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UNIVERSITY FOUNDRY SAFETY

An Interactive Qualifying Project Report

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1. **Metalcasting**
2. **Safety**
3. **University**

Abstract

This project, the culmination of many months of serious work, is a study of how universities handle safety issues in their foundries. It discusses safety issues unique to university foundries and how some issues are handled in industry. The project proposes a safety program and a set of safety practices that universities should adopt.

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1.0 Project Introduction and Goals

Foundry safety has been dealt with by industry for years. The safety records of countless foundries demonstrate the effectiveness of their safety programs. Mandates from unions and the Occupational Safety and Health Administration (OSHA) make operating a foundry without a safety program impossible. Consumers pressure foundries to have safe working conditions. The external pressures applied to today's industrial foundries causes them to make safety a priority. Today, there is evidence that through safety a company's bottom line can be improved by reducing workman's compensation payments and increasing productivity.[1]

This document addresses the unique issues associated with university foundries. A major problem with these foundries is the diversity of experience in them. The average Foundry Education Foundation (FEF) key professor has five years of industrial foundry experience.[2] Often, these experienced foundrymen work with young people who have never even heard of a foundry before. These young people are the undergraduate and graduate students that are the lifeblood of a university foundry. On average, FEF schools each educate 135 students per academic year, all of whom are relatively inexperienced in the foundry.[2] Inexperienced people need to be made aware of the dangers of foundry work. Personnel turnover is high in university foundries which requires constant new personnel training. Research assistants work for two years or less in the foundry; undergraduates may only work a week in the foundry. The work is never routine in the university foundry so safety issues are often overlooked when performing research. And probably most significant is that money is provided for research and equipment, not for improving safety.

This document is separated into three parts. The first part is on the survey used to formulate and guide the making of the proposed university safety program. Part two is the proposed program itself. The last part is a set of recommended safety practices which are either used in industry or from survey responses.

1.1 Project Goals

The goal of this research project was to create a university safety program that deals with foundry safety problems. The safety program should include industry standard safety practices that are modified for the university setting. It must be written in a form that is easy for universities to implement.

1.2 Current State of University Foundry Safety Programs

Literature abounds with information on industrial foundry safety and some of this work can be used in the university foundry. But, the author was unable to find any works that directly addressed foundry safety in the university setting. Work that addresses university safety discusses chemical safety or legal requirements from federal and state labor organizations.[3] The lack of literature on university foundries has driven the creation of this document.

Currently universities have two sources of literature to consider when developing a foundry safety program. There is literature that generically discusses concepts that all safety programs have. The other source of information are articles and papers from industrial foundries which provide specific examples of how these broad ideas can be used in the foundry.

General safety texts and papers give a generic overview of a safety program. Many discuss basic ideas that form the basis of any safety program. These text discuss the need for creating "safety conscious environments" or the need for a total commitment from management to make the program viable.[1] Other texts such as *Environmental and Workplace Safety: A Guide for University, Hospital, and School Managers* look at college safety programs in general.[3] In particular, this text covers issues with legal requirements and chemical safety. While these are all useful to universities with foundry programs, these pieces of literature leave many holes open for university foundries.

Universities try to use industry articles or books to help fill in the gaps that generic texts leave. For instance, papers on molten metal explosions can be used to develop safety practices that prevent water from coming in contact with molten metal. Industry literature provides information on selecting and using personal protective equipment. Procedures for maintaining and using different types of furnaces, like induction furnaces, are contained in the industry literature. Countless procedures can be found for operating an industrial foundry. Unfortunately, many of these procedures are aimed at industrial users who can make certain assumptions about the expertise of their personnel.

Currently, there is no literature on safety programs in universities with foundries. Universities develop their programs without any literature that specifically addresses their unique situation. Departments with foundries have to guess on what a good university foundry safety program is. The sore lack of literature in this area of safety needs to be addressed for the continued operation of all university foundries.

2.0 The Research Survey

The easiest way to fulfill the project's objectives was to use a survey to find out about the safety practices at different universities. It was recognized early in the project that no single institution could make a perfect safety program. By combining the best safety practices from several universities a better safety program could be made.

2.1 The Survey's Design

A survey can take many forms. Phone interviews could be used to collect data. Data can be collected through personal interviews. Questionnaires can be sent to people through the mail. The survey form used by this project was a mailed questionnaire. Using a questionnaire has several advantages. Phone and personal interviews require a considerable amount of time and effort to conduct. The respondents and interviewers have to make an appointment to talk to each other. Many of the schools surveyed were in different time zones which made making contact by phone very hard. The mailed survey does not require an appointment or a group of people to administer the questions. Also, the survey is not affected by bias from the person giving the survey. The mailed questionnaire's ease of administration and low cost to conduct made it the perfect form of survey for this project.

The questionnaire was designed to be easy to understand and fill out. All questions used standard industry terms to avoid confusing respondents.[4] Simple answers were used for most of the questions to make answers comparable from different respondents. Open ended questions were added to get a range of answers from respondents, and their opinions on safety.[5] Using multiple choice and open ended questions balanced the good and bad traits of both kinds of questions. Open ended questions provide a range of answers that cannot easily be analyzed numerically. Multiple choice questions do not allow for respondents to express their opinion, but they are easy to numerically analyze.

Selection of questions for the questionnaire was based on several factors. The first two sections were used to gain background information on the foundries themselves. Background information from these questions helped the author look at safety issues. For instance, the questions on metals and casting processes directed the author's efforts towards looking at safety issues associated with those metals and processes. Prior to the survey, the author was not sure which metals and processes were typically used by university foundries. The author felt this was a large problem since safety issues are associated with both. The next two sections asked respondents questions about melting and pouring practice that were issues that continually came up in the literature of foundry safety. Questions that asked about issues which continually came up in the general safety literature of several industries were in the next two sections. Until the open ended questions, the author decided what was important in foundry safety, but the last two questions allowed foundrymen with more experience than the author to express their thoughts on foundry safety.

The questionnaire was divided into sections for several reasons. Sectioning helped organize the questionnaire so it could be presented to respondents in an organized and logical manner. Order of the sections was determined by looking at the normal operations of a foundry and using the order that these are done as the order to ask respondents safety questions on. Using the operations of foundries as headings allowed respondents to think through their daily operations and remember what activities they do or do not do. Thematically relating questions allowed respondents to concentrate on that part of their foundry operations instead of randomly looking at their foundry operations.[5]

The questionnaire was evaluated for several possible problems. Prior to using the questionnaire it was tested on several people to make sure that the questions did not point to an answer. Checking the survey for "self reporting" questions was necessary to make sure that the survey did not unintentionally make respondents choose an answer that did not reflect the true state of their foundry.[5] The survey questions were also checked to make sure that they would not leave an answering institution or respondent open for litigation. If this type of question had been left in the survey, respondents might not have answered them. Another feature of the survey used to reduce the potential for litigation was the return postcard that came with the survey.[5] The postcard was used to know which institutions had filled out their survey without linking that institution with a specific survey questionnaire.

