# Recent innovations in the development of the "Policast" evaporative pattern process

### C.A. GORIA, G. MAGISTRALI and G. SERRAMOGLIA, Teksid S.p.A., Divisione Fonderie Ghisa, Carmagnola (Turin), Italy

#### Abstract

The Policast foundry process employs gasifiable expanded polystyrene patterns buried in loose sand and has already been introduced on the industrial scale. Research has therefore been concentrated on those of its features that are still open to further improvement, though satisfactory for the needs of high-volume manufacturing. Its aim is to reduce fabrication costs, improve product quality and make the process as a whole more reliable. Three of the innovations devised and perfected for this purpose are described. The first relates to a new procedure for making the metal tools used to mould the polystyrene foam patterns, based on electroforming, i.e. the electrodeposition of metals on suitably shaped supports that have been rendered conducting. The second innovation relates to a new system for the spheroidization of cast iron. This is carried out in special small ladles located outside the mould. Even so, it is similar in concept, and in terms of quality and yield, to in-mould spheroidization. In addition it is associated with Policast. The third innovation consists of the array of systems used for the instrumental checking of the most critical stage of the Policast process, namely compaction of the sand. These are systems and processes suitable for both on-line checking and experiments in the work-up of new castings.

#### Riassunto

Recenti innovazioni nello sviluppo del processo di fonderia "Policast" con modelli gassificabili di polistirene espanso.

Nello sviluppo del processo di fonderia Policast, che fa uso di modelli gassificabili di polistirene espanso, immersi in sabbia sciolta, si è pervenuti alle prime installazioni industriali; pertanto l'obiettivo delle attività di ricerca si sposta adesso su quegli elementi di processo che, pur soddisfacenti per l'avvio di produzioni su larga scala, sono però suscettibili di perfezionamenti.

Scopo di queste attività è ridurre i costi di fabbricazione, migliorare la qualità del prodotto, e rendere più affidabile il processo nella sua globalità. Tra le innovazioni sviluppate e messe a punto, sono descritte, nel presente lavoro, tre delle più significative.

La prima riguarda un nuovo procedimento per la fabbricazione delle attrezzature metalliche impiegate nella formatura dei modelli di espanso; questo procedimento si basa su tecniche di elettroformatura, cioè di deposizione elettrolitica di metalli su supporti di resina opportunamente sagomati e resi conduttori.

La seconda riguarda un nuovo sistema per il trattamento di sferoidizzazione della ghisa; esso, pur essendo eseguito in speciali recipienti situati fuori della forma, è però analogo, dal punto di vista concettuale, per i risultati qualitativi e per la resa, al processo di sferoidizzazione « in mold ». Non si tratta di un sistema specifico per il processo Policast, essendo adattabile a qualsiasi linea di colata automatica; tuttavia in modo particolarmente efficace permette il superamento di certi vincoli propri del Policast.

La terza innovazione è costituita dall'insieme dei sistemi per il controllo strumentale della fase più critica del processo Policast, cioè della compattazione della sabbia; si tratta di sistemi e procedimenti adatti sia al controllo « on line » che alle sperimentazioni condotte nella messa a punto di nuovi getti.

### Introduction

The Policast foundry process has reached its initial industrialisation phase. Its various stages have been described elsewhere (1). Briefly, a metal is poured into moulds made up of sand with no binders. The sand is compacted by vibration around polystyrene foam patterns that are gassified and replaced by the molten metal, which then solidifies to taken their exact shape in every detail.

Two high-volume production lines using this process are now in operation. One was set up for aluminium castings in autumn 1983 at Teksid-Alutek's Carmagnola foundry, the other for iron castings in autumn 1985 at Teksid-Castek's Crescentino foundry.

The plant and process arrangements adopted on these occasions were the result of several years' experience and can be regarded as sufficient for the needs of high-volume production. Since the process itself is a novelty, however, they are open to improvement and

— in some instances — radical transformation. There is thus plenty of room for research on solutions that must meet more stringent specifications and on aspects of the process that make the heaviest contribution to its manufacturing costs.

As far as process control is concerned, techniques furnishing significant parametric evidence of the effect of the various devices employed in the process have been devised.

