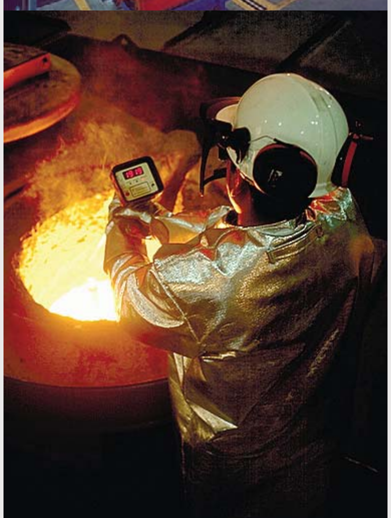
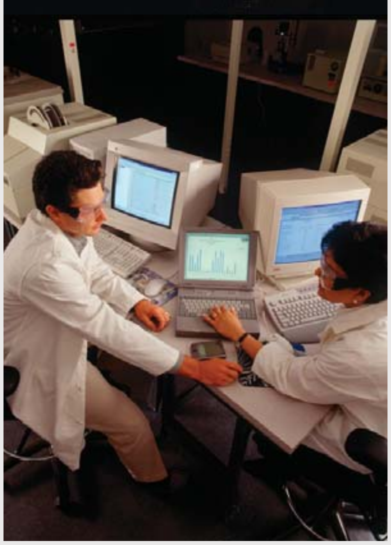
Casting Emission Reduction Program

www.cerp-us.org





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Foundry of the Future: Information that Management Needs - AFS Paper 07-072

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March 2007

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CASTING INDUSTRY SUPPLIERS ASSOCIATION

AMERICAN FOUNDRY SOCIETY

ARMAMENT RESEARCH, DEVELOPMENT & ENGINEERING CENTER PICATINNY, NJ

USCAR UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

DaimlerChrysler Ford GM General Motors

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This report has been reviewed for completeness and accuracy and approved for release by the following:

VP Research and Technical Development Hill and Griffith Company	*//Original Signed//* Victor S LaFay	Date
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1.0 ABSTRACT

The objective of this paper is to look into the future and attempt to develop an operational road map that meets the future needs of the successful foundry. These foundries will optimize processes and materials to produce high quality castings for the consumer at a profit! The focus of this investigation is to build the concept around a "typical" heavily cored iron foundry. This study will review the importance of environmental optimization, energy demand, material availability (in all areas of the foundry), process innovations, and changing customer expectations. Through the efforts of the Casting Emission Reduction Program (CERP)[1] and its members (USCAR, AFS, casting producers, Department of Defense and casting industry suppliers) work has been done to cooperatively develop leading edge technology to meet the needs of the "Foundry of the Future."

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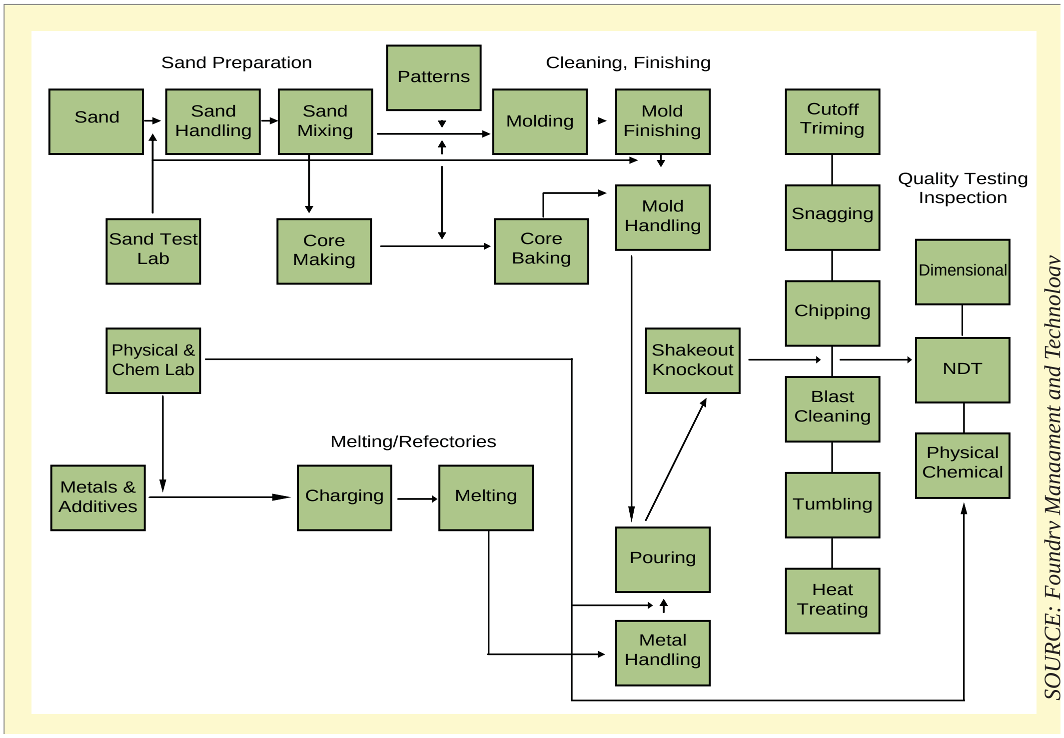
2.0 Background

Technikon, LLC is a privately held contract research organization located in McClellan, California, a suburb of Sacramento. Technikon operates the Casting Emission Reduction Program (CERP). CERP is a cooperative initiative between the Department of Defense (US Army) and the United States Council for Automotive Research (USCAR). The parties to the CERP Cooperative Research and Development Agreement (CRADA) include The Environmental Leadership Council of USCAR (a Michigan partnership of DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation); the U.S. Army Research, Development, and Engineering Command (RDECOM-ARDEC); the American Foundry Society (AFS); and the Casting Industry Suppliers Association (CISA). The US Environmental Protection Agency (US EPA) and the California Air Resources Board (CARB) also have been participants in the CERP program and rely on CERP published reports for regulatory compliance data.

The primary objective of CERP is to evaluate materials, equipment, and processes used in the production of metal castings. Technikon's facility was designed to evaluate alternate materials and production processes that could achieve significant Hazardous Air Pollutant (HAP) emission reductions. The facility's principal testing arena has been specially designed to facilitate the repeatable collection and evaluation of airborne emissions and associated process data.