Questionnaires were sent to FEF schools for several reasons. Using FEF was the easiest way to find those US universities and colleges that have foundry programs. Typically, FEF schools have long standing foundry programs so they have had sufficient time to develop good safety programs for their foundries. FEF has very high standards for membership so these schools represent the best foundry schools in the United States. Unfortunately, the author had no way of finding all schools that had a foundry program because there is not a central place to look for foundry schools. Schools that have art foundries were not considered in the survey because the author could not find a way to identify schools with this type of program. Art schools do not have an organization similar to FEF that makes it easy for students to locate schools with art foundry programs. To find universities and colleges with art foundries, the author would have had visit each art school's web page or write to the director of each art school to ask if they have an art foundry. There are hundreds of schools with art programs so taking the time to ask each and every school if they had an art foundry would have been a project itself.

2.2 Survey Results

The survey was analyzed in two different ways. Numerical analysis was conducted on all the questions where it was applicable. Open ended question answers helped the author find some good safety practices or look at safety issues he had not previously considered. Answers to multiple choice questions were studied on a percentage basis. Appendix A has tables, which summarize the results of the questionnaire.

2.3 The University Foundry Profile

Background questions included in the questionnaire gave the author an idea of what the university foundries he surveyed had for equipment, students, and capabilities. Most of the FEF key professors have worked in industry before they started teaching. Three quarters of these university foundries are primarily used to teach metalcasting to students, while others are primarily research foundries. Half of these schools teach graduate students metalcasting courses. All of the schools pour aluminum, but only a quarter also pour steel. Most of them use the green sand and lost foam processes.

2.4 Current Safety Practice in University Foundries

Survey results showed many good safety practices that university foundries are using. Three quarters of the universities preheat their melting and pouring tools and ladles. All require that safety glasses are worn in their foundry. During melting and pouring, these universities require full face shield protection. Most universities routinely check their tools and machines for excessive wear. The majority of university foundries have Material Safety Data Sheets (MSDS) for materials that are used in their foundries. About sixty percent of the schools surveyed review their safety procedures on a routine basis. Three quarters of the universities explain foundry dangers to their students.

While university foundries have some good safety practices, some of their other practices are not good for safety. Only half of the survey respondents had a written safety program. Eighty percent of them say that some, but not all, of their machines have written startup and shutdown procedures. Most universities said that they did not train people to properly lock out their machines. Sixty percent said that they do not have anyone responsible for training new personnel on foundry safety procedures. Three quarters of the universities either keep their MSDS sheets someplace other than the foundry or do not catalog and save MSDS sheets.

3.0 A Proposed University Foundry Safety Program

Using the survey as a guide, the following safety program has been proposed. Responses to the survey showed the author what parts of a safety program were important in the university setting. Combining the responses to the survey with the literature on designing a good safety program helped the author create this proposed safety program. The proposed program addresses issues such as training, which respondents felt was an important issue for a foundry safety program.[2] And issues that were not addressed by most universities(e.g., the benefits of a written safety program).[2]

An effective safety program must address the unique safety issues for the location it covers, but all safety programs have four basic ideas that make them effective. They define goals, give responsibility, give authority, and make people accountable.[6] Without these ideas forming the basis of the safety program, it is doomed to fail.

Goals

In life, nothing can happen without a goal. Goals direct and focus our energies. Usually industrial safety programs establish goals that establish limits on the number of lost work days or the frequency of accidents.[3] In the university setting, it may seem that establishing these kind of goals is inappropriate due to the up and down nature of the university foundry work cycle. Educating students on safety issues in the foundry can be a goal for a university safety program. Other valid goals include: keeping all people in the foundry safe, reducing accidents, and preventing major accidents from happening. Goals should be based on past experience with safety.

Responsibility

Without defined responsibility, people feel that safety problems are not their job.[3] Defined responsibility makes a person realize that safety is part of their job and responsibilities. When people feel responsible, they act on their responsibility and help ensure safe working conditions. Often, people correct unsafe conditions or work habits when they feel responsible for safety. The safety program should define who is responsible for each aspect of safety. For instance, one person should be in charge of overall safety, one for training new employees, and another for student safety. Each person who is involved with the university foundry should have a clearly defined safety role.

Authority

Authority must be assigned to enforce safety rules.[6] Lab instructors should have the power to dismiss students from class for safety violations. A professor who is in charge of graduate assistants must have the power to remove the assistant from the foundry for safety violations. A member of the university foundry team trains new personnel, and can stop people from using foundry equipment if they are not qualified. A faculty member makes sure that all equipment is running correctly and can have the machine shut down for repairs at anytime. There must be a clearly defined chain of authority that enforces safety protocol. Defined chains of authority make people realize that safety is taken seriously and violations will not be tolerated.

A Safety Committee

A safety committee made of concerned faculty and staff members is a good way to disseminate information and discuss issues that come up in the operation of the foundry.[6] To make the committee as small as possible only representatives of various departments and affected people should attend. For instance, a person from the industrial engineering, mechanical engineering, or any other department that teaches classes or does research in the foundry should be on the committee.[7] A staff representative should be included to give the technician's view of safety problems. The committee's purpose is to give a formal forum to evaluate and discuss safety problems. It is also used as the primary forum to judge employee's that violate safety rules. The committee should meet at least once a semester to evaluate the current state of safety in the foundry. Other meetings can be called when members want to discuss accidents or potential accidents that occurred in the foundry. Members can then make decisions on how to handle certain situations and change how the foundry functions. The representatives then take the changes back to their departments and make sure that anyone using the foundry is aware of the changes.[7] Once a year, the committee evaluates the entire safety program of the university foundry and takes any corrective actions to solve problems that are occurring frequently. Training materials should be approved by this committee so that it is uniform across all departments.

Accountability

Violation of safety protocol must be met with appropriate repercussions.[6] Students who violate safety should have an academic repercussion such as failing the lab, reducing the final grade by a letter, or failing the course. With regard to safety, graduate assistants should be treated as staff members. Staff and faculty should be routinely evaluated by the safety committee for safety violations, and terminated if they are found to be violating safety policy. The safety committee should get together and decide if a staff or faculty member intentionally caused an accident or accidentally found an unsafe condition in the foundry. Penalties for safety violations must increase with their frequency or severity. For instance, there is a big difference between the freshman who decides not to wear safety glasses one time in the foundry and a person who puts wet scrap in a furnace. By demonstrating to everyone associated with the university foundry that harsh penalties are inflicted on safety violators, safety will be considered a high priority.

A written safety program should be established for the university foundry. Unlike unwritten safety programs, people cannot dispute what the program specifies for different safety issues.[6] A copy of the safety program can be given to new members of the university foundry so that each person in the foundry is given identical copies of the safety program. It makes sure that everyone involved with the foundry is using the same set of safety rules and practices because the document can be distributed to everyone. The written program tells everyone the university's safety goals. These written goals allow everyone to work towards the same goals. When things are in writing, people are more committed to doing things that way. Written documents help focus foundry members efforts in safety. Authority is clearly defined when it is written down for everyone to see. By writing down who has authority over each safety issue, people can easily find their responsibilities for safety.

3.1 Handling Research Safety Issues

Research projects are an important part of the university foundry's work load. Every time a new research project is proposed, members of the university foundry meet together and discuss what resources the project needs. Equipment that is identified for use in the project should be checked for safe and proper operation before the project starts. Personal protective equipment (PPE) for the project should be checked for damage. Experimental procedures should be checked for unsafe actions that could put someone in danger.

