STEEL FOUNDERS' SOCIETY OF AMERICA

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Fourth Quarter, 2009

TECHNICAL COMMENTARY

STEEL FOUNDERS' SOCIETY OF AMERICA

The key measure of success of a trade association is what benefit does it bring to its' members. SFSA provides the most opportunities to extract the greatest value by bringing together people working within the same industry facing the same problems and finding solutions through networking

The most comment we received from attendees at the National T&O Conference in December was we are surprised that there are so many people in attendance. In truth we probably we saw a reduction in attendance of approximately 20%, which is much less than the reduction in business levels that foundries have experienced. This clearly indicates that the T&O is still one considered to be one of the most valuable activities of SFSA.

To maintain this level of value we need members to continue to be willing to share their experiences with their peers. We need your input and involvement in the T&O activities to ensure that the reputation of the conference is not only maintained but also improved upon.

Over the last few months it has been encouraging to see a number of younger people start to join the technical committees, three have joined the High Alloy Research Committee, one the Specifications Committee and one the Carbon and Low Alloy Research Committee. The Safety/HR Committee continues to flourish and holds two meetings each year.

Each of the four divisions holds a meeting in the year you should make sure you keep abreast of the meeting times and locations. This year the Western Division will hold a meeting at Tempe, which will include a tour of ME Elecmetal.

This year the divisional T&O and Safety/HR committees of SFSA will hold 6 meetings most of which will include plant tours. Attendance is open to all members regardless of location. These meetings provide a great opportunity to interact with your peers sharing experiences and solutions to problems.

Make sure you take advantage of these opportunities.

National T&O Conference

In spite of the poor business conditions the attendance at the National T&O Conference was higher than we anticipated. We received positive feedback and would like to thank all of the authors, companies and attendees that made this meeting a success.

We are now back at the start of the cycle as far as the T&O Conference is concerned. In January the T&O Committee will meet to start planning and identifying topics and speakers for the 2010 conference. This year we will be making a great effort to increase the number of papers from steel foundries. If you or your company has not presented a paper in the last 3 years then you should give some serious thought to contributing this year. Please don't use the excuse that you have not done anything interesting and innovative recently. Someone did this once so I invited them to present a paper on "How to stay in business without doing something interesting or innovative". One of the traps that people fall into is that they think that because they do something everyday that it cannot be interesting, they take it as a given.

2009 Conference

Presentations were made to the winners of the **Robert G. Shepherd Awards** for the 2008 T&O Conference

The **First Place prize, $500** went to Jorge H. Okhuysen, Corporación POK SA de CV - "A Molding Technique for "Near Net Shape" Casting of Sugar-Cane Mill Crown Wheels"

The Runner-up prize , $250 went to Brent Hanquist, Harrison Steel Castings Company – "EAF Melting Costs and Benefits of Acid and Basic Slag Practices"

Honorary Membership
Ron Bird, Stainless Foundry and Engineering and Mike Gwyn, ATI

Charles W. Briggs Medal
John Cory, Bradken Atchison

Schumo Foundation Scholarships
The Schumo Foundation has sent out invitations for members to compete for bright undergraduates to work as interns during 2010. The foundation anticipates awarding two Scholarships of $5,000 to at the 2010 T&O Conference. This program is designed to attract bright college students into our industry. Without these new young graduates our industry will not be able to maintain its' lead in technology and productivity.

Division/Technical Meetings

Make a note in your diary when arrangements are posted for the Divisional and Product Group meetings.

Feb 24/25 HR/Safety – Houston, TX

March 11 High Alloy Research Committee – Lehigh University

March 31 Carbon and Low Alloy Research Committee - UAB

May 18 Specifications Committee – St. Louis, MO

Nov 16 Specifications Committee – San Antonio, TX

Dec 8/11 Technical & Operating Conference – Chicago, IL

National T&O Committee

K. Sandell, Chairman – Bradken Atlas
J. Allyn, North Central Vice Chairman – Harrison Steel
R. Bone, Southern Div. Chairman - American Centrifugal (ACIPCO)
T. Dixon – Michigan Steel
G. Hartay, North Central Div. Chairman – FALK/Rexnord
V. Ionescu, Chairman Carbon and Low Alloy Research Committee – Bradken, London
R. Murillo, Western Div. Chairman - Pacific Steel
P. Tomlinson, Eastern Div. Chairman - Wollaston Alloy
R. Wabiszewski, Heavy Section Product Group Chairman - Maynard Steel

4th Quarter 2009

STEEL FOUNDERS' SOCIETY OF AMERICA
Research Summary December 2009

The Research activities of SFSA are overseen by the Research Committees – Carbon and Low Alloy and High Alloy. These committees will be meeting in March, HA at Lehigh on the 11th and C&LA at UAB on 31st. We have seen a number of people joining these committees over the last few months. If you are not a member of one of these committees then you should consider joining. Attendance at these meetings allows you to have the highest level of influence on the projects and also allows you to take advantage of the research findings as they proceed. If you are interested in finding out more or want to join a committee contact me Malcolm Blair blairm@sfsa.org or 815 455 8240 xt 202.

Determination of the effect of radiographic indications on performance
Effect of Niyama values on mechanical properties - AMC

Radiographic standards are workmanship standards; they do not indicate the effect of radiographic indications on performance. The need in the steel casting industry is to produce highly efficient designs that can optimize the properties of steel. This work is designed to develop an understanding of the effect of indications on performance followed by the development of a standard which can be used by designers to optimize casting design. This will lead to lighter and more competitive steel castings. UI have been asked to develop a quantitative method for the evaluation of the effect of indication size. A draft version of a new radiographic film interpretation standard has been prepared for review, there is now an ongoing Gage R&R study to determine the reliability of interpretations using this method.

CCT diagrams for DSS and Superaustenitic Stainless Steels - CMC

The required heat treatment and limiting section sizes can best be indicated by examining the CCT diagrams. Unfortunately these do not exist for some of the most recently developed alloys. This work will develop these new diagrams and assist the foundry in performing effective heat treatments. These diagrams will also assist in identifying where there may be problems in a casting design. Work on CK3MCuN (254SMO) and CN3MN (AL6XN), has shown that the reactions in these grades is extremely slow. Recent work on impact properties at NIST has shown that the toughness can deteriorate considerably when these grades are not quenched from the austenitizing temperature but are cooled and held at 1600^{o}F for an hour, this may be linked to the chicken wire cracking phenomena. Recent work has identified the existence of a very small grain boundary precipitate. Heat treating at higher temperatures for longer times has shown that the toughness can be restored. The ongoing task is to attempt to determine where the "nose" of these intermetallic formations occur to allow foundries to determine the preferred heat treatment cycle.

Instrumentation in the cleaning room and heat treatment - CMC

Short cycle heat treatment brings many benefits which include – reduced fuel cost, improved process flow. The need to control cycle time by monitoring the load condition is essential to the successful implementation of short cycles. Indications are that this can be achieved indirectly and simply by monitoring the gas supply control valve. It should be borne in mind that this does not deal with the issue of temperature uniformity. Control strategies for monitoring the load indicate that 20% reductions in energy cost can be achieved. This work is being developed further and has already led some members to reduce annealing times. Trials using wireless data transfer to enable load temperatures to be monitored are being investigated. One foundry has carried out trials using this device and is close to running some heat treatment trials, the results of these trials in terms of data transmission have been shown to be successful.

The fundamental problem of poor grinding efficiency i.e. poor metal removal rates utilizing hand grinders, can only be solved by some form of automation, ISU is developing a simple grinding device that will increase efficiency by removing the man.

One foundry is now using the weld feeding device to measure welding utilization.

Surface indications - CMC

Specification of acceptable surface indications can be one of the most contentious issues between the foundry and the purchaser. This work will characterize surface indications and form an integral part of assessing the effect of indications on part performance. Plates and castings with indications are being collected and evaluated. It s apparent that the 3:1 length to width ratio is not a good measure for discriminating the difference between a crack and a round indication. The Gage R&R of inspection by magnetic particle appears to be poor, but not worse than other studies of this operation. Typical probability of detection of indications is 50%.

Melting Efficiency - CMC

The use of chemical fuels has been shown reduce power consumption by ~24 kWh/t on two 20 t on EAFs. Recent plant trials have demonstrated reductions in energy consumption of 5 – 10% by changing the melting practices.

One member has rescheduled his melting shop, initial reports suggests that by employing a continuous melting schedule instead of single day or night arrangements the savings in power might be of the order of 20%.

Corrosion Testing - CMC

Some purchasers of castings are using corrosion tests as a requirement for product acceptance. The corrosion tests that are currently available have poor Gage R&R and consequently any test is more a measure of how good a laboratory is at running the tests rather than a test of the material performance. This work will examine and quantify the issues. In addition the work will also include a study of the effect of the Niyama criteria on the corrosion resistance of the 6%Mo stainless steels.

The tests on wrought grades appear to be strongly influenced by passivation time and surface finish of the specimens. However, their effect on cast grades appears to be minimal, suggesting there are other factors to be considered, e.g. segregation.

A recently developed heat treatment schedule has shown that cast materials can have similar corrosion resistance to their wrought counterparts. One of our members has adopted the heat treatment procedure and seen a drop in corrosion test failures from 12% to 5%.

High Strength Steels - AMC

High strength steels (YS>170ksi) have been largely ignored by users and producers alike. The Department of Defense is funding a project to examine the possibility of producing high strength steels that will compete with titanium. It is anticipated that these steels will be processed conventionally and be 4 to 10 times less expensive than comparative titanium castings. Several trial heats have been prepared for testing. The development work to date has been concentrating on the development of "17-4" grades.

Design Manufacture and Production of Steel Castings - Iowa

This program, which is funded by the DoD, is focused on the production of new and existing castings for the US Army. The Universities of Iowa, Iowa State and Northern Iowa are being contracted by SFSA to develop designs and manufacturing processes for these castings. The first casting to be developed is for a recoilless cannon. Trials are underway on the new casting and appear to be promising although some erosion of the part is evident.

Use of Solidification Simulation for Vendor Approval - MTI

A significant amount of work has been completed in the development of thermo-physical data for more reliable prediction of shrinkage in the high alloy grades. Instrumented plates have been cast for grades; CD4MCuN, CD3MN, N3M, CW6MC and CN3MN. The thermo-physical data will be made available to all SFSA members free of charge.

4th Quarter 2009

SPECIFICATION NEWS

STEEL FOUNDERS' SOCIETY OF AMERICA

ASTM

A1058 - Standard Test Methods for Mechanical Testing of Steel Products - Metric
This standard will be published in volumes of ASTM standards for steel.

Pressure Equipment Directive (PED) - A summary of the actions and conclusions of the discussion on the relationship ASTM steel standards to the requirements of the PED has been prepared. In effect the PED has been identified as a technical barrier to trade. Regardless of any changes that are made to ASTM standards they will not be accepted as describing materials that meet the requirements of the PED. As has already been established the PED (the law of the European Community) states that the only body that can write standards is the European Community and these are the EN standards.

C12A A Task Group is being organized to discuss the production of grades utilizing nitrogen as an alloying addition to ferritic grades to improve creep properties in all product forms. EPRI has assembled a significant amount of data that apparently demonstrates the need in all product forms to significantly reduce elements that tie up nitrogen. Information proposing compositional and mechanical property restrictions has been circulated to all SFSA members and the comments have been compiled as an industry response. Some of the restrictions do not appear to be too problematic. However, the proposal to reduce the Ni level to 0.20 will increase the charge material costs.

One of our members has asked about a material that is used in similar applications to C12A, i.e. E911, also called GX 12CrMoWVNbN 10-1-1. On enquiry this material is not well known in Germany and has not been incorporated in any EN standard

Composition limits
Committee A01 has suggested that composition limits should recognize the current product analyses rather than maintain what might be considered obsolete limits.

ISO
Three standards are being balloted at Final Draft International level these standards are:

ISO FDIS 4986	Magnetic particle inspection - Convener DIN
ISO FDIS 4987	Penetrant inspection - Convener DIN
ISO FDIS 10679	Cast tool steels this has been approved and the document has been issued as a FDIS.

The USA will carry out the following
Review EN10213, ASTM A487 and ISO 4991 and prepare a working paper for discussion.

Review ASTM A991 will be reviewed to determine changes and additions that may be necessary to develop an ISO TS or ISO standard.

Initiate the development of a table which will utilize the European and UNS numbering systems that could be used for marking the castings. The USA will provide a list of all ISO grades with their UNS numbers and Germany will provide the European numbers. The list will include the chemical composition of each grade.