The goals and objectives of CERP have been shown to be an ideal proving ground to the concept of the "Foundry of the Future." In addition to the organizations listed above, suppliers of materials and processes have contributed greatly to the detailed investigations completed at the testing facility. The suppliers have tested both evolutionary and revolutionary materials and process that will be discussed in this paper. Figure 2-1 is a representation of a typical foundry operation that was developed in cooperation with CISA in a recent Foundry Management and Technology article.[2] Figure 2-1 reflects the complexity of a foundry and the multiple areas requiring materials and process control for successful and profitable operation.

Figure 2-1 Typical Greensand Iron Foundry Production Flow Chart



3.0 REPORT OBJECTIVE

CERP has been evaluating sources of foundry air emissions since 1998. The program started with the approach of measuring the most common products utilized by the industry. This resulted in a database of “Baseline” emission factors that could be utilized to measure lower emission products and processes as they have been introduced by the casting suppliers.

The supplier base has developed products and processes that fall into two categories: evolutionary (example: revisions to binder formulations) and revolutionary (example: inorganic core binder systems).

The objective of this report is to look to the future and attempt to develop a concept of what an environmentally optimized foundry (including best energy practices) would look like. Global foundry environmental criteria discussions held at CERP meetings led to this concept of defining foundry operations that would include the most environmentally sound technologies into a report. The focus of this study was to build the concept around a typical heavily cored Iron foundry.

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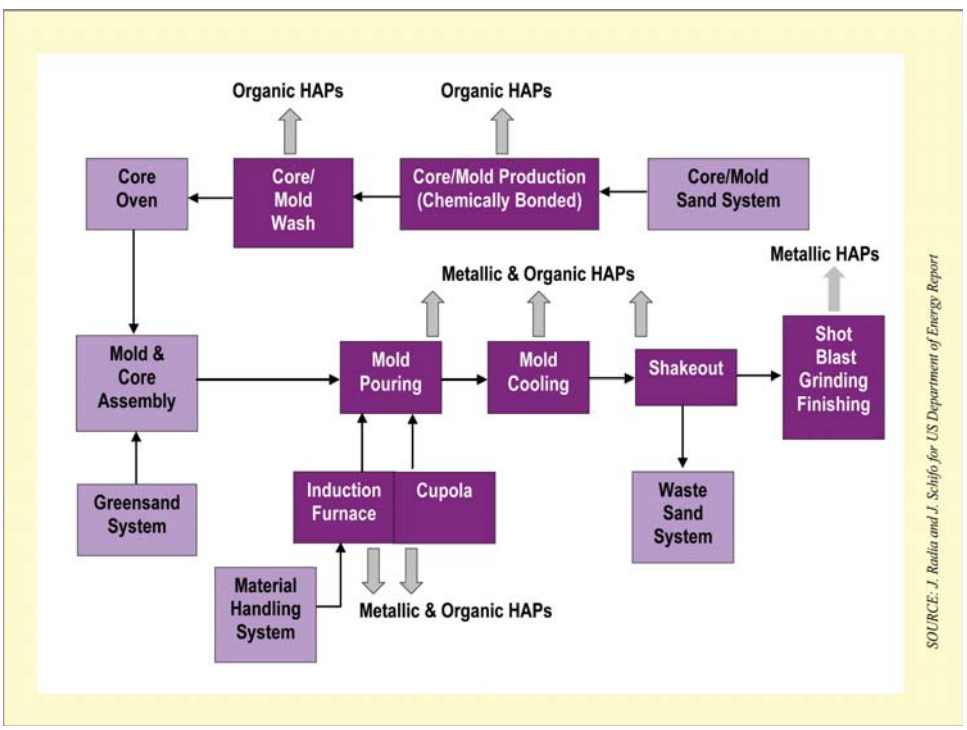
4.0 ENVIRONMENTAL TESTING RESULTS – WHY SHOULD WE CARE?

The following Emission Testing Results, described in chart format, show the testing done to date at CERP. These charts represent ranges of emission results of products and processes by Production area. Eighty to ninety percent of HAP emissions occur during the Pouring, Cooling and Shakeout (PCS) of molds.

Foundries are increasingly the victims of regulators and local citizens groups that perceive the industry as the source of major air emissions. This is just as likely to be caused by odor complaints as it is by actual stack test results. The successful foundry of the future needs to reduce its air and odor emissions to survive in an urban environment.

Figure 4-1 represents the sources of Hazardous Air Pollutant (HAP) emissions by area in a typical foundry.[1] These emissions are caused by the organics in the greensand molding system, No-Bake molds or the cores used in the molds. Metal emissions and fine particulate emissions need to be controlled with properly operating emission control equipment.

Figure 4-1 Sources of HAP Emissions in a Typical Green Sand Iron Foundry



The charts in Figures 4-2 thru 4-6 compare emissions of products and are broken into families of technologies. The baseline (conventional raw material inputs) is shown against new generation and lower emission replacement inputs. Figure 4-2 shows replacement or reduction of seacoal is necessary to have significant impact on greensand emissions from pouring, cooling and shakeout. Figure 4-3 shows many lower emitting no-bake molding binders choices exist. Figure 4-4 shows the amount and types of solvents in phenolic urethane binders affect core making emissions. Suppliers have made revisions in core solvent packages that reduce HAP emissions from the various core making processes. Figure 4-5 shows significant reductions have been achieved in phenolic urethane binders compared to baseline systems. Changes have been made to phenolic urethane binders (A thru H) to reduce HAP emissions and to improve core strength allowing reduced binder content in cores. Figure 4-6 shows significant advancements have been made to these binders. Most were developed for Aluminum Casting, but many can be used in light section iron castings. Productivity issues have limited the acceptance of these systems but new developments are in progress. These

