Technology Improving Your Meltshop Performance

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INTRODUCTION

Every casting (Fig.1) begins with molten metal and every foundry wants to make a profit. To melt metal, it requires energy and in the case of an induction furnace it means kilowatts.

More efficiently one uses those kilowatts, lower is the costs and the greater is the profit.

Fig. 1: Typical automotive castings.

There are "technologies" and practices out there designed to help, and the basis of this paper is to give a better understanding of what these are and how they can be implemented in an iron foundry.

Once it is established about how much molten metal is required per "batch" the frequency at which a "batch" is required, in conjunction with the "utilisation" would determine the kilowatts are required and the total production would determine the quantity of power supplies required.

The following are the stages one must go through to get a ladle full of metal with a specific analysis at the required temperature:

MELT CYCLE - is the period when maximum power is continuously applied to the furnace and charge is added.

NON-PRODUCTION CYCLE - is when no or reduced power is being applied, such as when the initial charge is being added, when slag is being removed, when a temperature dip or analysis sample is being taken, waiting for an analysis result and pouring the furnace empty.

PRODUCTION CYCLE - is the "melt cycle" and the "non-productive cycle".

UTILISATION - is the "melt cycle" divided by the "production cycle" expressed as a percentage. If the melting cycle is of 45 minutes and the "non-production" cycle is of 45 minutes, then the "production cycle" is 90 minutes. The 45-minute "melt cycle" divided by the 90-minute "production cycle" times 100 gives an "utilisation" of 50%.

If it is a process that requires 10 tonnes of iron poured into moulds per hour and the "production cycle" is such that it can only achieve 50% "utilisation", one will have to buy a power supply capable of melting 20 tonnes per hour.

CHARGE MATERIALS - for producing gray and ductile iron, the charge consists of steel scrap, pig iron, in-house returns and scrap.

CHARGE PREPARATION and CHARGING - irrespective of whether the furnace is to be charged manually or mechanically, the charge materials should be weighed and these ought to fit into the furnace. If the scrap sections are long and extend out of the top of the furnace, these, will ultimately melt but will take time, which will influence the "utilisation". The initial charge needs to be as quick as possible and of sufficient density to allow maximum power. The initial charge needs to be added to the furnace as quickly as possible. For optimum performance, the density should not be less than 1,750 kg per cubic metre and the furnace must be filled to a minimum of 30% and maximum of 60% of its rated capacity.

SLAG REMOVAL - an essential but unpleasant job. The slag produced during melting iron is usually viscous and, if not, the addition of a pearlite-based coagulant will create a viscous slag that can be raked or lifted off. For any sized furnace removing the slag manually is possible, but on larger furnaces it is unpleasant and time consuming. The options for larger furnaces are "back tilt slag removal" or a slag grab.

TEMPERATURE DIP AND SAMPLE ANALYSIS - a temperature dip to establish the bath temperature and a molten metal sample has to be taken to establish the chemical composition.

CHEMISTRY ADJUSTMENT AND SUPER-HEATING – as soon as the analysis result is known the "trim" materials should be weighed and charged into the furnace and full power applied to superheat to the pouring temperature.

POURING CYCLE - the time taken to empty the furnace.

To help one to achieve an optimum "production cycle" one needs to understand fully the technologies and practices that are available.

THE CHARGE - Every "melt cycle" starts with a charge (Fig. 2). The charge materials must be weighed before these are put into the furnace. When the charge is fully molten it is easier to calculate any "trim" additions, if the weight of the liquid iron is known.

If "standard" charges for various grades of iron are developed, it is much easier to achieve the target analysis. One will be able to use more lower cost materials, as one will learn the addition and recovery rates for the various materials used for element additions.

The quality of these materials and the charging sequence are important. Rust on steel scrap can influence lining life. Sand on in-house returns has to be melted and then removed as slag. Purchased cast iron scrap may contain unwanted elements and must be purchased with care. To melt slag, energy required is twice as much as that for iron.

Alloying materials also influence performance of the "melt cycle". As a base recarburiser, one can use a lower cost petroleum coke (Fig. 3).

