ADVANCEMENT OF CORED WIRE APPLICATIONS WITHIN THE STEEL AND CAST METALS INDUSTRIES

Heinz Mair
Odermath Stahlwerkstechnik, GmbH

Donald B. Marsh
Miller and Company

ABSTRACT

During the last five years the worldwide application of Cored Wire Technology within the Steel and Cast Metals Industries has significantly proliferated based upon demonstration of metallurgical benefits derived from the usage of cored alloy wires to deoxidize, desulfurize and micro-alloy. These benefits have been well documented in technical literature. More recent application developments within Gray Iron, Ductile Iron and Steel Foundries indicate increased utilization of Cored Wire technology within these industries.

This study offers a comparative overview of Cored Wire injection versus conventional alloying treatments relative to recovery, reproducibility, and environmental considerations, etc.

In addition to previously documented commercial production of Ductile Iron utilizing Magnesium Cored Wire a major European high production automotive foundry has recently installed a multiple line computer controlled cored wire system to facilitate micro-alloying and inoculation of gray iron castings. An equipment review and implementation status report is hereby offered.

INTRODUCTION

Low and inconsistent elemental recovery problems are often encountered when adding certain specific alloys to liquid steel and iron. This is often the case if the alloying element exhibits one or more of the following characteristics:

- LOW MELTING OR BOILING POINT
- DIFFERENTIAL DENSITY
- LOW SOLUBILITY
- HIGH OXYGEN AFFINITY
- HIGH VAPOR PRESSURE
- READILY FORMS TOXIC VAPOR OR REACTIVE DUST

Potential consequences or disadvantages are:

- LOW ELEMENTAL RECOVERY
- HIGHLY VARIABLE ELEMENTAL RECOVERY
- FORMATION OF EXCESSIVE NON-METALLIC INCLUSIONS YIELDING DETERIORATION OF QUALITY
- VIGOROUS PYROTECHNIC REACTION YIELDING POTENTIAL PERSONAL SAFETY AND/OR EQUIPMENT FAILURE
- ADVERSE ENVIRONMENTAL IMPACT
- EXPOSURE OF OPERATING PERSONNEL TO POTENTIAL HEALTH HAZARDS

With the development of powder injection techniques as applied to metallurgical refinement it became possible to remove some of the aforementioned disadvantages. With the development of cored wire technology nearly all disadvantages are minimized and controlled.

A logical consequence has therefore been an increased application of cored wire technology. The range of application is determined by the alloying element and the injection device utilized. It is however still a technology open for new ideas and developments.

Current requests for increased automation concerning actual cored wire injection treatment will lead to the development of a broader range of alloying wires and improved feeding devices. Computer-controlled devices have already been developed to provide economical and reliable treatment systems for various metallurgical applications.

I. STEEL TREATMENT

The application of cored wire technology for the metallurgical refinement of steel has already become common metallurgical practice.

In this respect metallurgical treatment with calcium is dominant as documented in innumerable technical publications. Nevertheless, the addition of other alloying and treatment agents has also reached significant importance.

The widespread application of the cored wire treatment method has occurred because the process is capable of yielding the following advantages:

1. ACCURACY OF MICRO-ALLOYING
2. REPRODUCIBILITY
3. LOW TEMPERATURE LOSS
4. MINIMAL ENVIRONMENTAL IMPACT
5. HIGH ALLOY QUALITY
6. LOW NITROGEN ABSORPTION
7. PROCESS ECONOMY
8. SUITABILITY FOR AUTOMATION
9. COMPACT TREATMENT STATIONS
10. MINIMAL CAPITAL INVESTMENT

THE ECONOMICAL FACTOR

This item represents a very complex topic. We are not only referring to less material consumption because of increased metallic recoveries. Adopting this point of view would only deal with this factor superficially and would disregard a number of equally important economic considerations.

As an example; a steel company in Finland has reported that the introduction of cored wire injection yielded positive results within two months after initial implementation. Diverted heats resulting from analytical deviation were reduced by 70%. Diverted heats create cost penalties resulting from:

- ALLOY LOSSES
- INCREASED INVENTORY COSTS
- REDUCED FABRICATION YIELDS
- REDUCED UTILIZATION OF STEEL PRODUCTIVE CAPACITY

A reduction of 50% would have been sufficient to recover cored wire expenses including wire costs. The following diagram shows developments from 1985 to 1987 at the subject company (Fig. 1). Automated development of their cored wire processing has continued.

Quantities of C, FeSi, FeMn, FeB, FeTi, CaSi, and Al to be added are calculated utilizing a computer system. Additives are sequentially injected according to a specially designed metallurgical practice program. The following figure shows a part of the coil storage and the wire injection unit (Fig. 2).

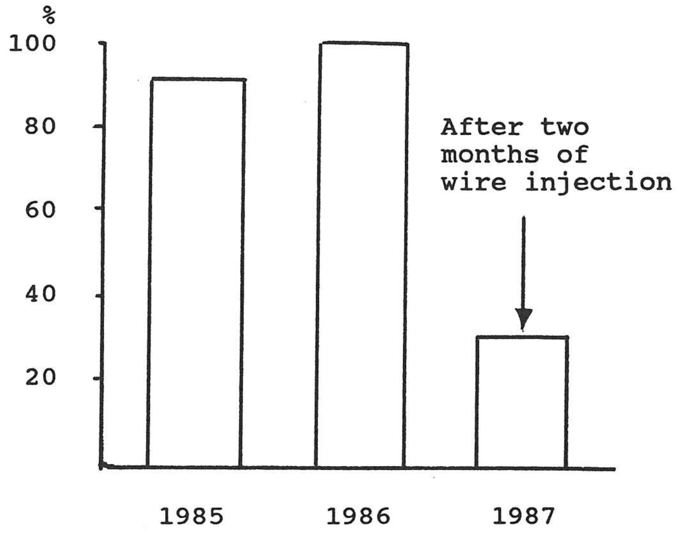

Fig. 1 Steel composition rejections at Rautaruukki, Finland [1,2]

Another economic factor to be considered is the temperature loss of a heat during treatment. It is typical for powder injection techniques which use inert carrier gases to yield temperature losses approximating 50°C whereas the typical loss associated with cored wire injection only amounts to approximately 7 °C. Tap temperatures may therefore be reduced yielding both energy and lining material savings.

REPRODUCIBILITY/ACCURACY

The reproducibility and accuracy of analytical values is an important feature of cored wire technology. The following table gives an overview of results achieved in production applications (Table I & II). Remarkable deviations from these tabular results may appear if certain wire injection guidelines are not followed.

TABLE I: STANDARD DEVIATION OF THE ALLOYING ELEMENTS [2]

Element	Composition Range %	Standard Deviation No Wire Injection	Standard Deviation Wire Injection
C	0.12 - 0.14	0.010	0.007
Mn	1.35 - 1.50	0.057	0.038
Si	0.35 - 0.45	0.027	0.018
Nb	0.030- 0.040	0.004	0.003

TABLE II: RESULTS OF NIOBIUM TRIMMING BY WIRE INJECTION [6]

Aimed Value	Obtained Value	Standard Deviation
0.0075	0.0073	0.0011
0.0150	0.0150	0.0013
0.0300	0.0296	0.0015

The following illustrations (Fig. 3) show the locations within a ladle where injection should take place. Lead injection is an exception whereas lead should be injected at a low speed and injected into the area of liquid turbulence.

If induction stirring is utilized instead of a lance or porous plug, deviations in recovery may occur caused by the induced stirring motion versus the point of wire injection. The arrangement shown in (Fig. 4) resulted in a 50% reduction in recovery of CaSi and C. The results were consistent for both case I and II but the recovery rates proved to be very different.

The following diagram provides an overview of the applications of cored wire technology within the steel industry (Fig. 5).

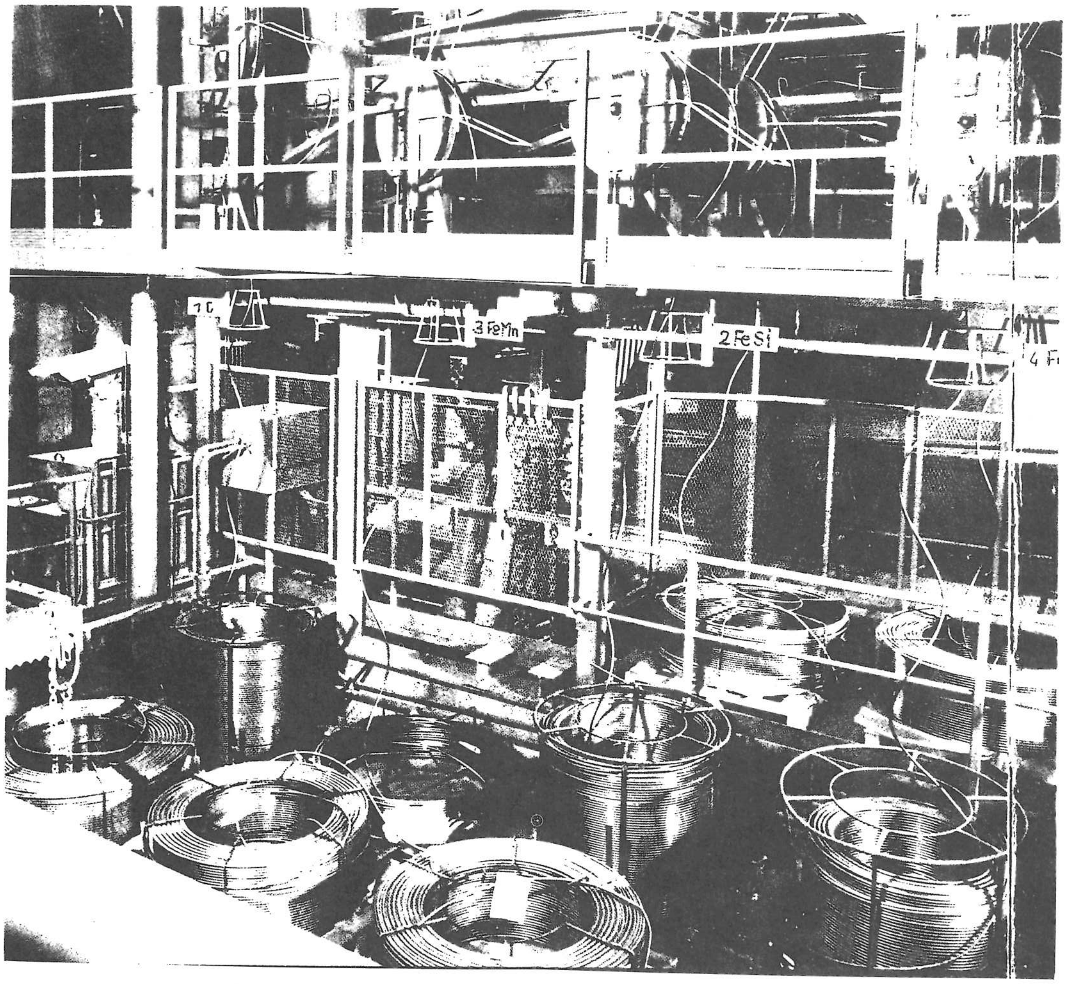

Fig. 2 Wire injection station (partial) for 6 different wire types (Rautaruukki) [1]