Figure 4-2 Greensand Seacoal Replacement Product PCS HAP Results

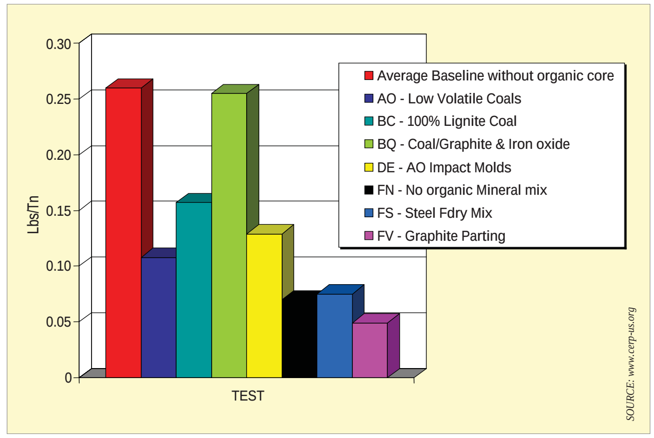


Figure 4-3 Chemically Bonded Dry Sand Binder PCS HAP Results

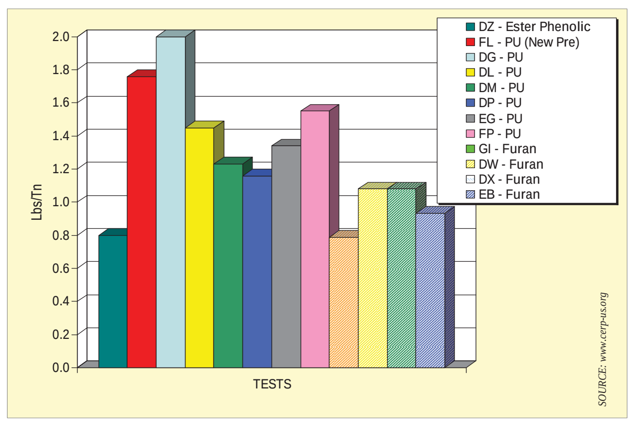
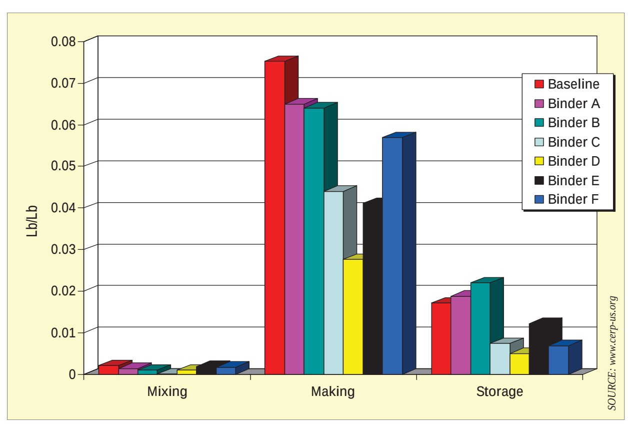


Figure 4-4 Phenolic Urethane Core Making HAP Emission Results



charts demonstrate that the foundry suppliers are responding to the environmental pressures on the industry by developing alternative lower emitting products.

The progressive foundries of the future must perform careful analysis as they test and adapt environmentally friendly products and processes. Casting quality requirements and productivity issues will arise that will need to be resolved. Once these issues are resolved the foundry will reap the advantages of lower air emissions, less regulatory requirements and, most likely lower, materials costs.

Figure 4-5 Organic Core Binder PCS HAP Emission Results

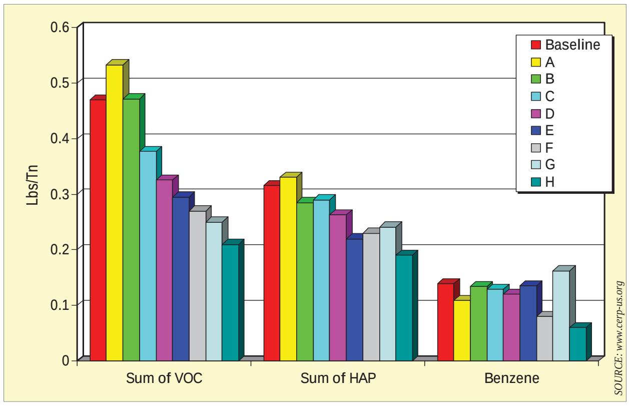
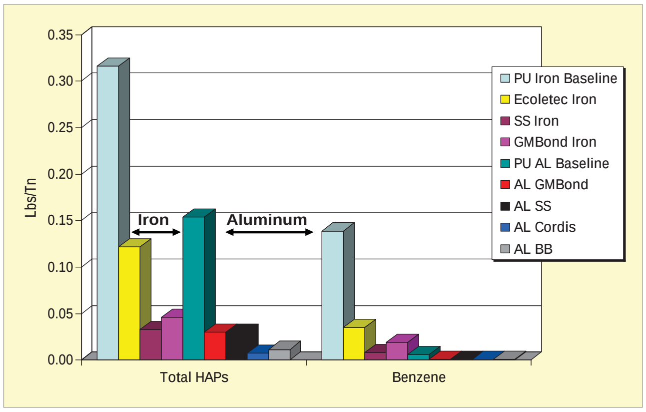


Figure 4-6 Low Emission Core Binder PCS HAP Emission Results



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5.0 Iron Foundry Production Processes

The Foundry of the Future must balance environmental, energy usage and productivity requirements. The following sections describe the major production departments in a foundry and recommend low energy usage concepts that are also environmentally friendly. These recommendations should be considered in operating the efficient and optimized iron foundry.