Fig. 3: Petroleum coke.

If this is for gray iron, materials with higher sulphur levels can be used as final sulphur of 0.5 to 0.12%, enhances the performance of ferro silicon-based inoculants. Silicon addition should be made using 75% silicon ferrosilicon as this is an exothermic reaction. An alternative source of silicon is silicon carbide which is 66% Si, 33% C and zero carbon and an important consideration if one is making a ductile or compacted graphite iron.

At the end of the melt, it is often necessary to make small adjustments to "trim" the final analysis.

The charging sequence will influence carbon pick-up. Pig iron is high in carbon and the carbon is already in the iron matrix. It should be charged late in the "melt cycle". In-house foundry returns and scrap are of known analysis

Fig. 2: Typical charge materials.

with the elements in the matrix so they can be added last. Steel is low in carbon and carbon can enter the matrix. The charging sequence should be steel scrap, recarburiser, in-house returns and scrap, pig iron (if required) and ferro alloys.

Any “trim” materials should be added after the slag has been removed and the charge is being superheated.

The furnace should not be overfilled. Any molten metal above the power coil at the end of the “melt cycle” reduces the surface stirring and subsequent surface, when “trim” materials are to be added. Movement caused by thermal convection and carbon boil does not enhance element recovery.

For any high production, a mechanised charging system is essential. The initial step is to weigh the charge. A crane scale can be used to weigh a charge as it is loaded into a feeder. A furnace feeder can be mounted on a track weighing station. A weigh hopper (Fig. 4) can be positioned to discharge into a feeder.

Fig. 4: Feeder and weigh hopper.

The best option is to select a feeder that can hold a full furnace charge. If it is a large furnace, then a feeder that holds half the charge can be used but, in this case, a weigh hopper also capable of holding half the charge is essential to ensure no delays in the charging sequence that could affect the “utilisation”.

The size of the scrap is important to ensure the charge does not bridge. On average, each piece should not have a dimension greater than 33 % of the furnace diameter and no dimension should ever exceed 50% of the furnace diameter. The feed rate of the system must be able to deliver the full charge into the furnace within 65 to 70% of the actual “melt cycle”.

The equipment must be sized based on the scrap density available (Fig. 5). There is no point in buying a 5-tonne feeder based on 2 tonnes per cubic metre, if the only scrap available is 1 tonne per cubic metre or less.

SCRAP DENSITY – Kg/M³	
Automobile scrap	670
Light Railroad scrap	720
Light bales	810
Crushed turnings	890
Heavy Railroad scrap	1,360
Steel Bails	1,500
Rails	2,000
Foundry gates & risers	2,101
Returns	2,500
Construction steel scrap	2,500
Car motor scrap	2,700
Billet ends	2,880
Pig iron	3,250
Cast iron machine scrap	3,300
Short heavy crop ends	3,800
Large scrap	4,802
Solid steel for comparison	7,700

Fig. 5: Typical scrap densities

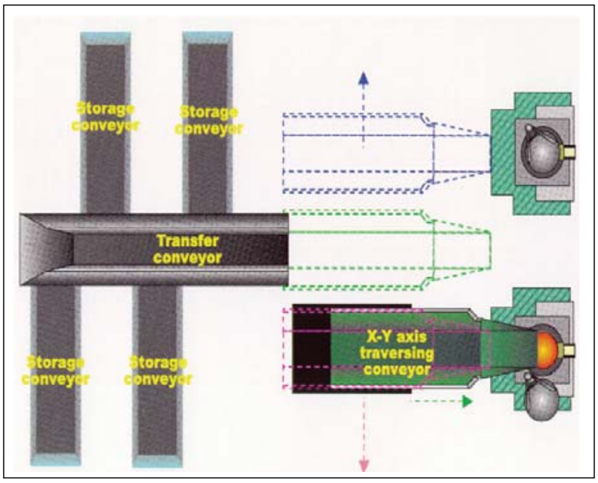

Fig. 6: A possible charging system configuration.