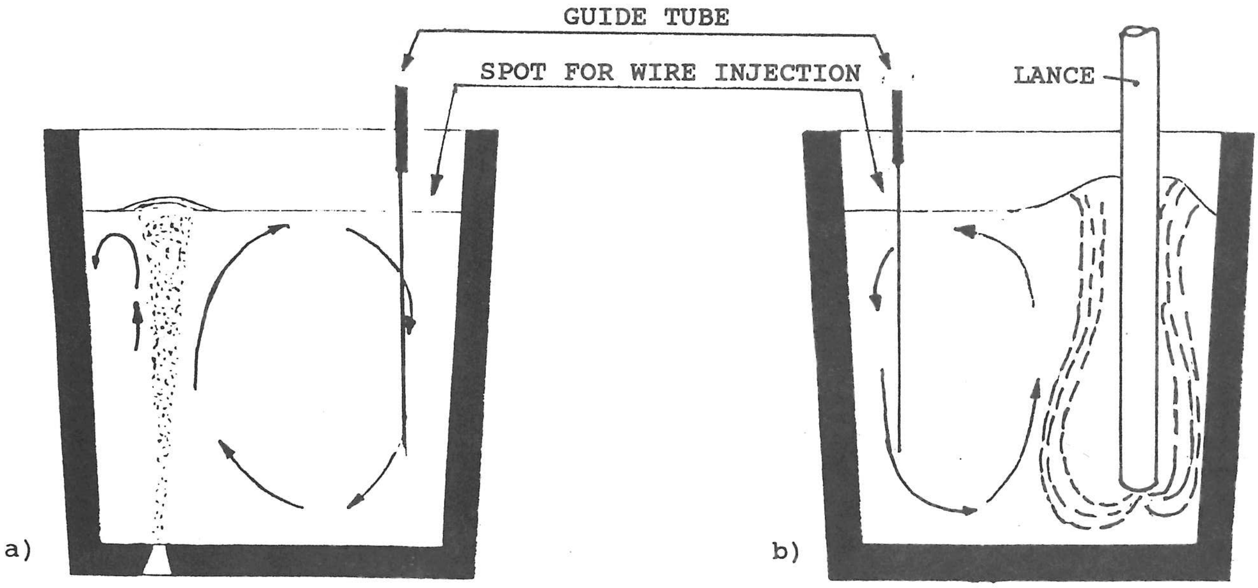

Fig. 3 Schematic diagram illustrating bath movement in a ladle during argon stirring through a) porous plug b) lance and recommended spot for wire injection

The most common application is cored wire injection into a ladle or ladle furnace. Tundish injections have become rare because proper distribution of the injected material is suspect especially if multiple strands are being cast.

Another method of cored wire injection is the FAST-process (Forced Acceleration of Solidification Technology) developed by TERNI (Italy) [3]. Cored wire is fed directly into the casting mold through the tundish via the open interior of a stopper rod. Industrial tests have been made with Fe for cooling and with Al and Ti for alloying. Structural and stainless steels have been treated utilizing this method yielding slabs measuring 232mm x 1080mm and 178mm x 1330mm. The maximum amount of Fe cored wire added reached 0.61% of cast weight. The maximum amount of Al wire added amounted to 0.33% of cast weight and 0.050% for Ti. The recovery of Al and Ti reached 90% with nitrogen absorption less than 5 ppm. Metallurgical product evaluation showed no differences between the cored wire injection method versus conventional production. Other elements such as Pb, B, S etc. are also considered to be suitable for this type of wire injection.

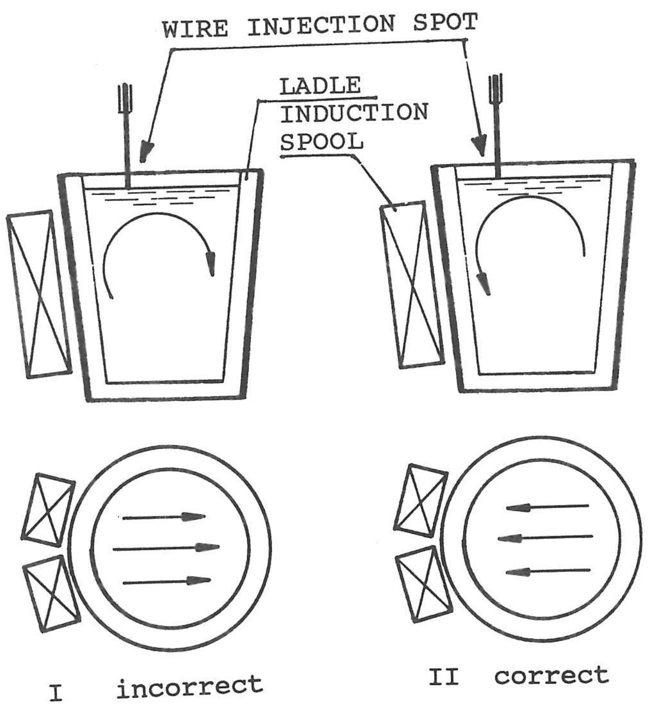

Fig. 4 Injection with induction stirring

MINIMAL ENVIRONMENTAL IMPACT

The need to safely produce quality leaded steels has yielded a new cored wire application (patent applied for) utilizing lead cored wire injected into the trumpet of a plate of bottom poured ingot molds. This innovative process is currently being evaluated at a major integrated steel mill in the U.S.A. The main advantage of this procedure is environmental protection by minimizing the evolution of toxic fumes while evenly feeding a low melting point, dense alloy.
Initial trials have been promising. The procedure is shown in (Fig. 6) and (Fig. 7).

Other environmentally difficult applications, i.e. alloying with tellurium and sulfur in steel and the treatment of base cast iron with magnesium and calcium carbide in the foundry sector yield process problems that are minimized by utilizing cored wire methods. The protection of operator personal health is certainly more important than purely economic considerations.

It is not acceptable to install processes which pose continued threats to our health or our environment for purely commercial reasons. It is not the physical characteristics or the reaction of these elements that endanger our living space but our own incapability to handle these factors correctly by utilizing improved processes.

NITROGEN ABSORPTION

Nitrogen absorption has been evaluated for the injection of CaSi cored wire. The average nitrogen pick-up is between 0-2 ppm, whereas powder injection values as high as 20 ppm have been observed.

Steels alloyed with boron require a low nitrogen content. Free nitrogen in boron heats negatively influence the hardenability of these steels. Such steels therefore must be treated with titanium in order to tie-up free nitrogen. In other steel grades where the nitrogen content must also be controlled corresponding process changes must be implemented if other alloy injection methods are utilized.

STEEL CLEANLINESS

When using the cored wire injection method to add treatment and/or alloying elements the air factor may be neglected (in the absence of turbulence) as oxides may only be formed with oxygen existing in a dissolved form or by the presence of oxides as an oxygen carrier, provided that the oxygen affinity of the introduced element is higher than that of the oxides present in the heat.

According to test results, steel cleanliness is improved for heats treated with cored wire versus powder injection. This fact is further confirmed by higher recovery rates experienced with cored wire use (Fig. 8). The diagram shows the total

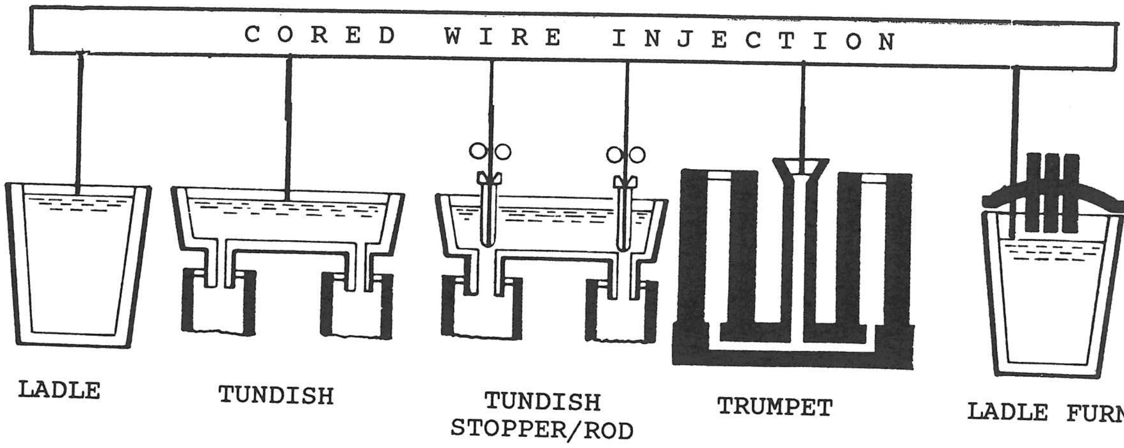

Fig. 5 Different possibilities for cored wire injection in steel.

oxygen contents of calcium treated heats during continuous casting. Gaseous injection by lance definitely yields higher oxygen values compared with cored wire injection therefore resulting in decreased cleanliness.

POSSIBILITY FOR AUTOMATION

The cored wire injection method offers excellent opportunity for automation. Many companies already use computer-aided process control to calculate and implement heat additions. Part IV "WIRE FEEDING DEVICES" discusses in detail this capability.

II. HOT METAL DESULFURIZATION

A preliminary desulfurization of hot metal (pig iron) is often necessary in order to produce steel with extremely low sulfur contents. For this application desulfurization with Magnesium injected by means of cored wire has shown good results. Provided that the ladle lining is suitable (preferably basic) and the top-slag is modified to support desulfurization S-values under 0.003% may be achieved with this procedure.