Materials that are ordered or donated may pose health risks to the researchers. MSDSs for every material used in the project should be obtained and reviewed. Each MSDS should be carefully reviewed because members of the research team may have never used some of the materials in the project. Research team members who are experienced with certain materials can recommend ways to handle them. If no member is familiar with a material and the MSDS does not satisfactorily explain handling the material or if any member of the team has questions, then the material's manufacturer should be consulted. A complete copy of the MSDS for the materials used should be kept on file in the foundry, not in a researcher's office. Additional personal protection equipment needed to safely work with research materials must be purchased, and team members familiarized with its proper use, prior to the start of the project.

3.2 Safety Training for University Foundries

The biggest safety problem is that most accidents are caused by people, not by unsafe conditions.[1] Often, people do not think about possibly unsafe conditions or actions in their workplace. Students, for whom this may be their first exposure to the foundry, are unaware of the safety issues in the foundry. The only way to solve a person's ignorance of foundry safety is through training.

University foundries have several training issues that plague them. Faculty may feel that their experience in school or work has given them sufficient safety training,and they feel they do not need to be trained at their current place of employment. Staff members and graduate assistants, when they are hired, often have never worked in a foundry before. Also, students may be working in the foundry for the first time in their lives.

3.2.1 Training Faculty, Staff, and Graduate Assistants

One person involved in the university foundry should be in charge of training all personnel.[7] By placing a person in charge of training new personnel, the university can avoid a problem that many survey respondents said they had which was that they did not know who was trained for the foundry and who was not trained.[2] In fact, one survey respondent stated that the most important safety issue for foundries was making sure people were trained to work in the foundry.[2] The training supplied by this trainer is based on the written safety program of the university. By using a written safety program the trainer and the university can be sure that everyone receives the same safety instruction. The trainer should keep a list of people who have received his training and post it where people will know who is and is not trained for the foundry. By posting a list of trained people, unauthorized users can quickly be recognized and stopped from working in the foundry before they can cause harm to themselves, other people, or the equipment. After training is complete, the trainer gives the trained person access to the foundry because he now knows they can safely use the foundry.

Faculty, staff, and graduate assistants should go through safety training when they are first hired and given further training as the need arises. The training should cover all emergency signals used in the building (i.e., fire, tornado, etc.). PPEs for different foundry operations must be explained to them. General house cleaning procedures need to be imparted on the new person. They should be briefed on the proper use of all foundry equipment using manufacturer recommended procedures. Scrap and ingot storage procedures need explaining. Furnace charging, pouring, and maintenance procedures need to be explained to them. The university's policy on letting students pour molten metal or when molten metal can be poured must be clearly explained. New members must be informed of the dress code for the foundry. The entire safety program is covered by this training.

Safety training has several formats it can be taught in.[7] One is a classroom style training seminar for new members. Another form, which is often used, is on the job training. The best approach to safety training combines the two. A written copy of all policies, procedures, and machine instructions should be given to new personnel. And a minimum of two months of on the job training with an experienced member of the foundry who teaches the new person about the equipment and procedures in the foundry. The on the job training should be followed by a probation period where more experienced members make sure that all safety procedures are followed by the new person during the next three months.

3.2.2 Training Students

Students are probably the greatest safety issue for a university foundry. Typically, they are not familiar with any of the dangers in the foundry. The first laboratory session needs to be devoted to foundry safety. Students should be told to wear safety glasses at all times while they are in the foundry. Explain the foundry's dress code which requires natural fiber clothes, no open style shoes, and no shorts. If the college allows students to pour metal then they should be told what PPEs to wear and how to properly use them. Also, if students pour molten metal, they should be familiar with the pouring procedure used in the foundry. Students that do not have the proper PPEs for the pouring and melting areas must stay out of them. These areas should be clearly marked and students told to stay out of them when they do not have the proper protection on.

Sometimes students do not understand foundry safety rules or why a laboratory instructor warns a student to stop doing something. When giving safety rules, the lab instructor should explain the reason for the rule. Students are more receptive to rules when they understand the reasons for them. Also, the student learns more about the foundry environment, when the instructor explains why something the student is doing is dangerous. Even when something is not covered by safety rules it can be dangerous. An instructor who explains why an action is dangerous will help the student learn to be more safety conscious. Anytime an issue of safety comes up with a student, instructors should explain the safety issues associated with that action or actions. Through these explanations students learn more about the world than just metalcasting. These explanations make the student realize that they need to think before they act.

4.0 Proposed Safety Program Practices

Safety practices from several sources are given in this section. The survey supplied good safety practices through responses from the open ended questions. Other safety practices are from industry. Also, responses to the open ended questions helped the author to concentrate on some practices which he did not consider before. All of the following safety practices are either from the survey or literature.

4.1 General Safety

Foundries should be kept clean and orderly. The reason that foundries should be kept clean and orderly is twofold. It helps the foundry industry dispel the myth that it is dirty and dangerous. The second reason is that foundry educators provide a safe place to work and teach. Everything in the foundry should have its own place when it is not being used. Aisles should be kept free so that people do not trip over objects and fall.[3] Shadow boards with labels help to keep the foundry organized and make sure that people place things back where they belong. Loose sand, metal spills, and castings should be properly placed in the scrap bin or trash to reduce trip hazards. Water spills should be cleaned up quickly to prevent falling and explosions from molten metal contact.[8]

The foundry should have several objects labeled to aid people. Exits and emergency equipment should be clearly marked with instructions on how to use them. The melting and pouring area should be clearly marked to make people realize that it is a dangerous area. Scrap and ingot storage should clearly label which alloys are stored where to keep people from mixing different alloys. Any place that is a hazard should also be marked off to let people know of the danger.

Conditions in the foundry can affect the human body, but two of the most important conditions are the materials used in the foundry and the large amount of heat the foundry produces. Many regulations state that people need to know how materials will affect their health. MSDS sheets have the information which explain how a material will affect the human body. Often, universities file the sheets in someone's office.[2] Prolonged exposure to heat can have a drastic affect on the human body. Our bodies are not designed to work at elevated temperatures for long periods of time.

4.1.2 Material Safety

Any chemical in the foundry must have an MSDS sheet for it. However, most schools place their MSDS sheets in some location other than the foundry.[2] This practice is highly frowned upon by medical personnel. The Emergency Medical Service personnel at Worcester Polytechnic Institute strongly urge that MSDS sheets are kept in the laboratories so they can quickly evaluate risks to themselves and their patients. Often, MSDS sheets contain instructions for first aid that is invaluable in saving lives. The author recommends a copy of the MSDS sheet for every chemical or material used in the foundry be placed in a clearly marked location inside the foundry.

4.1.3 Heat Exhaustion

Caution should be taken when wearing all of the protective gear foundry operations require. Wearing multiple layers of heavy protective clothing can significantly contribute to heat exhaustion. Lab instructors and other people working in the foundry should be trained to recognized the effects of heat exhaustion and heat stroke. Both of these can be avoided by taking frequent breaks in a cool place and drinking water.

Heat exhaustion occurs when the body's cooling system becomes overworked.[9] Heat exhaustion can affect a person outdoors or in a hot room. Symptoms can include the following: headache, muscle cramps, and weakness.