The degree to which a charging system (Fig. 6) can be mechanised is endless and depends on the degree of automation required. Software to automate the system is available from a number of suppliers (Fig.7). Different materials can be stored in separate weigh hoppers. The analysis of the various materials in the weigh hoppers can be entered in the computer along with the formula of the

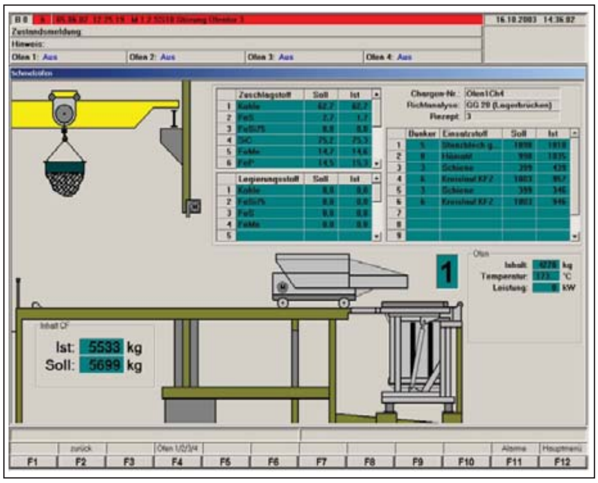

Fig. 7: Charge system computer screen.

grades of iron to be produced and the batch size. The software will select a charge-based on the materials available to ensure one get the maximum use of elements already in the charge. Based on the feedback from a spectrograph and the furnace load cells, the computer will calculate the "trim" materials required. Once all the necessary data has been loaded, a computer system will generally provide the following information:

- Weight and analysis of various materials in storage weigh hoppers with maximum and minimum stock levels.
- Recovery rates for materials used.
- Formulation for grades of iron to be produced.
- The grade of iron currently being produced with weights of the various charge materials required.
- A report to a crane operator to indicate what materials and weights are required.
- The total weight of each charge.
- Printed reports.
- Weight of any trim material required.
- The sequences in which multiple furnaces are to be charged.
- Information available from the computer system can usually be accessed through the internet or a LAN network.

When the weighed charge has been loaded on to the furnace feeder, the feeder will index to a position behind the furnace to be charged.

The only functions not automated are, indexing the feeder forward over the furnace and starting the feeder. This is for safety reasons to ensure the feeder is in the correct position and the area is clear. As the melt progresses, the operator needs to stop, and start the feeder to ensure the furnace is always full but not overfilled.

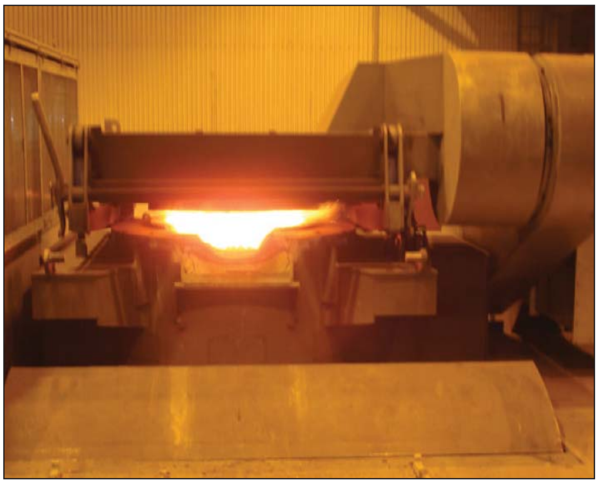

Fig. 8: Melting at full power.

THE MELT CYCLE - the "melt cycle" starts as soon as sufficient charge material is in the furnace to enable power to be applied (Fig. 8). Modern power supplies automatically control the power being applied to the furnace as the condition in the furnace changes (Fig. 9). The goal is to get the energy into the charge as quickly and efficiently as possible. A power supply able to deliver maximum power throughout the "melt cycle", always achieves the best melt rate. As the charge goes through "Currie", the voltage applied to the coil is allowed to increase. This increase gives two advantages:

Factors that will increase energy usage kW/tonne	
Returns with 25 kg/tonne of sand	12
Rusty charge material	27
Insufficient charge density	20
Recarburising when fully molten 20 kg/tonne	36
Melting with half power	18
Heel Melting	36
Excessive fume extraction	14

Fig. 9: Factors that will influence power usage.