4th Quarter 2009

COMMITTEE NEWS

STEEL FOUNDERS' SOCIETY OF AMERICA

Human Resources and Safety Committee

The HR & Safety Committee continues to hold meetings at 6 monthly intervals. The attendees tend operate more as a group than a committee which benefits from an informal approach to the discussions at these meetings. The meetings are open to all members, companies can and do send more than one person to each meeting. The topics discussed range from regulatory issues where we have had an attorney come t the meeting and give us their view of the effect on the way we might operate. In addition presentations are made by members on their experiences with exposure to Hexavalent chromium, methods to identify management skills, confined space and lock out–tag out procedures. This is to name just a few of the items presented and does not list all of the issues discussed during the less formal roundtable session.

Each of the meetings includes a tour of a member foundry and they are hoping to provide an aid to host foundries by developing feedback to the foundry on their observations during the tour.

The next meeting is on February 24/25 and includes a tour of Quality Electric Steel, Houston, TX.

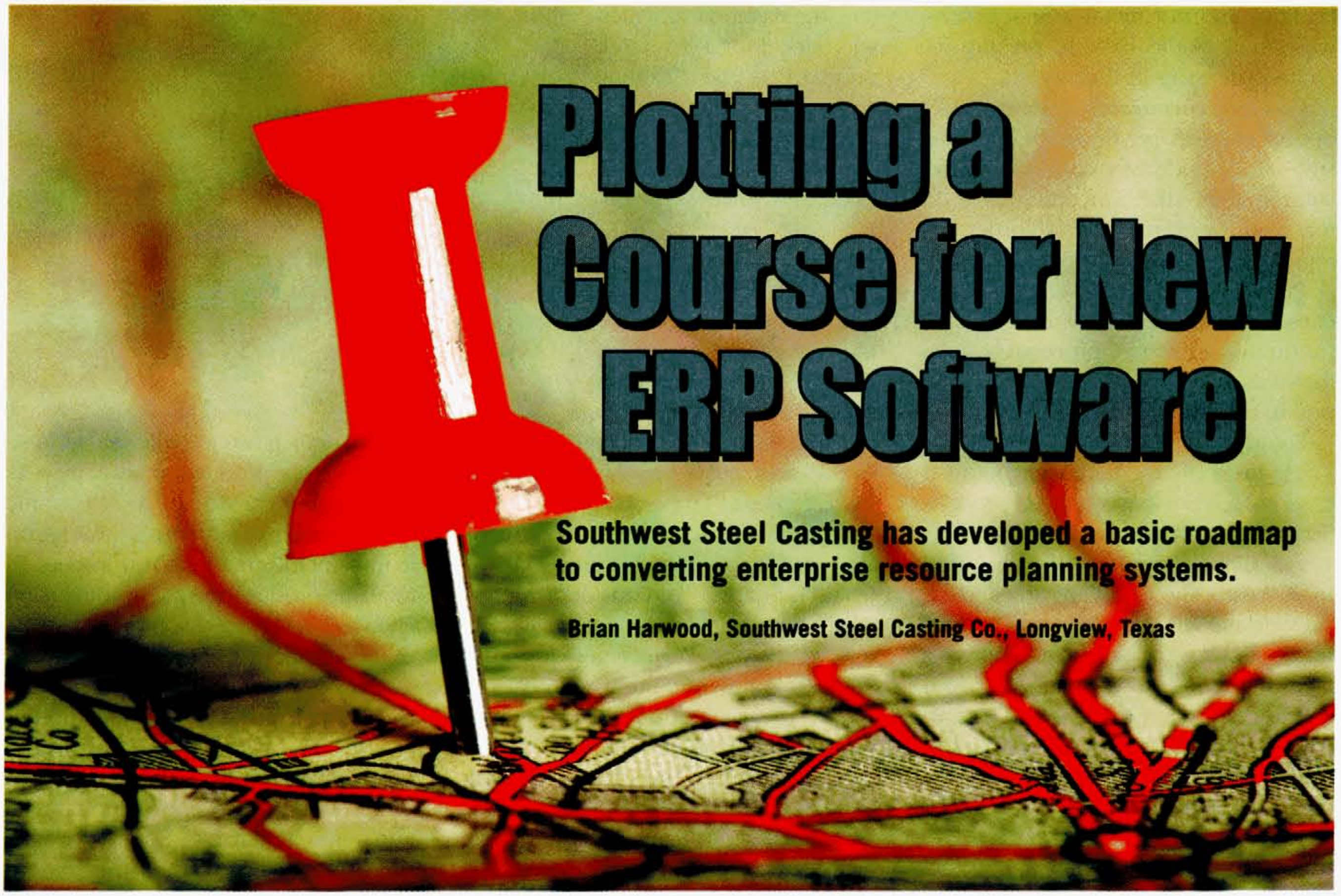
This is an extremely active group and you are encouraged to join.

Investment Casting Product Group

We have recently initiated the reestablishment of this group. This group has not been active for more than 20 years. There are 10 member plants of SFSA that produce investment castings. Although we have carried out some research into issues such as shell cracking and waxes there has not been an organizational focus on this important product. Rick Bauer of Mercury Marine has volunteered to be the chairman of this product group and we will be holding a meeting and tour of Mercury Marine in the Spring. In the meantime a teleconference has been held with the investment castings producer members where a list of topics was developed to develop a task list which includes; a manual risering system, training of operators, review of in-plant trials and, defect analysis.

We are looking to building a resource for investment casters that will provide support for their technical and operational needs.

If you have an interest in being part of this group please contact Malcolm Blair blairm@sfsa.org or 815 455 8240 ext 202.



Plotting a Course for New ERP Software

Southwest Steel Casting has developed a basic roadmap to converting enterprise resource planning systems.

Brian Harwood, Southwest Steel Casting Co., Longview, Texas

Since 1993, Southwest Steel Casting Co., Longview, Texas, managed its production operations with a DOS-based enterprise resource planning (ERP) system designed to manage the business needs of metalcasting facilities. By February 2002, however, management had growing concerns regarding the age of the server and the computers, data loss and technical support of the system.

The business took the concerns to its corporate owners, American Railcar Industries (ARI), with recommendations on how to solve the issues, but a proper course of action was debated for years. The necessary financial backing for a change in ERP systems was not in place.

The dynamics of the company changed in January 2006, when ARI became a publicly-traded company. The corporate management structure and its policies were altered to fulfill public company requirements outlined in the Sarbanes-Oxley Act of 2002 (SOX), and Southwest Steel's DOS-based ERP system was identified as a deficiency to providing accurate auditing of its production system. Approval to proceed with a new ERP system was granted in January 2007.

Just as it was difficult to decide to make a switch, selecting and enacting a new ERP system had its challenges. Converting systems is a complex venture because the project changes the "heart" of the business, affecting how it is managed. Despite these challenges, by July 2007, Southwest Steel's new ERP system was up and running-affording the business increased capability. Following is a basic roadmap to follow when making an ERP system transition at your metalcasting facility.

Selecting a New System

During the ERP system selection process, your system's necessary capabilities and constraints must be considered. For Southwest Steel, the key criteria was neither price nor the program's bells and whistles; instead, discussions focused on the ability of the system to meet the company's needs. A common question was whether to change the system to fit the process or change the process to fit the system. Different sections of each ERP system option will fall somewhere between the two choices. When selecting a new system, you'll have to determine which processes can be changed and which ones cannot.

Southwest Steel opted to select a production system with minimal changes to existing processes. The company looked both at outside software and internal options using the existing system. The options were:

Purchase existing software. Southwest Steel could purchase source code for its existing system and operate it as-is to eliminate process changes. The metalcaster would assume responsibility for maintenance. This option did not solve the aging server issue, however, and was deemed unviable.

Convert to SQL. Southwest Steel could purchase source code for the existing system and covert it to a Microsoft SQL database to minimize process changes. This would enable the program to be run on a new server; however, the ARI IT department would have to rewrite the program.

Switch to corporate's system. ARI corporate headquarters operated a software system to maintain its financials, and the system had the capabilities to be used to control production, as well. However, it was designed for assembly facilities and not metalcasters. Southwest Steel would have to revamp its entire process to fit the system.

Convert corporate's system. This option entailed rewriting the existing system as a module for corporate's software system. Like converting to SQL, this would require extensive programming, which was not a viable option.

Purchase new software. The company explored available programs, searching for one with minimal process changes that was also compatible with its corporate IT structure.

Southwest Steel wanted a system that knew metalcasting language because casting facilities have unique production needs, such as scheduling molds with specific chemistries to be poured in a heat. The software needed to provide metallurgical and mechanical traceability for each casting. Southwest Steel narrowed down its choices and selected a system that met the metalcasting criteria, complied with SOX standards and most closely resembled the current process.

Starting the Project

Southwest Steel was scheduled for an SOX audit in October 2007. Because demonstrating system utility would require two months of good data and another month to work out issues after going live with the new software, a completion date of July 1, 2007, was set. The following factors were used as indicators of a successful outcome:

- data transfer/intensity/collection of good data;
- meeting budget and timeline;
- in compliance with SOX (role-based access control).

During implementation, Southwest Steel had to complete two main tasks in parallel: convert data from the old system to the new system, which included a final conversion when going live with the latest dynamic data (open orders, chemistries, mechanicals, etc.), and train all participants to use the system. Because of the extent of the work, the software modules to implement were broken into two phases:

Phase 1: Order process, purchasing, shipping, quality/certification, scrap control, production control and heat analysis.

Phase 2: Integration with corporate system, returns, corrective action, scheduling, costing, ancillary modules.

Project managers met weekly to update the dashboard, which was developed to track progress as the deadline approached, discuss open issues, communicate tasks completed, make key decisions and review upcoming to-do lists.

Employee Involvement

Every employee, including management, plays a role in the implementation of a new production system. Setting up a hierarchy helps divide areas of responsibility among management. For Southwest Steel's conversion, executive sponsors, consisting of management representatives from IT, financial and business departments, made final decisions on all matters. Three project managers from the software company, Southwest Steel and ARI were assigned duties. Individuals with additional responsibilities, such as troubleshooting errors and providing feedback to the system were assigned as leads and subject matter experts (SME).

Every employee will be involved at some level throughout an ERP conversion. Expect a serious drain on the workforce, since employees will continue their daily duties in addition to the project. All employees should receive basic training on how to perform their job functions in the new system.

Some employees may have to change their processes completely in order to fit the new system, and some personnel may resign or be terminated due to their attitude towards the change in systems. At some point, responsibilities for the project may have to be changed due to an employee leaving the company or poor employee effort.

Expect a serious drain on the workforce, since employees will continue their daily duties in addition to the project.

Why So Complicated?

Converting production systems requires considerable behind the scenes work. Southwest Steel ran into challenges in the following areas:

Technical: The conversion required a review of technical details by a competent administrator who would manage the system on the server. This person needed to understand the software and network setup for future upgrades and be responsible for setting user files.

Linking: Southwest Steel's new production system was set up to communicate with ARI's corporate financial system, which was a challenge because the original production system was never set up to do so. An electronic data interchange system also was set up to transfer information to customers. In total, the production system conversion changed seven total software systems in the company.

Data conversion: The transfer of information from one system to another is affected by the type of data and how the system interacts with it. Two types of data exist informational data and transactional data. Southwest Steel tried to convert all data but experienced difficulty retrieving transactional data from one system and importing it into the other. In hindsight, Southwest Steel recommends doing the following to increase the success of a clean conversion:

- **Minimize download-** import only key informational data. Manually key in transactional data when going live. Maintain the old system as a reference for a while.
- **Focus on the details -** map out the data conversion process with as many details as possible. Most likely, the data conversion will be repeated again. Learn conversion process-request training on how to import data. Data will need to be added later because it has been either overlooked or must be created.
- **Watch format changes-** format differences between the two systems can prevent conversion and even corrupt the data imported.

Data creation: A possible selling point for conversion may be additional capabilities, but these features need resources for development before implementation. Informational data will need to be created and then tested extensively as a new process.

Communication: Finally, the conversion affects even those who do not interact with the system. Daily work on the shop floor is driven by reports from the production system. The key is to address reports early with tests before going live because interruptions to the shop floor can be devastating.

Going Live

After the system is set up in the test environment, users will begin acceptance testing to review the system and check for problems. They will continue interface familiarization, test transactions to verify proper flow through the system and review how data is stored in the database.

A few days before going live, all interested parties should make a consensus decision on whether to proceed. Southwest Steel had one major issue: the scheduling module was not completely functional. To mitigate the issue, the project manager and lead elected to produce schedules in the old system to last six weeks. Management agreed to the work-around, and the project proceeded to go live.

Going live is a two-step process in which data is converted one last time

In total, Southwest Steel Casting's production system conversion changed seven total software systems.

to the new system, and the systems are switched. At Southwest Steel, converting to the new system included a physical inventory, open orders, chemistries, etc. and took a weekend. When making the final switch, networks need to be activated, servers changed and programs installed. Southwest Steel recommends users follow test scripts to verify the live environment works as the test environment did. If successful, the next step is to begin daily production with every user.