Taken as a whole, these innovations will not only make the Policast process more competitive in economic terms. Thanks to improvements in its quality and reliability, they will also enhance its already considerable technical advantages.

### A) Tooling for moulding the foam patterns

The conventional way of obtaining the metal tools used to mould the polystyrene foam patterns is based on the machining of a block of aluminium alloy.

The shape or impression left in the block is the negative image of the foam pattern to be obtained and is usually prepared with the aid masters. For reasons specific to the moulding of polystyrene foam, the corresponding tools must be given the form of a shell. The thickness must be constant and kept down as far as possible compatible with the mechanical strength needed during sintering of the beads, during which rather high pressures are involved.

The impression must thus be machined to a high degree of precision and finish, since it determines both the shape and size of the pattern and hence the casting. On the opposite side, however, nothing more than roughing out is required. Even so, it may have a large influence on fabrication costs, especially in the case of particularly complicated shapes.

For brevity's sake, we will simply refer to these shell impressions for the production of foam patterns as "inserts".

These inserts are placed on a plate that is then mounted on the moulding machine. Further operations are required before the moulding

tools are ready for use (Fig. 1):

- Cutting out of windows to house the inserts in the plates.
- Insertion of centring devices and application of various screw threads.
- Drilling of the inserts for placing the vents.

The function of the vents is to allow the air to escape when the mould is filled with the foam beads, followed by the passage of steam when they are sintered. They are distributed rather extensively all over the surface of the insert sometimes in hard to get at places. The drilling operation thus has a by no means marginal incidence on the overall tooling cost.

In cases where production requirements demand the preparation of several inserts for the same part, these must be completely identical. If this is not so, unacceptably imprecise mating may occur when the pattern is assembled. Experience shows that it is very difficult for this condition to be met when the inserts are machine made.

Lastly, there is the question of the setting up of batches of experimental castings whose design has not yet been finalised. In all but exceptional cases, it will be found that the cost of Policast tooling is distinctly higher than that of the patterns and core boxes used in the conventional process. Added to this, the limited thickness of the inserts themselves means that they do not lend themselves to substantial changes in shape. In practical terms, new inserts have to be made each time there is an appreciable modification of the design.

#### **Electroforming of the inserts**

This array of factors has proved an efficient spur to the search for alternative solutions so as to achieve a marked reduction in insert costs.

The best results have been obtained by electroforming. This term is used to describe the production or reproduction of an object by the electrolytic deposition of metal on a support or "mandrel", which is then removed and leaves its impression on the metal layer (1). The plant and techniques required for electroforming are virtually the same as in other industrial electroplating processes. However, the pieces formed are much thicker (>1 mm) than 0.1 - 100  $\mu$ m coatings applied for ornamental or protective purposes.

The technology has long been applied in the manufacture of moulds for plastics. These, however, are supported on the opposite side by pourable materials (usually resins) to give them the rigidity they need. For reasons associated with polystyrene foam technology, however, the use of resins to stiffen the inserts is not compatible with the low thermal inertia required. The inserts must thus be all-metal and their thickness must be as constant as possible. These electroformed inserts must also be self-supporting. The new problems that therefore arose in the application of electroforming to the manufacture of inserts were linked to the securing of thicknesses that are unusually large and sufficiently uniform. Faraday's laws tell us that the amount of metal deposited on the cathode of an electrolytic cell is

Fig. 1 - Conventional tooling for moulding polystyrene patterns. Plate (a) and insert (b) with vents (c) and injectors (d) holes.



proportional to the quantity of electricity passing through it.

