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A Technical Paper on Automated Pouring and the Selection Process Used by One North American Foundry

R. Stanley Weaver

University of Northern Iowa

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Abstract

This report on automated pouring focuses on the selection process used by one North American iron foundry. The problem facing this facility and any operation wishing to implement this technology lies in the number of variables which must be addressed in their quest for a suitable system.

A TECHNICAL PAPER ON AUTOMATED POURING AND THE SELECTION PROCESS USED BY ONE NORTH AMERICAN FOUNDRY

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R. Stanley Weaver
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CHAPTER 1

Introduction

Automated pouring is an established, viable process used by foundries throughout the world. Appendix B provides the reader a short list of companies using this technology and their locations. Rodgers (1988) states, "many foundrymen realize that in all probability pouring molten metal is the most critical step of all" foundry operations (p. 36).

Whether used to pour ferrous or non ferrous metals, automated pouring provides the foundry industry many opportunities for improved manufacturing efficiency. Its importance lies in its placement in the casting process, dead last. Metal pouring, the filling of a mold, completes the cycle in creating a new casting. If the pour is successful, a quality casting meeting the customer's specification will result. If however some anomaly occurs during the pour, many resources, including labor and materials are wasted.

Background of the Problem

Productivity, the measure of performance output gauged against the sum total inputs required for that output must balance in favor of the producing company. One aspect of a foundry's loss in productivity is highlighted by Kanicki and Krohn (1984). They wrote, "There is no other scene that quite depicts the overall foundry operation as that of pouring off (filling of the mold). It makes for dynamic photographs with the fireworks of sparks and the glow of intense radiant heat" (p. 22).

The "fireworks" and "radiant heat" in their description are the wasteful result of spilled metal outside of the mold. This spillage provides no added value to the casting, rather it penalizes the foundry's customer by inflating the cost of molten metal.

Statement of the Problem

This report on automated pouring focuses on the selection process used by one North American iron foundry. The problem facing this facility and any operation wishing to implement this technology lies in the number of variables which must be addressed in their quest for a suitable system.

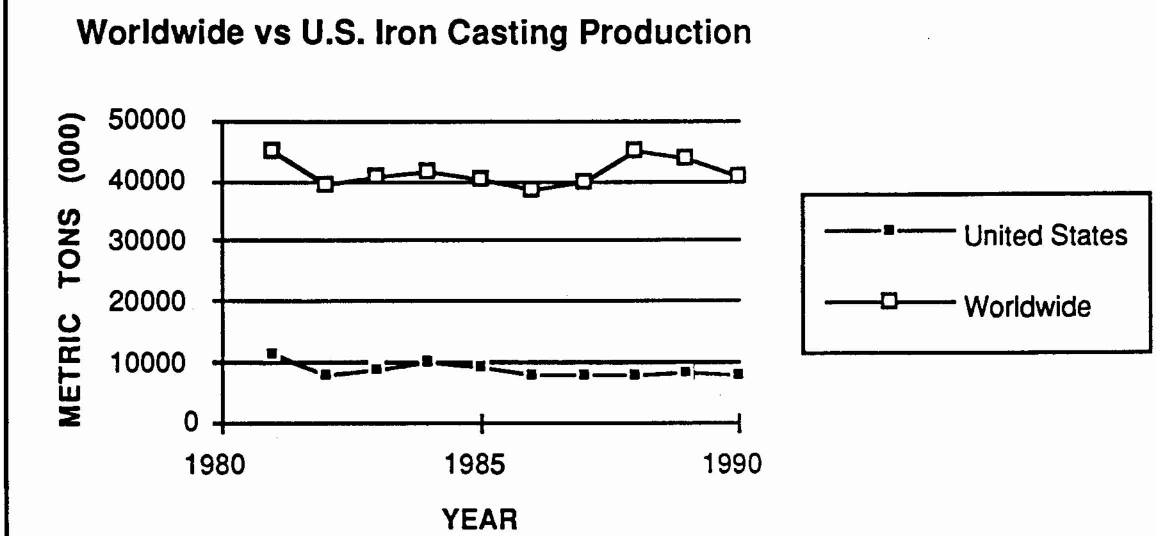
Statement of Purpose

This report documents the selection process and highlights many of the system variations found during the investigation. The study developed a list of criteria by which an automated pouring system and it's related equipment could be selected as most appropriate for the facility.

Statement of Need

Worldwide production of iron castings has declined during the past decade. A graphic representation of this trend is shown in Figure 1. The values shown are sourced from 10 years of the American Foundrymen's Society publication, Modern Casting.

Figure 1. Worldwide vs. U.S. Iron Casting Production.



Note: Graphical representation of data provided in Modern Casting ("25th Census of World Casting Production — 1990", et al.).

While modest gains and losses are depicted worldwide, North American production has remained essentially flat since 1985. With increasing pressures brought about by stable or shrinking markets, foundries throughout the world have turned to technology for improved productivity. Innovations are possible in many facets of the foundry operation, in particular, automated pouring systems have developed into a premiere candidate in reducing foundry costs. Research conducted by the International Metalcasters Council, Inc. (IMC) concluded that North American Foundries can save over $83 million in hot metal costs by installing automated pouring control systems ("Study shows Automatic," 1989).

The creation of a casting occurs when molten metal enters the mold and begins to solidify, taking the shape provided by the internal mold contours. While it may not be the final step in a string of processes used to produce a casting, it may well be the most important (Rodgers, 1988).

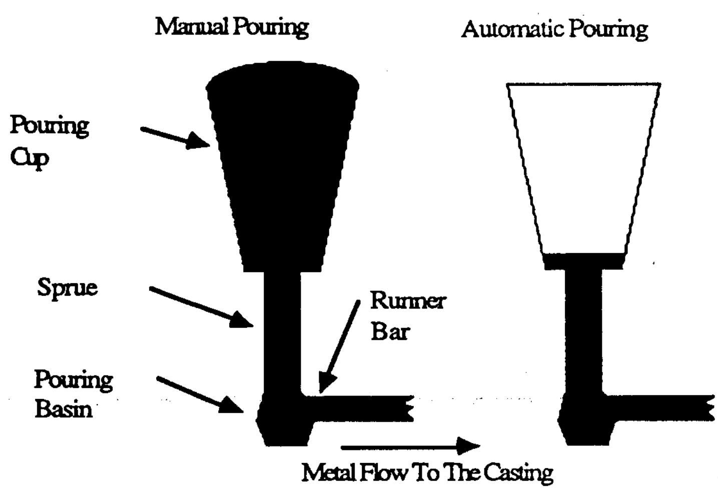
The complexity of the pouring process is not readily seen by casual observation of a pouring operation. Campbell (1991) provides a vivid description by writing, "The first moments of creation of the new casting are an explosion of interacting events; the release of quantities of thermal and chemical energy trigger a sequence of cataclysms" (introduction). Bex (1992) recounts Campbell by commenting on the "enormously complex and violent birthing pangs that are the culmination of the metal casting process" (p. 26). Both writers emphasize the complex interactions present when 2,700° F molten iron enters a mold whose temperature is fifteen to twenty times cooler.

With such violent and complex chemical and physical changes taking place in the mold it is difficult to understand how an automated system can overcome the what seems to be an insurmountable task. Manual pouring, using a tilting ladle controlled by a human, has long been the means utilized for mold filling. According to Bex (1992), it remains the choice for most foundries. However, advances in automated pouring technology have lead to greater accuracy and increased flexibility in the pouring process. These improvements "are making automatic pouring a more viable alternative to manual pouring" (Rodgers, 1986, p. 28).

Automation of the pouring process provides the foundry a new tool for controlling process variables not possible through manual means. Rodgers (1985) states four major reasons for installing automation, "1) increased productivity, 2) reduced scrap, 3) reduced operating costs, and 4) improved working conditions" (p. 26).

Using more than you need is a major obstacle in increasing a manufacturer's productivity. Figure 2 represents the writers version of an illustration found in an article by Rodgers (1985) of cross sections of two pouring cups and a photograph in the Kanicki and Krohn (1984) article. The left profile depicts a full sprue cup which is common in manual pouring operations. The profile on the right typifies the sprue cup from an automated pouring system.

Figure 2. Typical reduction in pouring cup comparison.



Note: Author's representation of illustrations found in Modern Casting and Foundry Management & Technology

Consistency is the key to producing quality castings (Rodgers, 1988). The most common variables controlled in the foundry melt department and pouring area include, metal chemistry (Thielke, 1987, October), metal temperature (Thielke, 1987, October), and pouring practice (Rodgers, 1985). The foundry's first line of defense in controlling scrap is metal chemistry. The typical foundry controls this by repeatedly taking samples of the metal and testing it's properties (Rodgers, 1985). By closely controlling the chemical properties of the metal, one variable in the scrap equation is minimized.

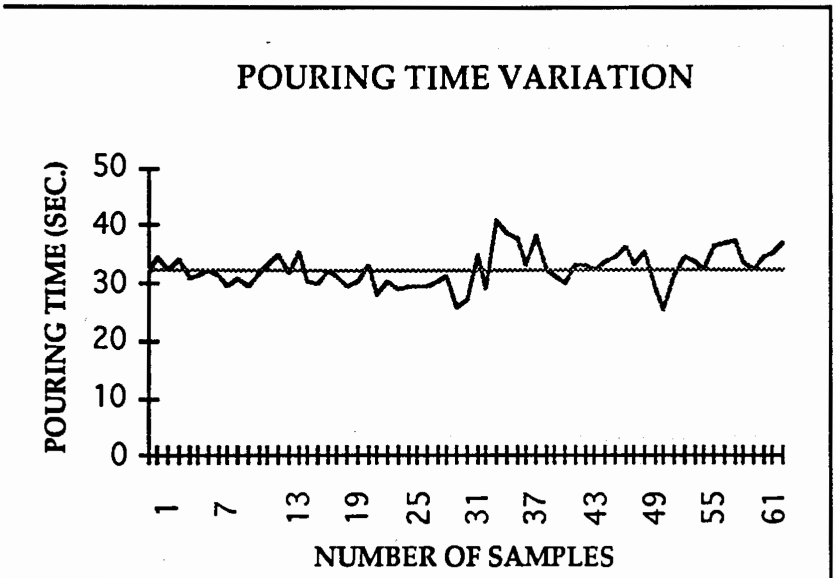
The second defensive line, metal temperature is most often accomplished through the use of holding furnaces near the actual site of pouring (Thielke, 1987, October). By taking small amounts of metal from the holding furnace and pouring relatively few molds, the foundry can maintain a reasonably narrow temperature range and control the second variable in the scrap equation.