During the few days after going live, users will voice their concerns and reveal how much time they spent with the test system. Contingency plans should resolve major issues, and the option to switch back to the old system if need be should be available. Southwest Steel dealt with imported orders not opening or closing correctly. This was resolved by comparing item-by-item the last open orders printed from the old system to those in the new system and manually closing or opening them, rather than reverting to the old system.

Even after the project is closed, issues will still arise. For instance, Southwest Steel worked on its scheduling module for six weeks until it was operational. Most problems were setup errors and careless troubleshooting during user acceptance testing. Every detail must be scrutinized during a production system conversion, but the benefits to doing so outweigh the risks and the headaches. **MC**

About the Author

Brian Harwood is plant engineer for Southwest Steel Casting Co., Longview, Texas.

For More Information

"Estimating & Costing: from Start to finish," C. Collins and S. Allen, MODERN CASTING, August 2009, p. 28.

Challenges and Resolutions

During its enterprise resource planning (ERP) system conversion, Southwest Steel Casting Co., Longview, Texas, Faced three major obstacles that threatened the success of the project. Following are the obstacles and how the company resolved them.

Obstacle 1. Insufficient Resources

In the original plan, all purchasing, raw material inventory, accounts payable and general ledger data was to be maintained in the corporate ERP system. However, the resources to implement the ideas were inadequate and indicated the modules would not be functional by the deadline.

The programmers discussed their challenges with the project manager, who brought the issue to the other project managers. They asked the programmers to investigate the feasibility of minimizing data transfer between the two systems by processing all transactions in Southwest Steel's production system except for some financial. The programmers came up with a workable solution that required additional funds to activate certain modules in the production system. After some discussion, Southwest Steel and the accounting and IT departments from corporate parent American Railcar Industries agreed to the programmers' solution. The project maintained its schedule with the change.

Obstacle 2. Scope Miscommunication

Accounting wanted a system where general ledger transactions linked into inventory movements in real-time, a value-added costing system. The aim was to value inventory by costing every job at each operation. But the requests from accounting were not explained in detail until halfway through the implementation process. The proposal required shop floor data collection to be functional at every operation, which was outside the project's original scope.

A feasibility study was conducted, and project management and accounting agreed on a workable inventory costing system. The compromise reduced the inventory tracking from data collection at each operation to four working inventory locations. Since the production system was designed to use two locations, acustom-written report was created combining costing with the four locations to value inventory.

Obstacle 3. Process Overlooked

After going live. aclerk received a special order. While the functionality of order entry had been tested and accepted. special orders had been inadvertently left out of the new system. To be compliant with the Sarbanes-Oxley Act of 2002, all incoming orders, inventory creation, inventory movement, shipping and invoices needed to be in the system.

The lead for production control developed the new process, coordinated its implementation with the leads for purchasing. order processing and accounts payable, and created the infrastructure inside the system to make it functional. The issue was resolved without involving upper management. **MC**

INDUSTRY ALERT

Growing experience with P91/T91 forcing essential code changes

By **Jeffrey F Henry,** Alstom Power Inc and ASME Task Group

1. Grade 91 increasingly is being used in combined-cycle steam systems because of its greater resistance to thermal fatigue and enhanced creep strength compared to alternatives. However, manufacturers, constructors, and HRSG users often are unwittingly damaging the microstructure, and thereby degrading the material's mechanical properties

With today's combined-cycle powerplants operating at more demanding steam conditions and in more rigorous cycling duty than facilities built only a few years ago, designers increasingly are specifying creep-strength-enhanced ferritic steels—such as the modified 9Cr-1Mo alloy—for use in critical sections of the steam plant and heat-recovery steam generator (HRSG).

Use of the modified 9Cr-1Mo alloy, commonly referred to as Grade 91 ("P91" for piping and "T91" for tubing), for high-temperature applications can result in substantial reductions in component thickness compared to weaker alloys, such as Grade 22. The thinner wall produces substantially reduced thermal stresses and thereby improves service life.

Unfortunately, there is a lack of understanding of the significant differences in the handling of Grade 91 versus the low-alloy steels traditionally used in the power industry. This lack of understanding—which extends from the purchasers, through the manufacturers, to the constructors, and all the way to the plant owner/operators—is imposing substantial costs on the industry in terms of premature failure of components, excessive forced outages, and extensive rework.

In response, key sections of the ASME Boiler & Pressure Vessel Code currently are being revised to better define the proper heat treatment, chemical composition, contamination limits, cold working, and joint design of Grade 91, as well as other creep-strength-enhanced ferritic steels. It is imperative for all industry participants to understand and comply with the new code requirements as they are published. In addition, plant owners and operators need to substantially upgrade their current quality-assurance (QA) practices in order to detect the problems known to exist with these materials.

Super material for superheaters

The frequent startups, shutdowns, and load changes imposed by cycling duty typically cause only minor trouble for a combined-cycle plant's gas turbine, but they pose very serious challenges to the HRSG. The most serious is thermal fatigue. Cycling causes rapid rates of change in steam temperatures, creating severe thermal gradients in thick-walled HRSG components—such as main steam piping and superheater headers. If the thermal gradients are large enough and are repeated a sufficient number of times, the result is thermal-fatigue cracking (Fig 1).

One effective way to fight thermal fatigue is to use higher-strength materials, such as Grade 91, which allow pressure-containing components to be made in thinner sections. Thinner components have smaller temperature gradients across the wall thickness and require less time to reach thermal equilibrium, thus they are less prone to thermal-fatigue damage.

Many existing plants are using, or planning to use, Grade 91 as a replacement material for failed components, and virtually all manufacturers now use the alloy for the superheater sections in new HRSGs. In addition to thermal fatigue induced by rapid changes in steam conditions, the superheater sections suffer creep damage because of the high metal temperatures at which they operate. Fortunately, Grade 91 also offers superior resistance to creep, compared to traditional low-alloy steels. For a typical superheater header, an upgrade from the traditional P22 alloy to P91 can:

- Reduce wall thickness by nearly two-thirds, and component weight by 60%.
- Raise allowable strength in the 950F-1100 F range by up to 150%.
- Raise the oxidation limit by 100 deg F, enabling a lower corrosion allowance.
- Increase thermal-fatigue life by a factor of 10 to 12.

Microstructure is key

Many in the industry are rightfully impressed with these mechanical properties, but they fail to grasp one fundamental principle: The superior properties of Grade 91 depend entirely on the creation, by heat treatment, of a precise condition of microstructure, and the maintenance of this microstructure throughout its service life. Specifically, the properties require the creation and maintenance of a tempered martensitic structure, which underpins the steel's high tensile strength at elevated temperatures and its high creep resistance (see sidebar).

Failure to obtain this precise microstructure during original steel production, or any subsequent action that alters the microstructure of the steel—such as the hot bending, forging, and welding that regularly occurs during component fabrication, plant construction, and steam-plant repairs—will seriously degrade the alloy's high-temperature properties. Making matters worse, particularly for end users, is the fact that this degradation in high-temperature properties is not always detectable with the standard QA tests.

This dependency on a precise microstructure represents a major difference from the traditional carbon and low-alloy steels that have for decades shaped the habits of the power industry. With traditional low-alloy steels—such as Grades 11 and 22—operating at the low stresses typical of power applications, the microstructure produced during processing was of only minor importance. In fact, for these materials it was found that a wide range of microstructures produced by both authorized and prohibited heat treatments would still provide satisfactory service.

The sensitivity of the Grade 91 microstructure recently was demonstrated at two combined-cycle plants in the Southeast. The owner detected several locations, in both bends and straight pipe, where material specified to be P91 was actually in the over-tempered condition rather than in the optimal tempered martensitic condition. In the over-tempered condition, this 9Cr material will exhibit a substantially higher creep rate at the plant's operating temperature of 1050F, and a much lower hardness value (<180 on the Vickers Hardness scale or HV, instead of the expected 200+ HV).

Significantly, this unacceptable material condition was discovered, not through the standard QA procedures conducted by the pipe fabricators or plant constructors, but only by special metallurgical replication ordered by a very concerned and vigilant owner. Subsequent investigation revealed that the post-bending tempering procedure had caused these sections of piping to cool far too slowly, with the inevitable result that the structure was over-tempered. Symptomatic of the industry's "business-as-usual" nonchalance toward Grade 91, the heat-treatment procedure used by the plants' contractor was similar to the one they had used for decades with P22.

"Code-compliant" is no guarantee

When users discover problems such as these, they're often surprised and frustrated because they specified compliance with the appropriate codes—ASME Boiler & Pressure Vessel Code Sections I and VIII for HRSG design, and ASME B31.1 for power piping systems. Being code-compliant, the users assume, should have prevented such problems. But this assumption represents a critical change in the perceived role of the ASME codes.

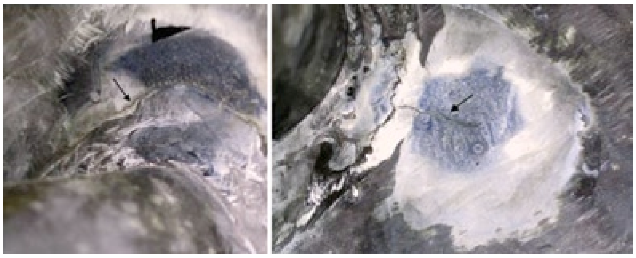
Throughout virtually all of its history, the sole purpose of ASME codes was to ensure safety—to prevent catastrophic failures and the resultant loss of life, injury, and property. Only in recent years have users come to view the codes as some sort of "design and construction handbook," in which they believe is distilled the essence of 100 years

(Continues on p14)

Metallurgy primer for P91/T91 users

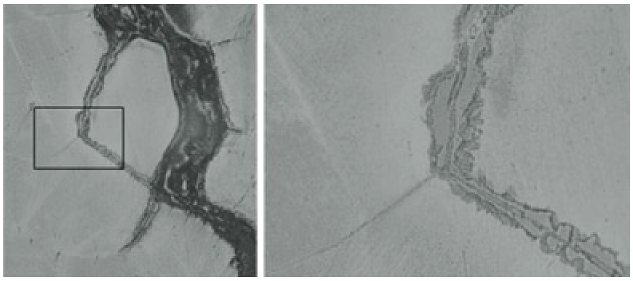
To better understand Grade 91 alloy, and the procedures needed for its inspection and maintenance in the field, over 100 HRSG users, manufacturers, and consultants gathered in October 2003 for a Maintenance Workshop sponsored by the HRSG User's Group. The following metallurgy principles were discussed during the workshop by Jeff Henry, Alstom Power Inc, Chattanooga, and Ron Munson, Mechanical & Materials Engineering, Austin:

- **Production of Grade 91.** This advanced alloy is produced by first heating the 9Cr-1Mo material to approximately 100 deg F above its upper critical transformation temperature (AC_3) until it is fully austenitic. Next, the steel is cooled in air to below 400F, at which point the austenite is fully transformed into untempered martensite. This precise heating and cooling process, referred to as "normalizing," produces a structure that is very strong, but brittle. The material then is reheated—or "tempered"—at a temperature around 1400F to improve ductility and toughness, and to induce the formation of critical carbide and carbo-nitride precipitates. These strengthening precipitates form at the sites of crystalline defects, which had been produced during the martensite transformation.
- **Chemical composition.** The critical transformation temperatures for Grade 91—including AC_1, AC_3, and the martensite start and finish temperatures—can vary significantly depending on small changes in the material's chemical composition. For example, nickel and manganese—two common alloying elements—suppress the transformation temperatures. As a result the concentrations of these elements must be controlled when formulating weld-filler materials, and the precise amounts of the elements present in a Grade 91 component must be known so that the appropriate PWHT temperature range can be identified.
- **Creep.** Steel under stress at high temperature—such as power piping exposed to 1050F steam during steady-state operation—will experience plastic deformation, even when the stress level is lower than the steel's measured yield strength at temperature. This deformation is called creep. The rate at which a given material will creep will be governed by the stress and temperature to which the material is subjected.
- **Hardness is not an intrinsic material property** dictated by precise definitions, in terms of fundamental units of mass, length, and time. Instead, "hardness" is the result of a specific measurement method. For practical reasons, the available methods are divided into a range of scales, defined by a combination of applied load and indenter geometry. Commonly used hardness-test methods include the Rockwell Hardness Test, the Brinell Hardness Test, the Vickers Hardness Test, and the Moh's Hardness Test.
- **Stress-corrosion cracking.** The combined effects of stress and corrosion can result in a special type of failure known as stress-corrosion cracking (SCC). This arises under a particular set of circumstances for a given alloy. Although the specific conditions under which SCC will occur in Grade 91 have not been fully defined, it is known that the mechanism requires some combination of a susceptible microstructure, a high local tensile stress, and the introduction of contaminants. It appears that mere condensation from exposure to a moist atmosphere may allow sufficient contamination to produce SCC in Grade 91 components left in the untempered condition.
- **The "Type" of a crack** provides some idea of the relative location and orientation of the crack. For example, Type I cracks are oriented transverse or longitudinal, and are located in the weldment itself. A Type II crack is similar to a Type I crack, but it grows out of and extends beyond the weldment. A Type III crack is located in the coarse-grained heat-affected zone of a weld. Type IV cracking takes place in the fine-grained section on the base-metal side of the heat-affected zone. Grade 91 is classified as a "creep-strength-enhanced" ferritic steel, and like all ferritic steels, it remains susceptible to Type IV cracking.



