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 and 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 metal castings 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 CADS for design engineers and ICME professionals, which has been used for over 5 years by the foundry industry and is accessible through their website. CADS needs to further expand to accommodate more ICME relevant data generation for optimization and more accurate predictions of thermo-physical and thermo-mechanical properties for materials beyond casting alloys, for example, molding media. The goal of this research project is to enhance the current CADS and create an additional module of CADS for the nonmetallics, such as molding and core materials, and populate it 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 variables, but do not account for many more, including dimensional, compositional and section thickness variability inherent to the metalcasting 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): Relocates to UCI

August 19, 2020

The Advanced Casting Research Center (ACRC) has moved to the University of California, Irvine (UCI) from its 30-year home base at Worcester Polytechnic Institute (WPI) in Worcester, Massachusetts. A research arm for the metalcasting industry, ACRC complements the work of AFS by (1) educating and reproducing new leaders and (2) acting as a source of knowledge creation to benefit the entire industry. UCI is investing $2 million to renovate space for a new state-of-the-art metal processing facility and an additional $2 million for equipment including a modern foundry (ferrous and nonferrous), vacuum arc melting, atomization unit, a complete Buehler Center for metallography, an Olympus microscopy suite, mechanical testing facilities and NDE.

Under the personal supervision of ACRC Founding Director Diran Apelian, construction at UCI is expected to be completed by the end of November, and the new facility will be operational by January 2021. ACRC, an industry consortium supported by about 35 U.S. foundries, is now part of the UCI Institute for Design and Manufacturing Innovation in the Samueli School of Engineering. Serving one of the largest manufacturing states in the country, UCI invested approximately $40 million for a state-of-the-art center for microscopy (IMRI), and also houses a digital manufacturing center replete with the latest additive manufacturing equipment (IDMI).

Apelian is widely recognized for his innovative work in metal processing and for his leadership as a researcher and educator. He is a member of the National Academy of Engineering, National Academy of Inventors, European Academy of Sciences and the Armenian Academy of Sciences. He officially retired in July from his position as Alcoa-Howmet Professor of Mechanical Engineering at WPI after 30 years. Apelian has joined the faculty at UCI as distinguished professor of the Materials Science and Engineering department at UCI, where he also serves as chief strategy officer in the school of engineering.

Meanwhile, for the last 2 years, ACRC's board of directors has been exploring with Apelian how to sustain the consortium into the future. His own activities at UCI and the ACRC's board decision-making dovetailed in a way he says he could not have orchestrated on his own. Board members visited UCI during the San Diego-based TMS meeting in February to meet with UCI's chancellor and deans—and quickly recognized the commitment and the infrastructural support of the university. The result was an unanimous board decision to relocate the consortium's headquarters to UCI.

"One of the big projects we're going to be pursuing is big data, machine learning and the foundry 4.0," said Apelian. "Another one is the measurement of heat transfer coefficients in metalcasting, which are so important for the models that we're developing—a lot of the models have heat transfer coefficient numbers and we don't really know where they came from, so we're actually getting some real data. Also, we have another project that's very exciting, which is an innovative heat treating process—we're looking at cryogenic treatments of cast parts after making them."

Randy Beals of Magna Intl., chairman of the ACRC board, said, "There has never been a more exciting time to be a part of the metalcasting industry, even though the demands on the business have never been greater. Customer expectations of higher quality are at an all-time high while simultaneously, there is pressure to reduce cost. An important result of the market forces taking shape is an increased focus within the casting industry on R&D knowledge generation. The new UCI-ACRC research programs serve as an engine of innovation in order to achieve these business goals. It is the collaboration between the brightest minds in Industry and academia that allows the ACRC consortium to have breakthrough ideas and develop cutting edge technology that will have lasting impact on the metalcasting community."

Emphasizing the sharing of knowledge even among competitors, Apelian says ACRC began with and fundamentally remains simply an idea, one which the industry rallies around and embraces.

"It's been a very successful experiment over the last three decades," he said. "It's a platform where people come together to learn from one another for the benefit of the industry, a rising tide that raises all the sailboats and causes everybody to win. The consortium really is holistic, not just a transactional consortium where you give us money and you get some data at the end of the year. It's about how can the university and how can this consortium help the industry to be better and to advance not just people and knowledge, but also management and human resources issues."