Firstly, it ensures maximum kilowatts are continuously applied to the coil. Secondly, a high coil voltage means that the voltage induced into the charge is higher and therefore the contact heating in the charge is more efficient. Typically, this results in a ten percent improvement in the melting rate as compared to a power supply where the power draw drops as the charge passes through "Currie".

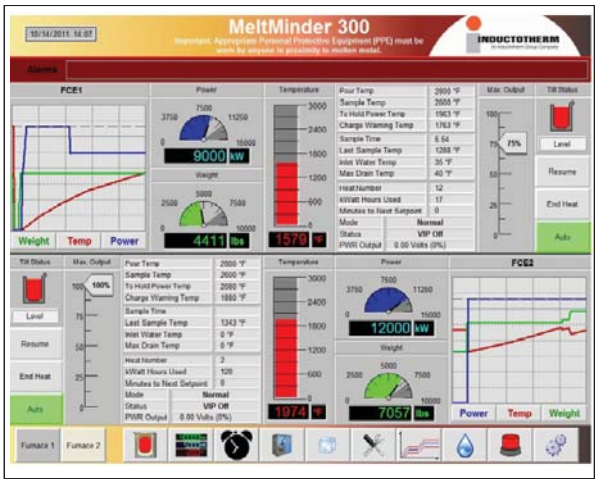

Fig.10: Melt cycle screen

Computer systems are available which will help manage the "melt cycle" (Fig. 10). The final pouring temperature is entered into the display. Taking a signal from the furnace load cells and the kilowatts being applied to the furnace, the computer's algorithm displays a calculated temperature as a vertical bar chart, which has set points for various alarms and functions. As the display temperature increases the operator is prompted to add charge to the furnace. A temperature alarm is set at the temperature the charge will be fully molten. This alarm calls for a temperature dip. However, it is also the point at which power should be turned off and the slag removed. The computer system generally provides the following functions and reports:

- Manages an automated "melt cycle" (Fig. 10).
- Starts the equipment at a predetermined time to preheat the charge.
- Provides an automatic sinter cycle (Fig. 11).
- Provides diagnostics.
- Displays a simulated bath temperature.
- Displays information about the power supply.
- Displays the weight of charge in the furnace.
- Displays drain temperatures and alarms.
- Maintains a record of alarm trips.
- Provides printed reports.
- Communicates via the internet or a LAN network.

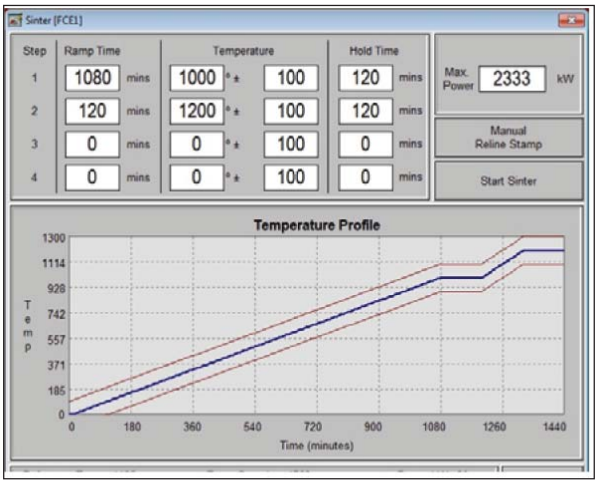

Fig. 11: Sinter cycle screen

SLAG REMOVAL - During the removal of any slag, the power must be off to ensure all the slag floats to the surface and can be removed. The longer the power is off the greater the effect on the overall "Utilisation".

Manual removal can be enhanced by using a pearlite-based slag coagulant, which will exfoliate to tie the slag pieces together so they can be lifted off. Howeve,r it is a hard and unpleasant job.

Fig. 12: Back slag removal.