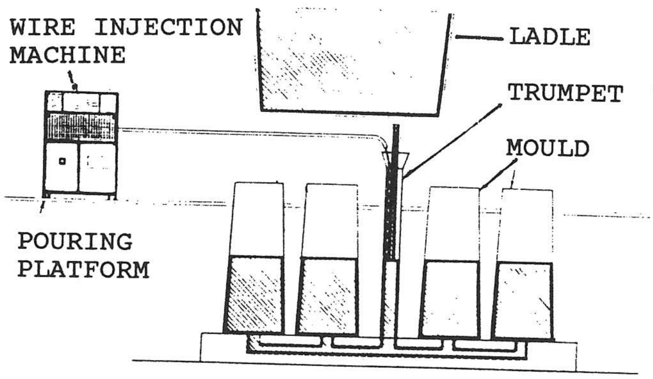

Fig. 6. Lead cored wire injection

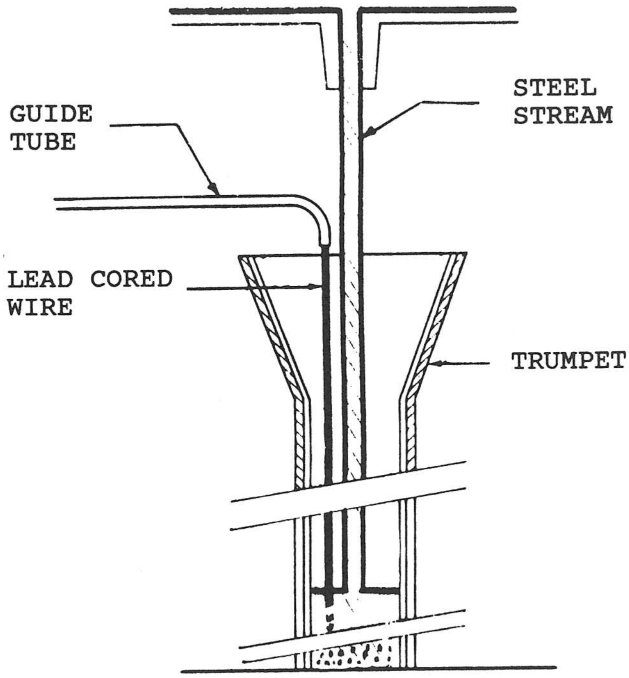

Fig. 7 Diagram for lead cored wire injection (Detail)

The advantages of this process are not only extremely effective and reliable desulfurization but the process only requires minimal capital investment compared to powder injection systems. Capital expense for a wire injection station may be as little as 5% of the expense required to install a powder injection station. Furthermore, maintenance expenses for wire injection are quite low whereas a powder station requires constant attention and more space.

Problems often arise when using powder injection discontinuously, i.e. pneumatic lines can become blocked by the build-up of hygroscopic raw material.

The following table provides a comparison of advantages and disadvantages for powder injection versus cored wire systems as applied to hot metal desulfurization:

	LANCE	WIRE INJECT.
INSTALLATION COST	-	+
MAINTENANCE	-	+
AVAILABILITY FOR OPERATION	-	+
SPACE REQUIREMENT	-	+
TEMPERATURE LOSS	-	+
CARRIER GAS	-	+
ENERGY REQUIREMENT	-	+
EFFICIENCY	-	+
RAW MATERIAL COST	+	-
ENVIRONMENTAL IMPACT	-	+

(+ = better, more favorable, lower cost)

(Fig. 9) shows the schematic of a wire injection station for hot metal desulfurization which is similar to the plant installed in 1984 at SOLLAC (Société Lorraine de Laminage Continu) in France. This process has so far been used to desulfurize in excess 1 million MT. of hot metal. Additional cored wire injection desulfurization stations have also been installed in other European plants. The following graphs provide information regarding Magnesium consumption and corresponding sulfur reduction (Fig. 10, 11).

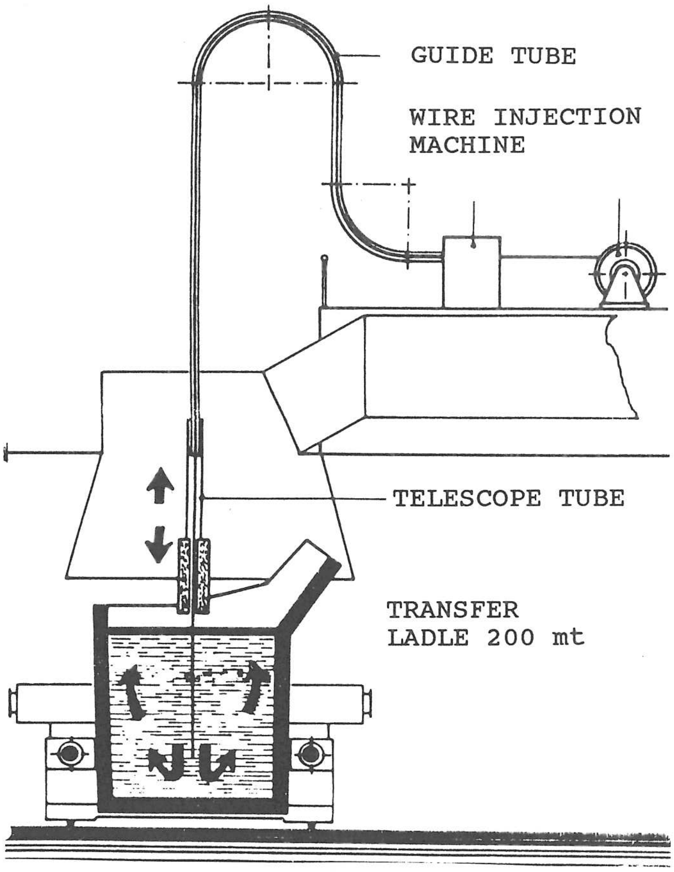

Fig. 9 Diagram for the desulphurization of hot metal. [4]

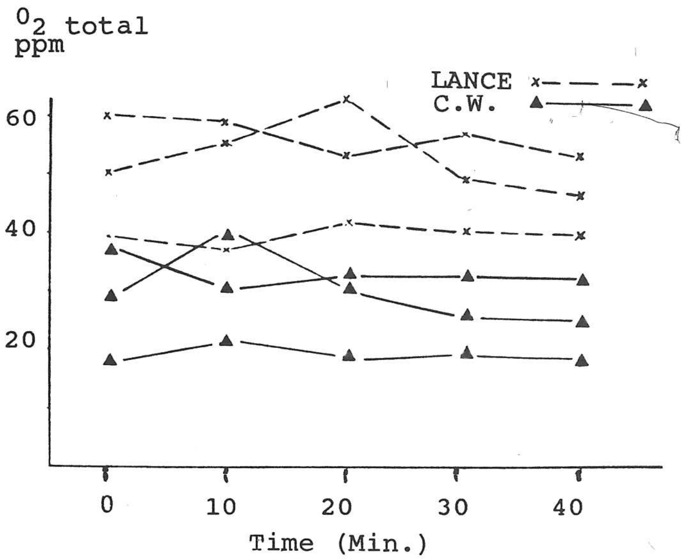

Fig. 8 O_2 total content versus time. Powder injection versus cored wire treatment.

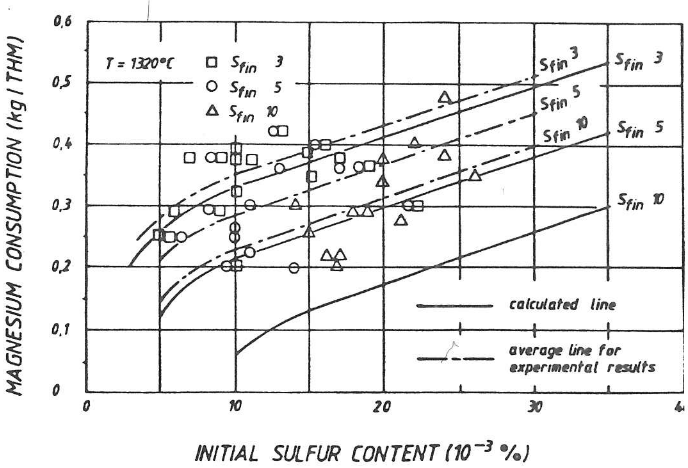

Fig. 10 Magnesium consumption to attain definitive final sulphur content values as a function of initial sulphur content [4]

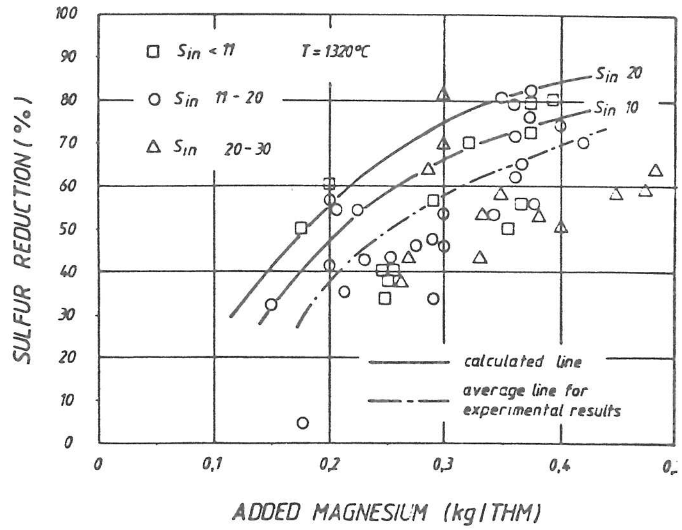

Fig. 11 Desulphurization as a function of added Magnesium [4]

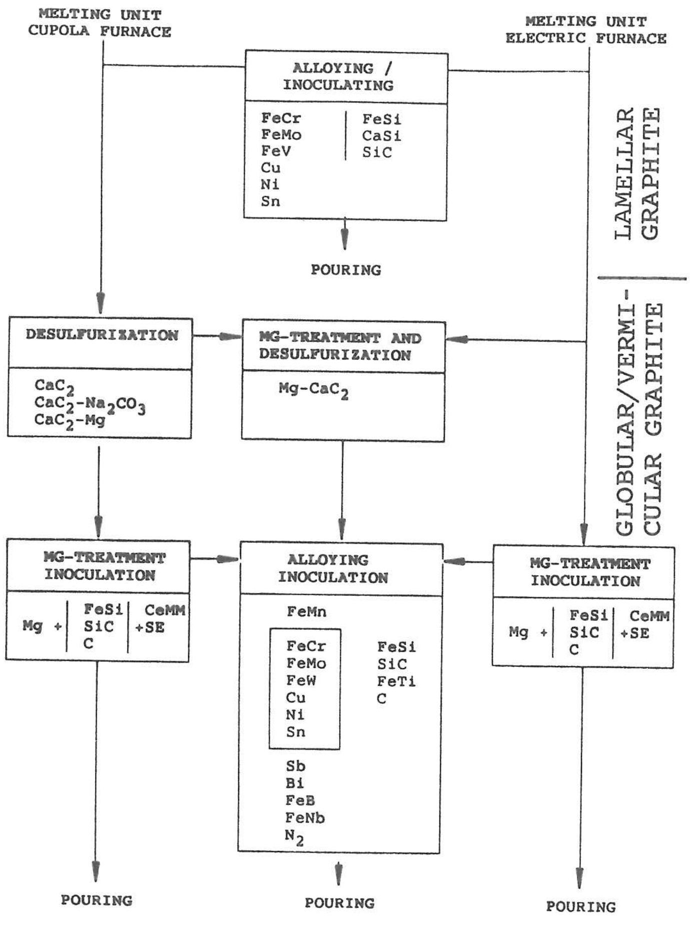

Fig. 12 Metallurgical processes for the production of cast iron with the application of cored wire in each particular process-step.