Stress Engineering Services Inc

A. Metallurgical replication revealed the crack in this nozzle adjacent to the weld's heat-affected zone and through the base metal. Here, the actual metal surfaces are prepared non-destructively using grinding and polishing disks



Stress Engineering Services Inc

B. The microstructure of a suspect metal surface is revealed on a cellulose acetate film, or "replica." The replica can be studied at the plant to provide prompt results, or it can be sent to a lab for even more sophisticated evaluation using special microscopes

NDE techniques

Perhaps the most important "take-away" from the 2003 Maintenance Workshop on P91/T91 was the need to closely monitor these advanced materials throughout their service lives. To support this effort, the HRSG User's Group focused much of its next Maintenance Workshop on nondestructive evaluation (NDE) techniques that users can deploy.

NDE kit. James Yavelak, manager of fossil services,

Special from the HRSG User's Group

Aptech Engineering Services Inc, Sunnyvale, Calif, advised attendees of the 2004 workshop to use an "NDE kit" that comprises at least: a digital camera wielded by plant personnel; visual inspection by qualified inspectors; magnetic-particle and liquid-penetrant testing to identify cracking in tube-to-header weld joints and downcomer-to-evaporator distribution pipes; and ultrasonic (UT) tools to check tube, header, and riser-pipe wall thickness. Other items that might be appropriate for a plant's NDE kit, using subcontracted specialists, include radiography, eddy-current, and pulsed eddy-current tests.

For HRSG users, Yavelak conceded, there are limitations to NDE. For starters, HRSG access is tightly constrained, compared to conventional fossil boilers, so users may not be able to perform certain tests that would give the most insightful results. The presence of finned tubing poses another problem for HRSG users, because it severely limits the use of UT for tube-thickness measurement. For owners of P91/T91 components, there is yet another limitation: The common NDE tests typically will not detect the degradation in high-temperature properties to which this alloy is vulnerable.

Metallurgical replication. Fortunately, a less common method of non-destructive testing called "metallurgical replication" can help. The method, explains Leo Vega, associate metallurgical engineer, Stress Engineering Services Inc, Houston, examines the actual microstructure of a suspect metal surface. It can be used as a complement to standard NDE techniques—to confirm observations made by such methods as ultrasonic or penetrant testing—but it also can go much further to detect early stages of creep damage and cracking, and to identify the specific nature of a flaw.

The technique begins with abrasive preparation of the suspect metal surface using successively finer grits of grinding and polishing disks, followed by a final diamond-impregnated cloth (Fig A). A sampling procedure then records and preserves the topography of the metallographic specimen as a negative relief on a cellulose acetate film or replica.

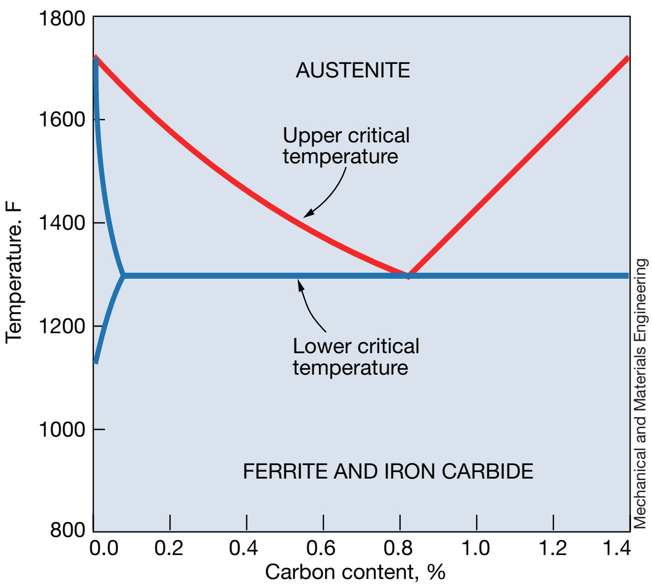
Vega says that a portable microscope with up to 400X magnification can be used in the powerplant to study the prepared metal surfaces, as well as to confirm the quality of the replica. These results can be presented to plant personnel during the on-site visit, so the technique saves a lot of time during a shutdown. For even more sophisticated evaluation, the metallurgical replica can be sent to a laboratory to be studied with a light optical microscope or a scanning electron microscope (Fig B).

Replication provides the metallurgist with a two-dimensional view of the microstructure, similar to that observed in a laboratory metallographic specimen. Such microstructure details as grain size, grain orientation, carbides, and cracks are easily identifiable to the trained professional. In addition to piping failures, Vega has used metallurgical replication to detect the following: manufacturing flaws in reciprocating-engine cylinder heads; cracking in the heat-affected zone of a compressor wheel; thermal-fatigue failures in a turbocharger exhaust wheel; and very early signs of creep degradation in gas-turbine components.

(Continued from p10)

of experience in the fabrication and operation of equipment. As the codes currently are written, this expectation is not truly fulfilled for any powerplant materials, and certainly not for advanced materials like Grade 91.

Fortunately, responsible parties within the industry recognize the discrepancy between user expectations and ASME-code reality, and have begun to take action. The chairman of Section II (Materials) of the ASME Boiler & Pressure Vessel Code has convened a Task Group of leading specialists to address the unique problems posed by Grade 91, as well as the four other creep-strength-enhanced ferritic alloys that have been approved for code use to date.



2. Two important parameters for Grade 91 components are (1) the lower critical transformation temperature (AC_1), above which the alloy's phase transformation from martensite back into austenite begins, and (2) the upper critical transformation temperature, above which the phase transformation to austenite is complete

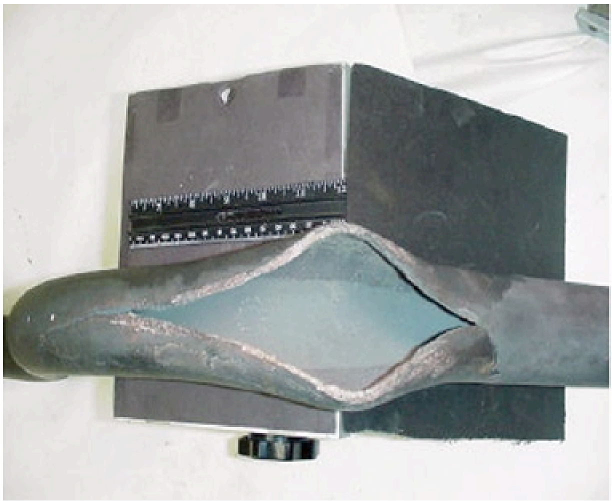
Thermal processing

A Task Group priority is to establish more rigorous rules for proper thermal processing of these materials. "Thermal processing" refers to any heating process that has the potential to alter the microstructure of the material. Problems that can significantly impair the creep-rupture strength of these alloys are over-tempering, under-tempering, and exposure to temperatures in the intercritical region.

Over-tempering causes a coarsening of critical precipitates, with a corresponding loss in creep-rupture strength because of the loss of the restraining influence of these precipitates. *Under-tempering* also can jeopardize the high-temperature properties, since the required precipitation does not go to completion, and the precipitates either are absent or are of insufficient size to stabilize the structure. Other complications associated with under-tempering—such as the risk of brittle fracture and stress-corrosion cracking—also must be considered.

Perhaps the most common problem with Grade 91 is post-production exposure to temperatures in the *intercritical* region—above the temperature where the tempered martensite begins to transform back into austenite (referred to as the lower critical transformation temperature or AC_1) and below the temperature where phase transformation is complete (the upper critical transformational temperature, AC_3). When Grade 91 is heated into this intercritical region, the material partially re-austenitizes, and the resulting structure will have substantially reduced creep-rupture strength (Fig 2). In the worst case, this material will have lower creep-rupture strength than that of traditional Grade 22.

It is this intercritical heating—rather than the over-tempering often cited in the literature—that



3. These superheater tubes fabricated from Grade 91 material failed after only four years of service in a conventional fossil-fired boiler. The lot of tubing from which they were fabricated had been exposed to improper intercritical heat treatment causes the substantial reduction in strength observed in the Type IV (refer to sidebar for definition) region of welds made using these alloys (Fig 3). In a Type IV failure, cracking takes place in the fine-grained section of the heat-affected zone of a weldment. There have been about a dozen such failures in P91/T91 components, mostly in the UK, where the alloy has been in service longer than in the US. These failures are a matter of significant concern because they have occurred at a relatively early stage in component life—20,000 to 40,000 hours—and at lower operating temperatures than the maximum design temperature of 1110F.

In response to these problems, the Task Group has made several recommendations for new rules governing the thermal processing of Grade 91. These recommendations, which are awaiting action by approving committees, include:

- Normalizing in a tightly defined temperature range of 1900F-1975F. The minimum temperature limit for normalizing will be established to insure complete re-solution of the most temper-resistant of the precipitates, while the maximum temperature limit will be imposed to minimize detrimental grain coarsening.
- Tempering in a tightly defined temperature range of 1350F-1470F. The minimum temperature limit for tempering will be established to ensure that sufficient precipitation is induced to stabilize the structure, and that a reasonable level of ductility is imparted to the material. The maximum temperature limit will be established to minimize the risk of the reduction in rupture strength that can occur when heating above AC_1.
- During the course of their work, the Task Group learned that some US manufacturers had adopted the practice of hot-bending thick-walled pipe at temperatures above AC_3, and then performing a local re-normalization and tempering of the bend area. Since this practice leaves a broad zone of material on either side of the heated area that has been intercritically heated, the Task Group has further recommended that if any component fabricated from Grade 91 is "locally" heated above 1470F, then either the entire component must be re-normalized and tempered, or the heated section must be removed from the component in its entirety, re-normalized and tempered, and then re-inserted into the component by whatever means is appropriate.

Post-weld heat treatment

The ASME Task Group also is studying specific changes to the post-weld heat treatment (PWHT) rules. Proper PWHT is essential in order to temper Grade 91 material and to eliminate the risk of stress-corrosion cracking (SCC). The rule changes are needed both because of the risk of tempering at too high a temperature and because recent studies have shown that certain alloying elements—principally nickel and manganese—alter the transformation characteristics of the materials.

The new recommendations, which recently were adopted by the ASME Boiler & Pressure Vessel Code, state that the maximum PWHT temperature for P-No. 5B, Group 2 materials will be 1425F, except as indicated below:

- If Ni + Mn < 1.5% but ≥ 1.0%, the maximum PWHT temperature is 1450F.
- If Ni + Mn < 1.0%, the maximum PWHT temperature will be 1470F.

The new rules also make some provision for microstructure recovery if these limits are exceeded during processing.

SCC in weldments

During the period when materials such as Grade 91 are left in the untempered or as-welded condition, they can be susceptible to the severe problem of SCC. Although case histories of this failure mechanism in Grade 91 are still rare and the specific conditions under which SCC will occur have not been fully defined, it is known that the mechanism requires some combination of a susceptible microstructure, a high local tensile stress, and the introduction of a contaminant. In fact, it appears that mere condensation from exposure to a moist atmosphere may concentrate sufficient contaminant under certain circumstances to produce SCC in P91 piping left in the as-welded condition.

While further study of this failure mechanism is still needed, the Task Group is concerned because current industry practice in both shop and field fabrication of P91 piping does not guard against this SCC risk. Batches of piping welds often are left in the as-welded condition for weeks, months, even up to a year where the welds are exposed to the elements, until a convenient number are ready for furnace or localized PWHT.

To eliminate the risk of SCC in P91, the Task Group is considering amendments to code rules to keep the weldment sufficiently hot to prevent condensation between the completion of welding and the initiation of PWHT. A disadvantage of this option, however, is that it might prevent users from performing the radiographic testing typically performed on welds prior to PWHT. Mandating a sufficiently dry environment, rather than an elevated temperature, may be an alternative way to eliminate SCC while still allowing pre-PWHT radiographic testing.

If hot or dry conditions cannot be assured, it would be prudent to limit the time between completion of welding and initiation of PWHT, to minimize the time that contaminants can enter the weldment. The risk of undetected SCC also can be minimized by inspecting the weldment via liquid-penetrant or magnetic-particle testing following completion of PWHT. Because SCC can initiate on both the inner- and outer-diameter, these nondestructive tests should be performed on all surfaces of the weldment.

Cold working

Recent studies have indicated that cold strain can adversely affect the creep-rupture strength of creep-strength-enhanced ferritic alloys. Even at low levels of cold strain, there is a discernable reduction in Grade 91's creep-rupture strength. Based on the results of the studies, the Task Group is considering action that will establish maximum limits for cold strain, above which it will be necessary to re-normalize and temper the full extent of the strained component. The likely maximum limit for cold strain, based on the available data, will be around 15% to 20% for Grade 91.