The third line of defense, pouring practice, is a general term used to describe the actions required to fill the mold. In manual pouring the primary goal is to maintain consistency. Rodgers (1988) best describes this struggle:

> "Most foundrymen acknowledge that pours can vary with each worker's pouring experience, technique, concentration, amount of fatigue, and how he feels at the moment and throughout the day. Psychophysiological highs and lows among workers throughout a work shift can lead to over pours, under pours, and improper pours" (p. 36).

Figure 3 gives the reader an example of pouring consistency attained in a manual pouring system. The data presented represents a sample of 65 identical molds poured in succession at the author's facility. The casting being poured is a gray iron, six cylinder diesel engine block head. The total metal pour weight for each mold was 310.25 pounds (210.5 pounds for the head and 99.75 pounds for the gating system.

Figure 3. Mold pouring times for diesel engine block heads.

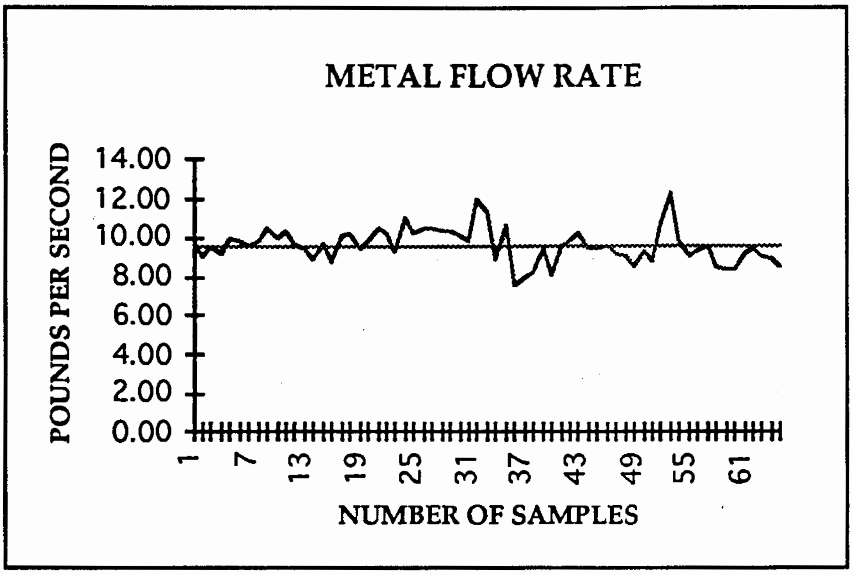


Note: Graphical representation of data gathered during actual pouring operations in the author's facility.

Figure 3 shows the pouring time variation of the sixty-five samples. The longest time required to fill the mold was 41.30 seconds. The shortest fill time was 25.20 seconds. This variation represents a range from the fastest time to slowest time of 16.10 seconds. The average pour time represented by the straight horizontal line in the figure is 32.52 seconds. Keep in mind these values represent the pouring times of identical molds.

Figure 4 presents this same data in terms of metal flow rates for the same engine block head illustrated in Figure 3. The information represents the calculated average metal flow rate for each individual mold. Measured in pounds/second, the highest value shown in the figure is 12.31, the lowest is 7.51, for a range of 4.8 pounds/second. The straight horizontal line in Figure 4 indicates the average metal flow rate for all samples combined is 9.64 pounds/second.

Figure 4. Metal flow rates for diesel engine block heads.



Note: Graphical representation of data gathered during actual pouring operations in the author's facility.

The importance of these figures goes beyond time and flow rate. These numbers show the lack of consistency in the current manual process. Wide fluctuations in these variables create opportunities for turbulence in the metal stream, gas generation, mold erosion, and many other effects that hinder the casting process.

Consistency from skill, concentration and attitude are the keys to good pouring practice. Automated systems remove the human element of metal pouring and replace it with mechanical and electrical components capable of emulating the human actions used to pour a mold.

Consistency will increase productivity, whether from improved yield or reduced scrap and will reduce the operating costs for the foundry. In addition to these factors many automated pouring systems can reduce the manpower required in the operation (Rodgers, 1985). All three of these factors combine to reduce a foundry's cost of operation.

Through the use of high speed computers and various forms of feedback control, the human element not eliminated can often times be located remote from the actual pouring process. This isolates and better protects the operator from the smoke, gases, and sparks produced during mold pour (Rodgers, 1986)

Assumptions

The project team made the following assumptions during the investigative portion of it's assignment;

- An existing system would be found with a proven track record of success.
- The system selected would require minimal re-work of the existing facility.

- Financial allocations would be available should the selected system provide an acceptable return on investment (ROI).
- Projected annual tonnage requirements were realistic and acceptable to the parent corporation.
- Projected scrap reductions and reduced metal requirements were realistic and acceptable to the parent corporation.
- Reduced energy consumption was possible.
- Labor needs would be reduced.
- Health and safety standards would improve over the existing manual system.

Limitations

This investigation focused on automated pouring applications in a gray iron foundry. For this reason, all data presented slants towards a ferrous metal caster rather than nonferrous producers. All weights and measures are given in terms of English units, (pounds, etc.).

No attempt was made to compare the results of this study with any data concerning nonferrous investigations. In addition, this report follows the project only through the investigation and selection stages of the project.

Definition of Terms

Burn in ....A thin layer of fused sand which has adhered to the casting. The surface has a vitreous and possibly a pockmarked appearance. The condition is most prevalent at the hottest locations of the mold surface (Hénon, G. (1974), p. 202).

Cold Shut .... A linear discontinuity with rounded edges. The defect has a characteristic appearance and may vary in depth, extending either partially or entirely through the section of the casting (Hénon, G. (1974), p. 154).

Gating .... The elements of a basic and very common gating system are the down sprue, through which the metal enters the runner, and from which it in turn passes through the ingates into the mold cavity (Heine et al. (1967), p. 214).

Mold .... A device used to form intricate shapes by introducing a material, such as molten metal, to fill the cavity within. Example, a person can produce a mold by placing an impression of a hand in a bucket of moisten sand. The resulting depression forms a mold which can then be filled with plaster to form a likeness (a casting) of the hand.

Pouring cup .... The conical cup used to funnel metal into the gating system (Campbell, (1991), p. 35).

Shrink .... Open or closed cavities, generally with rough, often dendritic walls (Hénon, G. (1974), p. 106).

Slag .... Small, rounded surface cavities, generally greenish-gray in color (Hénon, G. (1974), p. 196).

Turbulence .... The violent motions created by the metal entering and flowing through the mold gating system (Campbell, (1991), p. 19).

CHAPTER 2

Review of Related Literature

The foundry industry has long held a desire to automate the pouring process. The earliest reference the author found describes the Buhrer automated pouring system, circa 1959. This device promoted a "tilting mechanism which permits rotating the pouring ladle around a virtual axis located near the lip of the ladle" ("Automatic Pouring Eliminates," 1959, p. 84). The article on this possible first attempt in automation continues to herald the machine's benefits by stating it's automatic weighing device assures the correct amount of metal enters every mold.

In 1965, Western Foundry developed an automated pouring system capable of pouring 250 molds per hour ("Automated Pouring of Gray Iron, 1965). Productivity before and after system development were compared in the statement, "Two or three men were hard pressed to pour 150 molds per hour," but, " now one man pours up to 250 molds per hour" with the automated system (p. 185). Western's pouring system incorporated bottom pour ladles capable of holding 1,200 pounds of iron. Metal flowed through an orifice located in the bottom of the ladle. Control of the metal stream was initiated, maintained and terminated through the vertical stroke of a graphite stopper rod above the orifice. Following the start of a pour sequence, timers were used by the system to end mold filling.

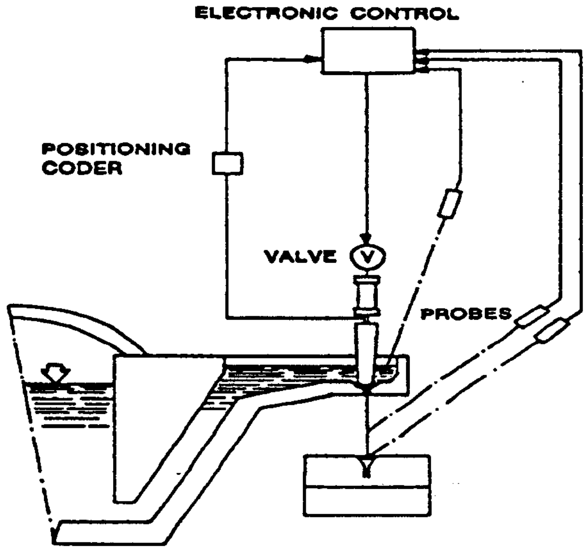
Northern Automatic Electric Foundry Incorporated began using an automatic pressure pouring device in 1969 ("Automatic Pressure Pouring," 1969). A three ton pressure pour holding furnace capable of pouring up to

300 molds per hour was installed adjacent to their molding line. The furnace was so arranged to allow metal from the pouring spout to directly enter the mold pouring cup. Metal flow rate was maintained through the use of a refractory float located in the furnace spout. Electronic signals derived from the float's position were used to increase or decrease "furnace pressure to maintain a predetermined flow rate" (p. 62). The advantage of using an induction furnace lies in its ability to maintain a desired metal pouring temperature.

Figure 5 illustrates a typical pressure pour furnace equipped with a stopper rod mechanism and optical sensors for controlling metal flow rates.

Additional information from the late 1960's and early 1970's on the advances in automated pouring through the use of pressurized channel type induction furnaces are found in the Bibliography. In all cases the primary factor limiting the use of induction furnace pouring units centers on a requirement they remain stationary (limited travel). This restriction results from the power cables and water cooling lines required by the furnace. Movement was limited to at most a couple of feet in any direction. This restriction proves to be no problem when the molding equipment is designed to index molds through the pouring zone. However, on a continuous moving mold line, the distance traveled by the mold during the pour can reach many times the travel restrictions imposed by the restraints imposed on a pouring furnace.