In the case of copper plating from CuSO<sub>4</sub> acid baths, for example, about 1.185 g/Ah are deposited. The theoretical deposition for cathode with a surface area of 1 dm<sup>2</sup> and a current density of 5 A/dm<sup>2</sup> is thus 66.4 µm/h. Fifteen hours are needed to obtain a coating 1 mm thick and 75 h for one 5 mm thick. At first sight, it would appear that greater thicknesses can be achieved by simply increasing the electrodeposition time as required. However, the question is greatly complicated by the fact that current does not flow uniformly through the cathode, but tends to concentrate on sharp points and edges at the expenses of holes and grooves. Where the current density is high, the thickness is built up more quickly. Where it is low or nil, the thickness grows to a virtually negligible degree even after a very long period, as



Fig. 2 - Diagram of the metal growth during the electroforming process: without special techniques the thickness of the electrodeposited layer turns out very un-uniformed.

shown schematically in Fig. 2. This diagram also represents what actually occurs in conventional electroforming. There is a total absence of mechanical strength at points B, C, E and H, while thermal inertia is very high at points A, D, F and G. One of the earliest electroformed inserts is shown in Fig. 3a. Its thicknesses are highly irregular. The metal build-up is chaotic and dendritic forms are common. The use of special electrodeposition techniques and various measures in the design of electrolysis cell geometry, such as screening, supplementary anodes and pulsed currents, have enabled the incidence of these phenomena to be drastically reduced. The inserts now obtained display a sufficiently uniform thickness (Fig. 3b).

The feasibility study, the development of the technology, and the setting up of a pilot plant for the electroforming Policast inserts, were carried out by the Centro Ricerche Fiat, Electrochemistry Department, and Teksid, Iron Foundry Division.

Insert fabrication is illustrated in Fig. 4. The part to be reproduced as a polystyrene foam is shown as D. The first step is to make the masters A and A'. These must reproduce the parting plane of D and a negative version of its surface development, as well as the accessory parts needed to obtain the surfaces used to attach the inserts to the plates. A and A' are then boxed and a resin is poured over them to harden and form supports B and B'.

B and B' are then removed and mounted on a chemically inert support. A layer of electroconducting paint a few  $\mu$ m thick is applied on the surfaces to be used for electroforming. The supports are now placed in the electrolytic bath and connected to the cathode of a d.c. generator opposite to the anodes, usually formed of the metal to be deposited.

Fig. 3 - Example of the improvements in the electrodeposition techniques: a) one of the earliest electroformed inserts; b) insert obtained with the present techniques.





Vol. 4 [2] (1986)



The arrows on the diagram give a general idea of the flow of ions from the anode to the cathode to form a compact metal layer by deposition.

When the layer reaches the required thickness, the supports are removed from the bath and the electroformed inserts C and C' are carefully detached. After the usual mechanical finishing operations, the inserts are mounted on the plates of the machine ready for the reproduction of D in an infinite number of examples.

Uniform insert thickness, however, was not the only research objective. A further aim was to dispense with the drilling operations needed to place the vents so as to cut down the finishing machining considerably and obtain inserts that are virtually ready for use. This result has been obtained by the adoption of two

different, but equally effective solutions.

The first solution involves incorporation of the usual vents in the electrolytically deposited metal (Fig. 5). In the second, special treatment of the support surface and particular chemical and physical parameters of the electrolysis system are used to prepare a metal deposit with through holes. The diameter of these holes is of the order of 0.1 mm. Since there are only 5-10 of them per square centimetre, the ruggedness of the insert is in no way prejudiced.

# **B)** Spheroidization system

The experiments leading to the development and

Fig. 5 - Vents englobing directly by the electro-deposited metal.



industrialisation of the Policast process not only established the feasibility of nodular graphite iron castings. They also brought out some of the advantages peculiar to the process for this type of cast iron. In particular, it was shown that castings free from shrinkage could be obtained even without using risers, resulting in a marked increase in the poured metal yield. This was because of the faster cooling rate and the greater mould rigidity obtainable with the Policast process (2). On the other hand, certain critical metallurgical conditions emerged owing to the presence in nodular iron castings of carbon inclusions derived from the pyrolysis of polystyrene foam. Steps have since been taken to do away with these defects or reduce them to acceptable limits (3).

These phenomena are linked to the chemical and physical characteristics of nodular iron, the foam material and the paints used for the patterns. They are determined by the particular cooling and solidification conditions occurring in the Policast process. By contrast, they are totally independent of the type of metallurgical treatment used to spheroidize the graphite.

Feasibility studies on nodular iron castings and experiments to solve the quality problems they raise have usually made use of the ladle or "sandwich" system for spheroidizing iron. This system is acceptable for the few consecutive casting operations required in an experimental plant, since fading of the spheroidizing effect of the Magnesium alloy is negligible.