FIRST AID

1. Have the victim lie in a cool place with their feet raised. Remove excess clothing.
2. Cool the victim by applying cool, wet cloths to the victim's body and by fanning the victim.
3. If the victim is fully alert, let the victim sip from a glass of water which you have added a pinch of salt.
4. Recovery should be rapid. If symptoms persist, call for medical help.

Heat Stroke happens when a victim's cooling system is so overworked that it stops functioning.[9] The victim's temperature soars to life-threatening levels. Symptoms can include the following: very hot skin, red skin, they can be dry or damp with sweat, rapid and quick pulse, noisy breathing, confusion and irritability, unwillingness to accept treatment, or unconsciousness.

FIRST AID

1. Get emergency medical help immediately.
2. Move the victim to a cool place.
3. Cool the victim in any way you can. Remove all outer clothing and sponge the victim with cold water. Cover the victim with wet towels, wet clothing, or whatever is handy and fan the victim. Put the victim in front of an air conditioner. You can use any combination of all the available treatments.
4. Keep the victim lying down and comfortable with their head and shoulders slightly raised.
5. Watch the victim closely. Their temperature could go up more, they might vomit, and may need rescue breathing.

4.2 Equipment Safety

Machines and other equipment have safety issues associated with them. These issues must be addressed for a safe foundry. People need to know how to operate these machines properly so they do not hurt themselves or others. The equipment should be checked for unsafe conditions.

4.2.1 Startup and Shutdown Procedures

Academic foundries use an assortment of different machines to teach and perform research, but many university foundries only have startup and shutdown procedures for a few of their machines.[2] Many of the machines have specific startup and shutdown procedures to prevent harm to people and the machine.[3] Sometimes the function of a machine can be adversely affected by improper startup or shutdown of the machine. Often manufacturers supply instructions on how to startup and shutdown their machines, but these instructions are not posted since they can be easily lost. Even machines that are commonly used in many industries need to have startup and shutdown procedures. Students need to know how to properly start and stop these machines. It is imperative that written instructions are posted on all machines.

Written instructions for foundry machines cover startup, shutdown, and safe operation. Startup procedures instruct the operator as to which buttons, levers, switches, etc. to push in a specific order to start the machine. The startup procedure should be made as safe as possible to prevent harm to people and the machine.[3] Any calibration steps that are needed for the machine to operate should be put in the startup procedure unless they are not required every time the machine is turned on. Shutdown procedures cover the steps to turn the machine off. The shutdown procedure should turn off all possible sources of energy from the machine and render it inoperable.[3] Buttons, levers, switches, etc. on the machine should be clearly labeled to help operators identify them. After the procedure is written it should be posted on the machine in a plastic protective sheet to help people operate the machine properly. See Appendix B for an example.

4.2.2 Lock Out

Even if startup and shutdown procedures are posted people can use a machine incorrectly. Through training people can be made aware of the dangers that machines present. The best way to prevent unauthorized use of machines in the academic foundry is by locking out the machine's energy sources. By eliminating energy sources to the machine, the machine can be rendered inoperable. Energy sources should be locked with a lock that only trained personnel have the key to it. Energy sources can be air, gas, electrical, mechanical, hydraulic, or anything else that the machine needs to operate.[7] By isolating the machine from energy sources, unauthorized people cannot run the machine. When machines are not in use, they should be brought to a zero energy state, a state where there is no energy coming into or stored in the machine, and locked out to prevent unauthorized people from operating the machine.[3] Also, the foundry itself should be locked when it is not being used. These steps help to prevent unauthorized use of foundry machines and keep people from being harmed.

4.2.3 Evaluating the Safety of Foundry Machines

When new equipment arrives in the foundry, there is a flurry of activity. A place has to be cleared for it, energy services brought to its new location, ventilation may need to be increased. Sometimes, the one thing not looked at during installation is safety; it is an after thought. Safe operation of the machine should be the utmost priority. When a new machine comes in, a group of professors, technicians, and staff members should take a look at the operation of the machine. Pinch points, moving blades, and other unsafe conditions should be identified in the drawings and other manufacturer supplied information. Sometimes guarding supplied on machines is inadequate for a university foundry setting. Additional guarding may need to be added to provide good protection from danger. Signs that warn people about the hazards of the machine are made and posted in a protective sheet near the machine. Special tools may need to be made to make the machine safer. Fixtures may need to be made to help the machine accomplish its intended task.

Machines naturally wear as they are used. Excessive wear can cause the machine to become unsafe and extremely dangerous. Before the start of each semester machines that are used in class should be checked for excessive wear or damage and repaired before classes start. Before research projects are started, every machine that will be used to perform the research should be checked for damage and unsafe operation. Flaws in procedures, guarding, or tooling should be changed as soon as possible. After classes or research projects finish, machines should be checked for excessive wear or damage that makes the machines dangerous.

4.3 Melting and Pouring Practice

The most dangerous part of metalcasting is in melting and pouring metal. The foundry can be approached like any other laboratory with respect to safety, but once metal is being melted it is unlike any laboratory at a university. Burns can occur when a hot casting, pigmold, or molten metal comes in contact with a person. Hot ingots or pigs can fall on people's feet. Sharp scrap can cut a person while they are placing it in the furnace, which may cause molten metal to splash on them. For these reasons, great care should be given to this phase of the laboratory session.

Injuries in the foundry can be prevented in several ways. Personal protective equipment prevents people from receiving burns when hot metal contacts their skin. Good metal charging and storage procedures minimized the likelihood a furnace will explode. Tool maintenance and repair makes sure that equipment failure does not cause injuries to people using those tools.

4.3.1 Personal Protective Equipment in the Foundry

Eye and face protection is needed to guard against molten metal splashes. Safety glasses with side shields are the minimum protection around molten metal. Face shields should be worn in addition to safety glasses with side shields when greater exposure to molten metal splashes occurs, during degassing, fluxing, drossing, pigging, and pouring.[8]

Good foot protection should be worn at all times. When working with molten metal, laceless safety toe shoes or pourer's (molder's) boots are recommended.[8] These types of shoes can be easily removed if molten metal enters the shoe. Laced safety boots can be worn if they are covered with spats to prevent molten metal from entering them. When molten metal can enter the wearer's shoes, leggings with spats should be worn to prevent metal from entering their shoes.[8] It is also good practice to wear spats over laceless safety shoes to provide extra protection from molten metal.

Industrial, heat resistant, and flame retarding gloves should be worn around the furnace and other hot surfaces to prevent burns. The best protection is provided by gloves that cover well above the wearer's wrists.[8] Gloves that provide cover above the wearer's wrists reduce the risk of molten metal entering the glove and burning the wearer.

Ordinary work clothing that protects the wearer from minor cuts and abrasions is not sufficient to protect people near the furnace. These work clothes do not protect people from burns, especially when molten metal is involved. Synthetic materials and synthetic blends offer no protection to foundry personnel.[8] Natural fiber clothing should be worn by people that are not exposed to molten metal, typically students.