III. TREATMENT OF CAST IRON

To date cored wire technology has been applied to the production of cast irons in order to accomplish the following metallurgical processes:

1. DESULFURIZATION
2. MAGNESIUM TREATMENT
3. ALLOYING
4. INOCULATION

The process utilized is determined by the type of cast iron being produced as well as by the characteristics of the base iron being treated. The schematic illustration in (Fig. 12) shows the respective cored wire treatment processes applicable to cast iron production.

A. GRAY IRON PRODUCTION:

ALLOYING AND INOCULATION

ALLOYING - similar to steel applications cored wire technology offers a highly efficient and precise controllable method of introducing alloy trim additions to liquid cast irons. Elemental recoveries are maximized due to minimal oxygen exposure. Alloy trim additions can be made to furnaces or even full ladles which otherwise would be difficult to analytically adjust once molten metal transfers have occurred. Precise cored wire alloy additions offer the opportunity for alloy cost savings by minimizing total alloy additions.

INOCULATION - gray iron inoculants are already being introduced by some foundries utilizing cored wires. The same metallurgical reactions that apply to the alloying of gray iron apply equally well regarding inoculation. Once again, the precise controlled addition of inoculants yields maximum effectiveness and therefore reduced consumption and cost. Cored wire addition for either inoculation or alloying applications is ideally suited for process automation.

Cored wire treatment procedures have been initiated in a few automated foundries. Treatment takes place at points shown in (Fig. 13) according to the type of molten metal handling equipment used. The methods shown under (A) and (B) are preferably used whereas method (C) is not often applied.

As an application example a major European automotive foundry with a production of 1000 MT/day decided in 1986 to apply cored wire technology to the alloying and inoculation of their gray iron production. This decision was based on thorough pretesting. Their evaluations showed that in addition to a reduced consumption of alloys (up to 60%), more precise alloying and inoculation could be achieved. Actual production within their new plant has further confirmed their earlier findings.

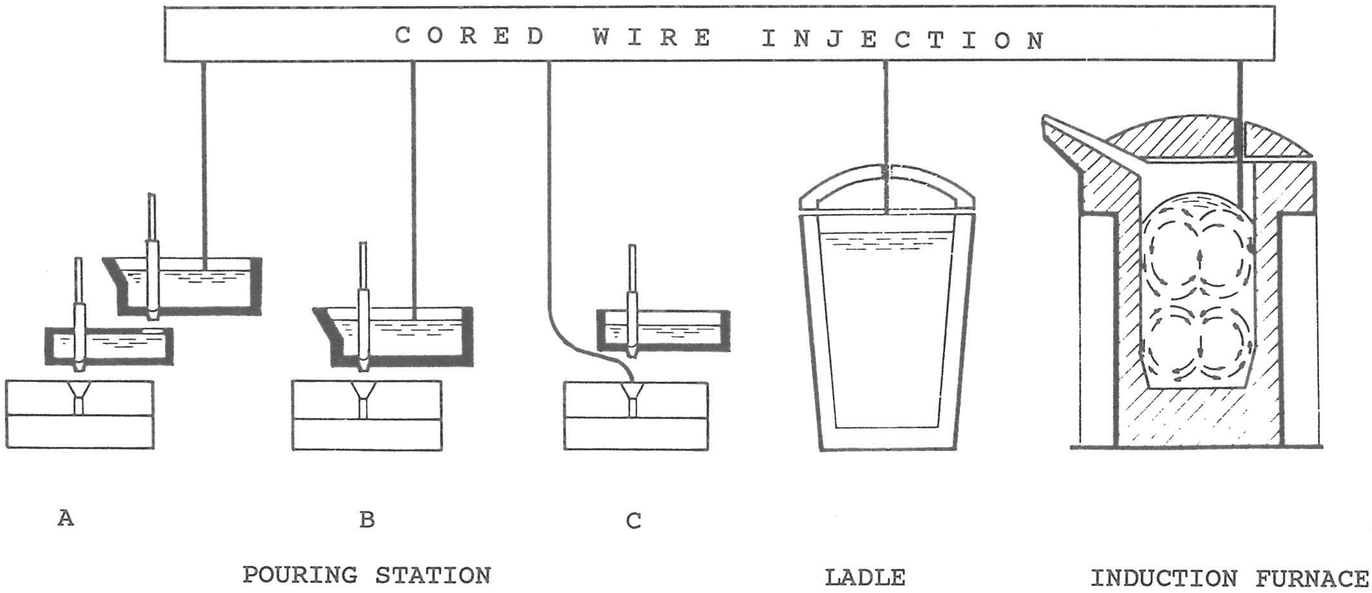

Fig. 13 Different possibilities for cored wire injection in cast iron.

Fifteen wire injection machines, each with dual wire feeding strands, have been installed on two fully-automatic and one semi-automatic molding lines. Three machines are located in each machine block.

Wire injection is executed according to method (A) (Fig. 13). The alloying elements utilized are FeCr and Cu with FeSi being used as the inoculating agent. A special drive and control system guarantees an accuracy of +/-5 mm of wire added per work cycle. The complete casting facility is based on producing one standard base iron with specific alloying and inoculation additions for each mold produced. (Fig. 14) describes the process controls.

During the information period the analysis of the base iron and the specification required is registered. The computer then calculates the necessary alloying and inoculation additions during the calculation period. Calculated values including the injection speed are transmitted to the control module of the machine.

During the execution phase the calculated lengths of cored wires required are injected and registered. The computer then compares calculated versus actual wire length injected and with each acceptable comparison will issue the command to start the next process, actual casting. The complete cycle time from the initial check of information to the end of casting amounts to approximately 15 seconds. (Fig. 15) shows a schematic presentation of the treatment line. The following average alloying and inoculation quantities are being used:

FeCr	approx.	0.20%
Cu	approx.	0.20%
FeSi	approx.	0.10 - 0.25%

TABLE III - ELEMENTAL STANDARD DEVIATION

Element	Range	Standard Deviation No Wire Inject.	Standard Deviation Wire Inject.
Si	1.90-2.20%	0.09	0.05
Cr	1.15-0.40%	0.03	0.02
Cu	0.20-0.25%	0.07	0.01

Advantages of the complete treatment system are summarized as follows: Only one base iron is produced by charging the cupola with the same metallic charge make-up. This practice yields a constant and controllable base iron. All castings are classified by specific criteria such as wall thickness, weight, application, etc. Each classification corresponds to a customized cored wire treatment program. All molds can be poured at random with every mold having identification corresponding to a preprogrammed treatment plan.

Because cored wire alloying and inoculating additions are so precise, predictable and accurate, raw material consumption is greatly reduced versus conventional methods. The occasional tendency to over inoculate for safety factor reasons as well as the danger of insufficient inoculation is eliminated. Human failure that exists at operations where treatments are added manually is also essentially eliminated. Quality is further assured by the additional ability to apply statistical process control techniques.

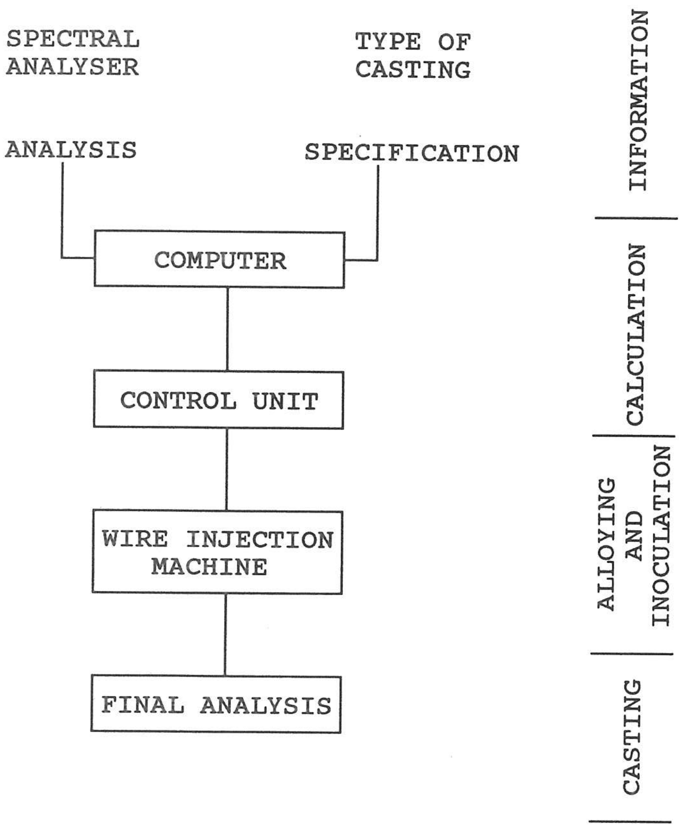

Fig. 14 System of automatic analysis, alloying and inoculation control.

B. DUCTILE IRON PRODUCTION TREATMENT:

DESULFURIZATION

The sulfur content of cupola produced ductile base iron can routinely run as high as .15% S. To economically produce quality ductile iron it is necessary to reduce the sulfur content of a base iron to approximately .015% prior to magnesium treatment. Currently, desulfurization is usually achieved via preliminary metallurgical treatment with calcium carbide. The necessary sulfur values are thus achieved.

Calcium carbide desulfurization is easily accomplished by using various batch or continuous treatment methods whereby granular calcium carbide is either injected or gravity fed into ductile base iron. These conventional methods are both low in cost and are unsophisticated [5]. However, such processes do produce two major disadvantages:

1. Unreacted reagent can become entrapped in refuse slag and thus create a hazardous waste disposal problem. Unreacted calcium carbide when exposed to water generates highly flammable acetylene gas. Disposal of these slags at proper government approved dump sites is a high cost nuisance.