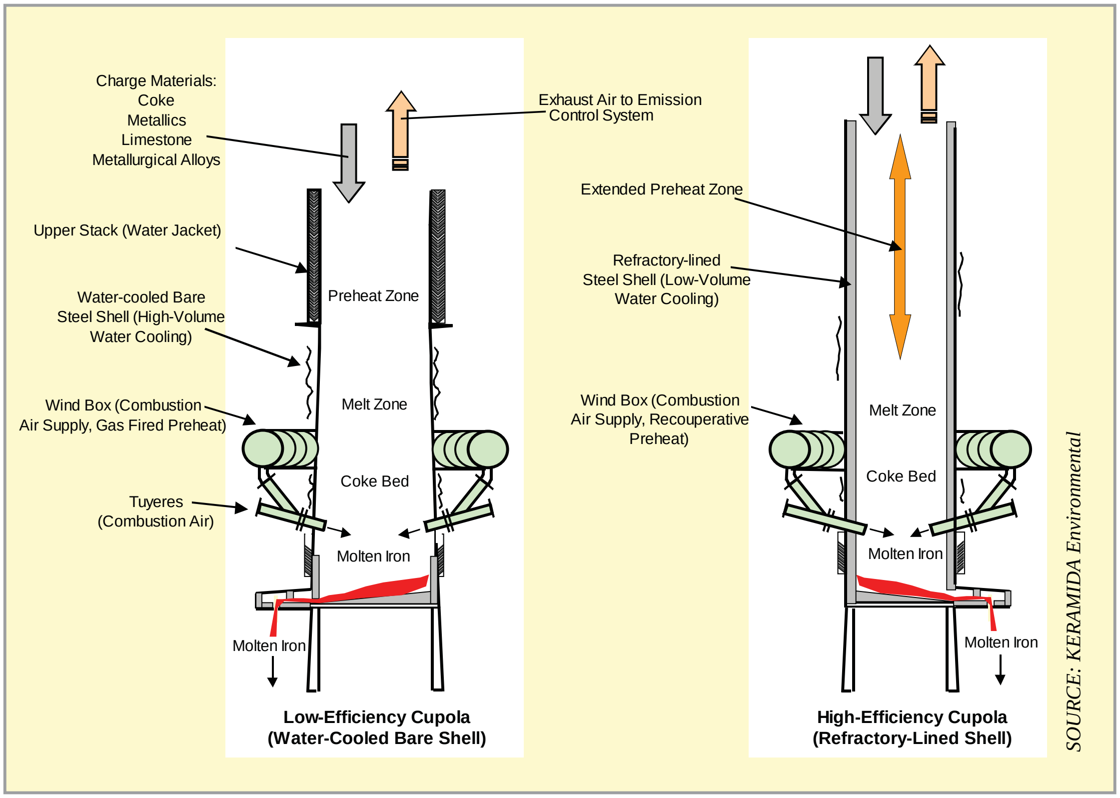
5.1. Melting Department

Typically, large iron foundries utilize cupola melting furnaces because of the economics. Many other operations have installed large Induction furnaces because they are less capital intensive and have more flexibility as to production hours. They each have their advantages and disadvantages. The following recommendations describe the attributes needed by each system to be the most environmentally friendly. The decision on what melting method to use is not a clear choice, but one based on production volumes, alloy types, energy costs, ferrous scrap availability, and technical support staff. This section discusses both methods and makes recommendations on how to utilize each melting method more efficiently.

5.2. Cupola Recommendations

The Cupola is a vertical shaft furnace that is either refractory lined or water cooled. It is equipped with a windbox that feeds combustion air into a charge mix of coke and scrap iron and steel. The heat source for the cupola is supplied by metallurgical coke, which has an energy value of 14,500 Btu/lb. The cupola is potentially the least expensive furnace for melting gray and ductile iron (Figure 5-1), in terms of energy usage and operating cost for larger operations; i.e. 25 tons per hour and above.

Figure 5-1 Two Styles of Cupola Furnaces



Prior studies have shown cupolas to be in the range of having a 20% to 25% overall energy cost savings over Induction melting. The total heat distribution of coke in a cupola has about 42% of the energy going into the metal and the remainder being lost to a) creating Carbon Dioxide (CO_2) and Carbon Monoxide (CO) b) hot stack gases, and c) heat transfer to the cupola shell cooling water. The majority of cupolas burn off the CO in the upper stack and many lose the potential heat energy that could be recovered. Environmental and energy saving concepts for a cupola system include:

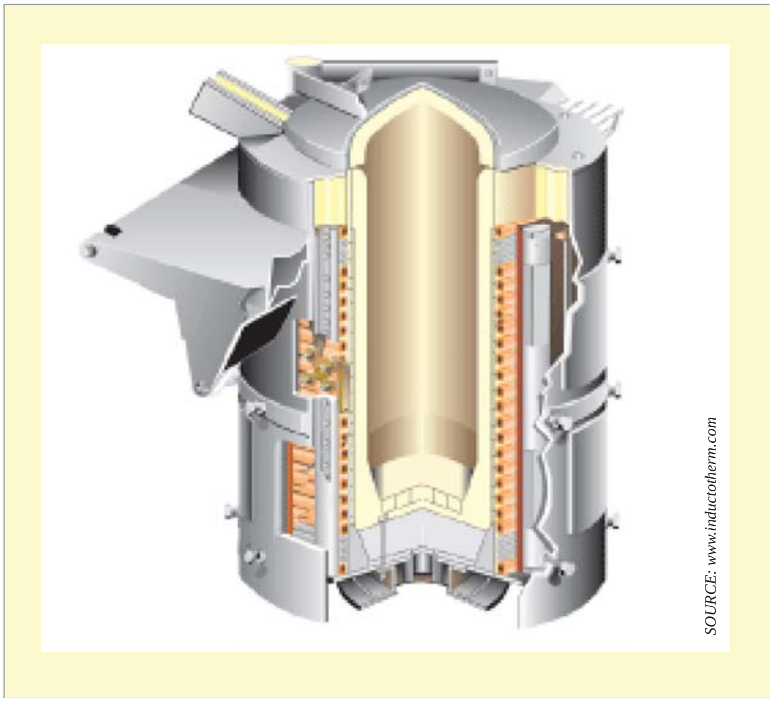
- Install a recuperative hot blast system that utilizes the energy from burning CO to supply the heat for the hot blast air. Cupolas operate most efficiently when pre-heated air is used for combustion - 900°F to 1200°F (482°C to 649°C).
- Add oxygen into blast air, most effective directly into the tuyeres. This oxygen injection combines with the CO to recover the latent heat, providing additional heat that can lower the amount of coke required by up to 30%.