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)**
  The processes and designated alloys to be investigated in this project are listed below:
  - High pressure diecasting process for A360 and A380.
  - Permanent mold casting process for A356 and E357.
  - Cryogenic treatment process for A206, A355 and E357.
- **Castable High Strength Al–Mg–Zn Alloys Development (ACRC)**
  Develop a castable, high strength and a high ductility aluminum alloy, which has:
  - Good castability. Hot tearing and fluidity indices to be significantly better than A206 alloy.
  - 40Ksi (276MPa) 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.
- **Heat Transfer Coefficient Variation in Permanent Mold Casting**
  This knowledge is a key input parameter for solidification modeling. With proper input parameters, the simulation/modeling results may be used as predictive tools as the fidelity between modeling and plant data will be more congruent.
- **FEA Correlation of 3D Scanned Model of Cast Porosity**
  The advancements in CT technology and software enables complete digital reconstruction of castings and mapping of the internal porosity. This allows for simulation of components with real porosity and more representative results for deflection and bending.

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 Diecasting Operation (Mercury Marine)
- Numerical Modeling of Segregation and Shrinkage Porosity Formation in Multicomponent Al-alloys (Montupet)

AFS Funded & 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.

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. It is typically restricted to high-volume production. Significant market 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 use 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 pick up, pattern bead type and density is not tested and defined aside from tolerable pattern density levels. Coating type and permeability are not yet established nor are 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 studying 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 the 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 Investigators: 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," result in unsatisfactory welds. Both 206 and 2319 weld rod are typically used for repair welding of 206 castings. A recent project to determine the effect of weld repair on the static & 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 use 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 a new weld wire alloy.
- Develop improved repair welding practices.
- Establish the effect of welding parameters on weld quality.
- Determine the effects of homogenizing post-weld heat treats.
- Determine the effect of weld repair on tensile properties of A206 sand castings.

The work is being monitored by the AFS Aluminum Division. Those interested in 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 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 & Light Metals Division. Those wishing more information about the project can contact the principal investigator 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, 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, it 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 to 60ppm 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).

Effect of Ceramic Sand on Cast Iron Mechanical Properties

Principal Investigators: Dr. Scott Giese, University of Northern Iowa

Due to the OSHA Silica Rule under enforcement in the foundry industry today, many foundries are considering changing from silica sand to a ceramic sand/media to alleviate the issue. There are many questions associated with this change, but one that is of primary importance is understanding the effect, if any, in microstructure and the associated mechanical properties that might accompany the use of the ceramic sand/media.

The purpose of this project is to evaluate the effect of ceramic sand/media on the mechanical properties for Class 30 iron and 80-55-06 ductile iron.

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).

Turbulent Gating Effect on C89833

Principal Investigator: Andy Shea, A.Y. McDonald Manufacturing Company

Brass foundries have seen an increase in "leaker" scrap when pressure testing brass castings since the switch to no-lead materials. This investigation will examine the impact of turbulent gating on pressure tightness and mechanical properties.

The purpose of this project is to help determine if turbulent gating has an impact on pressure tightness and mechanical properties of C89833 material.

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

Assessment of the Efficacy of Deep Cleaning in Foundries

Principal Investigator: Eric Pylkas, Insight IH Consulting, LLC

Since OSHA issued the standard for respirable crystalline silica, foundries have attempted a number of activities to

reduce employees' exposure to respirable crystalline silica, including deep cleaning, or the removal of settled dusts on equipment, floors, walls, rafters, and other surfaces in order to eliminate a perceived exposure risk associated with the disturbance of settled dusts through production activities.

The purpose of this project is to confirm questions regarding whether deep cleaning is effective at reducing fugitive concentrations of respirable silica within a facility and to determine whether settled dusts that are dispersed through weekend cleaning present an exposure hazard to production employees post-cleaning.

The project is being monitored by the AFS Safety & Health Committee. Those wishing more information about the project can contact AFS Senior Technical Associate Bo Wallace, (bwallace@afsinc.org).

PVD Coatings to Aid Release for Permanent Mold Castings

Principal Investigators: Dr. Stephen Midson, Colorado School of Mines

Aluminum often strongly solders to uncoated steel dies when casted in permanent metal molds. To address this problem, metalcasters use lubricants, which often need to be applied to the die prior to the production of each casting. For high-pressure diecasting, organic lubricants are sprayed onto the die, while for permanent mold casting, ceramic coatings and graphite are used. Although the application is necessary, they cause various problems, such as reducing the quality of the castings and the creation of costly housekeeping issues. In addition, they are expensive and add to the cost of the casting.

The purpose of this project is to develop and utilize a laboratory test that can provide a quantitative measurement of the impact of different PVD coatings on the level of adhesion and force required to extract long cores from aluminum coatings.

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

LFC Molds Produced Using Additive Manufacturing

Principal Investigator: Marshall Miller, Flowserve Corporation

Tooling constructed of T6061-T6 is considered expensive and requires special programing software and skilled programmers.