Proper joint design

Yet one more problem that has been experienced in the field is imprudent joining of Grade 91 materials to dissimilar alloys—typically to Grade 11, 22, or austenitic stainless steels. One plant owner in the US was forced to rework the welded connection between the main-steam piping and the steam-turbine stop valve—not on one, but on three of its 500-MW, F-class combined-cycle plants.

The oldest plant, which had fewer than 5000 service hours, found a through-wall crack 135 deg around the circumference of the weld, and 24.5 in. long, while the steam line was in service. The second oldest plant used liquid-penetrant testing to find a crack that was 20 deg around the joint but had not yet penetrated the wall. The youngest of the three plants could not detect a crack with liquid-penetrant testing, but replaced the weld anyway because its joint design was the same as that for the other two plants.

The failed weld connected an 18-in.-diameter P91 pipe with a wall thickness of 1.562 in. to a valve casing made of 1.25Cr-1Mo-0.2V with a wall thickness of 3.000 in. The filler selected was B3 (2.25Cr-1Mo) with no dimensional transition piece. An investigation confirmed that no codes were violated in the welding or PWHT procedures.

But the failure mechanism was determined to be initiation and propagation of the crack through the carbon-depleted zone that is an inevitable feature of welds joining materials of different chromium content. In other words, the joint design, with its lack of a dimensional transition piece between P91 and a dissimilar alloy, was entirely inappropriate and was guaranteed to fail prematurely, yet it did not violate existing code rules.

At all three plants, the joint was replaced with a P91 dimensional transition piece, which matched the pipe-wall thickness at one end and the valve nozzle at the other. The piece featured a P91-to-P91 weld at the thin end, and a P91 to 1.25Cr-1Mo-0.2V weld at the thick end using B9 filler. This new joint design placed the weakened but inevitable carbon-depleted zone in the thicker section of the joint where the stresses were lower and more favorably distributed.

During the root-cause analysis of this piping failure, investigators learned that many, if not all, P91 piping systems are installed without "cold spring." This common practice once again demonstrates the industry's "business-as-usual" approach toward Grade 91, because it is based on the faulty assumption that Grade 91, like traditional alloys, will relieve high-temperature steady-state stresses by creep relaxation during the early stages of operation.

In many cases, however, the high-temperature creep strength of the Grade 91 material is such that at normal operating temperatures the material will not "relax" sufficiently fast to relieve these stresses. This can lead to a condition of "elastic follow-up" in which the joint is subjected to a secondary stress that behaves like a primary stress. Thus, a better industry practice would be to install P91 piping with cold spring, so that the piping system is not stressed when at elevated temperatures, where accelerated creep damage will occur.

QA testing

To determine whether the processing of creep-strength-enhanced ferritic steels has been performed correctly, users need tools that can quickly and inexpensively provide information on the overall condition of the material. Because hardness provides a direct indication of a material's room-temperature tensile strength, which can be used to roughly estimate its elevated-temperature properties, portable hardness testing has been used as one such tool.

However, this has created significant problems because of a lack of understanding of the variables that can affect the accuracy of hardness readings. For example, there are several types of portable hardness testers available that operate on entirely different principles, each of which exhibits certain peculiarities that are capable of influencing the accuracy of the measurements relative to testing with a laboratory instrument. In addition, the condition of the work piece itself can create considerable difficulty in accurately assessing the hardness.

For example, it is not uncommon for the surfaces of tubing and piping to be decarburized to varying degrees as a result of mill heat treatments. If the decarburized layer is not completely removed prior to testing, the hardness measured will be reduced by some amount corresponding to the depth of the layer affected and the depletion of the carbon.

One possible action that could be taken would be to identify a recommended hardness range for each grade that would be considered acceptable for all applications, with the stipulation that hardness readings outside of that range would require evaluation to determine (1) accuracy of the measurement and (2) fitness for service. It also should be emphasized that, for Grade 91 material that has been heated into the intercritical temperature range, the hardness may not be adequate to indicate damage, since the re-formed martensite can mask the effects of the undesirable heat treatment. CCJ

Subject: Non-Contact Heat Treatment Load Sensing
From: "Robert C. Voigt" <rcv2@engr.psu.edu>
Date: Wed, 6 Jan 2010 10:35:43 -0500
To: "jemmerichs@pacificsteel.com" <jemmerichs@pacificsteel.com>
CC: Malcolm Blair <blairm@sfsa.org>, Raymond Monroe <monroe@sfsa.org>

Joe

Here is a bit more information about the instrumentation that we used for infared load temperature sensing during heat treatment:

There are a number of manufacturers of IR pyrometers
-Land, Omega, Raytek, Pyrometer Instrument Co, Mikron, (costs from $3000-$3500)
-IRCON ($??)
-Heittronics ($6000 with un-needed bells and whistles)

We (Carpenter) chose IRCON. It was probably overkill, but we wanted the 'best' IR thermometer for our testing. I think that any of the $3000-$3500 would be adequate for heat treatment load sensing control.

I hope that this helps.

Bob Voigt

Modline 5

Lowest Measured Temperature	122°F / 50°C
Highest Measured Temperature	5432° F / 3000° C
Operating Wavelengths	0.85 - 1.1 0.85 - 1.05 / 1.05 (two color) 1.5 - 1.6 2.0 - 2.8 2.3 - 2.6

Modline 5 is the latest and most advanced infrared thermometer series in the IRCON lineup, built to serve a wide range of industrial temperature measurement applications. Designed with extensive customer input and engineered with the expertise that comes from over 45 years experience in the business, Modline 5 offers advanced features available with no other infrared thermometer series on the market.

Modline 5 56 Series Sensor Highlights:

- 2 micron (2.0 - 2.8 or 2.3 - 2.6) and lower temperature (as low as 50° C / 122° F) units to serve a wider range of applications
- Thermo-electrically cooled detector
- Internal self-calibration feature

Modline 5 Sensor Features:

- Self-contained, Stand-Alone infrared thermometer -- no remote electronics needed for operation
- PC software for remote sensor setup, configuration and monitoring included
- Durable, sealed stainless steel NEMA 4 housing
- Total System Health Check diagnostics feature verifies that the Modline 5 is working within factory specifications

- Innovative Match Function allows you to input the process temperature (if known) and automatically adjust emissivity
- Our optional Dirty Window Detector (DWD) checks the temperature sensor window to determine if there is any build-up
- A complete line of accessories to help the Modline 5 perform in any temperature sensing application
- Easy-adjusting optics to focus precisely on target
- Built-In, thru-the-lens Visual or Laser sighting

System Health Check
The Total System Health Check diagnostics tool lets the user verify that the Modline 5 spot pyrometer is working within factory specifications. By activating this check from the rear panel or remotely via the Digital Panel Meter (DPM) the Total System Health Check verifies that the temperature detector, internal circuitry, and even the output signal are all working with the original factory specifications for the sensor. The Total System Health Check is a great verification tool for preventative maintenance programs, start-up, and application troubleshooting.

Dirty Window Detector (Pat. # 5812270)

Dirt, mist, dust, and other types of build-up can affect the accuracy of any infrared thermometer regardless of measurement wavelength. Traditionally it has been up to the enduser to routinely clean the optics of their sensor to ensure that the accuracy of their measurement signal did not degrade too much. The optional Dirty Window Detector (DWD) can sense build-up on the window of the Modline 5 and provide an alarm output to alert the user. Programmable coarse and fine parameters within the Modline 5 setup menus let the user tune the DWD depending on how severe their process is. The DWD is an important option for those processes that cannot tolerate fluctuations in accuracy or the extremely dirty applications where the user wants an alarm to notify his personnel that the sensing window needs to be cleaned.

Match Function
Probably the most common question with non-contact temperature measurement relates to the emissivity of different materials. Now Ircon has taken away some of the guesswork with the Match Function. The Match Function is a standard feature of the Modline 5 Infrared thermometer. If the user knows the exact process temperature (usually verified with a thermocouple / RTD) then they can program the temperature into the Modline 5 prior to start-up and AUTOMATICALLY adjust the emissivity. Equations within the Modline 5 will calculate the emissivity. It’s just that easy!

Specifications

	5R Series	**52 Series**	**5G Series**	**NEW: 56 Series**
Temperature Range	1112°-5432° F / 600°-3000° C	932°-5432° F / 500°-3000° C	482°-3632° F / 250°-2000° C	112°-1472° F / 50°-800° C
Spectral Region	0.85 – 1.05µ and 1.05µ (Two Color)	0.85 – 1.1µ	1.5 – 1.6µ	2.0 – 2.8µ
Typical Applications	Difficult high temperature processes such as furnaces, kilns, molten metals, thin wires or rods	High temperature processes such as metal forging, annealing, hardening and foundries	Ferrous and non-ferrous metal treating applications	Spot welding, induction heating and lower temperature rubber, thick plastic or textile applications
Accuracy @ 25°C **Inputs/Outputs**	0.5% of Reading, + 2°C	0.3% of Reading, + 12°C	0.3% of Reading, + 1°C	0.3% of Reading, + 1°C or 2°C (whichever is greater)

Analog Output	0-20mA, 4-20mA, 600 ohm max.
Analog Input	4-20mA
Relay Output	System alarm (24 VAC/DC @ 1 amp resistive)
Digital Input/Output	RS-485 (57.6k baud max.)
Power Requirements	24 VDC +/- 10%, 8 Watts max.
Signal Processing Features	Peak Picker, Track & Hold

Industry Having Breathing Problems

Air contaminants and respiratory protection violations lead the list of the top-10 OSHA violations for metalcasting facilities.

The U.S. Occupational Safety and Health Administration (OSHA) has released a list of the top-10 most frequently cited safety and health violations for the metalcasting industry for fiscal year 2009.

Air contaminant violations (no testing, overexposures to silica, metals, etc.) was the first or second most common violation in iron, steel and copper casting facilities. Fines totaled $21,411 for 39 citations against all casting facilities. Respiratory protection violations (no written program, not medically evaluated, worn over beards, not stored properly, maintained or cleaned) were among the top-three violations among all casting facilities, resulting in $20,029 in fines for 54 citations. Lock-out tagout violations (no written program, improper isolating device, no annual inspection, employees not trained, machine not locked-out) resulted in $23,713 fines for 32 citations (Table 1).

OSHA plans nearly 40,000 safety investigations annually and conducts unplanned investigations based on imminent hazards and employee complaints. Enforcement "remains the foundation for reducing workplace injuries, illnesses and fatalities," according to Jordan Barab, acting OSHA administrator, and those investigations continue to be a principal enforcement tool for the agency. **MC**

For more information on the frequently cited violations, contact Stephanie Salmon, AFS Washington Office, 202/842-4864 or ss@wafed.com.

Table 1. Top-Three OSHA Standards Cited at Iron, Steel, Copper and Alumium Casting Plants

Standard	# Cited	# of Inspections	Penalty	Description
IRON				
1910.1000	23	11	$9,186	Air Contaminants
1910.134	21	9	$5,989	Respiratory Protection
1910.147	16	8	$17,262	Control of Hazardous Energy (lockout/tagout)
STEEL				
1910.1000	13	3	$8,350	Air Contaminants
1910.147	9	5	$3,588	Control of Hazardous Energy (lockout/tagout)
1910.134	8	5	$5,300	Respiratory Protection
COPPER				
1910.1025	12	3	$3,020	Lead
1910.1000	6	2	$1,475	Air Contaminants
1910.134	5	2	$840	Respiratory Protection
ALUMINUM				
1910.134	20	9	$7,900	Respiratory Protection
1910.132	10	9	$8,330	Personal Protective Equipment General Requirements
1910.212	19	9	$7,429	Machine Guarding

Note: For a full list of the top-10 OSHA violations, visit www.moderncasting.com.

On the Hill

Senate Committee Passes Climate Change Bill

The Senate Environment and Public Works Committee passed climate change legislation by an 11-1 vote on Nov. 5. Utilizing a cap and trade system, the bill would seek to reduce greenhouse gas emissions by 20% by 2020 from 2005 levels. The measure was approved despite a boycott by committee Republicans who wanted a more detailed cost analysis on the legislation from the U.S. Environmental Protection Agency before moving forward. Sen. Max Baucus (D-Mont.), the lone Democrat voting no, was concerned that the bill would disproportionately hurt western states that largely rely on coal-fired power plants for electricity.

At least five other Senate committees have jurisdiction over energy and climate change legislation; only the Environment and Public Works and Energy Committees have acted to date. With the Senate slated to consider health care and other year-end priorities, the full Senate may not consider comprehensive legislation until 2010. MC

H1N1 Sick-leave Bill Introduced in Congress

With growing concerns over HINI flu, legislation requiring employers to provide up to five days of paid sick leave per year to workers afflicted with influenza or similar contagious illness es has been introduced in the House of Representatives. The Emergency Influenza Containment Act would guarantee five paid sick days for part-time and full-time workers sent home with a contagious illness. Employers that already provide at least five days' paid sick leave and/or employ fewer than 15 would be exempt from the bill's requirements. The legislation would "sunset" after two years.