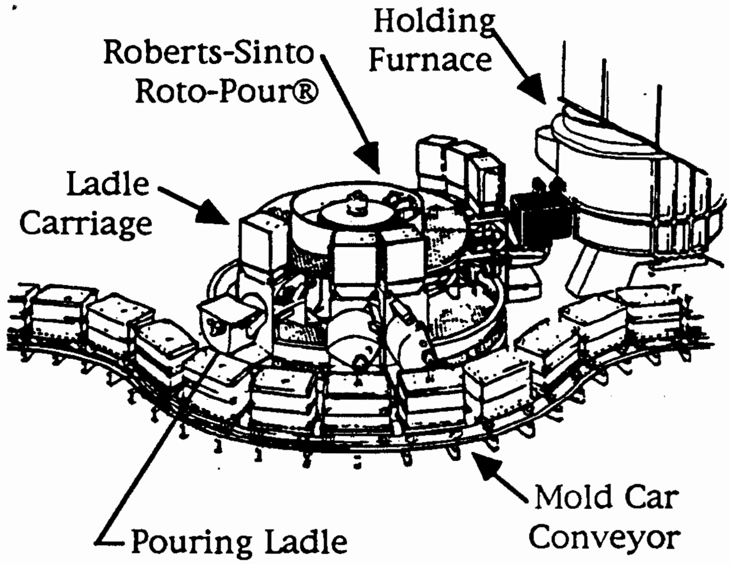
Figure 5. Direct pouring from a pressure pour furnace.



Note: Illustration from a descriptive brochure provided to the author by ED. Mezger AG.

In October 1972, the Saginaw Malleable Iron Plant, Central Foundry Division of General Motors began using a new automated pouring system designed for continuous moving mold lines ("Automatic Iron Pouring At," 1974). The new system, dubbed Roto-Pour®, was capable of pouring up to 450 molds per hour and up to 120 tons of iron per hour. Advantages cited in the article included cutting foundry costs by "improving yield, eliminating pigging, reducing scrap, improving inoculant effectiveness, reducing gate weight and eliminating over pours" (p. 38). Figure 6 illustrates the general layout of the Roto-Pour®. The primary components used in the Roto-Pour® include, 1) a holding furnace, 2) a circular track of which the mold car line must enwrap 120 degrees, and 3) five to six ladle carriages used to transfer metal from the holding furnace to individual molds.

Figure 6. Intermediate ladling system — Roberts-Sinto Roto-Pour®.



Note: Illustration from an article entitled "Central Foundry adapts lasers to foundry operations," Modern Casting, (March, 1984).

The intervening years have witnessed many innovations in the field of automated pouring. Rodgers (1985) informs us on how technological advances are making automatic pouring more attractive each year. With the ever rising level of sophistication in design technology, automated pouring devices are becoming "more precise, faster and less costly" (p.26).

Regardless of which technique is used, the trend in automated pouring is ever increasing speed, accuracy, and flexibility stemming from "advances in microprocessor based programmable controllers, computer software, and a wide array of reliable metal level sensor systems" (Rodgers, 1988, p. 36). These characteristics are "making automatic pouring increasingly attractive" (p. 36).

CHAPTER 3

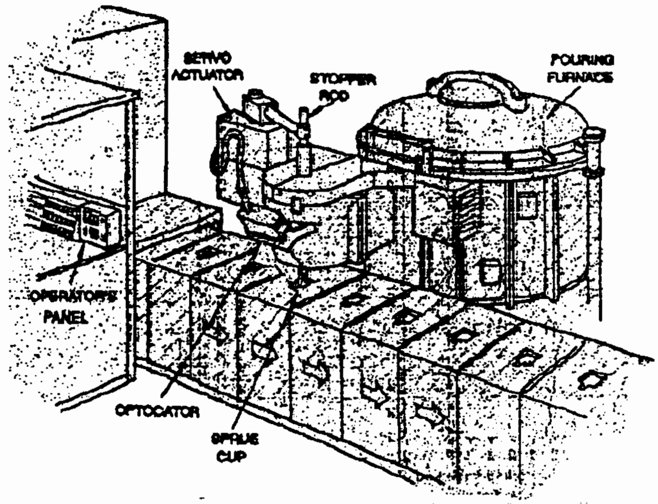
Aspects of Automated Pouring Technology

Automated pouring systems are divided into two major categories, direct pouring and indirect pouring units. Systems using the direct approach center on placing the metal in the mold directly from a holding furnace, usually a pressure pour furnace as described earlier (Thielke, 1987). Indirect pouring systems receive and dispense metal via an intermediate ladling system. An example of this would be the Roto-Pour® system described earlier and illustrated in Figure 6.

Figure 7 illustrates a typical direct pouring induction furnace equipped with a stopper rod mechanism used to dispense metal. The molding equipment indicated in this sketch produces flaskless vertically parted molds.

In nearly every case observed by the author, direct pouring systems were utilized on indexing mold lines, examples of which include the DISA-MATIC vertical parted molding lines, George Fischer Impact molding lines and the Kunkel-Wagner Vacupress molding lines. This is not to imply foundries using an indexing mold line cannot use indirect pouring systems. Figure 8 illustrates an intermediate bottom stopper rod ladle filling molds produced with a DISA-MATIC molding machine.

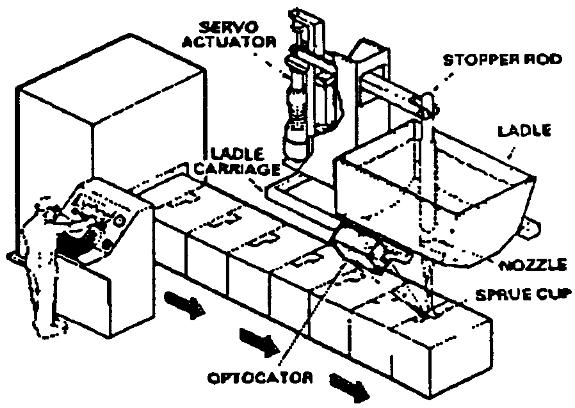
Figure 7. Direct pouring of vertically parted flaskless molds.



Note: Illustration from a descriptive brochure provided to the author by Selcom - Selective Electronic, Inc.

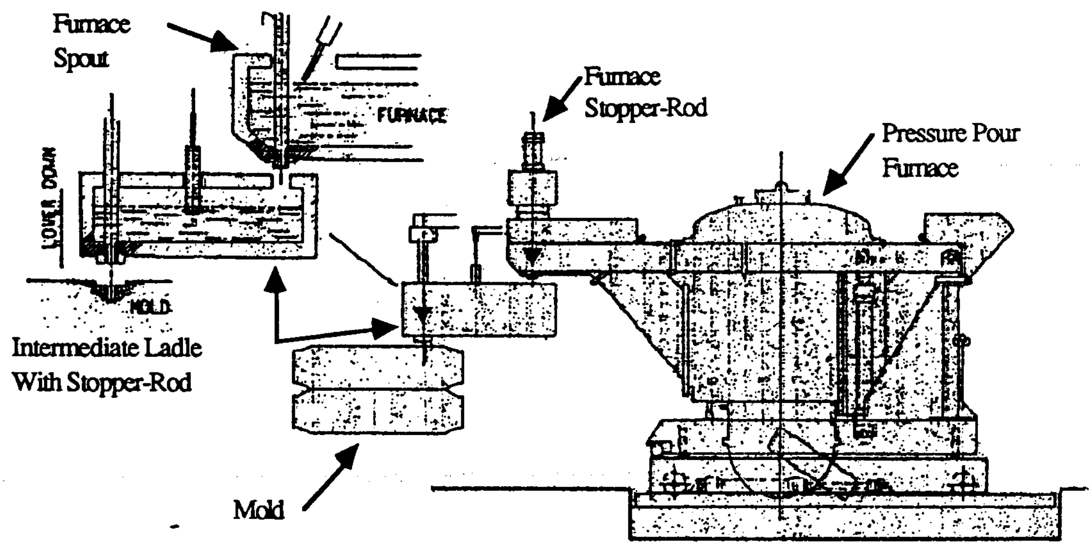
Another example of indirect metal pouring on an indexing mold line is shown in Figure 9. This profile represents the system used by Eisebwerk Brühl located near Köln Germany on a George Fischer Impact line. This system uses two side by side pressure pour furnaces to fill four separate bottom pour ladles. Molds are indexed under the pouring ladles in groups of four and filled simultaneously.

Figure 8. Bottom Stopper Rod Pouring Vessel With Vertically Parted Molding Machine.



Note: Illustration from a descriptive brochure provided to the author by Selcom - Selective Electronic, Inc.

Figure 9. Bottom Stopper Rod Pouring With An Induction Holding Furnace and an Intermediate Ladle.



Note: Sketch provided by George Fischer Foundry Systems for the mold pouring system used by the Eisebwerk Brühl located near Köln Germany.

Direct automatic pouring of metal at the pouring line has several advantages according to Thielke (1987, November). The list includes;

- Improved utilization of pouring manpower.
- Capability of holding metal at the pouring line during interruptions.
- Improved quality due to reproducible pouring patterns.
- Reduction of metal returns by utilizing less complex gating and risering systems and the elimination of overfilling (p. 25).

Continuous molding lines e.g., SPO-Matic and Osborne, etc., tend to use the indirect method of automated pouring due to the restricted travel limits of holding furnaces as mentioned in Chapter 2. Except for the "capability of holding metal at the pouring line," most indirect pouring systems provide the same advantages listed for direct pouring systems. However many auto pour installations on continuous molding lines do include a small induction holding furnace to dispense metal to the traveling ladle as a means to limit temperature variations. An excellent example of this is shown in Figure 6, the Roto-Pour® installation at General Motors Saginaw Malleable Iron Plant, Central Foundry Division.

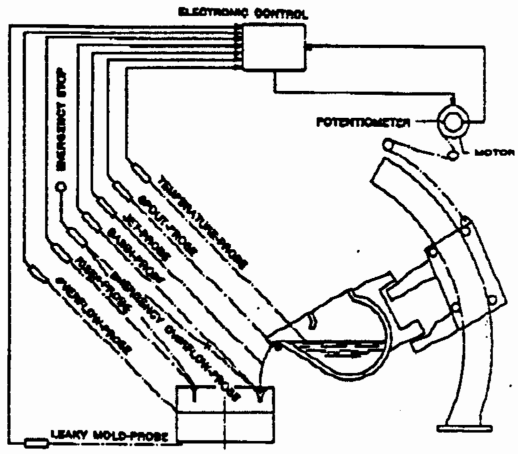
From the descriptions and illustrations provided, the reader should have an understanding of the gross mechanical components of automated pouring. However, the key to improved productivity does not lie in these major elements, rather it stems from the control systems placed on the equipment. The heart of any pouring unit resides in the system controls used to guide and regulate metal flow from the pouring device to the mold.