If the furnace is larger, a back slag (Fig. 12) feature may be available. In this case, the furnace is constructed with two stanchions, which allow it to tilt in two directions, and there is a second spout at the back opposite to the pouring spout. When required, the furnace is back tilted and the slag is raked into a slag bugging positioned under the rear spout. The advantage of this system is that the operator has to rake rather than lift, and the process can be completed much quicker but there is a cost involved at the time of purchase.

Another option is to use a slag grab (Fig. 13). This is a pneumatically powered unit, which is suspended from a crane or hoist above the furnace. It comprises of two replaceable steel plate jaws that are opened and closed by a pneumatic cylinder. With the jaws open the unit is lowered into the slag, the jaws are closed and lifted out of the furnace. It is then swung to the side and the jaws are opened to drop the slag.

Fig. 13: A slag grab.

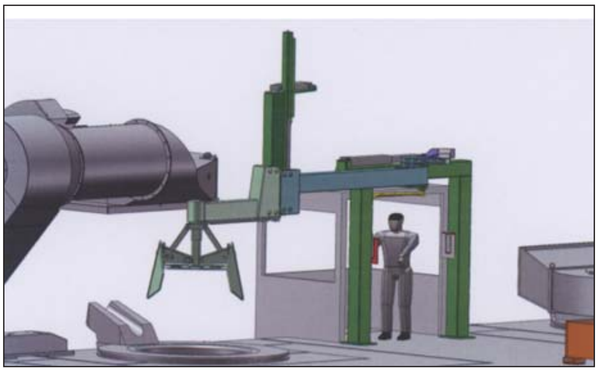

Fig.14: A mechanized slag grab.

A variation of the slag grab is a powered unit, which is mounted on a structural steel frame that forms part of the melter's cabin between the furnaces (Fig. 14). The unit can be swung to either side of the cabin to service two furnaces. The jaw assembly is moved up and down by a power cylinder and the action of the jaws is the same as the crane mounted unit. This type of unit is useful if the slag has a strong crust that needs a force to break through the slag surface.

The key is to remove the slag as quickly and efficiently as possible.

Fig. 15: Carbon, silicon and CE unit

TEMPERATURE DIP AND SAMPLE ANALYSIS - in most iron foundries, a thermal analysis system is used and the metal is poured based on the resulting carbon equivalent reading and a carbon percentage (Fig. 15). If a spectrograph analysis result is required then there will be a delay, which adversely affects the untilisation.

Just after the temperature dip (Fig. 16) and analysis sample are taken, holding power is restored to the furnace.

Fig. 16: Dip temperature unit.

CHEMISTRY ADJUSTMENT AND SUPERHEATING - depending on which analysis system is used, just as the result is known, the "trim" materials should be weighed and charged into the furnace.

If a spectrograph is to be used, the positioning of the unit and the means by which a sample is delivered to the laboratory and the result transmitted to the furnace operator needs to be carefully thought out to ensure it can be accomplished in the shortest possible time.

The carburiser used to "trim" needs to be small-grained (Fig. 17) to increase its surface area and full-graphitised as this ensures that it goes into solution quickly. The function of carbon entering the iron matrix requires time, temperature and a large contact surface. If a large-grained petroleum coke is used at this point it will take longer to enter the matrix and adversely affect the "utilisation". Silicon additions should be made using a crushed 75% Si material.

Fig. 17 : Correctly sized "trim" graphite.

Immediately after the "trim" materials are in the furnace full power should be able to superheat the charge and create surface movement to increase the contact area. The rate at which a given furnace capacity and power supply will always superheat can be established, during the commissioning. When the required degree of superheat has been established, maximum power can be applied for the required time and further temperature dip is not necessary.

If the "melt cycle" is being managed by a computer a mouse click will restart the power supply and the computer will control the power to ensure only the required amount of energy has been applied. At the conclusion, an alarm will signal to alert the operator and the power will be reduced to holding power.

ROBOTICS - software which allow a robot to carry out a number of the these functions include:

- Slag removal by raking or slag grab (Fig. 18)
  ·Temperature dip
- Taking a liquid sample and pouring it into a thermal analysis cup or chill mould
- Adding pre weighed "trim" materials.