The purpose of this project is to determine the applicable metal additive manufacturing method and material for medium and high volume considering material durability, material costs, cycle time, equipment costs and skill level required for production as compared to conventional methods.

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

LFC Molds Produced Using Polymer FDM & SLA Additive Manufacturing

Principal Investigator: Marshall Miller, Flowserve Corporation

Tooling constructed of T6061-T6 is considered expensive and requires special programing software and skilled programmers.

The purpose of this project is to determine the applicable FDM (fused deposition modeling) polymer additive manufacturing and SLA (stereolithographic additive) method and material for low and medium volume considering material durability, material costs, cycle time, equipment costs and skill level required for production as compared to conventional methods.

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

Casting of Aluminum Cerium Alloys Over Ferrous Inserts

Principal Investigator: Paul Sanders, Michigan Technological University

Lightweighting vehicles can be enabled by multimaterial designs. Joining of aluminum castings to ferrous material will facilitate structural and material optimization of these metallic systems, however, current methods of forming metallurgical bonds between aluminum overcast on ferrous inserts are complicated and expensive with high process variation.

The purpose of this project is to identify a potential low-cost and robust process for multi-material joining of aluminum to ferrous materials; this work may enable utilization of more aluminum castings in the transportation industry.

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

Dimensional Tolerance Assessment Using 3D-Printed Sand Casting Process

Principal Investigators: Jiten Shah, Product Development; Tyler Nooyen, Waupaca Foundry, Inc.

The use of 3D-printed sand (3DPS) casting process is growing in the production environment, and the initial feedback is comparable to the precise sand casting processes. The adoption of the 3DPS is seen mainly with the hybrid approach, where the mold is made with the conventional green sand process and the complex core assembly is redesigned with a three-piece consolidated core using 3DPS. Very little is studied and known in the public domain about the dimensional tolerances achieved with this toolingless precision sand casting process, especially the potential of achieving much better true position and internal feature tolerances.

The purpose of this project is to identify and provide guidelines for improved dimensional tolerances with 3D-printed sand iron castings to design engineers.

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

Dynamic Testing and Analytics From Working Green Sand Systems

Principal Investigators: Dr. Sam Ramrattan, Dr. Lee Wells, Western Michigan University

Green sand control is a conundrum because there exists a wide array of factors, such as water, clay, additives, sand grain surface, etc. that continuously fluctuate during a foundry's day-to-day operations. Foundry engineers have long known that baseline standard green sand properties test provide limited information for green sand control.

The purpose of this project is to provide a statistical model demonstrating the ability of newly developed "dynamic" green sand control tools to augment standard tests and effectively detect near real-time process shifts affecting casting quality. The tests and strategy will reveal the influence of advanced oxidation bentonite treatment on green sand stability, scrap rate, energy signature, dimensional stability and labor per shipped unit at a working green sand foundry.

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

Iron Casting Life Cycle Analysis

Principal Investigators: Dr. Greg Keoleian, Dr. Daniel Cooper, University of Michigan

There are limited life cycle inventory data available to characterize the energy and environmental performance of ductile iron cast products for the automotive and other industry sectors. The data are used by industry and other analysts to inform material selection and design decisions. Consequently, the ductile cast iron industry is missing the opportunity to compare the energy and environmental performance of their components against equivalents.

The purpose of this project is to develop a Life Cycle Analysis (LCA) model to characterize the energy consumption and greenhouse gas emissions for cast ductile iron parts and wrought steel equivalents.

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 & process selector, *Casting Alloy Data Search (CADS)*, is located on the AFS website, www.afsinc.org under the *Designers & 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@afsinc.org.

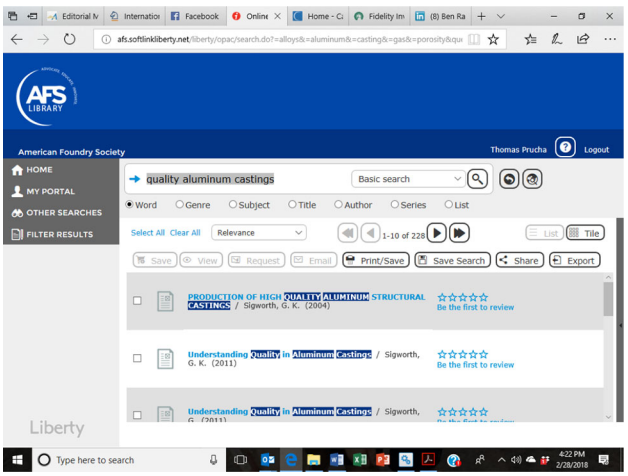
Casting Source Directory

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 & Buyers* tab or can be accessed directly at https://www.castingsource.com/metalcaster-directory. For more information, contact Steve Robison, AFS Chief Technical Services Officer, at 847-824-0181 ext. 227, or srobison@afsinc.org.