Consistent, repeatable pouring from mold to mold is the key to automated pouring. Using digital computers, programmable controllers, and remote sensors, auto pour systems are capable of dispensing molten metal consistently from one mold to the next.

Development of powerful low cost computers and programmable controllers during the last decade has enhanced automated pouring technology. These tools are used to monitor the primary pouring characteristics in real time. Through the use of various types of remote sensing devices, metal temperature, ladle position, metal stream width, metal level in the pouring cup, and many more characteristics are monitored as they occur. Using these inputs along with complex algorithms developed from fluid dynamics, the computers determine what actions are required of the pouring unit in making precise, minute adjustments to the metal stream.

The computers used to control a pouring system must have real time data inputs to initiate, maintain and complete the pour of a mold. As mentioned, these inputs are derived from sensors located near the exit point of metal from the ladle. These sensors exist in three primary forms, optical, vision, and laser. All three perform similar functions in gathering information for the pouring system's central controller. Figure 10 illustrates one scenario of sensor locations in relation to the pouring cup of a mold.

Figure 10. Typical arrangement of optical sensors.



Note: Illustration from a descriptive brochure provided to the author by ED. Mezger AG highlighting their use of optical sensors.

While different manufacturers of automated pouring systems utilize various forms of sensing apparatus, each system typically has the following capabilities:

- Sensing the location of the mold and it's pouring cup
- Tracking the level of metal in the pouring cup
- Monitoring the weight of metal dispensed
- Determining when the mold will accept no additional metal.

The combination of computers and data gathering sensors provides the foundry with a means to reduce and compensate for the many variables found in the pouring process.

The author strongly suggests those individuals wishing to implement this technology research the articles found in both the Reference List and the Bibliography found near the end of this document.

CHAPTER 4

Methodology of the Selection Process

A small project team was formed to investigate the state of automated pouring technology and what benefits might be derived given the opportunity to implement a system. The composition of this team included engineers, toolers, production managers, maintenance personnel and accountants.

Determining what forms the technology took was the first challenge. Three approaches to this task were used to gain background knowledge of what was available. The first centered on researching past publications catering to the foundry industry. From these, an assemblage of information on various systems, their manufacturers, their general characteristics of operation, and what foundries were using automated pouring was compiled.

The second approach for gathering information enlisted the help of industry experts, including the American Foundrymen's Society (AFS) and the Iron Casting Research Institute (ICRI). These organizations assisted in finding both users and manufacturers of automated pouring systems willing to help in the investigation. Utilizing these resources enabled the author to gain entry into many foundries using automated pouring for a first hand look at working technology.

The third segment of this preliminary investigation involved actual observance of automated pouring in action. As mentioned, the author had many opportunities for travel to remote sites to view systems in operation and discuss with the operators the advantages of automated pouring.

During this phase of the project, many questions, concerns and characteristics of the various systems were recorded. Compiling this information for analysis provided a base from which comparisons between the facilities visited and the author's own operation would be drawn. Information gathered during these trips included, the type of metal being poured, molding equipment characteristics, and pouring system characteristics.

Since the project goal was to implement automated pouring in the author's own facility, the observations focused primarily on the iron founding industry. While ferrous and nonferrous operations were investigated, a majority of the information collected dealt with gray and ductile iron installations.

In addition to the metal properties, data surrounding the types of castings produced was collected. It was desirable to find units with the flexibility to pour a sequence of up to seven different molds requiring varied pouring characteristics. This constraint resulted from the molding systems used in the author's own facility.

The systems studied were used on both continuous moving and indexing mold lines. While the planned installation was for a continuous molding line, the author did not wish to limit the scope of research unduly. During the investigation several indexing style pouring systems were found being used on modified continuous molding lines. These hybrid systems warranted the plan of investigating all systems in use.

The primary molding line characteristics of interest included: mold line speed (molds per hour); flask/mold size; smallest, largest, and average mold pour weight; and the types of castings produced. An automated system capable of pouring 200 molds per hour with a weighted average total mold pour weight of 275 pounds was required.

The product mix flowing across the molding line targeted for this first attempt at automated pouring consisted of a combination of engine blocks, heads, covers, hydraulic components, sheaves, weights, hubs, flywheels, and brake drums. Hence, the importance in finding a system with flexibility in adjusting the pouring requirements presented by a mixture of molds entering the pouring zone.

The combination of reviewed literature, information provided by both AFS and ICRI, and plant visits provided the author with a good understanding of the various pouring system characteristics available. These attributes include: direct versus indirect pouring; holding furnace (if any) characteristics; bottom pour-stopper rod systems; single versus multiple mold pouring; laser, vision, and optics controls for metal flow; and environmental aspects.

In addition to seeing automated pouring systems in operation during the plant visits, the author was able to discuss with operators the advantages of automation. Of primary concern were the aspects of improved productivity. These areas included reductions in manpower, material usage, energy consumption, and the environmental impact these systems had on the pouring line surroundings.

Compiling the information gathered from these sources focused the research on finding a system capable of meeting the needs of the author's facility. Using a comparative method of decision analysis, three automated pouring systems with a proven history of performance were isolated. The manufacturers of these systems were provided with a set of the organization's specifications for foundry equipment and asked to provide recommendations and proposals for automating the pouring operation on one of the facility's three molding lines.

Financial justification for this expenditure also fell under the scope of defined project responsibility. The accepted means of qualifying this expenditure was through the calculation of a return on investment (ROI) and cash pay out time as defined by the organization's accounting practices.

Identifying the potential areas of process improvement and increased productivity required investigation in detail, all existing operational data. Data collected during this phase of the project formed a baseline of information for comparison of manual and automatic pouring. Along with this collection of information, assumptions regarding the impact automated pouring would have in areas addressing productivity improvement were made.

Based upon the literature reviewed and the plants visited, the following areas for improvement were identified.

- Reduced molten metal requirements,
  - Lower internal and external scrap.
  - Less spillage.
  - Smaller pouring cups.
- Reduced alloy usage,

  - Lower rates of inoculate usage.
- Reduced energy consumption.
- Reduced manpower.

After identifying these areas, it became possible to project savings dollars for each topic. These values along with the anticipated annual expenditures for maintaining the system and the initial capital investment were then used in the calculation of a return on investment for each system under consideration.

Based upon the ROI standard of measure all three systems were viable for the operation. Techniques of decision analysis were enlisted to select the most appropriate system for the facility. The results of that analysis will be found in Chapter 5: Report of the Selection Process Findings.

CHAPTER 5

Report of the Selection Process Findings

Following an exhaustive search of the literature and many on site evaluations of automated pouring systems, three manufacturers producing systems capable of meeting the needs as defined were found. These systems and their respective manufacturer included:

- Roto-Pour® Roberts-Sinto Corporation
  Lansing, MI U.S.A.
- Mobile-Pour® CMI Equipment & Engineers
  AuGres, MI U.S.A
- MEKA P-20 Ed. Mezger AG
  Kallnach, Switzerland

Letters of inquiry including existing facility drawings, Standard Specifications and a Summary of Work were sent to these manufacturers. Each was asked to propose a turn-key installation for an automated pouring system within the author's operation. See Appendix D for a copy of the Summary of Work.

The information presented in Table 1 outlines the basic background data supplied to each manufacturer. This data reflects baseline information describing the molding unit targeted for automated pouring.

Table 1.

Baseline Information For Molding Unit 803.

Characteristic	Attribute
Maximum operating speed	200 MPH
Maximum iron pour weight per mold	700 lbs.
Weighted average iron pour weight per mold	275 lbs.
Flask data:	
Inside / Outside length (Cope & Drag)	40" / 52"
Inside / Outside width (Cope & Drag)	40" / 52"
Cope / Drag depth	14" / 14"
Cope weight	3400 lbs.
Drag weight	2400 lbs.
Mold car pitch	6'-0"
Mold line speed	20'-0" / minute
Maximum delivery ladle capacity	6000 lbs.
Nominal pouring temperature range	2530°F to 2710°F

Note: Data presented in this table was sourced from manuals, drawings and physical measurements of the actual SPO-Matic tight-flask molding unit in operation.

While waiting for the proposals, the project team began quantifying the anticipated areas of savings. As mentioned in Chapter 4, these areas included:

- Reduced molten metal requirements.
- Reduced alloy usage.
- Reduced energy consumption.
- Reduced manpower.

Three primary waste streams, (the inefficient use of valuable production materials), contributing to the excessive use of molten metal were identified. These streams included, casting scrap, spillage, and pouring cups. Table 2 illustrates the team's findings in annual scrap reductions believed possible from the installation of automated pouring.

Table 2.

Annual Savings From Reducing Excess Scrap.

Internal Scrap	Percent Reduction		Annual Savings
Mold Blow	5.00 %	$	2,000
Cold Shut	47.50 %		20,000
Slag	60.00 %		90,000
Shrink	5.00 %		4,000
Sand Holes	1.5 %		5,000
Short Pours	95.00 %		44,000
Total Internal Scrap Savings		$	165,000
External Scrap	**Percent Reduction**		**Annual Savings**
Slag	75.00 %	$	8,000
Sand Holes	1.5 %		6,000
Short Pours	95.00 %		15,000
Total External Scrap Savings		$	30,000

Note: Data presented in this table was developed by the project team using a combination foundry experience, responses from automated pouring system users and foundry records documenting internal and external scrap.

The second component of excess metal requirements centered on waste caused by spillage. This identified segment of the savings equation was assembled by gathering all of the metal spilled across the mold top and on the floor for two separate four week periods of time. Daily weight records of this metal and the casting tons produced that day were recorded. Analysis of this data and historical data from four years earlier produced an average ratio of 36 pounds of spillage to every ton of good castings produced (1.8%). Based upon this information, the internal value of molten metal and the tonnage forecast for the molding unit, an annual savings in excess of $60,000 should be derived from installation of an automated pouring system.