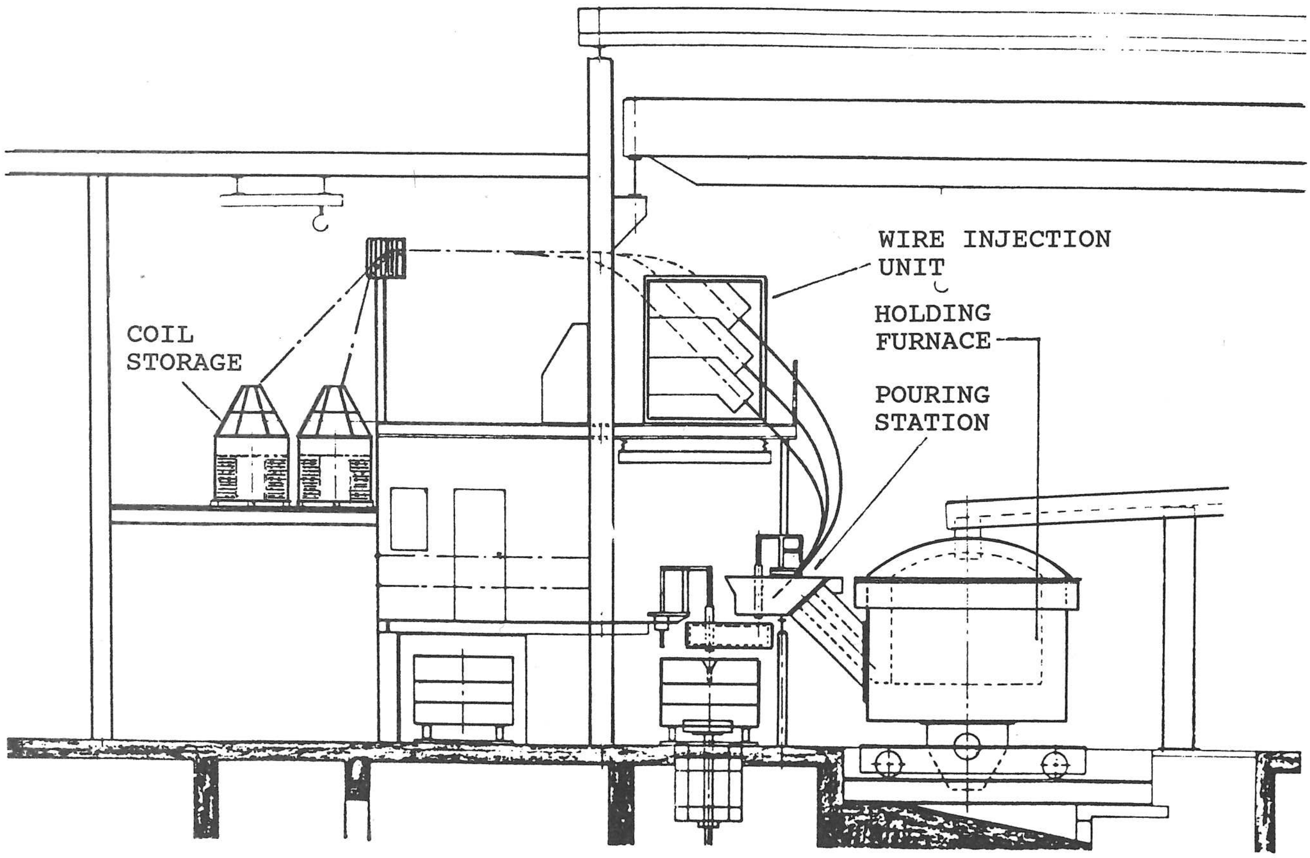

Fig. 15 Diagram illustrating one section of an automatic wire injection station in a foundry

2. Fine particles of unreacted calcium carbide are usually carried away from the process reactor either by process turbulence or convection currents. These fine particles are a potential source of human skin irritation leading to possible labor relation difficulties which are of course costly as well.

Reduced environmental impact is therefore an important consideration when applying cored wire methods to the desulfurization of ductile base irons. The comparative economy of this process is still under study however production trials have been initiated (Fig. 16-17). Results achieved thus far confirm once again the efficiency of wire injection. Essentially, all calcium carbide is consumed without the formation of hazardous slag. The evolution of reactive dust is also eliminated. An analysis of the results achieved in fifteen different foundries which utilize conventional calcium carbide desulfurization processes show calcium carbide usage up to 11 KG/MT to typically remove 0.10% S. The top five most efficient foundries studied require approximately 7.0 KG/MT. The calcium carbide cored wire injection method has thus far yielded a comparable consumption of 4.5 KG/MT to remove 0.10% S.

A summary of process advantages is as follows:

- HIGHER EFFICIENCY THEREFORE LESS REAGENT CONSUMPTION
- IMPROVEMENT OF WORKING CONDITIONS
- ELIMINATION OF LADLE BUILD-UP
- REFRACTORY SAVINGS
- INERT SLAG
- PROCESS AUTOMATION CAPABILITY

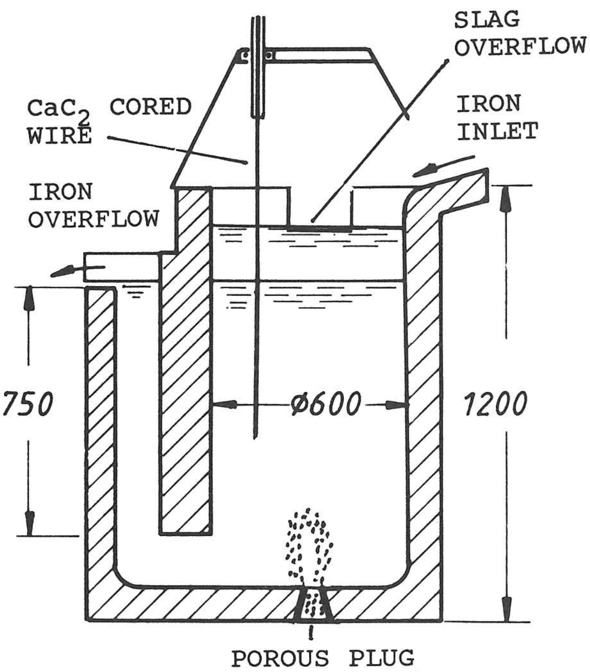

Fig. 16 Diagram for continous desulphurization of foundry iron in a teapot ladle with calcium carbide cored wire (mm).

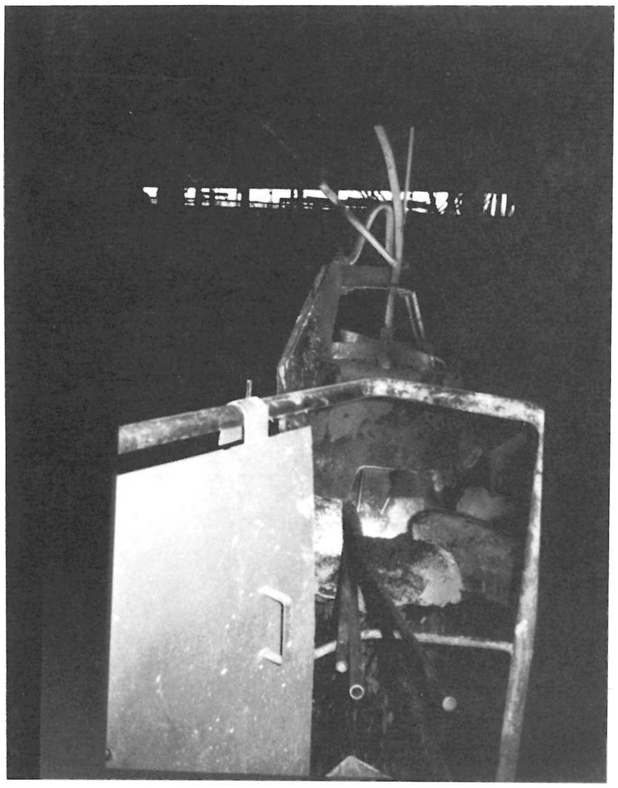

Fig. 17 Desulphurization of cast iron with calcium carbide cored wire.

TREATMENT: MAGNESIUM TREATMENT OF CAST IRONS

The pyrotechnic reaction of magnesium experienced when producing ductile or compacted graphite iron has always presented foundrymen with process control problems. Over the years a number of magnesium treatment process have been developed and implemented with various inherent advantages and disadvantages. Table IV displays a brief summary of comparative conventional magnesium treatment processes. Please note that other than cored wire injection, all other treatment processes that utilize elemental magnesium require complex expensive equipment. In other words, the lower the cost of the elemental magnesium unit used the higher the cost of equip-ment required as well as a higher degree of process difficulty (Fig. 18). This statement does not apply to magnesium treatment via cored wire.

The addition of magnesium to liquid iron by means of a cored wire actually is not a recent innova-tion. Blast furnace iron (hot metal) desulfuri-zation utilizing this method has been done for more than five (5) years, however, it took a long time until a similar process was commercially used to produce ductile iron with cored wire.

TABLE IV: COMPARISON OF DIFFERENT MAGNESIUM TREATMENT METHODS

METHOD	SANDWICH	PLUNGING	CONVERTER	INMOLD	WIRE INJECTION
Mg-Alloy Mg %	MgFeSi 03-10	Pure MG MgFeSi 05-35	Pure Mg	MgFeSi 05-10	Pure Mg + other elements as required
Mg-Recovery %	35-60	40-60	45-60	70-80	35-70
Investment	-	Low	High	-	Low
Air Pollution	Medium/High	Low/Medium	High	-	Low
S-Limitation %	0.040 S	0.080 S	0.15 S	0.010 S	No Limitation
Inoculation effect through Mg-treatment	Irregular	Small/No	No	Very High	High
Applicability	Simple, no further equipment required	Plunging bell plus treatment station required	Equipment must be well prepared	High Production Only	Easy, automatic control possible
Max. quantity per treatment (MT)	No Limit	No Limit	5t	No Limit	No Limit
Disadvantages	Dross; variability in Mg content of alloy	Dross; Mg deviation in alloy; plunging bell required; labor cost	Continuous operation	Danger of heterogeneous Mg distribution; Dross	Cost of Wire

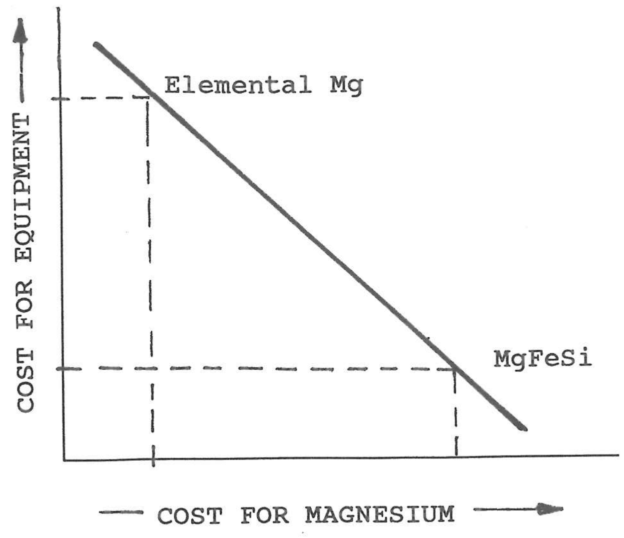

Fig. 18, Cost for equipment versus cost for Magnesium

Various possible reasons for this delayed development are:

- NO EXPERIENCE WITH THE APPLICATION AND USE OF CORED WIRES
- UNSUITABLE INJECTION DEVICES FOR CORED WIRE
- IMPROPERLY SIZED CORED WIRES
- HIGH COST FOR CORED WIRE FILLED WITH MAGNESIUM

As time has passed, it has been possible to collect practical experience derived from applications of cored wire in the steel industry and partly derived from many foundry test runs so that now other applications of magnesium-filled cored wire have become a reality. The fill content of the cored wire may of course be easily adjusted according to application requirements. For base irons with high sulfur contents the Magnesium fill is blended with another desulfurization agent such as calcium carbide.