Fig. 18: A robot being used to remove slag.

The robot's advantage is that it cannot be hurt, it does not take rest breaks or holidays and it performs the same way every time.

POURING - at the conclusion of the superheating/trim addition cycle the furnace is ready to be poured empty.

If it is wanted to get the maximum advantage of the contact heating as the charge goes through Currie one must pour the furnace empty.

Very simply, the faster the furnace is emptied the better (Fig. 19). During the pouring cycle, only low power is applied and the time it takes to empty the furnace has the greatest effect on the "utilisation".

SUMMARY – If it is desired to purchase a specific amount of energy from the utility supplier and biggest profit is planned.

The one factor that will have the most effect is the level of "utilisation" that can be achieved. Higher "utilisation"

Fig. 19 : A large capacity crane mounted ladle.

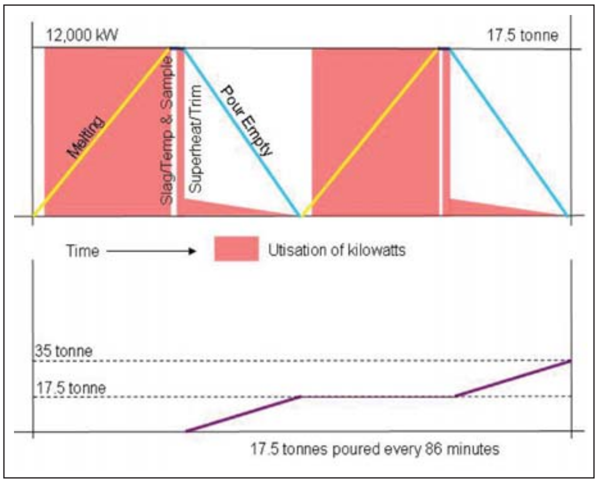

Fig. 21: A typical melt and pour cycle for a Power-Trak delivering batches to the casting plant.

is better. High utilisation means energy efficient production cycles.

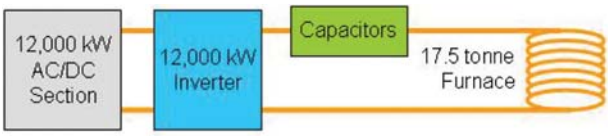

Fig. 20: A simple Power-Trak circuit.

EXAMPLE 1 - A 12,000 kW Power-Trak working with a 17.5-tonne furnace with a hot lining and an empty furnace will melt iron to 1,550°C at a rate of 25.2 tonnes per hour at 100% "utilisation" +/-5% (Figs. 20 & 21).

It will melt 17.5 tonnes to 1,450°C in 39 minutes +/-5%.

A 12,000 kW will superheat 17.5 tonnes of iron through 100°C in 3 minutes +/-5%.

The 17.5-tonne furnace with a silica lining holding iron at 1,550°C will require 250 kW per hour to overcome the thermal losses +/-5%.

The following are two charts listing the operations required for a full melt cycle (Fig. 22). In both cases, the kilowatts and furnace size is the same. The time required to melt and to superheat is the same in both.

Power Tracking Power Supply

Furnace batch size	17.50	Tonne
Power Supply	12,000	kW
Melt rate to 1,550 dg C	25.20	tonnes per hour

Operation	Melting Power Minutes	Holding Power Minutes	Power Off Minutes
Level Furnace Heel			1.00
Open Hood			0.50
Feeder Forward			1.00
Close hood			0.50
Start Feeding			3.00
Power on melting 1,350 deg C	36.30		
Open Hood		1.00	
Feeder back		1.00	
Remove Slag			6.00
Temperatue Dip			1.00
Sample analysis			1.00
Close Hood		1.00	
Waiting for analysis		2.00	
Open Hood		0.50	
Charge Trim Materials		4.00	
Close Hood		0.50	
Power to Superheat 200 deg C	6.00		
Pour off		20.00	
Totals	42.30	30.00	14.00

Total cycle time	86.30	Minutes
Utilisation	49.02	%
Production rate	12.35	Tonne per hour