There are two types of clothing used around the foundry: secondary clothing and primary clothing. Secondary clothing is used when people have intermittent exposure to molten substances.[8] Secondary clothing is designed to stop burning when the ignition sources is removed. This clothing is often made from specially treated wool, cotton, and non-melting synthetics. Primary clothing is for during casting, melting, or other operations that require significant exposure to molten metal.[8] Jackets, aprons, chaps, leggings, and spats made from materials that can withstand the assault made by molten metal are examples of primary clothing. Two students are fully clothed with face shields, long gloves, spats, and safety glasses in Figure 4.1. Anyone working with molten metal should wear this, or similar clothing. The materials used in these garments are aluminized fabric, leather, specially treated wool, or specialized synthetic fabric (such as FR-9B).[8] Primary clothing should be worn over secondary clothing to give the wearer the maximum possible protection.

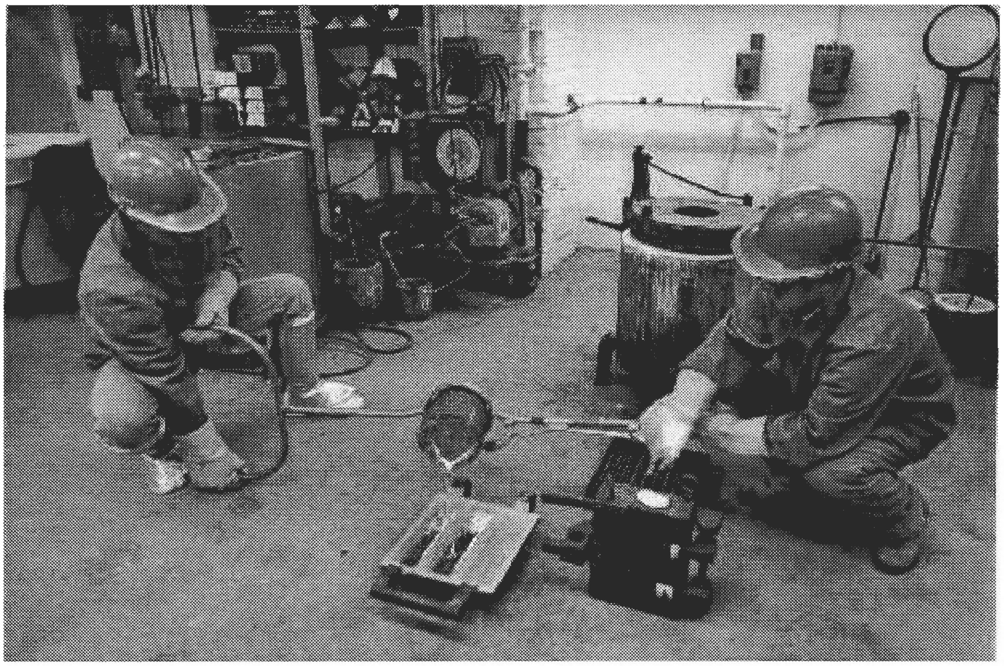

Figure 4.1 Students wearing primary clothing pour metal in the Aluminum Casting Research Laboratory

4.3.2 Metal Storing and Charging Practice

One survey respondent wrote, "The effect of molten metal and moisture coming in contact with each other,"when asked what the most important safety issue was in the university foundry.[2] When water is trapped under the surface of molten metal, the water will turn into superheated steam and propel itself and the molten metal above it out of the furnace. Molten metal explosions like this are called "steam-trap" explosions. When aluminum is melted at 1263°F, trapped water expands to 1900 times its original volume.[8] Such a large increase of volume demonstrates why these explosions are so violent. Charge materials that have moisture in or on them can create conditions in a melt for an explosion like this. Water on charge materials can take several forms from surface oxides to condensation.

Charge material should be inspected when received. The inspector should look for any unusual amounts of surface oxides which often chemically combine with water which cannot be driven off during preheating.[10] Pieces with these extra oxides should be treated with extra care when they are being added to the melt. The safest method of using these pieces is to use them as part of the initial charge material so that the water can be driven off from the oxides. By using these pieces first, they can safely reach temperatures in excess of 600°F, which are needed to drive out the water.[10]

After inspection, charge materials should be stored in a clean, warm, dry place. Moisture pick up during storage is common in industry.[10] Condensation can build up on materials during storage. This occurs when the temperature of the charge material drops below the dew point of the surrounding air. If ingots or pigs are stored skim side up then it is possible for condensation to puddle on the top of the ingot or pig and seep down in it's shrink cavity. Therefore, it is recommended that ingots and pigs are stored skim side down during storage.[10] In Figure 4.2, pigs are shown skim side down in storage. The storage room should be kept reasonably warm to reduce the risk of condensation occurring while charge materials are being stored.

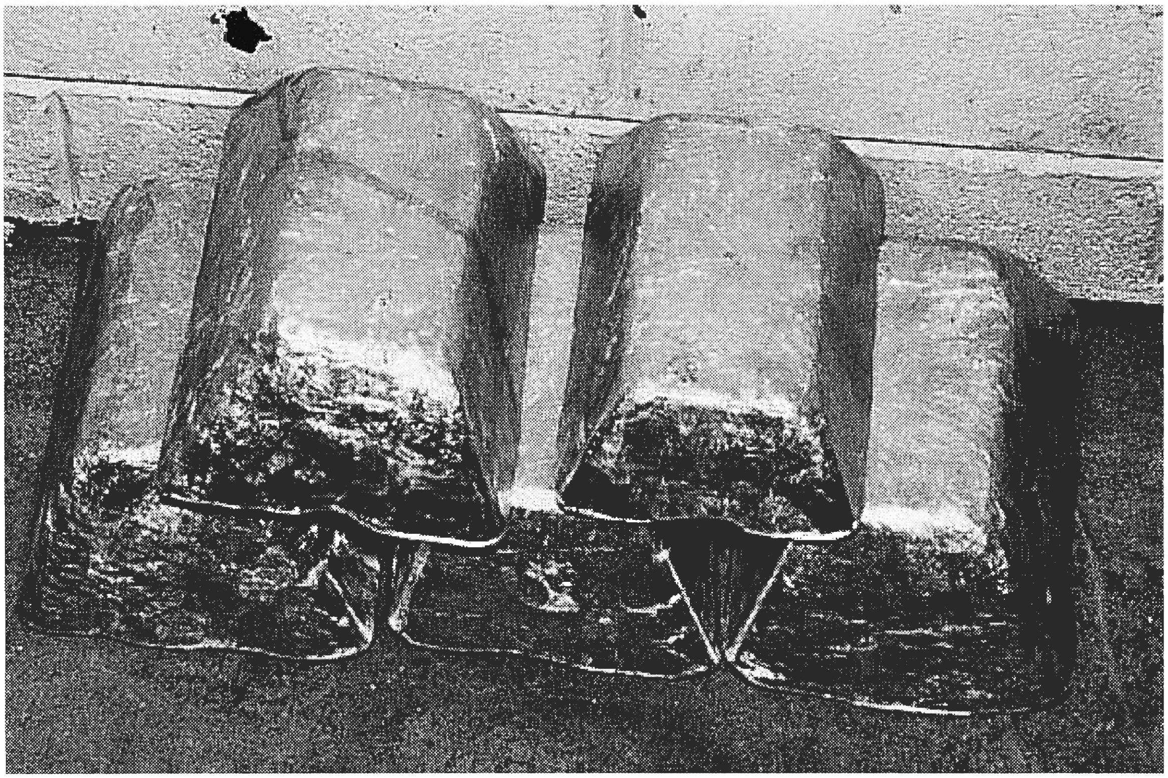

Figure 4.2 Pigs being stored skim side down.