The third and final component of excess metal usage centers on the mold pouring cup. Automated pouring systems developed in recent years have shown repeatedly their ability to minimize metal remaining in the pouring cup upon completion of the pour (Figure 2). This vital part of the mold gating system, if left full after the mold has been filled wastes several pounds of metal. An analysis of the pouring cup characteristics for the molding unit under investigation and found the average cup weight following a pour weighed 57 pounds. Based upon observations made in the field and input from the manufacturers, it was determined an average 40 pound reduction in pouring cup weight could be realized with automated pouring. Taking into account the number of molds required to produce the forecast tonnage, an annual savings of nearly 7000 tons of molten metal will be realized. This equates to an annual dollar savings in excess of $350,000.

The second major division of savings identified deals with alloys added to the pouring ladle prior to pouring. The practice of adding a ferrosilicon inoculant to the pouring ladle is common in most gray and ductile iron foundries. Without going into great detail, the material enters solution and provides nucleation sites for the carbon present in the metal to begin its precipitation in forming graphite flakes or nodules. The problem facing these operations is the fading effect of this material. As time between the introduction of this material and the solidification of the metal increases, the effect lessens, creating fewer and fewer nucleation sites. For this reason it is common for the author's facility to over inoculate by as much as ten percent.

All three candidate manufacturers could provide late stream inoculation apparatus and reduce the amount of material used over a year. Based upon the fade characteristics and the time required for pouring, the project team calculated a reduced annual inoculant requirement with annual savings in excess of $68,000.

The third division of anticipated savings, reduced energy consumption, had two components. Both dealt with the remelting and reheating cost associated with pigged metal. Standard practice in the author's operation required all metal remaining in a pouring ladle after a predetermined period of time be poured back into the induction holding furnace. The methods used for this sometimes resulted in the metal solidifying before it could be returned to the furnace. Excessive amounts of electrical energy were required to reheat this metal. All three automated pouring units addressed this problem and allowed an anticipated savings exceeding $240,000 per year.

The final segment of savings focused on the reduction of human resources required in the mold pouring area. Two of the systems under study were able to reduce up to six people from the two shift operation. It was questionable whether the third system being consideration would reduce manpower at all. Based upon the current labor agreement, the six individuals gross compensation exceeded $322,000 per year.

Table 3.

Summary of Anticipated Annual Savings From Automated Pouring.

Description of Savings		Savings
Internal Scrap	$	165,000
External Scrap		30,000
Spillage		60,000
Pouring Cup Reductions		350,000
Reduced Alloy Usage		68,000
Reduced Energy Consumption		240,000
Reduced Manpower		322,000
Total Anticipated Savings	$	1,230,000

Note: These values are documented in the Appropriation For Expenditure used to obtain corporate approval for the project.

Refer to Table 3 for a summary of the projected annual savings derived from installation of an automated pouring system on one molding line. The totals presented reflect a conservative estimate of the annual savings to the operation.

The project team reviewed each of the three manufacturer's proposals upon their submittal. Even though all three received the same information packets, each proposal required detailed analysis to determine whether the proposed equipment would meet the needs of the operation. These reviews generated many questions regarding possible short comings of the systems quoted. Further inquiry of each manufacturer was necessary for clarification of their intentions.

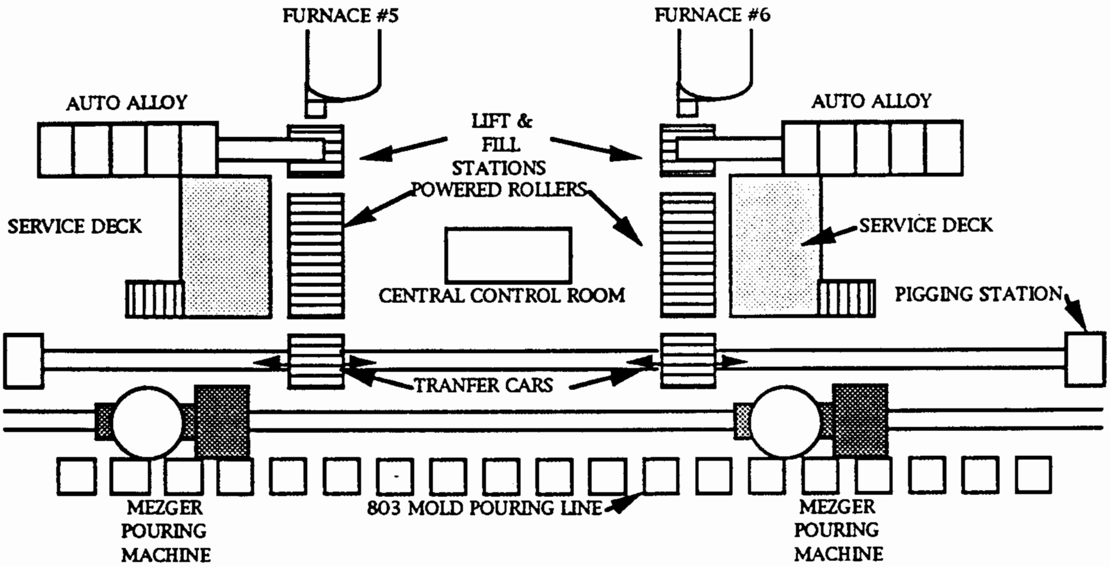
Each manufacturer responded to the questions related to their respective systems by visiting the proposed installation site and reviewing the concerns. The initial proposals for these systems ranged from just over one million dollars to just over three and one half million dollars. Based upon the anticipated savings, the project team determined the return on investment (ROI) would range between 25 percent and 60 percent depending upon which system was selected.

Once all questions were resolved, final selection was made based upon decision analysis methods taught within the corporation. The procedure followed was designed and taught by Executive Development, Inc., of Minneapolis, MN. Other similar techniques such as Kepner-Tregoe Decision Analysis are available to aid in the decision making process for complex, multifaceted tasks.

From the information presented by the manufacturer and observation of systems in use, the MEKA P-20 automated pouring machine produced by Ed. Mezger AG, located in Kallnach, Switzerland was selected.

Figure 11 illustrates the system proposed by Ed. Mezger AG and identifies the major components used by the system.

Figure 11. Ed Mezger AG Automated Pouring Machine Layout



Source: Original sketch by author

The reader will gain a better understanding of the Mezger system be reviewing Appendix C, Technical information on the Mezger P-20 automatic pouring machine. Ed. Mezger AG provided this information to the author as part o their system proposal.

- Two MEKA P-20 Automated Pouring Machines.
- Two ladle transfer cars.
- Two stationary sets of powered conveyors for transferring pouring ladles between the pouring machines and the induction holding furnaces.
- Two automatic alloy batching stations.
- One central control room for monitoring the pouring operations.

Final negotiations with Pangborn Corporation and Ed. Mezger AG are expected to be complete soon with system installation planned for the summer of 1994.

CHAPTER 6

Summary and Conclusions

Automation of the pouring line is possible. The review of literature used to compile this report documents several hundred separate installations of automated pouring around the world. The primary techniques of auto pour center on one of two basic designs, using either direct or indirect pouring methods. Each of these major divisions typically incorporate various forms of equipment and controls to accomplish the primary goal of controlled pouring.

Those foundries wishing to update the pouring line have a wide range of pouring systems from which to choose. Because of the many variables requiring attention and the diversity of the systems available, the selection process may require the assemblage of a project team to sift through the mountains of information available on the subject. The leadership of the author's foundry assembled a team having a diverse background of foundry operations and gave them ample backing to conduct a thorough investigation of available technology.

Following an exhaustive search for information, including the observation of many systems in operation, the project team made a preliminary selection of three different systems. These systems included the;

- Roberts-Sinto Roto-Pour®.
- CMI Equipment & Engineers Mobile-Pour©.
- Ed. Mezger AD MEKA P-20.

Following the submission of proposals from these three manufacturers, the project team selected the system believed to best fit the needs of their organization. The system selected was the MEKA P-20 produced by Ed. Mezger AD in Switzerland.

Based upon the purchase price of the equipment, freight and installation, the anticipated return on investment for this system exceeded 35%. The projected cash pay out time neared four years due to the anticipated start of the project versus the completion or start-up date. Overall, the project team identified this automated pouring system as being capable of delivering at least $1,230,000 of savings annually.

Plans to install this first of three separate units is planned for the facilities 1994 fiscal year. Subsequent installations on the remaining two molding units will most likely follow at one to two year intervals following start-up of this first system.

References

16th Census of world casting production — 1981. (1982, December). Modern Casting, 72 (12), 18—19.

17th Census of world casting production — 1982. (1983, December). Modern Casting, 73 (12), 22—23.

18th Census of world casting production — 1983. (1984, December). Modern Casting, 74 (12), 19—20.

19th Census of world casting production — 1984. (1985, December). Modern Casting, 75 (12), 28—29.

20th Census of world casting production — 1985. (1986, December). Modern Casting, 76 (12), 32—33.

21st Census of world casting production — 1986. (1987, December). Modern Casting, 77 (12), 24—25.

22th Census of world casting production — 1987. (1988, December). Modern Casting, 78 (12), 32—33.

23rd Census of world casting production — 1988. (1989, December). Modern Casting, 79 (12), 18—19.

24th Census of world casting production — 1989. (1990, December). Modern Casting, 80 (12), 26—27.

25th Census of world casting production — 1990. (1991, December). Modern Casting, 81 (12), 24—25.

Automatic iron pouring at Saginaw Malleable. (1976). Foundry Management & Technology, 103 (7), 38—39.

Automatic pouring eliminates human error. (1959). Foundry, 87 (8), 84.

Automatic pressure pouring at Northern Automatic Electric. (1969). Modern Casting, 56 (2), 62.

Bex, T. (1992, August). Equipment review '92: Melting & Pouring. Modern Casting, 82 (8), 26—34.

Campbell, J. (1991). Castings. Oxford: Butterworth-Heinemann Ltd.

Heine, R. W., Loper Jr., C. R., & Rosenthal, P. C. (1967). Principles of metal casting (2nd ed.). New York: McGraw-Hill.

Hénon, G. (1974). International atlas of casting defects (M. T. Rowley, Trans.). Des Plaines, IL: American Foundrymen's Society. (Original work published in 1952).

Kanicki, D. P., & Krohn, B. R. (1984, October). Taking the heat off molten metal handling, part 1. Modern Casting, 74 (10), 22—24.

New product of the month: Automated pouring of gray iron. (1965). Modern Castings, 47 (6), 185.

Rodgers, R. C. (1985, June). Innovations in automatic control for metal pouring. Foundry Management & Technology, 113 (6), 26—34.