Earlier this year, lawmakers introduced the Healthy Families Act, which would require employers with 15 or more employees to provide up to seven paid sick days each year. The bill would provide for paid time off for an employee's or an employee's family member's physical or mental illness, injury, medical condition or preventive care. Paid sick leave measures are expected to be debated and voted on in 2010. **MC**

India's Casting Industry Holds Opportunities, Challenges

India's metalcasting industry is poised to become one of the top-three casting producing nations in the world. The key is establishing the infrastructure to support it.

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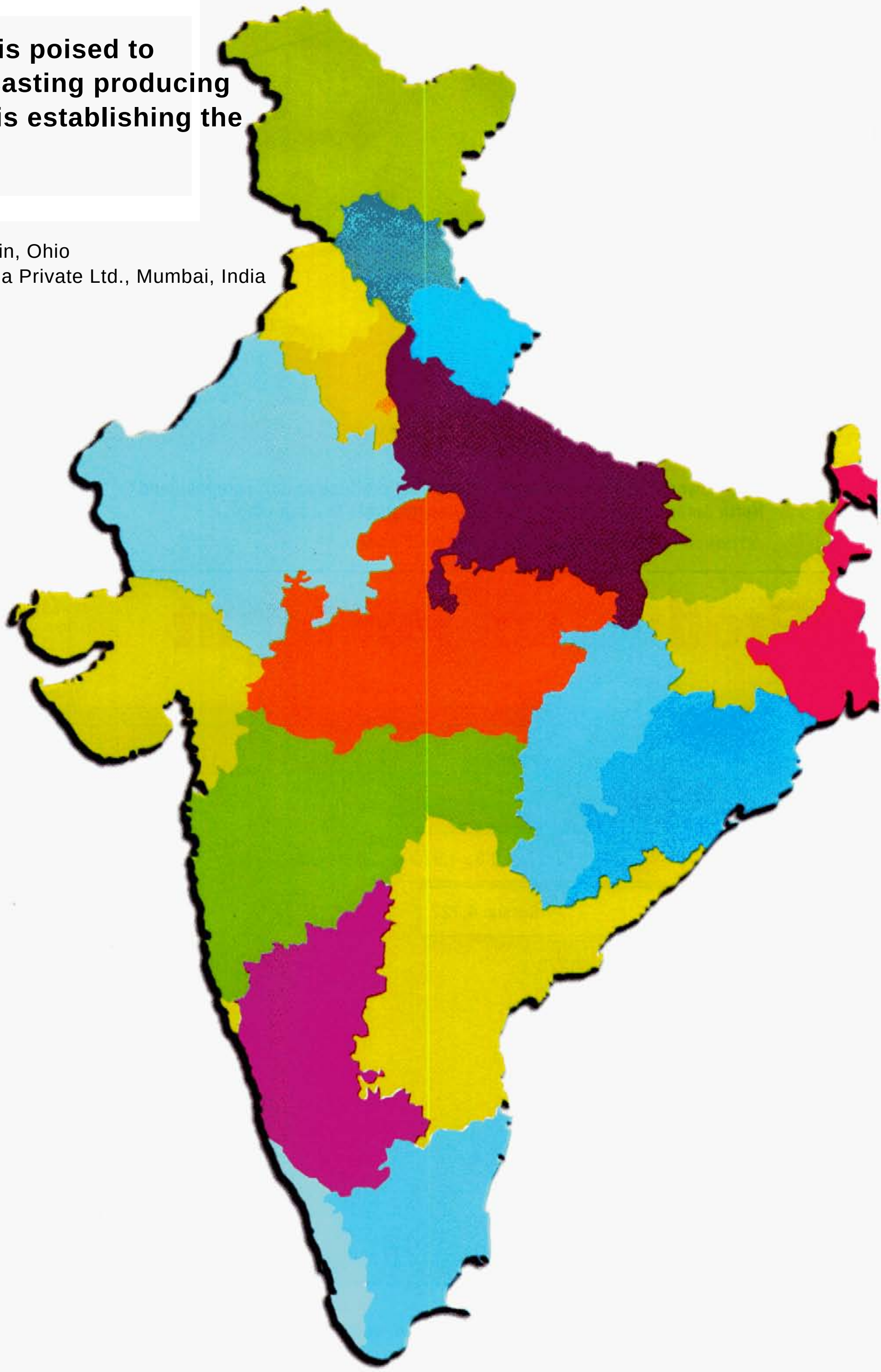


Now the fourth largest producer of metal castings worldwide, India has increased its casting production by more than 100% since 2002. No other large casting producer matches that growth during that time frame. The expansion stems from India's large and rapidly growing economy, which has the potential to raise its income per capita to 35 times current levels over the next 40 years.

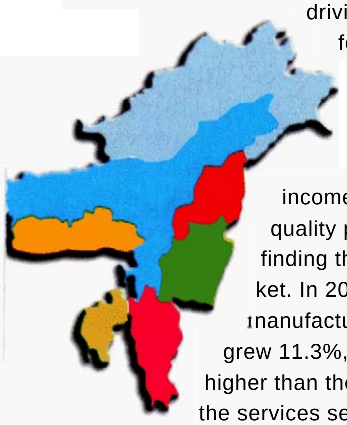
India benefits from low labor costs, a large population with strong domestic demand, and financially strong companies with revenues to invest in metalcasting. However, the country's infrastructure lags behind the rest of India's development. The Indian government has estimated the need of $500 billion in infrastructure development in the next five years if GDP growth targets are to be achieved. Private economists have indicated the government's estimate is low and calculate the need as closer to $1-1.5 trillion of infrastructure investment needed over the next five years.

With power outages common, manufacturing in India will not be able to reach its full potential unless considerable investment is made to support the industrial sectors.

Growth of Manufacturing

According to Goldman Sachs, in 2050, India is expected to have one of the three largest economies (by GDP) in the world, along with China (first) and the U.S. (second), and be an order of magnitude larger than Japan, which ranks fourth (Fig. 1). Estimates put the current size of the Indian economy at $1 trillion, with GDP growth rates around 7.5 to 8.5%, second only to China. Part of that growth will be attributed to the rise of manufacturing in India.

With a focus on call-centers, business process outsourcing and knowledge process outsourcing firms, India has traditionally been viewed as an economy driven by the service sector. The global demand for services from India has led to the creation of a large and growing middle-class with increasing disposable incomes. Of India's 1.16 billion people, more than 300 million are considered middle class, which is now driving a demand for manufactured goods, and given the higher disposable incomes, higher quality products are finding their market. In 2006-2007, the manufacturing sector grew 11.3%, which was higher than the growth in the services sector.



The automotive sector accounts for 4.2% of India's GDP. Since 2002, production volume has a 16% compound annual growth rate (CAGR), while automotive exports volume has increased 34% CAGR (Fig. 2). Some economists believe India has the potential to own up to 7% of the world's auto components market.

Two and three-wheelers constitute a large part of the industry by volume, but cars and commercial vehicles are growing faster and form a sizeable piece of the market in terms of dollars (Fig. 3). Global auto manufacturers are responding to this increasing demand by aggressively expanding their assembly capacities in India. Assembly capacity increased by 50% in 2008 (Fig. 4).

Metalcasting Expansion

Much of India's economical environment is advantageous for metalcasters. A strong domestic demand and a rapidly growing middle class seem likely to remain for years to come. The overall financial prosperity of Indian companies has given them the revenues and confidence to invest in metalcasting and expand internationally. Labor costs in India are some of the lowest in the world. Unskilled labor costs in many plants are less then $100 a month. Skilled labor is $200 to $400 a month or less. Recent graduates of metallurgical engineering programs from good universities can be hired for an annual salary of $6,000.

Table 1. Indian Metalcasting Clusters by Geography

Cluster	State	Approximate Number of Plants	Major End Use Markets
Belgaum	Karnataka	100	Automotive engines/pumps/valves
Coimbatore	Tamil Nadu	600	Pumps/valves
Batala/Jalandhar	Punjab	N/A	Machine parts/agricultural implements
Kolhapur	Maharashtra	250	Automotive/pumps/valves
Rajkot	Gujarat	500	Oil engines/automotive

Further, construction costs for new casting facilities, as well as time to complete construction and permitting, are low. Health and safety compliance requirements for molding binders are nearly non-existent, and tooling costs are significantly lower than in developed countries, although tooling quality is still lagging.

However, India faces some hurdles. Along with a lack of sufficient infrastructure, consumable costs are higher in India than in developed countries, and the quality and capability of the consumables are often limited. As a result, the quality of castings can be erratic, and improvement is needed to compete with those produced in developed nations. Further, energy costs are somewhat controlled, as the utilities and oil companies are state-owned, but energy is often a problem, particularly a reliable supply of electricity.

Finally, attracting and maintaining an enthusiastic, younger work force is a challenge in India. In order to keep younger employees, the Indian metalcasting industry will have to improve the environment, health and safety of its facilities, which will eventually be reflected in casting cost.

More than 5,000 metalcasting facilities with a capacity of 7.5 million metric tons make up the Indian metalcasting industry. According to the Institute of Indian Foundrymen, more than 95% of the metalcasting facilities fall under the small scale industry category. The institute groups the metalcasting industry into five geographic clusters in and near the cities of Belgaum, Batala/Jalandhar, Coimbatore, Kolhapur and Rajkot (Table 1).

Seven iron and steel casting groups now have casting capacity approaching or exceeding 100,000 metric tons per year. Six aluminum casting groups each have a casting capacity of 20,000 metric tons per year. Some industry observers estimate the potential for production capacity will reach 10 million metric tons by 2012, which will require as much as $2 billion of investment to achieve.

Due to the growing expectations of OEMs regarding the quality and quantity of castings, India is expected to produce larger casting facilities over the next few years. The size and scope of large plants are required to address investment requirements, power

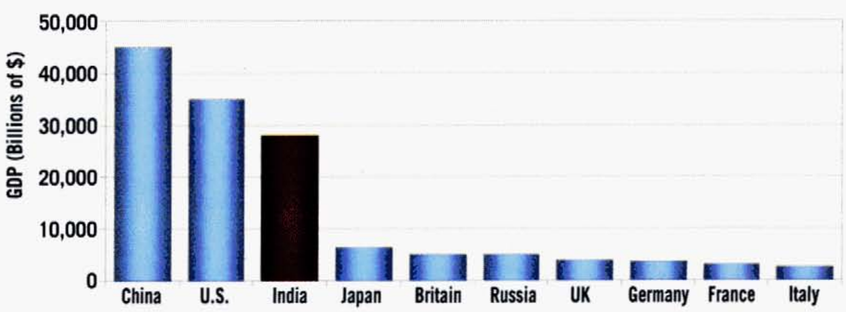


Fig. 1. Goldman Sachs predicts China, the U.S. and India will have the three largest economies by GDP in the year 2050.

shortages and a talent crunch.

Following are highlights of the developments at a handful of the major metalcasters in India.

Hinduja Foundries

Formerly known as Ennore, Hinduja Foundries Ltd. is part of the Hinduja Group, one of India's premier companies with holdings in transportation, banking, media, energy and chemicals. It is the largest producer of iron blocks, heads and other automotive and truck castings in India and serves OEMs in India and elsewhere. For fiscal year 2007-2008, sales were reported as $112 million, 14% higher than the previous year.

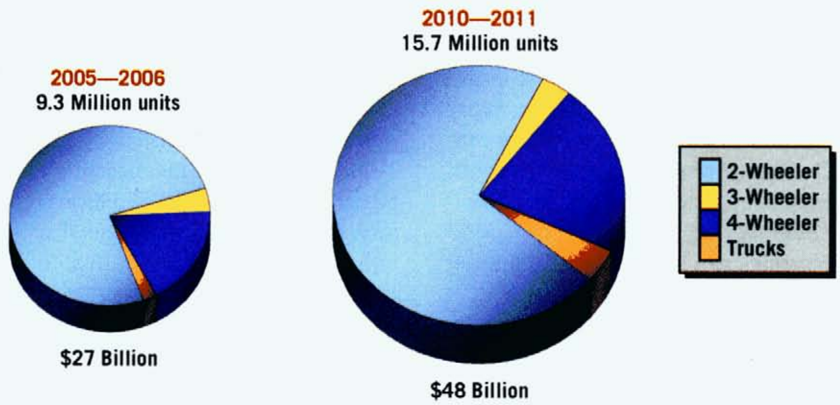


Fig. 2. The Indian two-, three- and four-wheeler and truck market is expected to grow by 11% from 2005-2006 to 2010-2011.