Establishment of a system suitable for industrial-scale production, however, meant that certain important factors had to be borne in mind:

- the better quality offered by in-mould spheroidization;
- the requirements and constraints peculiar to the Policast process.

The operating rhythm of a Policast line is determined by the rather slow sanding and compacting stage. If iron spheroidised outside the mould in the conventional way is used, therefore, metal requirement would be such as to render Magnesium fading critical. Yet even the classic in-mould system has proved impracticable for clusters of polystyrene patterns. Attempts to include in the cluster a dish containing the Magnesium alloy were thwarted by the difficulty of handling the clusters during coating and insertion in the container. The dish, in fact, contained an alloy mass almost three times the total mass of the rest of the cluster. It was also asymmetrically located with respect to the pouring sprue. It must be remarked, on the other hand, that however difficult it may have been in practice this system gave results that were metallurgically sound.

The upshot has been the development of an innovative spheroidization process which, even though it is carried

out in a special receptacle — known as a

" spherocaster " — outside the mould, is similar to the in-mould process and furnishes the same quality levels.

#### **Description of the spherocaster**

The spherocaster is a device outside the mould (Fig. 6) that enables nodular cast iron to be obtained starting from a molten mother alloy that is treated in its interior with Fe-Si-Mg (Mg 5%).

This process is very similar in principle to the in-mould spheroidizing process currently employed in Teksid's foundries (4). In addition to the dynamic aspect of the dissolution of the granulated alloy by the metal running over it, the results of the two processes are comparable in terms of quality. The high degree of spheroidisation, the short time that elapses between treatment of the metal and its pouring into the mould, as well as the Magnesium yield, enable high mechanical characteristics to be obtained, together

Fig. 6 - a) Diagram of the cross section of the "spherocaster"; b) "spherocaster" operations: feeding and spheroidization (left); pouring (right).

with excellent machinability.

The device is made of iron structural work and clad with refractory material. It is fed at intervals and can perform the entire treatment and pouring schedule in less than 30 seconds; a considerable number of treatments can' be carried out without stopagges for maintenance. Each treatment serves for the casting of one mould. The molten mother alloy is brought into the spherocaster via a basin and flows through a dish containing the spheroidizing alloy (Fig. 6a). At the same time, the treated metal is accurately weighed by means of a system of load cells integral with the spherocaster. The volume of the dish, its feed channel and its outflow channel to a chamber (Fig. 6a), where the treated metal is collected and homogenised, are dimensioned to bring about controlled dissolution of the Fe-Si-Mg during the treatment. The spheroidized iron is then transferred into the mould through a siphon that comes into action when the device is turned through its tipping fulcrum (Fig. 6 a, b).





left

The spherocaster most frequently employed at present can treat 40-70 kg of cast iron at a time. This corresponds to the weight of the clusters mainly produced. An approximately 25 kg device has given fully comparable results. By varying the size of the dish, the channels and the homogenisation chamber it is in any event possible to handle amounts of metal either above or below these limits.

The spout of the spherocaster is shaped so as to ensure constant feeding of the pouring basin throughout the casting operations.

The spheroidization unit has been built for easy periodic cleaning and inspection through a convenient access to its interior.

### **Operating schedule**

The device must be preheated by means of a burner inserted in the basin before being used at a regular rhythm. Its operating schedule consists of four stages:

- gravity feeding of the measured amount of Fe-Si-Mg into the dish;
- introduction of a measured amount of cast iron into the spherocaster;
- pouring of the spheroidized iron into the mould;
- return of the device to its starting position.

#### **Metallurgical features of the process**

The molten iron must first be desulphurised  $(S \le 0.015\%)$  and then inoculated with Fe-Si (Si 75%) to optimise the degree of eutectic nucleation and obtain a matrix with no free carbides (Fig. 7).

No special arrangements need be made with regard to the casting temperature, since the operating rhythm is such that no significant losses requiring alteration of the values up-line from the spherocaster occur.