- Addition of coke fines directly into the tuyeres to reduce the amount of coke added and to control carbon levels.
- The residual heat after the recuperative hot blast stage can be used to generate steam that can generate electricity. A 75 ton per hour cupola can generate up to three Mega watts of power.
- Use a refractory lined Cupola shell with minimal water cooling.
- Minimize the charge door opening to reduce the size of dust collection required. An above the door takeoff cupola with a charge bucket design can use twice the cubic feet of air as a charge feeder design or a below the door takeoff design cupola.
- Use of clean scrap for melting operations- minimize painted, oil covered and HAP containing metals in scrap (chrome, lead, mercury, etc.). Have scrap supplier instigate a Scrap Inspection program to remove items such as electrical components, chrome plated steels, and other foreign materials.
- To minimize water usage and water treatment, a dry cupola slag handling system should be installed. The dry slag material can be recycled if properly managed at the foundry to remain segregated and clean.
- The use of dry dust collection (baghouse) system is the best from the environmental perspective. It would eliminate the need for a water treatment system and could easily meet the regulatory HAP abatement requirement of < 0.005 gr.. / dscf. The system would have a dust treatment system render the dust non hazardous according to Federal and State waste regulations.
- Install inverter controlled drives on large motors, such as hot blast blower and air pollution control equipment exhaust motors, in place of dampers or waste gates (variable frequency and variable voltage). The use of these drive packages can reduce 50 percent of energy requirements with reductions of 20 percent in motor speed.

5.3. Electric Induction Furnace Recommendations

An Induction furnace consists of a refractory structure surrounded by a water-cooled copper coil through which alternating current is passed (see Figure 5-2). This electric current creates a magnetic field that induces a current on the surface of the metal. The heat generated

Figure 5-2 Cut Away of Typical Coreless Induction Furnace



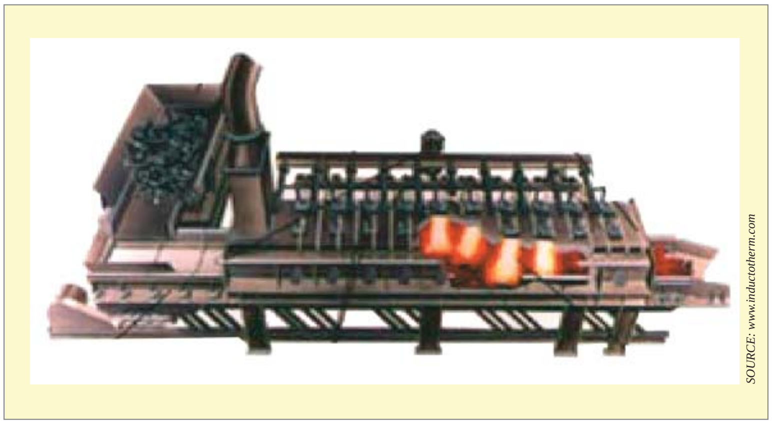
by this current is conducted into the metal, causing the scrap to melt. Two variables can affect the degree of heating achieved in an induction furnace: the magnetic fields rate of variation (frequency of the power) and its intensity (power input). 75% of the energy delivered is used in melting and in increasing the temperature of the metal in the furnaces. The remaining 25% is energy lost to: a) heat carried away through the refractory lining and into water-cooled coils; and b) heat radiation losses through the lid opening.

The following operational methods are suggested:

- The use of a dry dust collection (baghouse) system is the best from the environmental perspective. It would eliminate the need for a water treatment system and could easily meet the regulatory HAP abatement requirement of < 0.005 gr. / dscf. The system would include a dust treatment system that would render the dust non-hazardous according to Federal and State waste regulations.
- Use of clean scrap for melting operations- minimize painted, oil covered and HAP containing metals in scrap (chrome, lead, mercury, etc.). Have scrap supplier initiate a Scrap Inspection program to remove items such as electrical components, chrome plated steels, and other foreign materials.
- Minimize the time the furnace bath is uncovered. A 12 ton furnace will lose 14 kWh each minute the furnace lid is open.
- Reduce slag generation. Not only does it require about 410 kWh per ton to melt slag, it also requires opening the lid for removal. Suggestions to

reduce slag include: a) improving quality of scrap purchased; b) cleaning the sand from returns prior to charging; c) stabilizing tap temperature (lower temperatures produce less slag).

Figure 5-3 Horizontal Scrap Pre-Heater



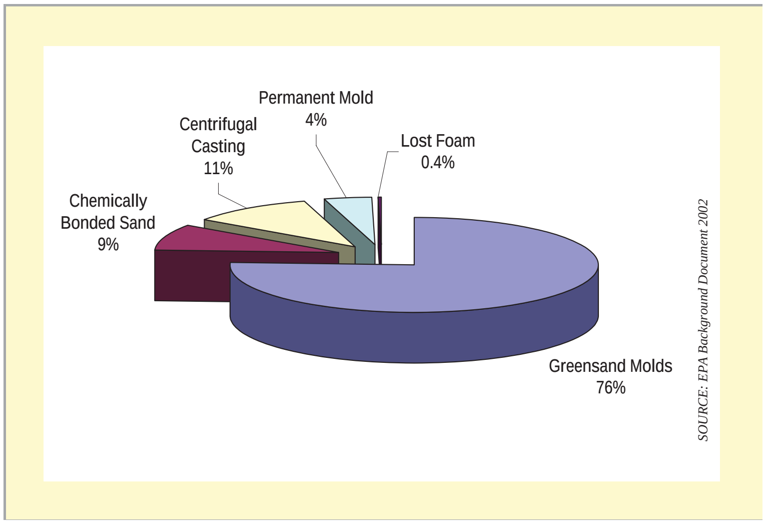
- When taking bath temperature or introducing additives, minimize the opening of the lid or add a hole through the lid for probe.
- Purchase properly sized scrap, which melts faster because it is more densely packed.
- Reduce power input while tapping and charging furnace.
- Scrap pre-heating is a simple way to reduce electrical demand in melting. The typical method is to use a vibrating scrap feeder that is heating the scrap with natural gas burners (Figure 5-3). In these systems, raising the temperature of one ton of scrap from ambient to 1000ºF (538°C) saves approximately 100 kWh of electricity, which is being offset with 600,000 Btus of natural gas. This amounts to about a 20% electrical energy savings in addition to a 20% melt rate increase. Another advantage to scrap pre-heating is that most moisture and oils are removed prior to entering the furnace, which has safety benefits. Offsets are: a) a dust collection system is required to control emissions form scrap preheating; b) the cost of natural gas for pre-heating has to be considered in the cost of melting, but generally there are significant energy and cost savings.

5.4. Metal Casting Operations

Metal casting methods vary widely among various alloys and cast products. Certain types of castings are well suited to a particular casting process while others are not. Required production levels also dictate the molding process and type of pattern material best suited for the number of castings required. As can be seen in Figure 5-4 for iron casting processes, the predominant casting method is the greensand process. This process is well suited to very high production castings with reasonable quality levels.