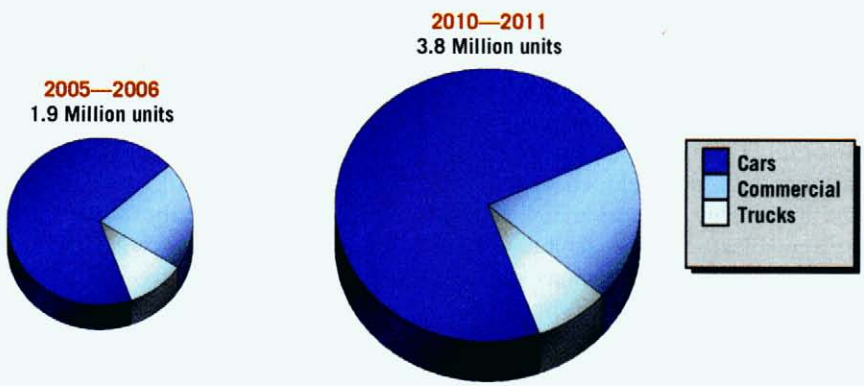


Fig. 3. The Indian car, commercial vehicle and truck market is predicted to grow by 15% from 2005-2006 to 2010-2011.

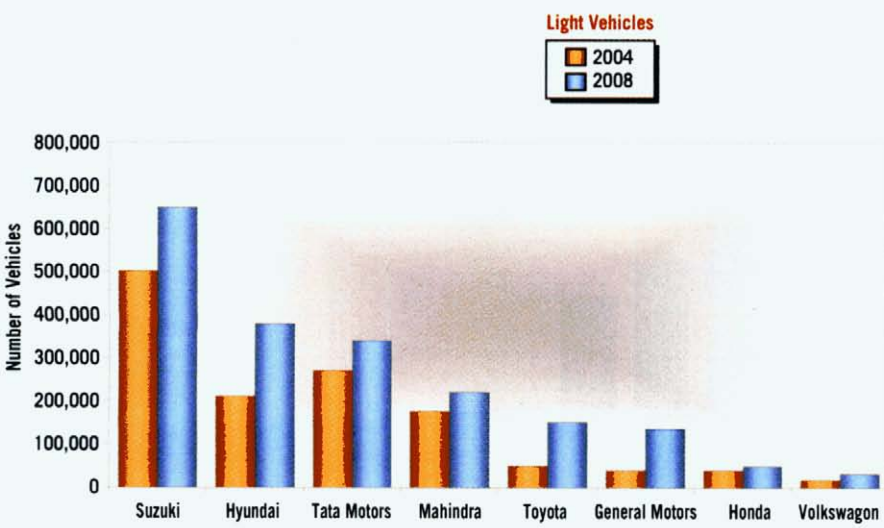


Fig. 4. Assembly capacity for automobiles has increased 50% since 2004.

Its recently completed metalcasting facility at Sriperumbudur, near Chennai, brings total capacity to 72,000 metric tons per year. Additional new plants and expansions are planned.

Sanmar Metals Corp.

Sanmar Metals Corp. consists of four casting operations. Sanmar Foundries Ltd. near Trichy, India, was originally built to provide steel castings for various joint venture companies of the Sanmar Group. Recently, a new plant has opened, adding 20,000 metric tons per year capacity that targets steel casting sales to OEMs in numerous market segments. In early 2008, Sanmar purchased Matrix Metal LLC, including Richmond Foundry, Richmond, Texas, Keokuk Steel Castings Co., Keokuk, Iowa, and Acerlan Foundry, Mexico. Sanmar acquired the German iron works Eisenwerk Erla, Schwarzenberg, in 2007, marking Sanmar's entry into the automotive market segment. Sanmar has subsequently built a modern iron casting facility with a capacity for 25,000 metric tons per year for automotive castings.

Amtek India

Amtek India Ltd. is primarily the automotive castings business of the Amtek Group, a major, growing automotive components producer. Amtek India has more than doubled capacity in the last few years and is doubling again, to a capacity of 165,000 metric tons per year of iron automotive castings. Amtek India owns Sigmacast of the U.K. Sales for Amtek India exceeded $20 million in the fiscal year ending June 2007.

Kirloskar Ferrous Industries

Kirloskar Ferrous Industries Ltd. (KFIL) built its first iron block and head metalcasting facility in the early 1990s near Hospet in the state of Karnatka, an area rich in iron ore. The plant is back-integrated into liquid iron ore processing and uses molten iron as part of the feed to the induction furnaces. KFIL is in the start-up phase of another casting plant at Solapur in Maharashtra. MC

About the Authors

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43rd Census of World Casting Production—2008

Global production dipped below 2007's volume, reflecting the worldwide recession that started in the final quarter of 2008.

A *MODERN CASTING* Staff Report

Global casting production in 2008 dipped below 2007's production, dropping 1.5% to 93.5 million metric tons from 94.9 million metric tons, according to this year's MODERN CASTING Census of World Casting Production.

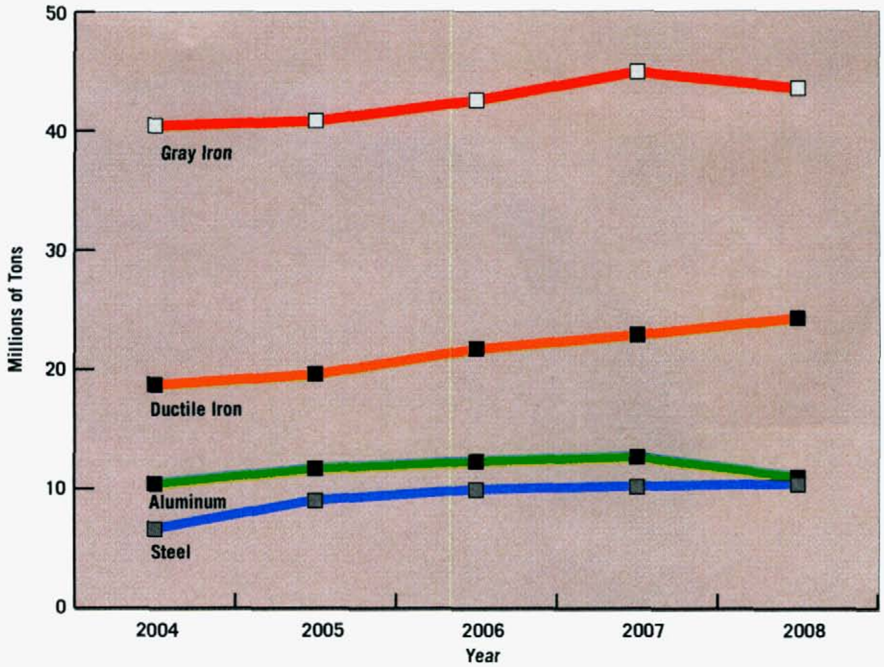
Most countries reported that production numbers were growing or remaining steady through the first three quarters of 2008 but began to wane in the final few months as industries started to reflect the global recession. Of the 28 countries who participated in the production survey this year, 22 reported casting shipments had decreased from 2007, including major casting producing nations Japan, India and the U.S. It is the third year in a row the U.S. has reported a reduction of casting volume, and the second year in a row Japan's casting industry has contracted.

China's rate of growth slowed in 2008 to 7.1%, down from double digit percentage increases the prior two years. However, its growth still reflects the world's largest gain. At 33,500,000 tons produced, China now produces 36% of the total supply of castings worldwide. Brazil, Korea, Poland, Norway and Denmark made gains of 5% or less.

The reduction in casting shipments was reflected in the top 10 nations' average production per metalcasting plant. With the exception of Brazil and Korea, both of which increased tonnage shipped, the countries' production fell. Germany remains the most productive nation, producing 9,639 tons per metalcasting facility.

The data reported in the 43rd Annual Census of Casting Production are production numbers supplied by each nation's metalcasting association or similar representative. Countries that did not participate this year were Ukraine, Slovokia, South Africa, the Netherlands, and Russia. These countries remain listed according to the last year they participated.

Want to compare 2008's production to previous years? Visit www.moderncasting.com for past census results.



Gray iron and aluminum casting production dipped worldwide in 2008, according to the annual census of casting nations.

Number of Operating Metalcasting Plants By Nation—2008
43rd Census of World Casting Production

Country	Iron	Steel	Nonferrous	Total
Austria	30	4	43	77
Belgium	16	7	10	33
Brazil	566	177	597	1,340
Canada	41	29	115	185
China	18,000	5,500	6,500	30,000
Croatia	15	3	23	41
Czech Republic	95	32	73	200
Denmark	7	0	10	17
Finland	9	6	16	31
France	107	37	335	479
Germany	201	53	346	600
Hungary	62	31	97	190
India				4,700
Italy	180	27	960	1,167
Japan	458	75	1,169	1,702
Korea	508	142	223	873
Mexico[A]				1,500
Netherlands[B]	16	0	5	21
Norway	7	3	10	20
Poland[C]	185	0	245	430
Portugal	47	6	39	92
Romania	59	43	74	176
Russia[C]				1,650
Slovenia	15	5	58	78
Slovokia[A]	12	7	32	51
South Africa[A]	87	51	117	255
Spain	60	31	52	143
Sweden	34	14	83	131
Switzerland	17	3	43	63
Taiwan[C]	478	40	330	848
Thailand[A]	230	26	220	476
Turkey	741	72	433	1,246
Ukraine[D]	400	233	437	960
United Kingdom	193	46	236	475
U.S.	564	239	1,367	2,170

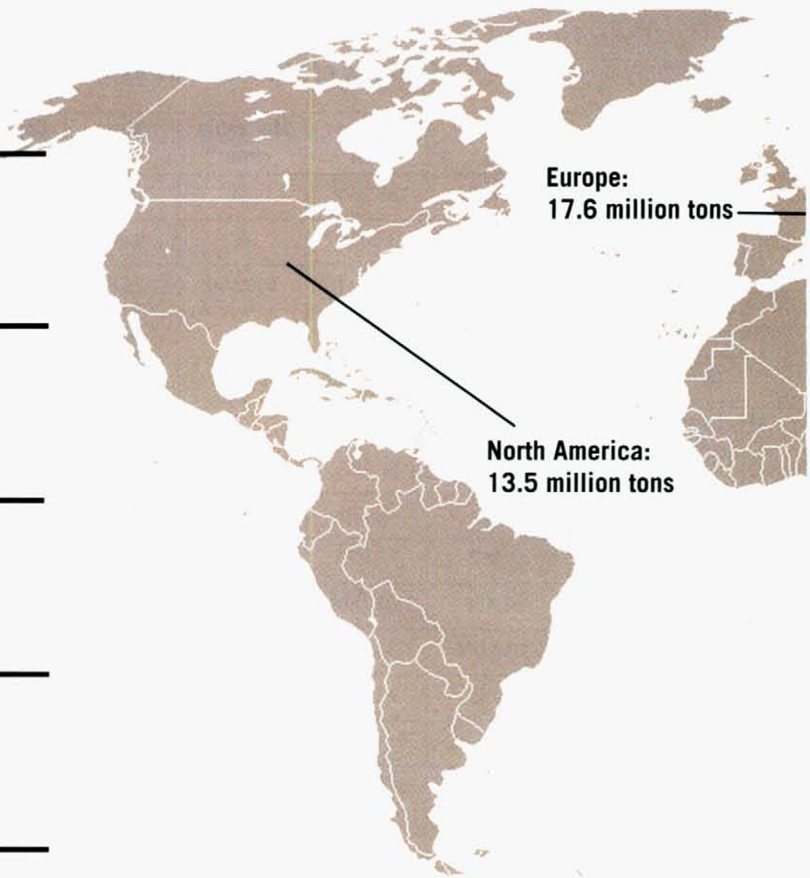
A)2006 data B)2004 data C)2007 data D)2002 data

Census of World Casting Production—2008 (metric tons)