Rodgers, R. C. (1986, May). Automatic pouring for short run — pro and con. Foundry Management & Technology, 114 (5), 28—31.

Rodgers, R. C. (1988, October). Automatic pouring '88. Foundry Management & Technology, 113 (6), 26—34.

Study shows automatic pouring control systems can reduce costs. (1989, April). Iron and Steel Engineer, 66 (4), 37.

Thielke, J. (1987). Using electric furnaces to store and pour treated ductile iron, part 1. Modern Casting, 77 (10), 33—36.

Bibliography

Auto pourer "learns" pouring profile. (1987). Foundry Management & Technology, 115 (4), 49.

Automated pouring system increases productivity at England's Chamberlain & Hill Iron Foundry. (1990). Foundry Management & Technology, 118 (10), 44—45.

Central Foundry adapts lasers to foundry operations. (1984). Modern Casting, 74 (3), 35.

Donovan, J. (1987). Planning and justifying automation. Plant Engineering, 41 (13), 42—43.

Dotsch, E. (1983). Holding and pouring of magnesium treated cast iron. Modern Casting, 73 (3), 23—26.

Metal pouring/filtering. (1989). Foundry Management & Technology, 117 (12), C-3—C-5.

Schaum, J. H. (1973). Cover story: Three men operate million dollar foundry. Modern Casting, 63 (3), 34—36.

Soderlund, K. G. (1972). Cover story: Pressure pouring channel furnaces. Modern Casting, 62 (2), 27.

Thielke, J. (1987, November). Using electric furnaces to store and pour treated ductile iron, part 2. Modern Casting, 77 (11), 25—27.

Waupac Foundry saves $6,000/wk with laser controlled pouring. (1987). Foundry Management & Technology, 118 (10), 44—45.

APPENDIX A

Automated Pouring System Suppliers

APPENDIX A

Automated Pouring System Suppliers

Roberts Sinto Corporation	Lansing, MI
Ed. Mezger AG	Kallnach, Switzerland
CMI Equipment & Engineers, Inc.	AuGres, MI
George Fischer Foundry Systems	Holly, MI
ASEA-Brown Boveri	North Brunswick, NJ
Inductotherm	Rancocas, NJ
Selcom, Inc.	Garden City, MI

APPENDIX B

Automated Pouring Systems Users

APPENDIX B

Automated Pouring Systems Users

General Motors Central Foundry	Defiance, OH
General Motors Central Foundry	Saginaw, MI
Ford Motor Company	Cleveland, OH
Harvard Industries	Albion, MI
Erie Malleable Iron	Erie, PA
Grede Foundries, Inc.	Reedsburg, WI
Waupaca Foundry	Waupaca, WI
Navistar	Indianapolis, IN
Tupy Foundry	Joinville, Brazil
FMB Foundry	Bello Horizonte, Brazil
Citroen Automobile	Charleville, France
DeGlobe Foundry	Weert, Netherlands
Halberger Guss	Saarbrucken, Germany
Eisenwerk Bruhl GMBH	Bruhl, Germany
Renault Foundry	Le Mans, France
Peugeot Foundry	DomPierre, France
Heidleberger Druckmachinen	Amstetten, Germany
Damiler Benz	Mannheim, Germany

APPENDIX C

Technical Information on the Mezger P-20 Automatic Pouring Machine

APPENDIX D

Summary of Work

APPENDIX D

Summary of Work

Section 01010 - List of Article Titles

PART 1 GENERAL

1.01 Note

A. The Contractor shall consult all Contract Documents for instructions pertaining to work in the Owners Operation.

1.02 Scope Of Work

A. General

1. The work shall consist of engineering, providing and installing equipment and work as necessary to provide a complete and satisfactorily operating Automated Iron Pouring System for Department 801 within the building limitations provided by the Owner in accordance with these Specifications.

2. The Contractor shall assume full responsibility for obtaining all necessary details of pertinent existing equipment and work, and for design, engineering, purchasing, supplying, erecting, installing, field connecting, interfacing new and old equipment, starting, coordinating, testing, debugging, and performance of all work furnished and/or altered by himself and his Subcontractors.

3. It is the Contractor's responsibility to coordinate the installation of new equipment, relocation of existing equipment and the removal of obsolete equipment without interference with present operations. All work which may interfere with present operations and production must be performed during scheduled down time as determined by the Owner.

4. The revised and new systems furnished and installed under the Contract shall be fully capable of meeting all production requirements at sustained stated rates.

5. The Contractor must submit drawings and information for approval prior to construction. Work or material that does not meet the Owner's Specifications will not be approved and may cause payment to be withheld until satisfactory corrections have been made.

6. Whenever possible, the Contractor shall submit drawings that have been prepared on a CAD system. These drawings must be on a system that can be readily converted to IGES or DXF translation files. The storage media to be used for this transfer shall be either 3 1/2", 1.44 MB diskette or 40 MB Streamer tape. (AUTOCAD, INTERGRAPH, and COMPUTERVISION

are acceptable systems.) Contact the Owner's Representative for details.

7. In addition to the preceding documentation, all as built drawings must be provided on reproducible Mylar sepia.

8. Three copies of all operating manuals, repair manuals, etc. must be provided. For additional requirements on this topic, see Section 01730 of these Specifications.

9. It is not the intent of these specifications to cover all items or details of design and construction, but, to outline and define the completed system requirements and not unduly limit the Contractor's design and responsibility to furnish a complete and satisfactorily operating facility with adequate capacity to perform the work specified with optimum utilization of energy, material and resources and with maximum efficiency and minimum manpower. Alternates and suggestions in the interest of the Owner will be given full consideration.

10. The System shall be capable of tracking active pattern wells in the pattern shuttle. As the cope half of the mold is made, the system should enter the pattern characteristics (defined in paragraph 13 of this section) into a stack of molds to be poured. Provisions to override a pouring sequence must be included at the mold close up and mold pouring stations. The shuttle runs between five and eight separate pattern wells at any time. Any pattern well sequence can be repeated any number of times.

11. Pattern wells have either full, half or quarter section patterns mounted. Full section patterns have only one part number. Half sections have two different patterns mounted. Quarter sections have four different patterns mounted. Any combination of half and/or quarter section patterns may be mounted together.

12. Pattern wells will be permanently identified under a separate project currently under way. Provide for a minimum of thirty (30) sets of pattern well identification numbers.

13. Provision must be made to allow input of a minimum of the following pattern characteristics:

    a. Pattern number.
    b. Pattern well identification number.
    c. Pattern pour weight.
    d. Iron code number or type.
    e. Alloy additions, (minimum of four (4)) alloys;
        1) Alloy type.
        2) Alloy weight.

f.. Inoculation weight.

The system used for storing this information shall be capable supporting 400 different part numbers and associated data. Input of the information will be by dedicated CRT's, one located in Department 801, and located within the Foundry's office complex. The data entry interface shall be designed to minimize operator training and ease the operation of information updating.

14. Provision must be made to receive pattern well identifications from an existing pattern well tracking system and its correlation with the pattern characteristics previously listed. Blending of this system information will be updated periodically via dedicated CRT's as pattern and pattern well changes are made throughout the production day.

15. Mold Line 801 operational data,

Maximum operating speed	200 MPH
Maximum iron pour weight per mold	700 lbs.
Weighted average iron pour weight per mold	275 lbs.
Flask data:	
Inside / Outside length (Cope & Drag)	40" / 52"
Inside / Outside width (Cope & Drag)	40" / 52"
Cope / Drag depth	14" / 14"
Cope weight	3400 lbs.
Drag weight	2400 lbs.
Mold car pitch	6'-0"
Mold line speed	20"-0" / minute
Maximum delivery ladle capacity	6000 lbs.
Nominal pouring temperature range	2530°F to 2710°F

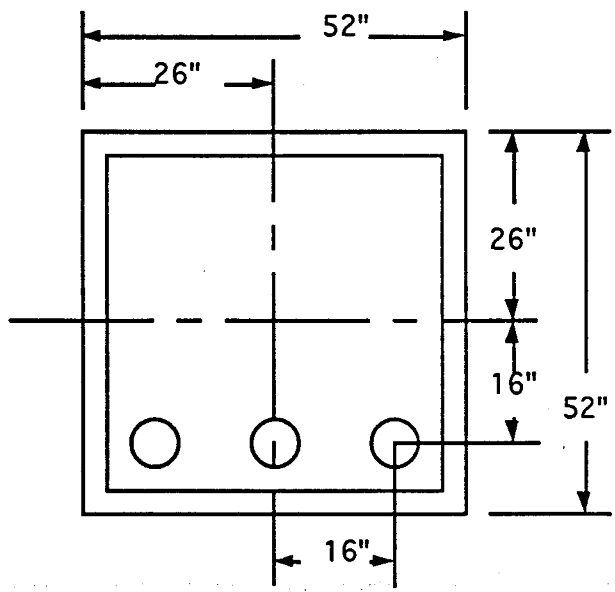
16. Iron will be sourced from two 85 ton, (45 ton usable) induction holding furnaces. The current method of delivery from these furnaces is a monorail system using an underhung carrier. The carriers have a maximum travel speed of 250 FPM.

17. If required, provisions for an intermediate pouring/holding furnace(s) capable of supporting the maximum volume throughput of metal should be included. The use of either a channel type or coreless furnace is acceptable. The furnace should have the following features. **Two pouring temperature ranges must be supported by the automated pouring system.**

    a. If using a channel type furnace, inductor(s) must have quick change capability.
    b. Back tilt to completely drain the vessel.

c. Pressure pour, using dry air and stopper rod/orifice.
d. Method and equipment for pigging residual heel and/or the entire capacity should it be necessary.
e. Method of slagging with minimal interruption of the pouring operation.
f. Refractory forms for the furnace body, spouts, roof, and all other components requiring the protection from heat.
g. The furnace shall be provided installed, with refractory consistent with materials selected by the Owner.
h. If required, any use of a ceramic orifice will require,
   1) A minimum of four (8) hours run time before replacement is required.
   2) A method must be provided for cleaning the orifice without removing the pouring unit from production.
   3) Any use of stopper rods for fluid flow control must include a means of rotating the rod as it's tip contacts the orifice. This function is an attempt to provide a non leaking seal between the orifice and the stopper rod.