In case of low sulfur base irons it is possible to effect magnesium treatment and inoculation simultaneously by blending the magnesium wire filling with an inoculating agent in an appropriate ratio. This method insures a sufficient distribution of the inoculating agent due to ladle turbulence caused by the magnesium reaction which has a favorable influence on the process. If tramp elements are present in the base iron, it is of course possible to also add rare-earth metals to the wire filling.

The magnesium treatment of base irons utilizing cored wire also makes feasible the covering of the surface of a molten bath with a protective gas during magnesium injection. This shield reduces the formation of oxides thereby improving process efficiency and increasing quality. The following tables demonstrate results achieved during the actual production of ductile iron.

TABLE V - TEMPERATURE LOSSES DURING MAGNESIUM CORED WIRE TREATMENT (AVERAGE VALUES)

	TREATMENT WEIGHT (KG)	NO. OF TREATMENTS	T1°C
1.	750 - 850	20	1453
2.	1650 - 1750	3	1366
3.	2000 - 2500	7	1463

	T2(°C)	T1-T2(°C)	MG%
1.	1392	61	0.053
2.	1324	42	0.075
3.	1427	36	0.042

T1 = Temperature Before Treatment
T2 = Temperature After Treatment

TABLE VI - RECOVERY RESULTS FOR BASE IRON TREATMENT WITH MAGNESIUM CORED WIRE (AVERAGE VALUES). TREATMENT TEMPERATURE: 1366°C

TREATMENT WEIGHT (KG)	SULFUR CONTENT START (%)	END (%)
1650 - 1750	0.011	0.005

MAGNESIUM ADDTN (%)	FINAL (%)	RECOVERY (%)
0.110	0.075	70.1

Number of Treatments: 4

TABLE VII - RECOVERY RESULTS FOR BASE IRON TREATED WITH MAGNESIUM CORED WIRE (AVERAGE VALUES), TREATMENT TEMPERATURE: 1453°C

TREATMENT WEIGHT (KG)	SULFUR CONTENT START (%)	END (%)
750 - 850	0.012	0.007

MAGNESIUM ADDTN (%)	FINAL (%)	RECOVERY (%)
0.115	0.053	49.8

Number of Treatments: 20

TABLE VIII - MAGNESIUM RECOVERY WITH AND WITHOUT THE USE OF A NITROGEN COVER.

TREATMENT WEIGHT (KG)	TEMPERATURE (°C)	RECOVERY WO/N2	W/N2
750 - 850	1470	46.5	--
750 - 850	1470	--	51.0

TABLE IX: DEVIATION OF AVERAGE VALUES WITHOUT THE USE OF NITROGEN

MAGNESIUM CONTENTS %

REQUIRED	ACTUAL	STD DEVIATION
0.0250	0.0244	0.004
0.0550	0.0566	0.005
DEVIATION OF AVERAGE VALUE FOR USE WITH NITROGEN		
0.050	0.052	0.003

As is common knowledge treatment temperature has a considerable effect on Magnesium recovery. In the range of 1400 to 1500 °C 1.5% of recovery loss per 10 °C may be taken as basis for calculations.

The cored wire injection of Magnesium provides the following advantages in comparison to conventional methods:

- HIGHER DEGREE OF CLEANLINESS
- REPRODUCIBILITY
- IMPROVED MAGNESIUM RECOVERY
- APPLICABILITY OF INERT GAS SHIELDING
- MINIMAL SMOKE EVOLUTION
- LOW LADLE MAINTENANCE EXPENSES
- REDUCED TEMPERATURE LOSSES
- SIMULTANEOUS OR SEQUENTIAL ADDITION OF INOCULATION AGENT
- WEIGHING OF ADDITIVES IS ELIMINATED
- PRECISE ADDITIONS
- POSSIBILITY FOR AUTOMATION

IV. WIRE INJECTION DEVICES

Cored wire injection machines are divided into two categories: (1) single and (2) multiple strand devices with either electrical or electrohydraulic drive systems. Electrically driven single strand machines have been predominantly used in the past. With the range of applications continuously increasing a tendency toward multiple strand systems with automated control has developed.

In order to increase reliability double strand machines have been developed with completely independent drive and power supply systems. A movable operating panel enables the operator to control both lines of the machine from the side he chooses for the operation. When dual strand machines are equipped with only one common drive and power supply system, both strands become useless in the case of mechanical or power failure. This type of unit is not a true dual strand machine.

If a machine is equipped with more than two strands, electrohydraulic drive systems have been developed and are available. A programmable controller facilitates the automatic operation of each line which could theoretically be set up as follows for the production of boron containing steel grades:

STRAND 1 - DEOXIDATION WITH SOLID AL ROD
STRAND 2 - FERROTITANIUM CORED WIRE TO COUNTERACT NITROGEN
STRAND 3 - ALLOYING WITH FERROBORON CORED WIRE
STRAND 4 - TREATMENT WITH CASI CORED WIRE FOR INCLUSION MODIFICATION.

The following figures give an overview of standard wire feeding devices (Fig. 19-23). Installed power ranges from 5.5 to 24 KW per injection unit. This type of equipment has the ability to feed wires with diameters between 5 and 18 mm. The illustrated equipment features modular construction with easy access to main machine components. The two-strand machine shown is equipped with completely independent components for each strand. Remote control is also a standard feature of this unit. Four-strand machines which feature electrical (patented) or electro-hydraulic (patent pending) drive units are also available.

Apart from standard feeding devices it is also possible to acquire special feeding units (Fig. 24) according to custom requirements. This type of special device consisting of three dual-strand machines per block is being used at the automotive foundry mentioned earlier in this paper for the inoculation and alloying of gray iron. The positioning of this unit has already been shown (Fig. 15). Inoculants as well as the alloying cored wires (FeCr and Cu) are drawn from a staged inventory of 30 coils. This particular equipment currently operates continuously 16 hrs./day (Fig. 25).

Another arrangement to treat ladles is shown in (Fig. 26). Here we see the layout of an automatically controlled unit for application within a high production foundry for Magnesium treatment and the inoculation of ductile iron. The cover of the ladle is fitted for the supply of inert gas including an insulation layer made of refractory fibers which constitute a filtering element through which fume and excess pressure is vented during the treatment process.

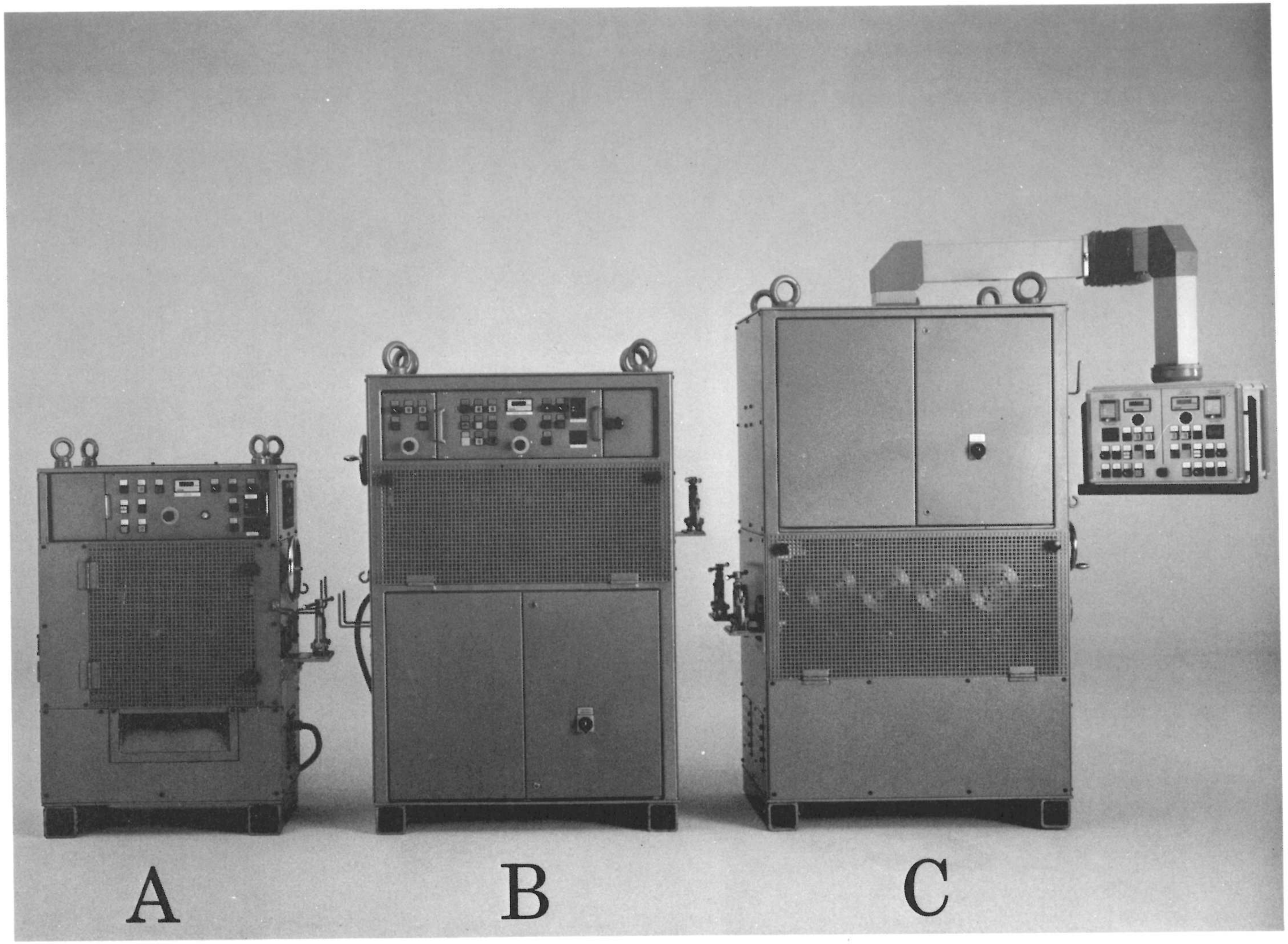

Fig. 19 Different wire injection machines. (A.B) single strand, (C) dual strand machine.