Country	Gray Iron	Ductile Iron	Malleable Iron	Steel	Copper-Base	Aluminum	Mag.	Zinc	Other Nonfe	TOTAL
Austria	48,400	153,000[A]	na	20,800	na	112,155	8,039	12,740	na	355,134
Belgium	61,100	8,900[A]	na	45,800	na	na	na	742	na	116,542
Brazil	1,589,886	677,611	509,596	323,818	19,888	224,966	6,005	3,462	na	3,355,232
Canada	458,850	na	na	111,720	17,656	268,090	na	na	na	856,316
China	16,400,000	8,200,000	500,000	4,600,000	600,000	3,000,000[B]	na	na	200,000	33,500,000
Croatia	29,528	21,849	27	2,517	465	16,715	na	420	927[C]	72,448
Czech Republic	252,964	52,150	11,644	97,863	2,662	114,973[B]	na	4,101	432	536,789
Denmark	32,367	48,020	na	na	1,433	na	na	6	5,778[D]	87,604
Finland	42,852	77,423	na	20,371	4,589	7,406	na	247	na	152,888
France	861,488	1,089,555	na	109,642	24,685	274,902	na	24,518	3,248	2,388,038
Germany	2,677,674	1,846,793	40,838	220,132	94,588	802,202	31,532	67,908	2,024	5,783,691
Hungary	31,133	15,750	16	7,638	1,407	90,342	46	2,950	490	149,772
India	4,532,000	785,000	60,500	916,000	na	na	na	na	547,000[E]	6,840,500
Italy	915,811	646,778[A]	na	93,122	81,000	820,000	10,000	70,000	1,300	2,638,011
Japan	2,753,476	1,995,349	48,082	298,720	98,782	414,002	9,268	30,207	5,912	5,653,798
Korea	1,010,500	595,700	40,300	152,000	24,100	232,500	na	na	10,800[BF]	2,065,900
Mexico	801,210	59,740	na	77,650	202,407	680,958	171	1,264	4,295	1,827,665
Netherlands[G]	78,241	6,209	438	na	na	na	na	na	na	84,888
Norway	19,115	55,639	na	3,255	4,517	13,466	na	na	17,983	113,975
Poland	513,800	167,100[A]	na	3,300	8,200	236,800[B]	na	6,000	1,400	936,600
Portugal	22,324	57,305	na	7,859	11,400	19,800	na	500	60	119,249
Romania	46,718	4,574	836	31,596	3,509	33,651	2,500	558	4	123,946
Russia[H]	3,320,000	1,800,000	180,000	1,300,000	200,000	840,000	80,000	30,000	50,000	7,800,000
Slovenia	76,820	33,353	na	38,114[B]	na	26,472	na	na	7,645	182,404
Slovokia[I]	8,760	na	4,300	2,160	2,160	26,260	na	1,800	5	45,445
Spain	493,600	641,400[A]	na	86,600	9,472	115,155	na	11,674	1,212	1,359,113
South Africa[J]	14,700	86,000	na	184,000	3,000	77,000	na	4,000	na	368,700
Sweden	170,700	66,300	na	22,000	12,500	43,300	2,000	5,400	na	322,200
Switzerland	28,000	49,800[A]	na	2,421	2,315	21,919[B]	na	1,696	na	106,151
Taiwan	780,175	211,052	na	77,945	35,588	309,503	5,845	63,968	2,934	1,487,010
Thailand[J]	70,000	30,000	30,000	28,600	28,600	100,000	na	16,900	na	304,100
Turkey	565,000	400,000	5,000	140,000	16,000	122,080	na	17,000	na	1,265,080
Ukraine[K]	626,610	40,000	10,000	266,060	11,000	20,500	na	na	na	974,170
United Kingdom	192,000	215,000	3,200	72,000	12,000	110,000	3,500	9,500	1,000	618,200
United States	3,502,640	3,597,894	60,000	1,172,082	274,877	1,739,980	109,769	273,970	52,617	10,783,829
TOTALS	**42,958,542**	**23,841,444**	**1,504,777**	**10,538,385**	**1,808,580**	**10,932,434**	**268,675**	**664,136**	**916,997**	**93,449,270**

A) includes malleable iron B) includes mg C) lead castings D) mostly aluminum E) all nonferrous F) includes zinc G) 2004 data H) 2007 data I) 2005 data J) 2006 data K) 2002 data

Top 10 Casting Producers



1. China

33.5 million tons

Gray iron	16.4 million tons
Ductile iron	8.2 million tons
Steel	4.6 million tons
Nonferrous	3.8 million tons

2. U.S.

10.8 million tons

Gray iron	3.5 million tons
Ductile iron	3.6 million tons
Steel	1.2 million tons
Nonferrous	2.5 million tons

3. Russia*

7.8 million tons

Gray iron	3.3 million tons
Ductile iron	1.8 million tons
Steel	1.3 million tons
Nonferrous	1.2 million tons

4. India

6.8 million tons

Gray iron	4.5 million tons
Ductile iron	790,000 tons
Steel	910 million tons
Nonferrous	550,000 tons

5. Germany

5.8 million tons

Gray iron	2.7 million tons
Ductile iron	1.8 million tons
Steel	220,000 tons
Nonferrous	900,000 tons

6. Japan

5.7 million tons

Gray iron	2.8 million tons
Ductile iron	2 million tons
Steel	300,000 tons
Nonferrous	560,000 tons

7. Brazil

3.4 million tons

Gray iron	1.6 million tons
Ductile iron	680,000 tons
Steel	320,000 tons
Nonferrous	250,000 tons

8. Italy

2.6 million tons

Gray iron	920,000 tons
Ductile iron	650,000 tons
Steel	90,000 tons
Nonferrous	980,000 tons

9. France

2.4 million tons

Gray iron	860,000 tons
Ductile iron	1.1 million tons
Steel	110,000 tons
Nonferrous	330,000 tons

10. Korea

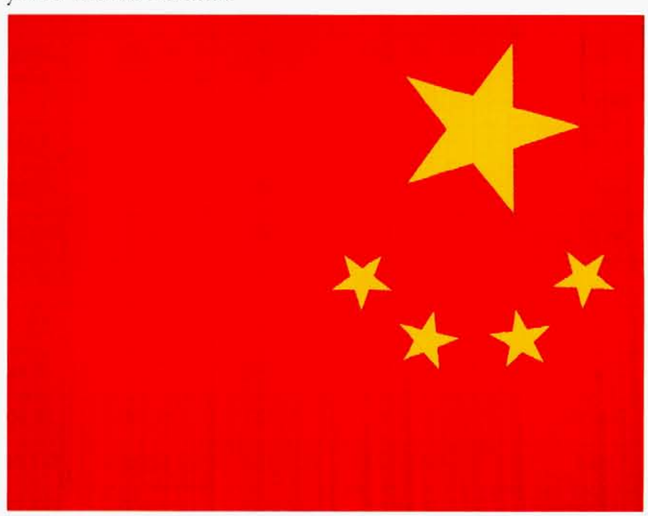
2.1 million tons

Gray iron	1 million tons
Ductile iron	600,000 tons
Steel	150,000 tons
Nonferrous	270,000 tons

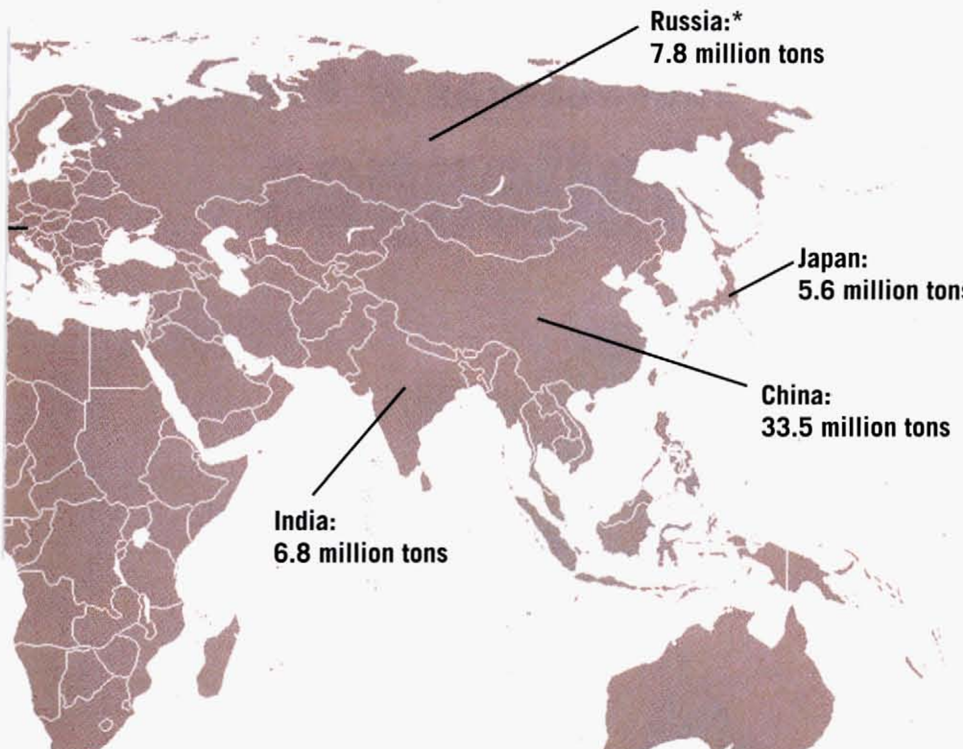
**Production total for Russia based on 2007 numbers.*

Without China

China's production makes up 36% of the total global casting production, which can skew the global outlook. Below are the global casting tonnages over the last five years without China.



Year	Million Tons Produced	Percent Change Without China	Percent Change With China
2004	57.32	+3.5	+8.4
2005	61.32	+7	+7.5
2006	63.27	+3.2	+7.2
2007	63.65	+0.6	+4
2008	59.95	-5.8	-1.5

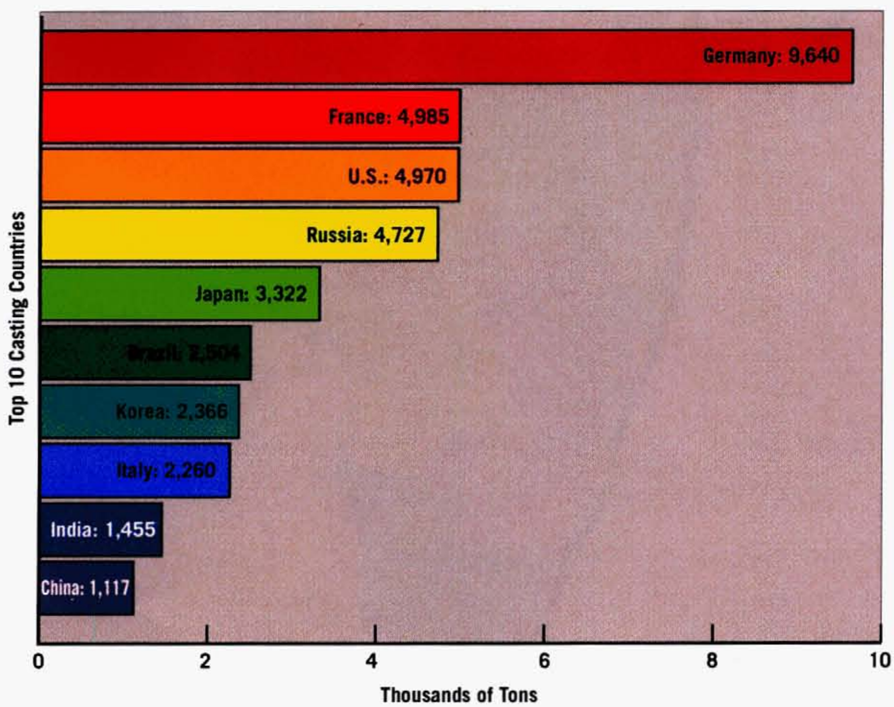


Regional Production

China dwarfs other world regions in casting production, but European and North American production are fairly comparable to each other.

**Production total for Russia based on 2007 numbers.*

Production Per Plant



Ilustrated above are the top-10 nations' average productivity per metalcasting plant in 2008. Germany continues to be the most efficient country according to this formula. Only eight of the top-10 nations improved productivity in 2008.

Ahead of the Curve

The majority of the worlds casting producing nations saw production volumes decrease, but a handful made modest gains in 2008. Besides China, which grew 7%, below are other notable growing countries.

Brazil: This South American nation continues to make gains, growing 4% from 2007 to 2008 to 3.35 million tons.

Korea: Korea experienced its 10th consecutive growth year in 2008 with a 2.2% increase to 2.06 million tons. In the last five years, this Asian country has seen its aluminum casting production grow leaps and bounds, increasing from 78,000 tons in 2003 to 232,500 tons in 2008-an improvement of nearly 200%.

Poland: Its increase in casting production was slight at 1.6%, but it came in a year where the rest of Europe saw a combined decrease in production of 3.8%. Poland as a whole saw a gradual economic slowdown but still experienced relatively high economic growth (4.8% GDP growth).

Hit Hardest

Some countries felt the pinch of the beginnings of the worldwide recession more than others.

Japan: In 2006, Japan produced 7.9 million tons of castings, a 19.9% increase from 2005, but that gain is gone after two years of double-digit percent decreases. Of the top-10 countries, Japan's production shrank the most, reaching 5.6 million tons in 2008, an 18.8% decrease from 2007. It has dropped behind India and Germany in rankings.

India: This country has been the fastest growing large casting producing nation in the last five years, but 2008 proved to hold a yield sign. Casting production dropped from 7.8 million tons in 2007 to 6.8 million tons in 2008.

U.S.: An 8.8% decrease in casting tonnage is the third largest percentage loss of the top-10 casting countries. The U.S., which produced 11.8 million tons in 2007, shipped 10.8 million tons in 2008. It remains the second-largest casting producing nation. MC