18. Pouring cup sizes vary dependent upon the pattern. Location of the pouring varies as shown below,



19. The system shall be capable of alloy additions to each individual pouring ladle (delivery ladle) if an indirect method of pouring is used. Otherwise, the alloy additions must be added to the metal stream prior to entering the mold. A minimum of five (5) separate alloys, including ladle inoculant may be used in ladle treatment. All alloy and inoculant weights shall be determined by percentages of iron weight to be poured.

20. If indirect pouring is used, the pouring ladles shall be capable of controlled rate of pour in terms of pounds per second. The mechanism used to transfer pouring ladles to and from the pouring line must be capable of quick change over of both the mechanism and the ladle to minimize the impact of equipment failure.

21. The system shall monitor and provide real time performance reports, plus provide hard copy of the following information on the following key indicators:

    a. Total tons poured & tons poured by iron type.
    b. Molds poured & mold car number.
    c. Part numbers poured, with quantity of pieces.
    d. Hours of operation.
    e. Average pour time.
    f. Average rate of pour.
    g. Alloy and inoculant usage.
    h. Number of by passed molds.
    i. Hours of down time.
    j. Furnace operating characteristics,
        1) Power factor.
        2) Electrical usage.
        3) Power usage profile.
    k. Pour temperature of each mold.
    l. Average mold pour weight.
    m. System faults,
        1) Failure to inoculate.
        2) Power failure.
        3) Etc.

22. All equipment provided under these Specifications must be shielded and guarded against iron spills, mold run outs, parting line explosions and iron splatter in general.

23. Methods to override before or during the pouring cycle must be provided for the following conditions. Locations for these override features shall be placed at both the pouring unit and the mold close up station.

    a. Dummy molds.
    b. Run outs.

24. A method must be provided to return iron not poured to either the holding furnace or to a pigging station.

25. During start up and major system failures, an alternative means for continued operation of the molding unit must be provided. Continued operation of the existing iron delivery carriers is an acceptable solution.

B. Outline Of Mechanical Work

1. The Contractor shall be responsible for the design and installation of a Automated Iron Pouring System composed of the following:

   a. Pouring/Holding furnace, (if required).
   b. Indirect method pouring equipment, (if required).
   c. Alloy additions system.
   d. Exhaust collection.
   e. Revisions to existing iron handling system.
   f. All platforms, ladders, and miscellaneous fabrications.
   g. All pits, foundations, piers and slabs required by products supplied by the Contractor, his Subcontractors and the Owner.

2. The Contractor shall be responsible all phases of the construction installation, including but not limited to:

   a. Demolition of existing area scheduled for installation of the Automated Iron Pouring System.

   b. Excavation, forming and finishing of all pits, foundations, piers and slabs required for the installation of new and used equipment.

   c. Placement, alignment and level of all equipment provided under this Contract, both provided by the Contractor, his Subcontractors or the Owner.

3. Ancillary facilities, equipment and related work to be provided by Contractor include, but are not limited to.

   a. Complete independent supporting structures for all equipment provided under the Contract, except as otherwise indicated. All loads to overhead building steel must be applied at truss panel points only, with final connection by Owner approved truss clamps. Design and installation of truss reinforcement where required by excessive loading will be provided by the Contractor.

   b. Guarded platforms, catwalks, stairs, ladders, protection shields, etc. as required for safe operation, access to and maintenance of all equipment furnished under the Contract.

   c. Pneumatic and hydraulic components for all equipment requirements.

d. Piping, tubing, and fittings for all equipment requirements, including tapping and connecting to building service mains

e. Centralized lubrication provisions for the facilities installed.

f. Electrical power and control equipment, conduit and wiring as required for complete, safe, interlocked system operation. The design and installation of all motors and all necessary electrical power and control equipment including programmable controller, static components, conduit and wiring required for operation of 460 Volt, 3 Phase, 60 Hertz supply. All control and special voltage power shall be provided for within the equipment.

g. Painting, as applicable, for all work provided under the contract.

h. All equipment and system test operations.

i. Field piping systems work includes the furnishing and installation of all piping and fittings, which of necessity must be field installed. <u>This does not include</u> the furnishing of any valves or control devices, or the installation of any pipe, fittings, valves, etc. that can reasonably be pre-assembled and shipped intact on the various units or assemblies. Also, field piping does not include the furnishing of any production material conveying pipe. Field piping systems work includes the providing of all work at the job site for the entire Contract which is the normal function of the piping trade.

j. Field wiring systems work includes the furnishing and installing of all conduit, fittings and wire which of necessity must be field installed. <u>This does not include</u> the furnishing of any motors or electrical power and control equipment, or in the installation of any electrical equipment, conduit, and wiring which can reasonably be pre-assembled and shipped intact on the various units or assemblies. Field wiring systems work includes the providing of all work at the job site, for the entire Contract which is the normal function of the electrical trade.

k. Equipment installation and erection work includes the field assembly and setting in place of all items furnished and assigned under this contract. It is the intent that equipment installation and erection shall include only labor, utilities and erection equipment.

l. Irrespective of whether the Owner shall elect to have the equipment field piping and wiring work performed under Separate Contracts, the Contractor shall supervise and inspect all of the work and accept it if performed by other Contractors. In the performance of this function, he shall provide a full time staff whose working hours shall be the same as the working trades. This staff shall include competent field engineering capability and shall in all ways be adequate to provide the necessary understanding of the work, supervisory capability, and to avoid delay in execution of the work.

m. The cost of the above supervision, as well as the design Drawings and Specifications, shall be included in the Lump Sum Contract Price. The Contractor shall also include the cost of all unloading. If other trades such as electricians and pipe fitters, which the Owner already has on site are required to do the unloading, the Contractor shall arrange with the Owner to have the respective trades do the unloading, the cost of which shall be charged to the account of the Contractor.

n. Building mechanical utilities revisions and truss reinforcement shall include the design and installation of the following work.

   1) Relocation of steam lines, air lines, gas lines, and conduit to eliminate interferences.
   2) Relocation of ventilation duct work to eliminate interferences.
   3) Installation of required truss reinforcing.

o. In all cases, it shall be the Contractors responsibility to minimize interferences and to bring those interferences to the Owner's attention at the earliest possible date, but, no later than that specified in the "Time Schedule." If the Owner selects to design and install the mechanical utilities revisions and truss reinforcement, the Contractor shall design (subject to Owner's review) and install all work through the actual connection to the structure and shall supply the Owner with the loadings at that point, and the Owner will design and install the required building modifications to support that load. The loading data must be provided no later than the date specified in the "Time Schedule."

p. These modifications shall in no way be construed as a release by the Owner of total responsibility of the Contractor.

1.03 Scope Of Electrical Work

A. General

1. The Automated Iron Pouring System will be located in the Melt Department on Mold Line 803. The Contractor shall be responsible for all modifications, relocations and installation of new equipment including power distribution, interlocking and control wiring required to provide an operational facility.

2. The Contractor shall furnish all labor, materials, equipment and incidental services required to complete and leave ready for operation the electrical system as indicated on the drawings and hereinafter specified. Provide all items not specifically mentioned in the Specifications or noted on the drawings, but, which are obviously necessary to make a complete working system.

3. It is not the intent of these Specifications to cover all items or details of design and construction, but, to outline and define the type of provisions required and not unduly limit the Contractor's responsibility to furnish a complete and satisfactory operating system. Alternates and suggestions in the interest of the Owner will be given full consideration.

4. The Contractor shall assume full responsibility for purchasing, supplying, installing, field connecting and protecting all equipment furnished by himself. The Contractor shall have a representative on the job site during start-up of the equipment to correct any problems associated with his work.

5. The Contractor shall make maximum use of prefabricated, pre-finished, and pre-assembled components wherever possible.

6. Refer to the Time Schedule for starting and finishing date of the work.

7. Material provided by the Owner will be listed in the detailed Scope of Work for each area of work required.

B. Outline of Electrical Work (General)

The following items are suggested guidelines for the electrical consultant to follow when designing the electrical power and control modifications for the 803 Automated Iron Pouring System project.

Items included in the Standard Electrical Specification Section 16000 <u>are not suggestions but requirements</u> that shall be adhered to concerning the electrical design revision and installation for this project.

1. The design and installation of this project is meant to be "TURN KEY". That is, the successful bidder will be responsible for the outside design. With the exception of providing information, The Owner's involvement must remain minimal.

2. The successful bidder is expected to provide the following

    a. Issue drawings and specifications to electrical contractor.
    b. Supervise electrical installation.
    c. Provide on site start-up support.
    d. Develop control logic and programming design.
    e. Provide instruction manuals and video tapes for operator training.
    f. Provide system flow charts or block function diagrams.
    g. Troubleshooting procedures.

3. The successful bidder must supply complete system documentation. This includes, but is not limited to, the following:

    a. Hardware installation layouts (drawn to scale).
    b. Connection schematics of hard wired devices.
    c. Electrical device locations.
    d. Communication schematic diagrams.
    e. PLC ladder logic with labels and comments.
    f. PLC I/O wiring diagrams.
    g. BASIC or C-language program listings.
    h. Material lists.
    i. User option settings.
    j. Pin connections for communication connectors.
    k. Back-up program tapes or disks for logic and drawings.

4. Any software program compilers or special programs used in the control software, or in the development of the control software, shall be made available to the Owner for future programming modification.

5. The electrical designer must submit drawings and information for approval prior to construction of control panels or enclosures. Work or material that does not meet these Specifications will not be approved and will cause final payment to be withheld until satisfactory corrections have been made.

6. Information must be submitted on all pre-packaged devices such as flame detector safety modules, temperature controllers, modulating valve controls, etc.

7. The electrical designer shall provide all material, equipment, drawings, instructions, field support, programming, software, cabling, connectors, and miscellaneous electrical related items for a complete and operational control system.

8. There shall be "working drawings" and a current program listing and backup tape present in the electrical cabinet at all times. The electrical designer is responsible for submitting final documentation as described in the Standard Electrical Specification.

9. Electric motors supplied shall be sized for the required load. Over sizing of motors causes poor power factor and under utilization of equipment. Motors shall meet the Standard Specification for construction and service duty. Motors shall be energy efficient. Motor protection shall be sized according to the nameplate data, not a generic motor chart. Motors 20 horsepower and over require power factor correction capacitors in accordance with the specification. Capacitors shall be NON-PCB and mounted external to the control enclosure.

10. Control enclosures shall be mounted so they are insulated from radiant heat, physical damage, and vibration from fans and moving loads.

11. If possible, the programmable control system shall be assembled, checked, powered up, and functionally tested for correct wiring and logic programming, before being shipped to Owner for installation.

