loper Symposium is being held in Bilbao (Spain) and organized by IK4-Azterlan Metallurgy Research Centre, SPAIN, and includes keynote presentations along with invited and contributed papers from leading academic and industrial community.
- **2019 Safety 101 Seminar (October 6–7, 2019):** This course is designed for people with only a few years of experience in the health and safety field, those new to the metalcasting industry, and those who have worked in a foundry for decades in foundry facilities with direct responsibility for managing safety and health.
- **31st Environmental, Health, and Safety Conference (October 8–10, 2019):** You can learn about cutting-edge, relevant EHS issues facing metalcasters at the 31st annual Environmental, Health, and Safety Conference. Participants will share case studies of successful EHS projects, network with peers, and meet with vendors of EHS equipment/services.
- **2019 Young Professionals Program (October 14–18, 2019):** Join fellow metalcasters from around the world at the Young Professionals Program this October in Chicago and Milwaukee. This gathering promotes career development and networking among young metalcasting

professionals from the USA, Japan, and Germany. This conference is a week of foundry tours, manufacturing presentations, industry discussions, and more, all designed to enhance the competitiveness of the metalcasting industry and promote global exchange and networking.

- **2019 International Ferrous Melting Conference (October 30–November 1, 2019):** The 5th International Ferrous Melting Conference is a 3-day gathering co-sponsored by the AFS Melting Methods and Materials Division. The conference will be held Oct 30–Nov. 1, 2019, in Nashville, Tennessee, USA, with over 200 attendees expected. Speakers from the foundry and related melting industries will focus on the topics of coreless melting, channel furnace melting and holding, pressure pouring, cupola melting, metallurgy, and charge materials.

### Web-Based Events

AFS also offers a series of technical webinars. Open to all industry personnel (offered at no-cost to AFS members), the web-based seminars provide relevant information presented by industry experts on a wide variety of metalcasting subjects. An archive of past webinars is also available. For a full listing of upcoming and past webinars, visit the "events" tab on the AFS website at www.afsing.org.

### Information and Registration

AFS educational events provide relevant and practical information to improve casting quality, productivity, and profitability for metalcasting facilities and provide expertise in marketing and management issues. For more information, contact the AFS Technical Assistant, Kim Perna, 847/824-0181 x246, technicalassistant@afsinc.org, or Chief Technical Services Officer, Steve Robison at 800-537-4237 x227, stever@afsinc.org. For a full listing of AFS educational opportunities, visit the "events" tab on the AFS website at www.afsinc.org.

# Loper Cast Iron Symposium; World Foundry Congress 2020

AFS is a co-sponsor of the 2nd Carl Loper Cast Iron Symposium held September 30–October 1, 2019, in Bilbao, Spain. The program will include (38) papers, keynotes, and conference proceedings during the two-day event, with selected papers to be published in an upcoming IJMC focus issue. Conference registration and program information can be obtained at: www.azterlan.es/en/carl-loper-symposium.html.

The 74th World Foundry Congress will be in Busan, Korea, October 18–22, 2020. Authors wishing to submit an abstract or the 2-page extended abstract (form for conference paper) should contact abstract@74wfc.com. Those that wish for more information on paper submissions, event details, and updates can also check the website: www.wfc2020.kr.



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