From the metallurgical standpoint, the presence of the homogenisation chamber is particularly advantageous in terms of quality by comparison with the in-mould system.

The siphon between this chamber and the pouring spout prevents the exit of slag derived from both the mother iron and oxidation of the Magnesium, resulting in a clean cast metal. The quantity of spheroidizing alloy that must be used in the device is around 1%, i.e. exactly similar to that in the in-mould process. It should be noted in this connection that other alternative processes, such as the "sandwich" system, use up to twice this amount. Moreover, the pouring of iron treated for a single mould is undoubtedly an advantage as far as fading is concerned.

Optimisation of the amount of Fe-Si-Mg to be used is also much dependent on the constancy of the desulphurisation process. If the sulphur level varies very little, it is possible to cut down the quantity of spheroidizing agents to the minimum indispensable. Metallurgically speaking, it is a great advantage to be able to operate under these conditions, since by limitation of the amount of Mg, which is a carburigenic agent, one can obtain castings with lower hardness, even at the heart, without altering the concentrations of the other elements in the alloy.

Lastly, use of the spherocaster does not prevent stream inoculation during casting, with the advantages this entails in terms of machinability, especially in the case of thin castings.

# C) Systems for controlling compaction of the sand

One unusual feature of the Policast process by comparison with conventional foundry processes is that the sand (usually siliceous) is employed directly dry, with no additives nor binding agents.

This is clearly an advantage. Since there is minimal contamination during casting, the sand cycle is extremely simple. No reclaiming is necessary other than possible cooling on a fluid bed. Even so, certain precautions must be taken to ensure the reliability of the process.

Leaving aside certain aspects of the sand cycle that have been the subject of refinement since the Policast process was first set up, attention will here be concentrated on the substantial problems that present themselves when the cluster of patterns is sanded in the container. This stage consists of gravity feeding of the sand and its appropriate compaction by vibration. When working out the sequence of these operations experimentally for the various types of pattern it must be remembered that:

- on account of their poor rigidity, care must be taken to prevent the patterns from being distorted by any convective movements in the sand during its compaction;
- the sand must be capable of penetrating and filling all the cavities of the patterns.

The degree of compaction of the sand in the container is vital to successful casting. Excessive compaction makes a mould poorly permeable to the gases given off when the polystyrene foam burns off during casting, while weak compaction carries the risk of yielding and slumping of sand into the pattern as it collapses. The reliability of the Policast process is thus largely dependent on correct sanding and compaction. This explains why much effort has been devoted to perfecting methods to check the process capable of providing fast results, or even being applied on line. Some of the measurement techniques developed for this purpose will now be described. Fig. 7 - Metallographic structure of a ductile iron casting 10 mm thick obtained with "Policast" process:
a) "sandwich" treatment unetched (100 x);
b) "sandwich" treatment Nital etched (100 x);
c) "Spherocaster" treatment unetched (100 x);
d) "Spherocaster" treatment Nital etched (100 x).

- ... a) b) c) d)

Metallurgical Science and Technology

# Checking the vibration pattern during compaction

As an initial step towards full analysis of the sand compaction process the vibration pattern set up in the container plus sand system must be known to be able to work out the relation between cause and effects. This, of course, is a general problem. Reference will be made here to the sanding system currently used in the Policast process, where the vibrations are applied to the container by a vibrating platform to which it is locked by hydrodynamic clamps.

The platform is made to vibrate by rotating eccentric masses synchronised in various ways to suit different types of patterns.

One or more B & K No. 4370 capacitive accelerometers placed at different points (and in different directions) on the base and/or side wall of the container provide direct acceleration signals D.

Integration of these values in function of time gives the displacement rate, while a second integration gives its amplitude (both functions are obtained with a B & K No. 2511). Combination of the values read in various directions provides a spatial representation of the vibration pattern.