5.5. Molding Sand

Figure 5-4 Iron Casting Processes



The greensand process uses a sand mold prepared with a mixture of sand, clay, water, and (typically) seacoal as the organic component. The typical greensand molding processes consist of sand being squeezed, or somehow compacted, on a steel pattern. When the pattern is removed, the sand retains the form of the pattern. The mold consists of two halves, a cope (top) and drag (bottom). The cope is placed on the drag and iron is poured into the top of the cope, forming castings in the void formed by the pattern. Depending on the type of casting being produced, a core is sometimes used, such as when the casting produced require internal passages. A core is sand formed to the configuration of the casting's internal passages and typically held together by some form of organic binder. The predominant core binder type is a phenolic urethane based binder system.

Chemically-bonded sand molds are prepared by mixing sand with binders, similar to those used to make cores. The mold holds the shape of the pattern by hardening on the pattern itself, due to the relatively fast reaction of the catalyst and the binder system. The molds are then separated from the pattern and the two halves are put together to form a mold. Chemically-bonded molding is much slower than the greensand process. Chemically-bonded molds may take several minutes or more to cure while a greensand-molding machine can make up to five molds per minute. The chemically-bonded molding process, however, uses less expensive pattern materials and forms a more precise reproduction of the pattern and therefore a higher quality part.

The difference in energy usage is not very significant when considering that the molding process is roughly 6 to 12 percent of the total energy used in a metalcasting facility. Slight differences in molding process energy requirements are not likely to affect the overall energy profile of the facility. Other issues, such as machine utilization and casting yield, will likely overshadow any casting process energy differences.

Green Sand Molding Line Environmental Recommendations:

- Use a dry baghouse on the pouring, cooling lines and shakeout lines for particulate matter emission control. Designed abatement requirement is <0.005 gr. / dscf.
- Low Emission Seacoal system for addition in greensand system sand.
- Use an emulsion of water, vegetable oil and graphite for pattern spray.
- Selection and use of sand additives that reduce the generation of HAP and VOC emissions.
- Consider using an advanced Oxidation (AO) water system to be added for sand cooling and sand mixing water additions. Studies show bond usage savings and lower air emissions.
- Cores needed in molding process to be made from low emission binder system.

Chemically-Bonded Dry Sand Molding Environmental Recommendations:

- Use of low emission binder Systems to make molds.
- Control Sand and Resin temperature before mixing to reduce amount of resin and activator used.
- Minimize time molds cool before shakeout (testing has shown on phenolic urethane molds that emissions continue as long as hot metal is present).

5.6. Core Room

Core making involves the mixing of sand with a binder system to create a damp sand mixture that can be tamped or blown into a core box. A curing system causes the core to harden to a degree that it can be removed from the core box. Post curing may be required to finish the process. The common curing systems include: a) a catalytic gas that causes a chemical bond, such as triethylamine (TEA) used in the Phenolic Urethane process; b) a heat activation of a chemical process, such as the hot box or shell process; and c) a dehydration process to remove water which is used to activate a dry resin or binder which was mixed on the sand. Examples of the last system would be Sodium Silicate and GMBond® binders.

Frequently, in iron systems, a coating needs to be applied that improves the casting surface finish. This coating normally is water based and requires a gas or electric furnace to dry the coating. Ideally this coating operation could be eliminated saving the emission and energy used in this drying process.

Emission testing at CERP has shown that VOC emissions from the organic binder systems are generated during core sand mixing, core blowing and core storage. Inorganic systems do not generate these types of air emissions.

Core Making Environmental Recommendations:

- Use of low emission or inorganic binder systems.
- If using a Phenolic Urethane system, replace triethylamine (TEA) with less toxic catalyst such as DMIPA (not on HAP list).
- Some systems utilize SO_2 or CO_2 as catalyst, which reduces emissions.
- TEA and SO_2 scrubber systems, if required, would be operated within parameters and liquid bath sent out for recycling. Requirements are 99% TEA/DMIPA control efficiency, collection efficiency, or 1 ppm at exhaust with 90% capture efficiency.
- TEA / DMIPA Catalyst Sulfuric Acid Scrubber should be equipped with 150% containment to prevent spills should the scrubber systems leak.
- For catalyst gassing system, maintenance of good core box seals is necessary.
- Core Box cleaning to be minimized and utilize non hazardous chemicals. Some new systems utilize water for cleaning.
- Sand Reclamation: All scrap core sands should be able to be easily reclaimed with minimal thermal reclamation.
- Heated core systems such as Shell Sand and Hot Box should be a new generation of shell resins systems with reduced formaldehyde and phenol concentrations.
- New inorganic based resin systems eliminate most environmental issues in core making, but presently are not capable of supporting all variety of cores or

achieve production rates of organic core systems.

Core Resin Handling and Delivery System Recommendations:

- All Core resins, core release agents, metal pattern cleaners, and other core sand additives must be low VOC, low or zero-HAP-containing.
- Core Resin Storage Tanks must be sealed.
- Recommend Tanks be equipped with Nitrogen blanket and resin temperature controlled.
- Protecto-seal-type vacuum breaker release valves on tanks.
- 150% design containment of largest tank for leak protection.

Sand Handling and Delivery System Recommendations:

- Use pneumatic transport to / from centralized silos.
- Use double walled pipe with cement reinforced elbows.
- Use cartridge or Herding Bin Vent Collectors at receiving silos and hoppers.

5.7. Casting Finishing

Casting finishing is usually the most labor intensive part of a casting operation. Decisions made in the core room and molding process directly affect the amount of labor going into cleaning a casting prior to delivery to a customer. Some of the proposed low emission binder systems and seacoal replacement products may make the casting cleaning process more difficult. In the Foundry of the Future concept, the cleaning room design may have to be more robust to support the low emission product selections.

Additionally, casting design and solidification modeling offer opportunities to minimize labor in the cleaning operation as well as improve casting yield and scrap rates.

Casting Finishing Environmental Recommendations:

- Utilize Solidification Modeling to minimize gating and risers that need to be removed from casting.
- Control Burn-in to minimize casting cleaning effort.
- Control amount of sand carry over to cleaning operation by greensand additive choices and core binder. This may be in conflict with reducing organics in molding and core process.