Power Tracking Power Supply

Furnace batch size	17.50	Tonne
Power Supply	12,000	kW
Melt rate to 1,550 dg C	25.20	tonnes per hour

Operation	Melting Power Minutes	Holding Power Minutes	Power Off Minutes
Level Furnace Heel			1.00
Open Hood			0.50
Feeder Forward			1.00
Close hood			0.50
Start Feeding			4.00
Power on melting 1,350 deg C	36.30		
Open Hood		1.00	
Feeder back		1.00	
Remove Slag			10.00
Temperatue Dip			1.00
Sample analysis			1.00
Close Hood		1.00	
Waiting for analysis		6.00	
Open Hood		0.50	
Charge Trim Materials		6.00	
Close Hood		0.50	
Power to Superheat 200 deg C	6.00		
Pour off		25.00	
Totals	42.30	41.00	19.00

Total cycle time	102.30	Minutes
Utilisation	41.35	%
Production rate	10.88	Tonne per hour

Fig. 22 : Utilisation.

However, in the right-hand chart, (Fig.22) the time taken for various operations is longer.

The calculation at the bottom shows the effect the "utilisation" has on the production rate.

In both cases, one has to purchase a 12,000 kW supply from the utility company. Yet only 40 - 50% of the total production capacity can be achieved.

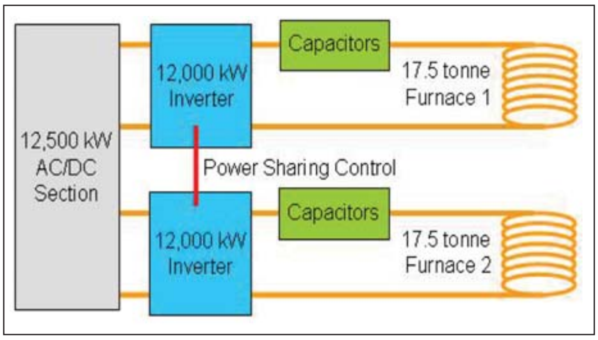

Fig. 23: A simple Dual-Trak circuit.

EXAMPLE 2 - A 12,500 kW Dual-Trak Plus has two 12,000 kW inverters (Fig. 23) working with two 17.5-tonne furnaces and each of these will provide the same performance as a single 12,000 kW Power-Trak. The extra 500 kW in the AC/DC sections allows the unit to simultaneously provide upto 500 kW to a second furnace to maintain temperature.

Each furnace will melt and pour in sequence (Fig. 24). If the "melt cycle" and the "non productive cycle" are equal in duration, then you will achieve close to 100% utilisation.

In practice, the utilisation of a Dual-Trak © power supply is between 85 and 95% and there is a constant supply of metal to the foundry casting process.

EXAMPLE 3 -A Tri-Trak has three inverters each rated at 100% kW and three furnaces (Figs. 25 & Fig. 26). The AC/DC section is rated at 210% of an inverter.

Each furnace will melt and pour in sequence. In this case, to achieve 100% utilisation the "non-productive cycle" must not exceed 50% of the "melt cycle" (Fig. 27).

THE MESSAGE: There is technology out there in practice, materials, hardware and software that will enable to run the equipment more efficiently. The more efficiently one runs the equipment the higher will be the