C. Outline of Electrical Work (Automated Pouring)

1. The Contractor shall be responsible for modifications, relocations and installation of new equipment including power distribution, interlocking and control wiring required to provide an operational Automated Iron Pouring System.

2. Install an Allen Bradley programmable control system that would be capable of the I/O requirements of the Iron Pouring System, communication for operator interface, and memory required for short term data storage.

3. Programmable control system shall incorporate the following:

a. I/O and logic to interface the mold pouring device to the 801 mold unit control. This may include, but is not limited to, the following:

   1) Allen Bradley PLC-5 processor.
   2) Digital I/O.
   3) Analog I/O.
   4) "Smart cards" such as DB-BASIC and motion control cards.
   5) Communication interface between computer and PLC processor.

b. Data table assignments for the storage of information pertaining to the status of the Automated Iron Pouring System. This may include, but is not limited to, the following:

   1) On-line monitoring of the pouring operation.
   2) Error conditions.
   3) Operator warnings.
   4) enunciator messages.
   5) short term production information.

c. Data highway control blocks to read the data table information from the 801 mold machine processors that control conveyor motion. This may include, but is not limited to, the following:

   1) Pattern well tracking information.
   2) Conveyor run permissive logic.
   3) Mold machine status for updating auto pour displays.
   5) short term production information.

d. Diagnostic logic for helping locate problems of pouring or communication between processors, computers, and related equipment.

e. Protection and warnings for equipment malfunctions.

f. Automatic mode wherein pattern well numbers are read from the data table for mold pouring characteristics. The part program is loaded from the storage file. The program is executed at the pouring station. The mold is released when the pouring operation is completed successfully.

g. Manual mode wherein the program may be selected by the operator and commanded to execute on the mold. Manual mode could also be used for creating a program by "teaching" the mold pouring device and then up-loading the part program into the part storage file. Manual mode would also be used to individually operate the mold pouring device functions.

10. Ancillary electrical facilities, equipment and related work to be provided by Contractor include, but are not limited to:

    a. Products: Materials used for this job shall be new, unused and without defects.

    b. Install the work according to manufacturer's recommendations and the Owner's standards and requirements. Refer to the preferred manufacturers list.

    c. Install equipment in location and manner that will permit convenient access for inspection and maintenance. Minimum clear working space in front of electrical enclosures as stated in the National Electrical Code must be maintained.

    d. Electrical distribution equipment located such that it's function is not self evident shall be marked in accordance with NEC 110-22. Engravings shall be white background with black lettering and attached with pan-head screws.

    e. Protect materials and equipment from damage during storage and installation. Replace or refinish damaged items as directed by Owner's Representative.

    f. Protect employees working on site by requiring the use of safety glasses with side shields and metatarsal safety shoes. The use of hard hats is also required in areas of overhead activity or construction. Hearing protection is also required while working on the Owner's property.

    g. All field wiring must be enclosed in rigid or IMC conduit as mentioned elsewhere in this specification. Minimum size is 3/4" with exceptions as listed elsewhere.

11. The electrical system for the mold pouring system shall include all necessary safety equipment for the protection of equipment and personnel. This may include, but is not limited to, the following:

    a. Control interlocks

b. Warning lights and audible signals
c. Emergency stop buttons
d. Non-contact presence sensor devices

D. Outline of Computer Equipment and Control Hardware

1. Programmable controls and computer equipment must be hardened for the manufacturing environment. Suitable non-ventilated enclosures must be provided. Panel cooling by air conditioning shall be provided if the components will not withstand the operating environment without cooling. Modems and communication equipment shall be mounted within the enclosures and shall have adequate space for servicing.

2. Control cabinet placement must be approved by the Owner's representative. Control cabinets must conform to the specifications for electrical control enclosures concerning spare space and construction. Verify that all working clearance dimensions conform to NEC.

3. CRT equipment, whether or not located within the control enclosure, shall be industrially hardened and suitable for the environment. These CRT terminals would be for the system console, operator interface, and parts programming.

E. Outline of Computer Control System

1. The system shall allow for off line (remote) programming for pattern number assignment to pattern wells and pouring characteristics of individual patterns.

2. Each pattern number shall have its own program for pouring characteristics. Storing these characteristics data rather than a compiled program is preferred.

3. Programming pouring characteristics shall be by single screen data entry for each pattern number.

4. Provisions must be made to allow programs to be developed from the mold pouring station and transferred back to a computer for storage.

5. Historical data must be maintained for the number of molds poured. This should include both the total number for the current run and the total number, life-to-date. Provisions should be made to reset the life-to-date totals manually.

6. The system should have a display to indicate which patterns are currently mounted in the wells. This screen

should also indicate the number of molds that have been made since that pattern was mounted.

7. The system shall be menu driven by prompts from the CRT display screen. These menu choices shall include, but may mot be limited to, the following:

   a. Create new part programs by:

      1) Entering characteristics described in Section 1.02.A.13.
      2) Teaching and uploading from the drag/cope molding machine area.

   b. Edit existing part programs by:

      1) Adding an alloy.
      2) Deleting an alloy.
      3) Modifying an alloy. addition.
      4) Modifying pour weight data.
      5) Deleting the entire program.

   c. Verify part program data by:

      1) Viewing information on CRT.
      2) Requesting printout.

   d. View and reset accumulation totals:

      1) Tons poured & tons poured by iron type.
      2) Number of molds poured.
      3) Average pour time.
      4) Alloy/inoculant usage.
      5) Number of by-passed molds.
      6) Furnace operating characteristics.
      7) Total hours of down time (delay).

   e. Request visual or printed reports:

      1) Shift activity report.
      2) Snapshot report (Activity before end of shift).
      3) Error logs.
      4) Program change/add logs.
      5) program inventory list with last date used.

   f. Maintenance information and manual functions:

      1) "Teach" mode for pouring profile by manual positioning and tilting.
      2) "Zero Calibration" for device positioning.
      3) Display mold part numbers at key positions.

4) Diagnostics for troubleshooting.
5) Handshake signal status.
6) Permissives (run/hold).
7) Automatic/Manual mode.
8) Single step through the pouring program.
9) Communication log (last N events).
10) Fault messages (last N events).

g. On-line monitoring of pouring activity. This screen shall display, but not be limited to, the following:

1) Part number(s) being poured.
2) Step number in the program.
3) Actual mold weight poured.
4) Desired mold weight poured.
5) Warning messages or faults that may occur

h. A "HELP" feature that would describe the system operation, menu choices, and offer assistance for troubleshooting or start-up of the system.

9. Menu choices that perform critical operations, or will change the operation, shall be confirmed by responding to an "ARE YOU SURE?" prompt. Data entered shall be range checked to avoid the system operating on values that are not valid or will cause operation errors when running.

10. The computer system control shall display messages to aid troubleshooting. It should indicate what the system is trying to do and also indicate why it cannot be done. Also, the system shall indicate if something happened that should not have happened. This is especially useful for checking interlocks and communications. (See On-line and Maintenance displays above.)

11. The computer shall anticipate the next part moving into the pouring station and position the pouring ladle over the intended pouring cup position to begin pouring while the flask is in motion. This will save motion time from a common "HOME" position.

12. The computer system shall have adequate communication ports to drive up to three CRT terminals and interface with an IBM TOKEN RING network. The TOKEN RING server shall be a backup memory storage device for part programs and production activity. The computer must communicate with the programmable control interface to the main molding unit control network.

1.04 Work Not Included

A. NOT APPLICABLE AT THIS TIME.

1.05 Alternatives

A. Alternative #1:

Provisions for installation of two separate pouring systems sized to support 60% of Mold Line 803 capacity. The units should be located adjacent to one another. The expected results being to minimize the impact of a major breakdown of one unit.

B. Alternative #2:

All proposals for improvement of the existing operation will be considered. Less extensive automation may provide benefits more easily justified. Attempts at smaller steps in this direction should include expected advantages over the current norm.

1.06 Design Criteria

A. All work shall be performed and all equipment shall be designed to conform to the following Standard Specifications:

1. Pneumatic systems shall conform to the applicable requirements of "Standard Specifications For Pneumatic Systems" except as otherwise specified.

2. Production equipment components shall conform to the applicable requirements of the "Standard Specifications For Foundry Production Equipment Components" except as otherwise specified.

3. Electrical systems shall conform to the applicable requirements of "Standard Specification For Electrical Systems" except as otherwise specified.

4. General service piping above and below ground for various utilities shall conform to the applicable requirements of "Standard Specification For General Piping" except as otherwise specified.

5. Hydraulic systems shall conform to the applicable requirements of "Standard Specifications For Hydraulic Systems" except as otherwise specified.

6. Lubrication systems shall conform to the applicable requirements of "Standard Specifications For Lubrication Systems" except as otherwise specified.

7. Supporting Structures and other miscellaneous iron work shall conform to the applicable requirements of "Standard Specifications For Miscellaneous Steel And Iron Work" except as otherwise specified.

8. All work ion this Contract shall be painted in accordance with the applicable requirements of "Standard Specifications For Painting" except as otherwise specified.

9. Production equipment shall conform to the applicable requirements "Equipment Noise Specifications" except as otherwise specified.

10 All work in this Contract shall meet requirements stated under "Cast-In-Place Concrete" except as otherwise specified.

11. Exhaust and dust collection systems shall conform to the applicable requirements of Dust Collection."

12. Lighting shall conform to the applicable requirements of "Standard Specifications For Supplemental Lighting."

13. Make up air systems shall conform to the applicable requirements of "Standard Specifications For Heating And Ventilating Duct-work Systems."

14. Electrical work and materials shall conform to the applicable requirements of "Standard Specifications For Electrical Methods and Materials."

15. Electrical testing shall conform to the applicable requirements of "Standard Specifications For Electrical Acceptance Tests."

16. All equipment and materials shall conform to the applicable requirements of "Standard Specifications For O.S.H.A. Requirements."

17. Structural steel systems shall conform to the applicable requirements of "Structural Steel," Section 05120 of these Specifications.

18. Steel Joists shall conform to the applicable requirements of "Steel Joists," Section 05210, of these Specifications.

19. Metal Decking for floors and roofs shall conform to the applicable requirements of "Metal Decking," Section 05300 of these Specifications.

20. Painting and coating of structural steel shall conform to the applicable requirements of "Structural Steel Painting And Coating," Section 09915 of these Specifications.