- Control exhausts from grinders and shot blast cleaning units to <0.005 gr./dscf.
- Potential of HEPA filtration to reuse air back into facility (cold weather climates only).

5.8. Heat Treat Operation

A heat-treating operation is typically a gas-fired oven that raises the temperature of a casting to a specific temperature for a specified length of time. Certain casting applications also require heat treat and liquid quenching of castings in high temperature oils. Heat-treating of castings is performed on different alloys for different reasons. Some require structural changes in the alloy being produced that cannot be achieved in the casting process, while others are the result of using a casting process not suited to the metallurgy of the part produced.

In certain iron casting and aluminum processes, some types of castings may also need to undergo a low temperature heat treat to relieve internal stresses in the casting. In ductile iron, some parts must be heat treated due to insufficient cooling time in the molding process causing too rapid a cooling of the part. The greensand molding process for ductile iron must have a long cooling time of 45 to 60 minutes to ensure proper structural properties. Cooling time is the amount of time between pouring molten metal to form a casting and removal of the cooled castings from the mold. Where insufficient cooling time is available, a separate heat-treating operation is sometimes required.

<u>Heat Treat Environmental Recommendations:</u>

- In Ductile Iron, minimize heat treatment of castings through use of in-mold cooling methods, which require adequately designed cooling lines.
- Reduce natural gas usage to heat treat furnace by preheating the combustion air with the exhaust gas from the heat treat furnace.

Assuming that the castings are starting from room temperature, 0.580 10^6 Btu per ton of ductile iron would be required to raise the casting temperatures to 1,750°F (954°C). Thus, steel heat treating operations would require 0.247 and 0.556 10^6 Btu per Ton or .803 10^6

Btu per ton of good castings to heat treat every ton of casting shipments. The overall furnace efficiencies of annealing or heat-treating furnaces are considered to be about 30 percent with the waste gas stream making up 50 to 60 percent of the losses.[3,4] The natural gas fired furnaces are typically cold-air burner systems, meaning that the combustion systems use ambient air for combustion purposes.

Heat treating and Annealing Department Recommendations:

- Use of zero HAPs quenchant (water based).
- Use of compact self-contained kiln, quench tank, and draw furnace.
- Use of double walled quench tank with interstitial space monitor.
- Use of short run duct work to abatement system.
- Use of integral CO_2 fire prevention system.
- If use of oil base quenchant required, then VOC abatement system needed.

5.9. Energy Usage

The metalcasting industry is very energy intensive. Metalcasting processes include melting, remelting, and heat treating castings, which are very energy-intensive processes. The industry is also a major recycler of scrap metals. In ferrous casting facilities, over 90 percent of the raw materials melted have been used previously in a casting or sheet metal part of some type.

The energy differences among various facilities are the result of the type of casting produced, production volumes, or the type of alloy melted. The total facility energy requirements, on a per ton basis, were generally influenced by the specific type of alloy melted. More specifically, the amount of theoretical energy required to melt a certain alloy affects the total energy consumption of the facility. This indicates that in order to make significant improvements in energy consumption levels, the melting methods and efficiencies are the primary issues that must be addressed. Melting efficiencies can also be affected by molding operating efficiencies as well as non-continuous operation and down time.

Concepts for energy savings have been included in each foundry area recommendation section. For more detail information please review the DOE Best Practices three guidance documents for foundries.

General Energy Usage Recommendations:

- Formation of Energy Team within facility to promote energy savings projects.
- Control of processes, particularly the melting department, is the most important variable to reduce energy usage.
- An energy management system should be installed to manage and reduce/ conserve energy use within the facility.
- Work with local utilities to do plant audits – usually a free service.

5.10. Pollution Prevention

Ideally, in the Foundry of the Future concept, hazardous material and hazardous waste would be eliminated by low emission product substitution. Realistically, that is not completely possible. The following recommendations capture best practices for these areas:

Water Pollution Control

- Process cooling systems should use closed loop with no discharge.
- Elimination of all wet dust collection system so that a wastewater treatment plant would not be required.

Solid Waste Management

- All waste should be profiled and disposed of in a manner that protects the environment and meets local disposal/reuse requirements.
- By using clean scrap and reduced organic systems, solid waste will now be non-hazardous, leading to improved recycling opportunities.
- Sand Reclamation or Sand Reuse Program should be implemented.
- Keep spent foundry sand free of debris.

Toxic Release Inventory Management

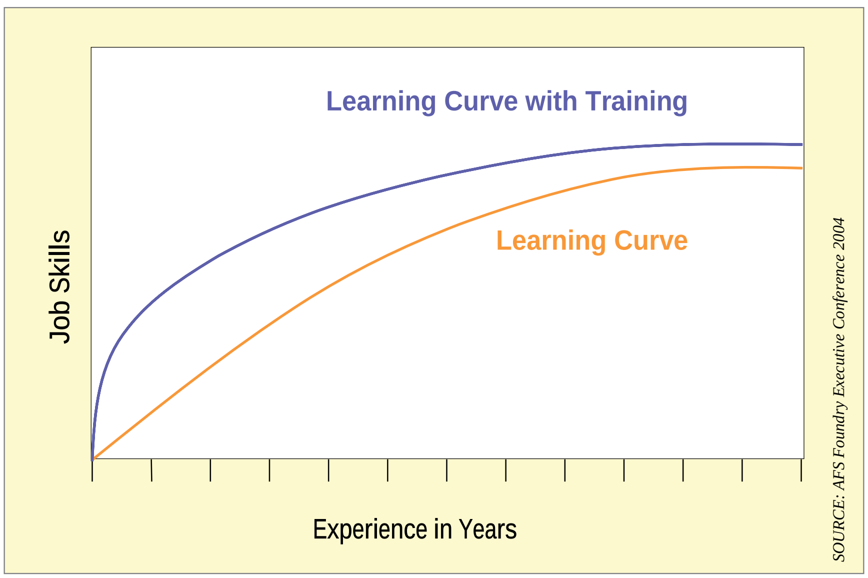
- An accounting of all toxic releases should be kept by the facility and a program in place to eliminate or minimize toxic releases.
- Selection of less toxic core binders and sand additives should minimize reporting requirements.