Charge materials should be preheated to dry off water before being added to molten metal. Also, charge materials should be allowed to sit in the foundry for several hours before using them to help dry off some of the moisture. A preheat furnace or the ledge of the melting furnace should be used to dry off the scrap. Ingots and pigs should be placed skim side down in the preheat furnace or on the melting furnace's ledge to facilitate drying their shrink cavities. Charge material should reach a minimum temperature of 400°F before being added to the melt.[10]

The Aluminum Association's *Guidelines for handling molten aluminum* recommends the following order for charge materials [8]:

a. Dry light scrap (including dry chips or scalpings)

b. Dry medium scrap

c. Dry heavy scrap

d. Sows, coils, ingots

4.3.3 Melting and Pouring

Like charge materials, foundry tools can accumulate moisture and oxides on them.[8] Tools that are for nonferrous castings should be coated with a refractory wash to prevent the metal from coming into contact with rust on the tool. Aluminum in particular reacts with rust. If aluminum oxide comes in contact with rust it can create a thermite reaction or explosion.[8] All tools need to be preheated before use. This can be accomplished several ways. A large burner for preheating ladles can also preheat foundry tools. Tools can be placed on the furnace ledge or cover to preheat them. Crucibles and ladles need to be preheated before metal is added to them. Preheating tools is very important since it is possible for water on the tool to be trapped in the melt and cause an explosion. Degassing equipment should be preheated before use. One possible way to preheat this equipment is to allow it to sit above the furnace for ten minutes before submerging it into the molten metal. It should be apparent that any equipment that will come in contact with molten metal must be preheated before it is used.[8]

Equipment should be routinely checked for wear and tear. Tools that have protective washes on them should be routinely examined for bare spots on the tool. Tools that have bare spots should be recoated and allowed ample time to dry and cure before their first use. Degassing equipment, pyrometers, or any equipment that is submerged into molten metal should be checked for worn or crumbling components. Crucibles and ladles should also be checked for excessive wear. Any equipment that is excessively worn or not operating correctly should be removed from service and promptly repaired or replaced before they can be used again.

Prior to pouring castings several steps must be taken to ensure people's safety. Pourers must put on primary protective clothing to protect them from metal splashes. Anyone who is not pouring must leave the pouring area. Pourers should make a couple of dry practice pours before actually pouring castings.[2] Everyone in the foundry should make themselves aware of where all of the exits and emergency equipment so in the event of an accident people can act appropriately.[2]

The pouring area should prevent molten metal from coming in contact with water or people. Loose molding sand should be placed on the floor around the molds to prevent molten metal from running toward the pourer if a mold breaks out. Castings should be poured on sand, firebrick, or any other dry surface.[8] Concrete floors soak up water from the ground like a sponge. If hot metal comes in contact with damp concrete then an explosion that flings hot metal and concrete fragments around can occur, which is caused by the water in the concrete turning into super heated steam. An organic coating can be applied to the foundry floor to prevent these concrete explosions.[8]

4.4 Shake Out Safety

The short length of the university laboratory session requires that castings be shaken out from the mold while they are hot. Personnel should wear face shields to protect their faces from hot gases that arise during shakeout. A pair of tongs should be used to lift the casting from the sand. Hot sand, whether bonded or unbonded sand, should always be handled with a shovel.

4.5 Quenching Castings Safely

In many instances, cast components have to be heat treated to bring about special properties. Quenching is often a part of the heat treatment schedule. Hot castings should be carried with tongs to a quench tank and immersed into the water. Tongs used to carry castings to the quench tank should never be used to load metal in to the furnace. The quench tank should be located in the finishing area far removed from the pouring area.

4.6 Finishing Cast Components

Safety in the finishing area is like safety in any laboratory that has machines. Care should be taken when working around all machines. Safety glasses with side shields protect students and instructors from flying chips. Gloves should be worn to protect people from sharp edges on castings. All castings should be cooled enough to prevent people from being burned during finishing.

A band saw is commonly used to remove the sprue, risers, and gating system from a casting. The band saw operator should always wear safety glasses when using the band saw. Gloves should never be worn while working with a band saw because the gloves can get caught and pull the person into the blade. Castings should be supported during sawing so that the saw blade does not yank the casting down. Irregularly shaped castings can be made stable on the band saw table by shimming them up with wooden blocks. An assortment of wooden blocks for degating castings is shown in Figure 4.3. A collection of different sized blocks should be kept next to the band saw to encourage operators to use them in stabilizing their castings. Figure 4.4 shows a casting stabilized by wooden blocks during degating. A push block should be used to push the casting through the band saw, which reduces the operator's exposure to the moving blade. Operators should know how to move the blade guard as close as possible to the casting. The blade guard, when properly used, reduces the operator's exposure to the moving blade.