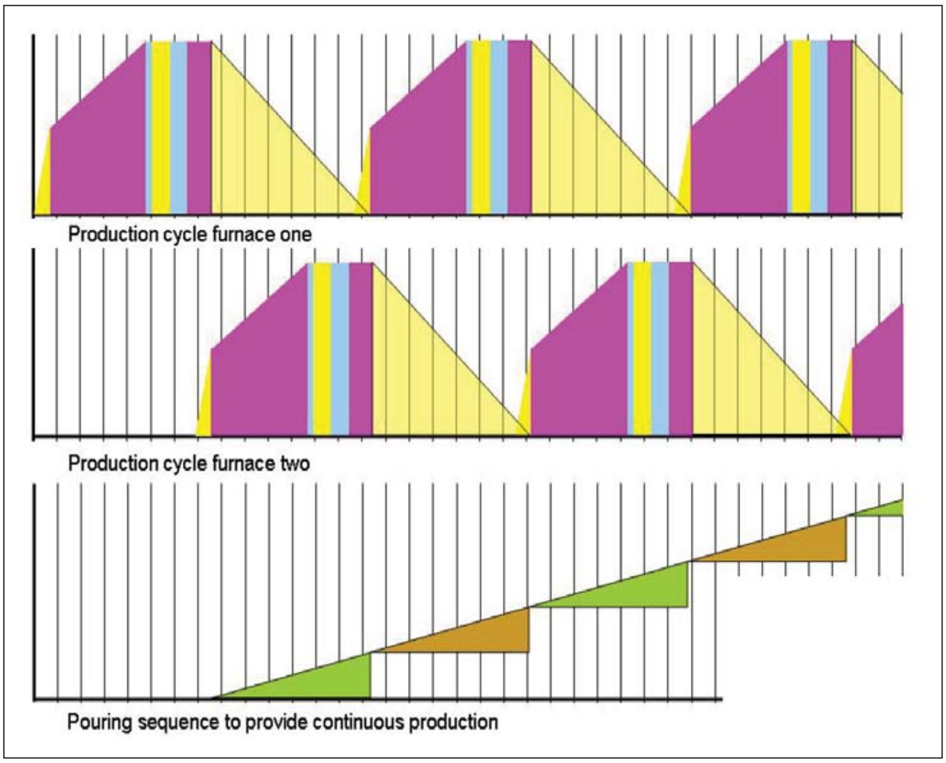

Fig. 24: Typical melt and pour sequence for a Dual-Trak delivering a constant supply of metal to the casting plant.

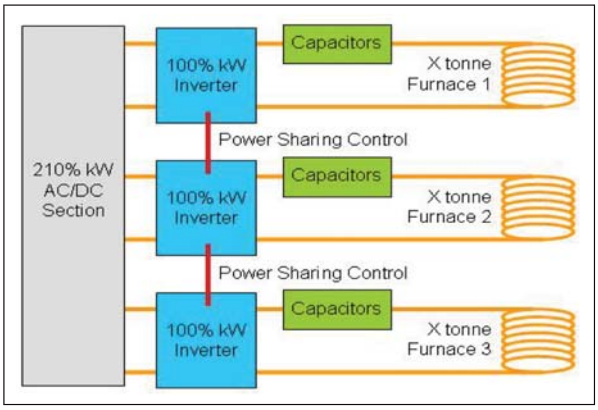

Fig. 25: A simple Tri-Trak circuit.

Fig. 26 : Tri-Trak installation.

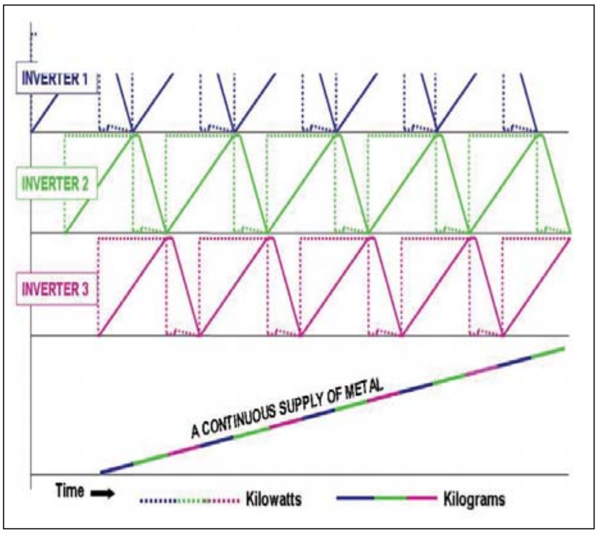

Fig. 27 : A typical melt and pour sequence for a Tri-Trak delivering constant supply of metal to the casting plant.

"utilisation" of the equipment, and the KVA power supply purchased from the utility company.

However, to achieve this, one will need properly trained personnel and a management structure that ensures training is kept upto date and the equipment is properly and timely maintained. ■