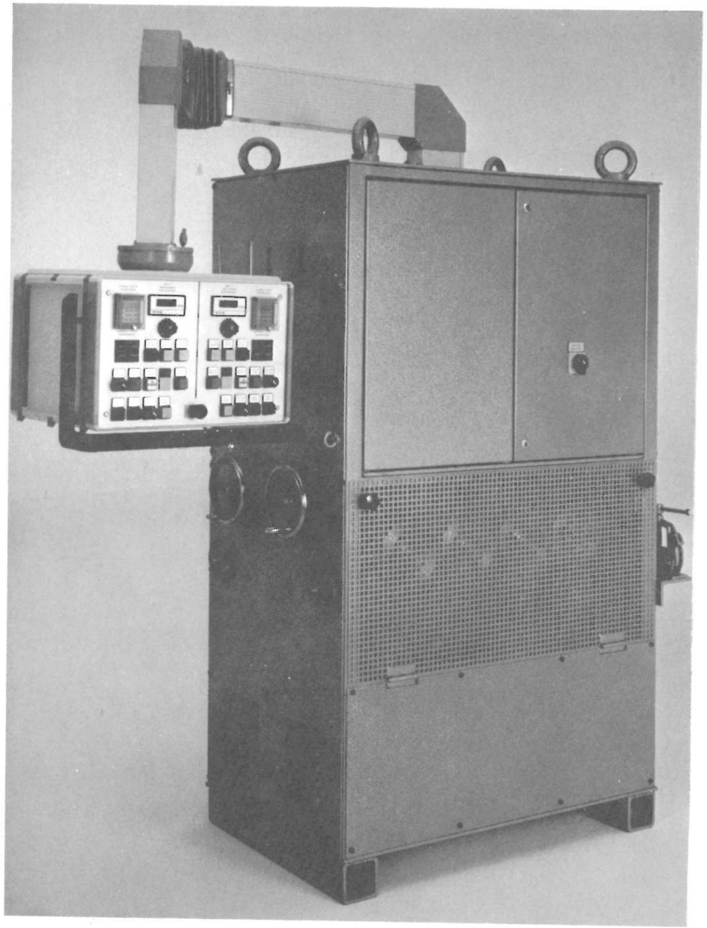

Fig. 20 Dual strand machine with movable control panel.

Fig. 21 Dual strand machine showing details. Each strand absolutely independent.

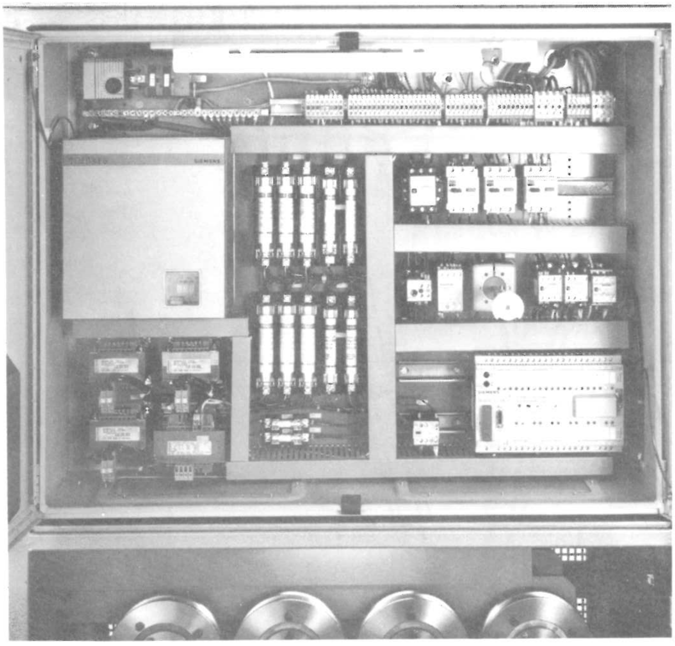

Fig. 22 Electric cabinet in US-standard. Easy to maintain.

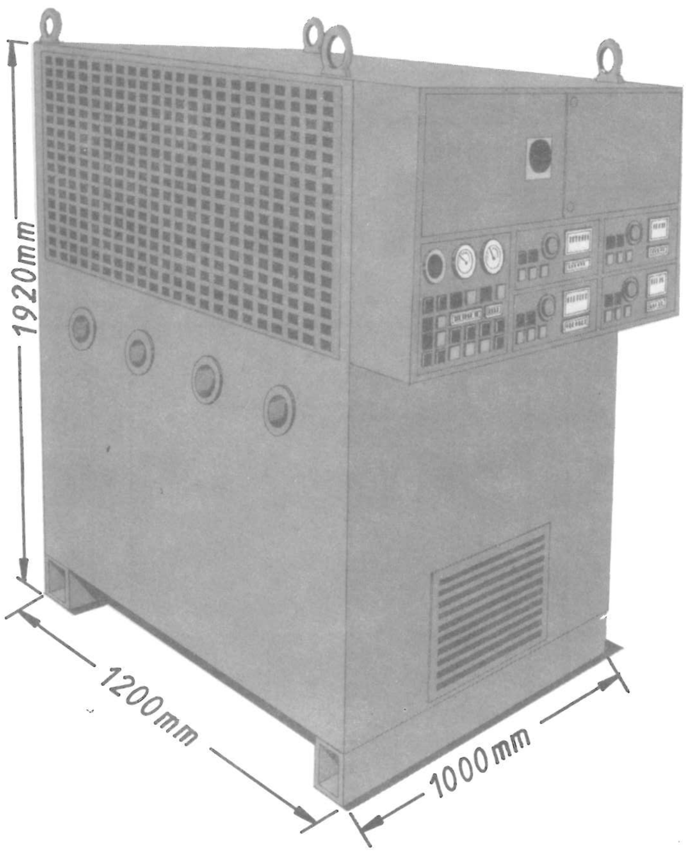

Fig. 23 Electro-hydraulic driven 4-strand wire injection machine

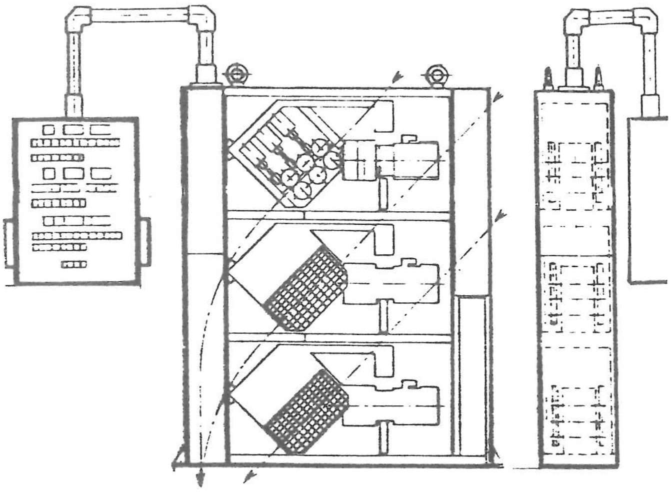

Fig. 24 6-strand wire injection machine consisting of 3 dual strand units

Portrayed in (Fig. 27) is another example of a wire feeding design for a steel mill. For space reasons it was necessary to combine the wire guide tubes of three injection machines into one bundle equipped with a mechanical device to lower or raise the common guide tube. This unit is also equipped with remote control and various other control systems.

During the past two years the tendency has been to extract cored wires from static coils. This system does produce a certain torsional tension in the steel wire shell. However, this tension does not exceed acceptable limits. As the coil does not move when this method is utilized a rotary uncoiler is superfluous. The static coil is either used with an exterior steel cage or with a fixed device for horizontal or vertical wire extraction (Fig. 28-29).

CONCLUSIONS

Cored wire technology has become a standard methodology regarding the metallurgical refinement of steel and cast irons.

The development of suitable wire injection machines with corresponding peripheral equipment has formed a basis for process automation.

Increased and improved production of cored wires has also led to more favorable production costs and competitive pricing.

This technology will continue to be applied to a wide range of applications because of the ability of cored wire treatment and alloying methods to achieve precise and reproducible metallurgical adjustments with minimal environmental impact at economical cost.

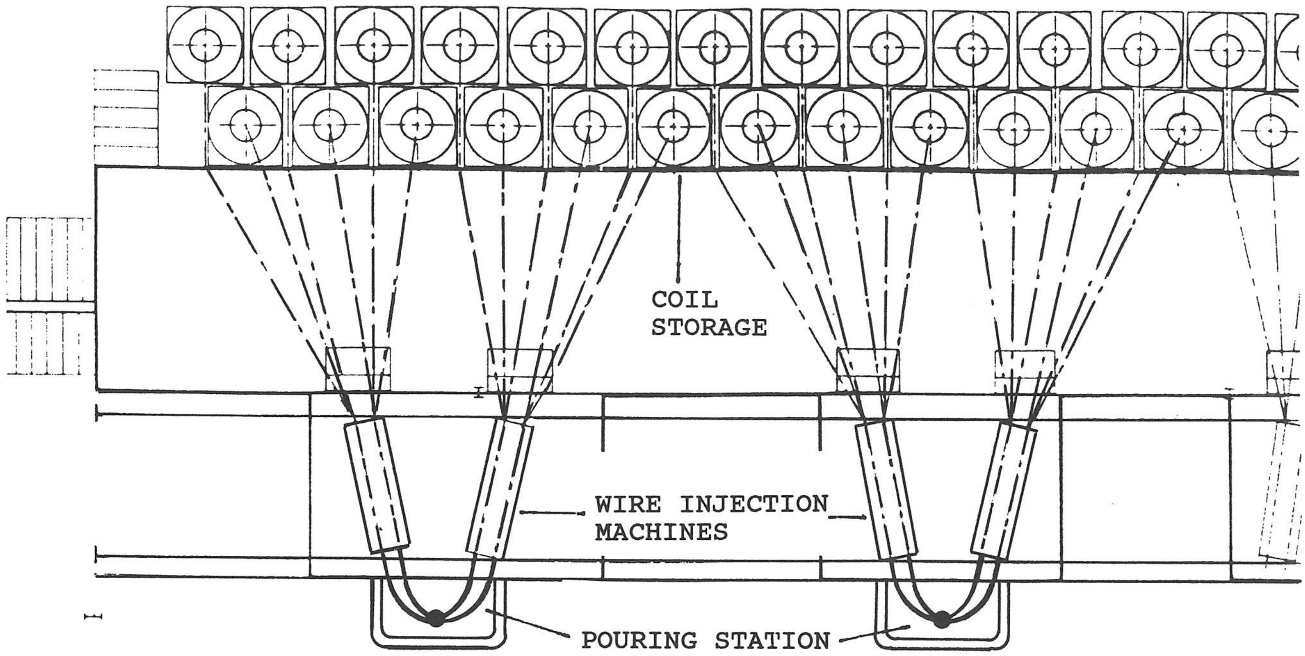

Fig 25 Diagram of wire injection station (top view) with 30 strands for the alloying and inoculating of cast iron