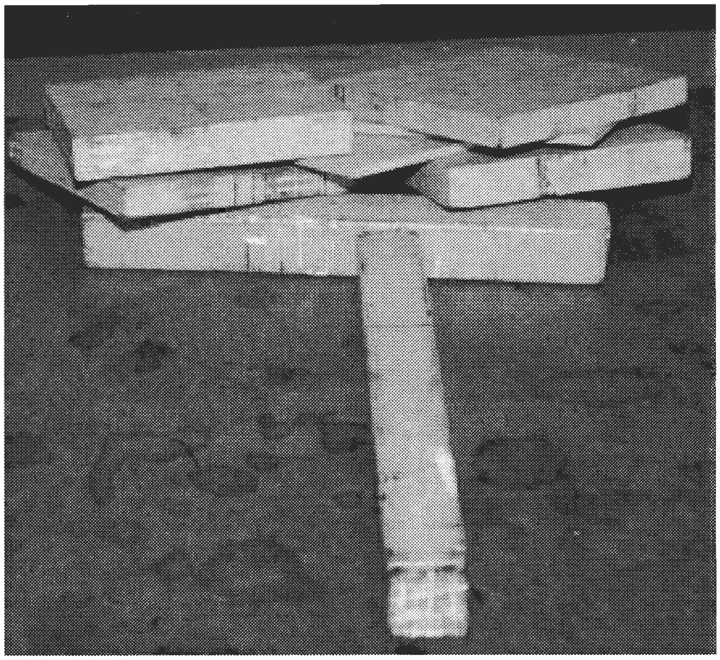

Figure 4.3 Assortment of blocks used to support odd shaped castings

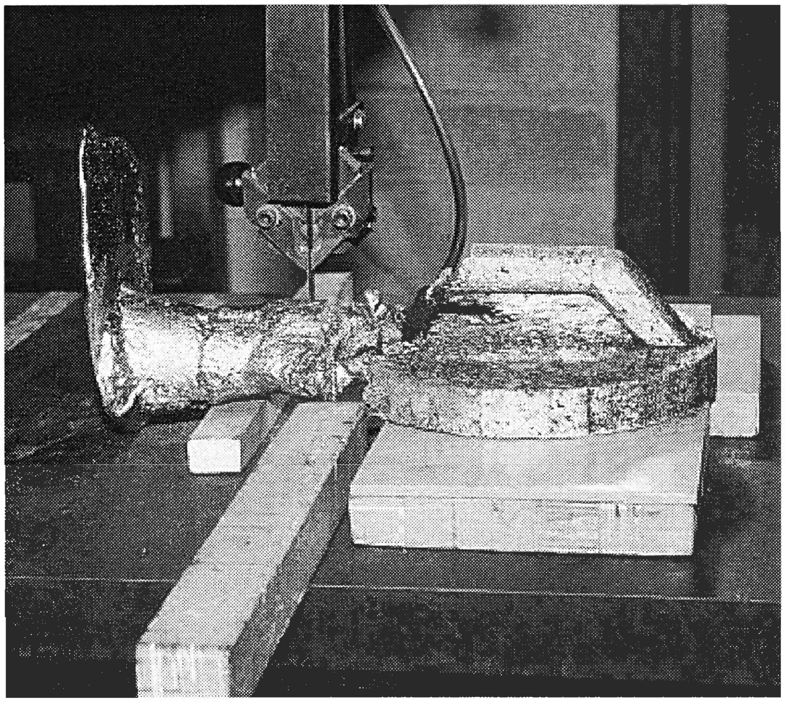

Figure 4.4 Oddly shaped casting being degated with support and push blocks.

5.0 Closing Remarks

The growing emphasis on safety is driven by several factors. Engineering students need a safety mindset to design new machines and technologies to avoid mistakes made in the past. Only by making students understand why different situations are a safety issue can they gain experience to design and use safe technologies. More and more universities use safety programs to limit their liability for dangerous education functions. A safety program must meet all of these needs for it to be successful in the university foundry setting.

The author's proposed safety program outlines a basis for implementing a safety program in the university foundry. The proposed program allows enough flexibility to be implemented at different locations. Safety practices that should be adopted by every university are outlined and explained. Best safety practices from several different universities were used to form many parts of the proposed program.

As mentioned in the introduction there is very little literature on university foundry safety programs. The survey the author conducted has been used as the primary source of information on the safety needs of university foundries. Survey responses have helped the author focus on the most important safety issues for university foundries. Literature for industrial foundries was adapted to work in the university setting based on the survey.

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Appendix A

Foundry Education Foundation School Survey and Results

Circle your answers. Please fill out all the sections with the answers that are provided. If an answer doesn't fit your situation then try to circle the answer that is closest to your situation. Please mail the survey by using the enclosed envelope to send it back to me. Also, separately mail the enclosed post card so that I know which schools have responded without being able to link that school with a particular survey. No names of participating schools or contact people will be used.

General Information

Did you work in industry before you started teaching?	Yes	No
If Yes, How many years did you work?	_______	
How many years have you taught foundry courses?	_______	
Per academic year, How many students(graduate, undergraduate) use your foundry?	_______	

Foundry Use

Is your foundry primarily used for research?	Yes	No
Are graduate students taught in your foundry?	Yes	No
Do undergraduate students take courses in your foundry?	Yes	No
Do professors or technicians pour metal?	Yes	No
Do graduate assistants pour metal?	Yes	No
Are students allowed to pour metal?	Yes	No
Do you cast aluminum?	Yes	No
.... iron?	Yes	No
........................steel?	Yes	No
.........................bronze?	Yes	No
........................brass?	Yes	No
........................copper?	Yes	No
.........................other? (please fill in the blank)	_____	
Do you use the green sand process?	Yes	No
.........................lost foam process?	Yes	No
.........................investment casting process?	Yes	No
.........................shell process?	Yes	No
.........................other? (please fill in the blank)	______	

Melting Practice

N/A means not applicable

Do you melt scrap?	Yes	No	N/A
Do you melt ingot?	Yes	No	N/A
Is your scrap stored in a dry place?	Yes	No	N/A
Do use your biggest scrap to initially charge your furnace?	Yes	No	N/A
Do you preheat scrap that you are adding to molten metal?	Yes	No	N/A
Are your ladles, crucibles, skimmers and other melting tools preheated?	Yes	No	N/A
Do you preheat ingots that you are adding to molten metal?	Yes	No	N/A
Is your degassing equipment preheated before use?	Yes	No	N/A

Pouring Practice

N/A means not applicable

Do you preheat your pouring ladles?	Yes	No	N/A
Is sand placed on the floor to keep metal from contacting the floor?	Yes	No	N/A
Are permanent molds preheated before use?	Yes	No	N/A

General Foundry Safety

Do your machines have written start up, and shutdown procedures?	Always	Sometimes	Never
How often are safety glasses worn in your foundry?	Always	Sometimes	Never
Are steel toe shoes worn by personnel who pour or melt metal?	Always	Sometimes	Never
Do melting and pouring personnel wear full face shields?	Always	Sometimes	Never
....leggings?	Always	Sometimes	Never
....aluminized gloves?	Always	Sometimes	Never
....aluminized jackets?	Always	Sometimes	Never

Are the tools that come into contact with molten metal coated with a ceramic slurry?	Always	Sometimes	Never
Are energy neutralization (lockout) procedures written for every machine in your foundry?	Always	Sometimes	Never
Do all personnel use these procedures?	Always	Sometimes	Never
Are hand tools routinely checked for wear?	Yes	No	N/A
Do you check for excessive wear on crucibles?	Yes	No	N/A
Routinely do you look for wear on your foundry machines?	Yes	No	N/A
Are crucible tongs and shanks checked for wear?	Yes	No	N/A
Do you have MSDS sheets for materials in your foundry?	Yes	No	N/A
Are they posted in the foundry?	Yes	No	N/A

Safety Training

Do you have a written safety program?	Yes	No
Do you train people in energy neutralization(lockout) on machines?	Yes	No
Are all personnel trained in this?	Yes	No
Are new professors, technicians, and grad students given safety training for your foundry?	Yes	No
Do you have a person in charge of training new personnel?	Yes	No
" routinely evaluate your safety procedures?	Yes	No
" explain to students the dangers in a foundry?	Yes	No

If you need more space to answer the following questions please write on the back.

What do you think is the most important issue in university foundry safety?

If you think you handle a particular foundry safety issue well could you explain what you do?

Thank you for taking the time to fill out this survey. If you have any more comments on your safety program, foundry safety in general, or issues you would like to see looked at then please write them on the bottom or back of this survey.

The summarized results from the survey are in the following tables. Questions are numbered from the first question asked to the last. Any questions that required survey respondents to fill in a answer are not summarized.