CastingConnection

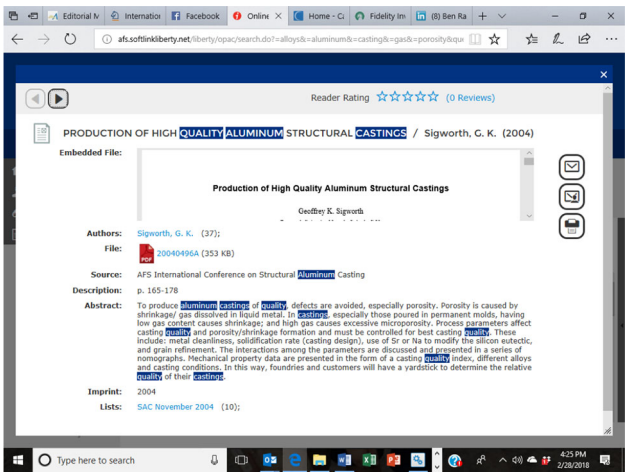
CastingConnection is a private, professional social network to connect, engage and share critical industry information and best practices in real time. Through the Open Forum and sites devoted to our special interest groups, members gather to network via a comprehensive member directory, and participate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

Library



The 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. 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 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.

AFS Technology Transfer

AFS Metalcasting Congress 2021

Offered as a virtual conference, Metalcasting Congress 2021 opens the door for suppliers, foundries and casting buyers to connect, anywhere in the world! Based on the popularity and success of recent virtual events from AFS, this tradeshow will offer top-grade presentations, interactive exhibits and business networking—suited for your schedule with no added travel costs. For more than a century, Metalcasting Congress has shaped the future of foundries. Be at the forefront of cutting-edge innovations with more than 60 technical and management educational sessions, two Hoyt Lectures, interactive virtual exhibits from top suppliers and foundries, awards and honors for industry excellence, and so much more. Join AFS for leading-edge education and networking opportunities at the premier virtual tradeshow!

Conferences and Workshops

AFS offers members and industry personnel an extensive program of professional development and learning opportunities 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 is sponsoring several workshops and conferences focused on best practices and the latest metalcasting technical developments, metallurgy, production and safety.

- **2020 Practical Cupola Workshop (May 18-19, 2021):** The Practical Cupola workshop presents a wide variety of cupola topics, including fundamental cupola operation and design, troubleshooting, operational control, refractories and cupola safety. The course materials reflect the expertise of industry leading course instructors, who are cupola operators and suppliers of the AFS Cupola Technical Committee. Course materials cover the basics of the cupola as well as some moderately technical information. This workshop is held in Rockford, Illinois, and is ideal for new operators, engineers and operation supervisors.
- **2021 AFS Government Affairs Fly-In (May 25–26)**: The AFs Government Affairs Fly-in connects metalcasters with legislators on Capitol Hill, giving them the tools they need to be a voice for the backbone of American manufacturing: the $44 billion U.S. foundry industry.
- **Foundry 4.0 Digital Manufacturing in the Metalcasting Industry (June 8–9, 2021):** What will a foundry look like in 10 years? The designation "4.0" is often used in reference to the next phase of the Industrial Revolution (the "Fourth Industrial Revolution") and generally expresses the impact of smart manufacturing and the implementation of technology in manufacturing. This conference will focus on how digital manufacturing is affecting all areas of the casting process today, and how this will change the foundry of the future. Key seminar topics are data collection and management, data-driven decision making, artificial intelligence, augmented reality, virtual reality, wearable technology, robotics, automation and cyber security, as well as the related issues of workforce development, recruiting and training. The conference will include foundry case studies demonstrating how implementation of data collection, automation and digital technologies have changed and improved operations today.

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.afsinc.org .

Information & 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 x 246, 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

On-Demand	AFS 32nd Environmental Health & Safety Conference
On-Demand	Sand Casting and Additive Manufacturing Expertise
April 12–22, 2021	AFS Metalcasting Congress 2021, Virtual Expertise
May 18–19, 2021	2021 Practical Cupola Workshop, Rockford IL
May 25–26, 2021	2021 AFS Government Affairs Fly-In, Washington, DC
June 8–9, 2021	Foundry 4.0, Itasca, IL
April 23–26, 2022	CastExpo 2022, Columbus, OH
July 11–13, 2022	LMT2022 (Light Metals Technology), Melbourne, Victoria Australia
October 16–20, 2022	74th WFC (World Foundry Congress) Busan, Korea
April 25–27, 2023	AFS Metalcasting Congress 2023, Cleveland, OH