- Optimize and reduce seacoal usage.

6.0 EDUCATION

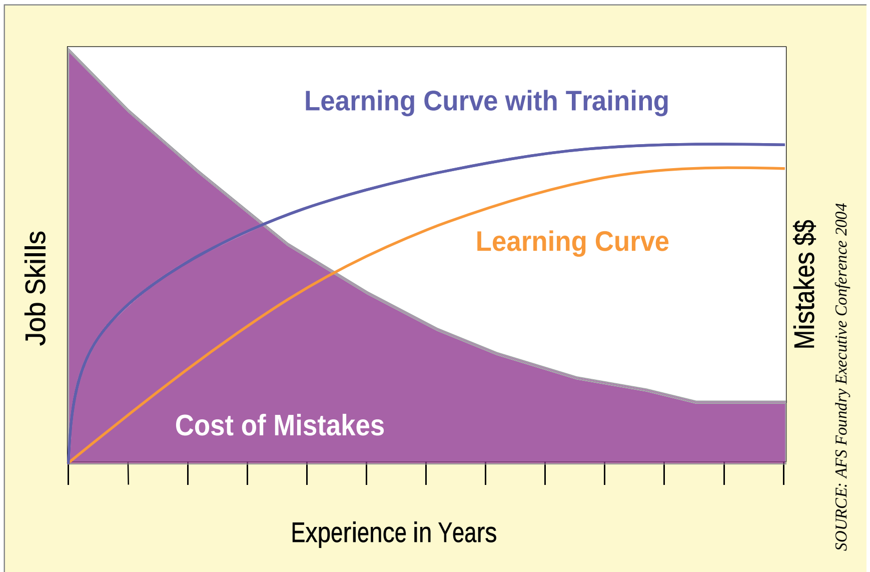
Foundry education programs are required to support the demand to meet the needs of the Foundry of the Future. First, there will be a shortage of foundry personnel as the baby boom generation retires. Also, there will be a skills gap in the workforce considering all of the changes in the foundry that have been previously discussed. In addition, studies have shown that the workforce that will be available to the foundry industry will come from immigration (with limited English speaking skills), with increases in women, Hispanic Americans, Asian Americans, and others. Education and training programs must be designed to meet the changing needs of the workforce and the skills required to operate the Foundry of the Future.

Figure 6-1 Job Skill Development with Training



Educational programs are critical to the learning curve that is experienced in the foundry applications.[5] Figure 6-1 reflects the advantage gained versus time (years) for employees that have improved job skills through training programs. Figure 6-2 reflects the reduction in the "cost of mistakes" with and increase in years of experience and training. With the retirement of the "baby boomers" and their job skills that have been developed over time,

Figure 6-2 Cost Reduction with Increase in Training



the need to replace these individuals and the required skills becomes critical.

In addition to the value of training and education, the requirements of tomorrow's employees become evident. Foundry employees need to use applications and programs that were unheard of a few years ago. Many examples can be observed: casting design and simulation, government regulations, process controls, and many others. When applying the principles and methods of training, additional adaptation must occur. These include understanding and documenting processes and procedures in multiple languages, measurement parameters (metric versus English), automation (and its maintenance), and others.

As demonstrated in Figure 6-2, the value to training in multitasking employees is critical. Tomorrow's foundry employee must be multi-tasking! These individuals will support operations that require skills in computer design and application, hands on applications, and the ability to communicate effectively in multiple languages. This multiplies the impact of the cost of mistakes that is shown in Figure 6-2 since the individuals are multi-tasking.

The question to be asked: How do we make effective training happen? This can be accomplished by utilizing Universities, supporting the Foundry Educational Foundation, foundry specific educational facilities (Cast Metals Institute), in-house training (both suppliers and internal training programs), trade journals, and support to professional foundry association like the American Foundry Society (attending chapter meetings, conferences and regional meetings).

7.0 CONCLUSION

If a foundry incorporated all the concepts and recommendations presented in this paper, how would the foundry be different in terms of emission and energy profile and what changes would there be in operational costs? Those are difficult questions to answer. But if we can make some assumptions that the supplier base will provide low emission products that produce quality casting that do not affect system cycle times, we can start to quantify the advantages. Some of these products are being run in high production today and others are evolving as this is being written. Many of these new products are lower cost materials and offer opportunities to reduce casting costs.

The Foundry of The Future would incorporate changes in processes that will be required to accommodate the material changes and government regulations. In addition, foundry personnel will have to have a higher level of training required to maintain the programs that will be implemented to meet the changing expectations. The demand for increased quality in castings (appearance, chemistry, performance criteria, and others) will have to be coordinated with the regulatory requirements while at the same time keeping the cost of producing a casting the same.

The changes suggested in this paper will help the management of a foundry implement the future goals and expectations of the future!

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Appendix A Acronyms and Abbreviations

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ACRONYMS & ABBREVIATIONS

AFS	American Foundry Society
ARDEC	(US) Army Armament Research, Development and Engineering Center
BO	Based on ( ).
BOS	Based on Sand.
CAAA	Clean Air Act Amendments of 1990
CARB	California Air Resources Board
CERP	Casting Emission Reduction Program
CFR	Code of Federal Regulations
CISA	Casting Industry Suppliers Association
CRADA	Cooperative Research and Development Agreement
DOD	Department of Defense
DOE	Department of Energy
EEF	Established Emission Factors
EPA	Environmental Protection Agency
ERC	Environmental Research Consortium
FID	Flame Ionization Detector
HAP	Hazardous Air Pollutant defined by the 1990 Clean Air Act Amendment
HC	Hydrocarbon
I	Invalidated Data
Lb/Lb	Pound per Pound of Binder
LOI	Loss on Ignition
MB	Methylene Blue
NA	Not Applicable; Not Available
ND	Non-Detect; Not detected below the practical quantitation limit
NT	Not Tested - Lab testing was not done
POM	Polycyclic Organic Matter
QA/QC	Quality Assurance/Quality Control
TGOC	Total Gaseous Organic Concentration
THC	Total Hydrocarbon Concentration
US EPA	United States Environmental Protection Agency

USCAR	United States Council for Automotive Research
VOST	Volatile Sampling Train
WBS	Work Breakdown Structure

APPENDIX B ACKNOWLEDGEMENTS AND REFERENCES

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