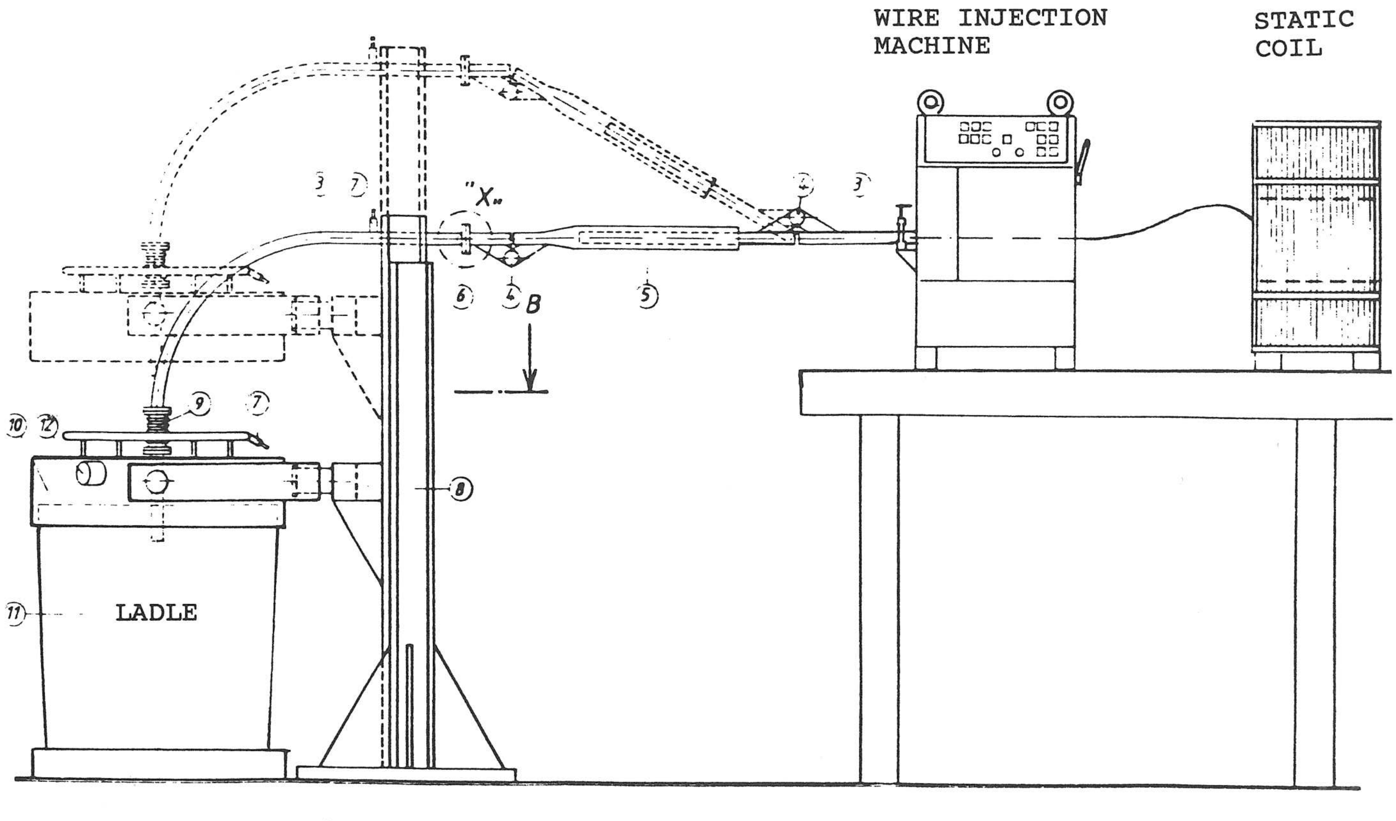

Fig. 26 Automated wire injection station. Movable lid with nozzles for inert gas application.

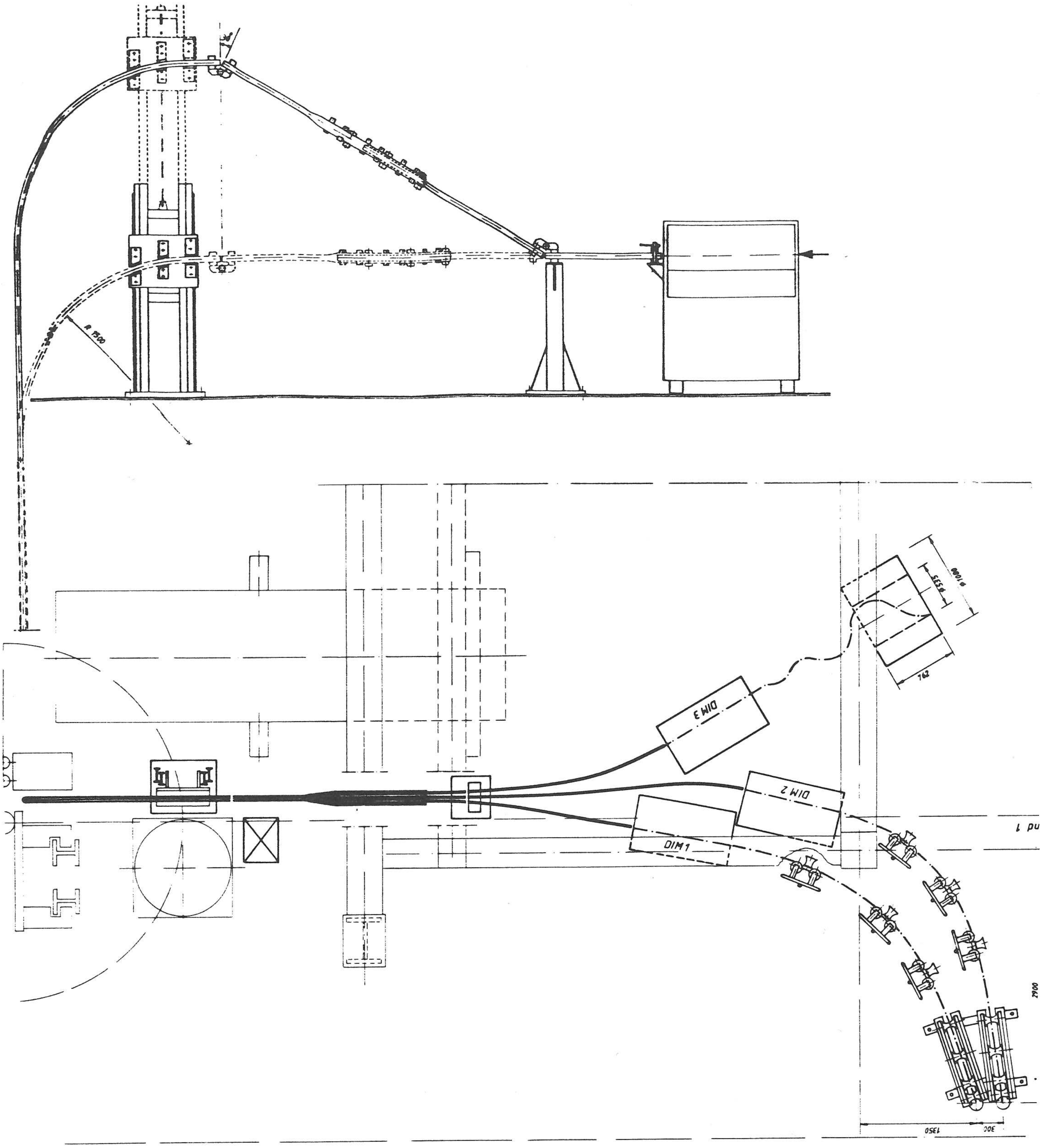

Fig. 27 Wire injection station in a steelplant. Movable guiding tube, consisting of 3 single tubes.

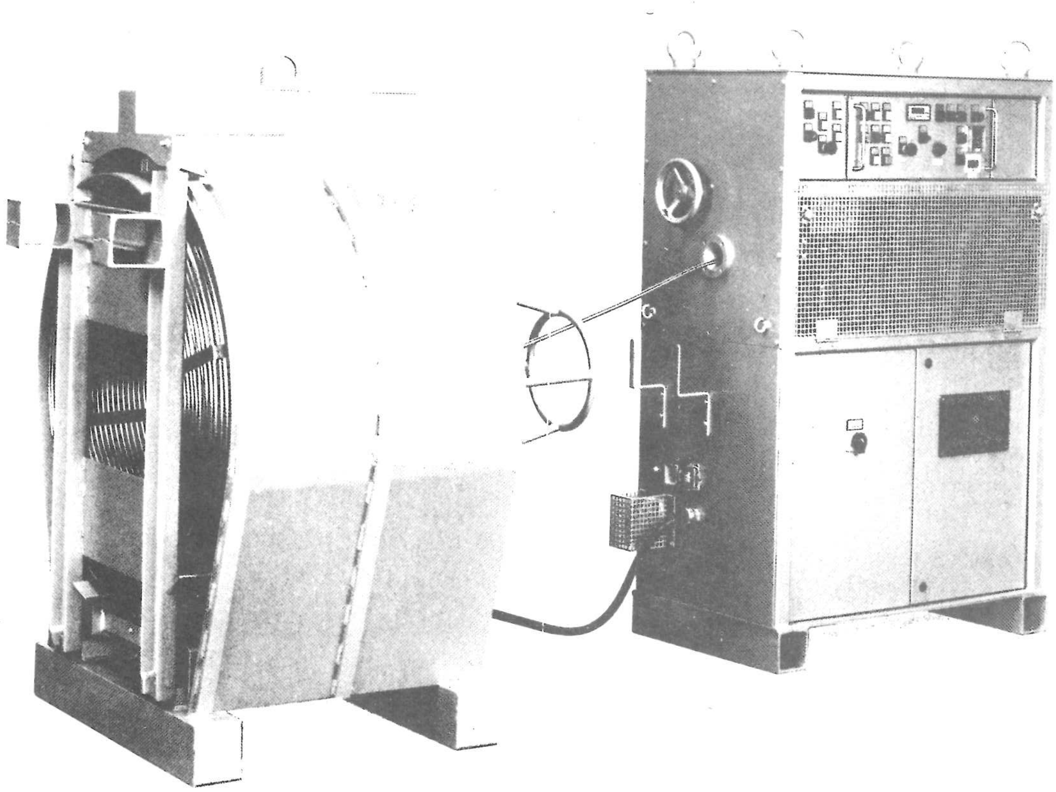

Fig. 28 Wire injection machine in combination with horizontal static pay off device

Fig. 29 Static pay off device for vertical uncoiling

REFERENCES

1. Rautaruukki Oy Engineering, Oulu, Finland High Quality Steel with Rautaruukki Ladle Metallurgy (Leaflet)

2. K. Vihma and H. Ylonen "Adjusting of Steel Composition by Alloy Wire Feeding", International Conference Secondary Metallurgy, Aachen, Fed. Rep. of Germany, 1987.

3. A. Spaccarotella, et al., "The Fast Process: A New In-Mold Treatment for Supplementary Cooling and Microalloying of CC-Slabs", International Continuous Casting Conference, Brussels, Belgium; May, 1988.

4. R. Piepenbrock and P. Schittly "Desulphurization Pig Iron with Magnesium Cored Wire", Steel Times, May, 1986, pp. 236-239.

5. W. A. Henning, "Efficiency in Desulfurization Practices: Committee 5L Report", AFS Transactions, Vol. 94, 1986 also Translation in Glesserei Praxis, Nov. 12, 1987, pp 198-203

6. A. Bergman and K. Olsson, "Production of Steel for High-Strength Strip and Sheet with Exceptional Consistency", Steel Times International, June 1988, pp. 48.