Questio	Yes	No
1	92	8%
	Average	Std Dev
2	5	5
3	18	11
4	135	204

Questio	Yes	No
5	25	75
6	50	50
7	92	8%
8	100	0%
9	67	33
10	92	8%
11	100	0%
12	42	58
13	25	75
14	58	42
15	42	58
16	42	58
17	50	50
18	67	33
19	75	25
20	58	42
21	42	58

Questio	Yes	No	Not Applicabl
22	67	33	0%
23	92	8%	0%
24	67	0%	33
25	58	17	25
26	58	8%	33
27	75	17	8%
28	67	25	8%
29	58	8%	33
30	75	8%	17
31	25	33	42
32	50	8%	42

Questio	Always	Sometimes	Never
33	8%	83	8%
34	100	0%	0%
35	8%	67	25
36	100	0%	0%
37	58	25	17
38	75	25	0%
39	50	33	17
40	33	42	25
41	17	50	33
42	25	42	33

Questio	Yes	No	Not Applicabl
43	83	17	0%
44	100	0%	0%
45	83	0%	17
46	83	17	0%
47	92	8%	0%
48	25	67	8%

Questio	Yes	No
49	50	50
50	42	58
51	42	58
52	67	33
53	42	58
54	58	42
55	75	25

Appendix B

Sample Machine Startup and Shutdown procedures

Operation of the Gas Fired Crucible Furnace

Exhaust Fan:

1. The exhaust fan in the foundry laboratory must be operating at high speed or the furnace will not start. Locate the Johnson Controls Auxiliary Heating and Ventilating Control unit on the wall behind the sand muller in the south center of the laboratory.

2. Turn the **vent damper control**, located on the bottom center of the Johnson Control Unit, completely counter clockwise. This will start the exhaust fan and bring it to the high speed position. The exhaust fan must be at high speed operation in order for the furnace to operate. Sometimes the exhaust fan is slow to start.

Gas Fired Crucible Furnace:

1. Open the **main gas valve** located above the furnace hood near the furnace controller on the left side of the furnace.

2. The furnace control temperature is set on the controller for normal instructional use. If you need to adjust the furnace holding temperature, contact one of the technicians.

3. Turn the **main control switch** on the furnace controller located on the left side of the furnace to **ON**. The furnace blower will now start up and run for a short time to purge the burner system. Next the system will ignite the pilot flame, open the gas flow and start the low flame burner and finally increase the gas flow and start the high flame burner.

4. When the furnace reaches the setpoint, the high burner will go off and the low burner will fire to maintain the temperature. If the temperature drops too low from the furnace set point, the high flame will again be activated to bring the temperature back up to the set point.

5. During the operation of the furnace, the furnace will cycle between high burner and low burner to maintain temperature. The sound of the furnace burner will get softer and then louder when this occurs. This is normal.

Ladles and Skimmers:

1 All ladles and skimmers must be preheated before being used each day. Place the ladle upside down **next to** the exhaust port on the cover of the furnace for 15 minutes prior to using it. **DO NOT place** the ladle over the exhaust port blocking the exhaust from the burner.

2. Ladles are filled by sweeping the surface of the melt with the back side of the ladle and then sweeping forward to fill the ladle. Remember that a ladle can ONLY effectively hold about 3/4 of its capacity. Use either the 5 lb or 10 lb ladle based upon the volume of molten metal need for the mold.

Skimming:

1. The ladle should be place on the sand bed in front of the furnace and held by the pourer. A second person should sweep the surface of the ladle with the 2" dia. skimmer to remove dross and flux. DO NOT pull on the ladle lining to remove solidified aluminum skulls from the ladle.

2. The dross and flux should be placed in the dross can at the left side of the furnace.

Pouring the molds:

1. ALL MOLDS, whether they are green sand molds or lost foam molds, must be place **under the furnace hood** either to the right side of the furnace or in front of the furnace. MAKE SURE that the molds are placed properly before proceeding with the pouring.

2. Check all green sand molds to be sure that the flasks are completely closed at the parting line.

3. Place some **sand** (green sand for green sand molds and unbonded sand for lost foam castings) **on the floor around the molds** to trap the metal in the event of a runout or spill during pouring.

4. The pourer should pour the metal at the ladle temperature designated by the team leader or the instructor. When the mold is poured, the remaining metal in the ladle **should be poured into one of the pig molds** located to the left side of the furnace.
NO STUDENT IS TO POUR MOLTEN METAL FROM A LADLE BACK INTO THE FURNACE.

Furnace Tilting:

1. The furnace may be tilted to make it easier to ladle metal out of the furnace. Push down on the **RAISE** button located on the left front of the furnace. The furnace will stop raising and maintain its position when the **RAISE** button is released.

   If the high flame burner is actuated when the furnace is raised, the burner will drop to the low flame operation to minimize the flame impingement toward the furnace operator.

   The high flame burner cannot operate with the furnace titled above about 30 degrees. Therefore, the furnace must be lowered to the level position to maintain the furnace temperature.

   The furnace can be lowered by pressing the **LOWER** button located on the left front side of the furnace.

   The furnace should be lowered to its level position when no ladles are being filled to permit the high burner to operate.

Emptying the Furnace:

1. At the end of the day (or the end of the last laboratory session in the day), the molten metal in the furnace must be emptied into the pig molds. The metal in the furnace should be ladled from the furnace and poured slowly into the pig molds located to the left of the furnace.

   If the pig molds are all full and there is still molten metal in the furnace, the molten metal MUST still be emptied. When the ingots in the pig mold are solid, (**tap the top of the ingot with the ingot mold wrench to verify that the ingot is solid),** the ingot molds can be emptied out onto the flour below them. The ingot molds can then be filled with more metal.

2. If the furnace was tilted to aid in ladling from the furnace, the furnace must be **returned to the full level position** before the burner is shut off.

3. Push in the **STOP** button on the front of the furnace controller on the left side of the furnace. This will shut off the burner and the controller gas line.

4. Close the **main gas line** which is located above the exhaust hood near the furnace controller. The gas line is closed when the valve handle is perpendicular to the gas line.

5. Shut off the auxiliary lights under the pouring hood at the **switch on the**

column to the right of the furnace near where the lost foam drums are kept.

6. **DO NOT SHUT OFF THE EXHAUST FAN.** The exhaust fan is left running for four to six hours after the operation of the furnace to clear the room of any odors from the pouring operation.

Furnace fails to start:

1. Check to see that the exhaust fan is operating at **HIGH** speed. The furnace is wired so that it will only operate when the exhaust fan is operating at high speed.

2. The furnace will shut itself down prior to the laboratory with the **Fire eye Flame Safety System.** (The fire eye system couldn't detect a flame at the burner and shut off the gas supply. The Fire eye Flame Safety system must be reset.)

   Open the furnace controller cabinet on the left side of the furnace. Move the controller unit itself to the left side of the cabinet on its hinges. The Fire eye Flame Safety module is located at the back of the cabinet. Push in the **RESET** button on the Fire eye Flame Safety console and the furnace should be reset.

2. Look at the side of the furnace. If the furnace is not in the full down position, then the bottom safety switch will not be contacted and the furnace will not start.

3.

   The furnace **cannot be lowered** with the LOWER button on the left side of the furnace unless the burner is operating.
   Contact one of the technicians who can override the offending limit switch and start the furnace.

4. The electrical breaker for the furnace controller, the burner blower and the hoist motor is blown. The power panel that contains the breaker is located in the next room of the laboratory on the north wall right behind the double doors from the main foundry. The breaker is marked. Reset the breaker by pushing it to the full **OFF** position and then pushing it to the full **ON** position..

5. The main gas line to the entire building has been interrupted due to a lightning strike near the building, a power loss to the building or a fire somewhere in the building. Any one of these events will cause the Maxon main line safety valve to close the main gas system to the building. The Maxon valve is located in the fire pump room on the first floor of the building in the south west corner high on the ceiling. Contact one of the technicians to reset this valve.