Despite their correlation, however, the parameter values for vibration in the container are not fully indicative of the vibration induced in the sand, nor of that in a given spatial location inside the container. More direct evaluation requires the taking of measurements in the sand itself during compaction. An accelerometer cannot be placed straight in the sand, since there is a relatively large difference between their acoustic impedances. This difficulty has been overcome by devising a very simple impedance adapter, i.e. a sheet of brass in the form of a wide cone (Fig. 8a), to the apex of which the accelerometer is attached. The geometry of the adapter ensures good mechanical rigidity and offers a broad surface for coupling with the sand. What it does is to convert a low-pressure vibration in a low-density medium (sand), and extended to a relatively large area (that of the cone), into an equivalent vibration at higher pressure concentrated on the smaller area of the accelerometer. The signal obtained represents the mean value (extended to the area of the cone) of the pressure component projected onto the axis of the accelerometer. By changing the orientation of the cone, one gets values for the vibration pattern in space (Fig. 8b).

# Measuring the degree of compaction of the sand

In the final analysis, measurement of the degree of compaction of the sand in the container gives useful information concerning the behaviour of the mould



Fig. 8 - Acoustic impedance adaptor.

a) Schematic view of the system: accelerometer-adaptor (the arrows represent the vibration applied to the cone by the surrounding sand); b) General vibration regime detected according to X and Y axis directions.

during pacting (normaphility to gappa, registered to

during casting (permeability to gases, resistance to slumping, etc.).

For this purpose, a measurement has been developed that is based on the correlation between the degree of compaction of the sand and the resistance it offers to penetration by a probe consisting of a small rod with an interchangeable penetrator on one end (F) (Fig. 9). This is chosen in accordance with the question being studied and may be in the form of e.g. a disc or an elongated spike to determine the maximum or the minimum resistance to penetration.

The measuring system is composed of a small doubleacting cylinder (B) that transmits the thrust or traction to the rod (C) through an appropriate strain gauge load-cell (C).

The length of the rod is such as to allow the penetrator to be located in a convenient point in the container in function of the type of cluster and the specific problem it raises with regard to the local degree of compaction. The penetrator is pushed a fixed distance of 25 mm into the sand, while the load cell measures the force required. For measurement purposes, the sand can be likened — at all events as a first approximation — to a perfectly plastic deformable medium. The load-cell signal will thus be more or less constant as the penetrator advances. Experiments have shown that this is true even at the end of the test distance, since there is no sagging of the compacted sand. Once the measurement has been taken, the rod is withdrawn. The space it occupied is readily filled by the sand and in any event so small that the compaction around the cluster of patterns is unaffected. In reality, of course, the penetration force measured by the load cell also includes the friction resistance exerted on the side of the rod. This factor can readily be eliminated by enclosing the rod in a sheath with a little



Fig. 9 - System for the sand compaction measurement in the container (see in the text for details).

clearance, though trouble may be caused by seizure due to the infiltration of grains of sand. At all events, the fact that the signal is constant throughout the passage of the penetrator suggests that this resistance can be ignored in practice.

One unusual feature of the technique is that the double-acting cylinder B produces a fixed stroke between two mechanical reference points, which means that the air pressure is not critical for measurement purposes, but need only be sufficient to produce the force required to drive the rod under the most unfavourable situation, i.e. maximum compaction of the sand.

The guide bush D is always outside the sand. It is designed to be able to guide the rod without excessive friction that would detract from the accuracy of the measurement. For this reason, as already mentioned, the rod is not provided with a sheath. The device can be set up on line in the compacting station to provide a real-time signal.

#### Measurement of the ability of the sand to penetrate into the cavities of the patterns

It is obvious that the cavities of the patterns forming the cluster must be completely filled with sand. Even though this is promoted by the vibration, the ability of the sand to flow into a cavity is itself an important parameter to be kept under observation for the sake of the reliability of the process. It is, in fact, a property that depends on grain size and shape. Furthermore, variations are likely to appear over the course of time due to contamination of the sand and rounding of the edges of its granules.

Flowability, as it is usually called, is normally tested in the laboratory (e.g. with the Ford cup method). In the

Fig. 10 - Measurement of the sand flowability (and its capacity to penetrate into cavities) by means of a thin walled hollow penetrator. (see in the text for details).



68

Policast process, however, it is of specific interest when working with hollow patterns, since the sand must in effect take the place of conventional cores and occupy spaces that are relatively large compared with the inlet orifices.

For this reason, an *ad hoc* method more in keeping with the specific way sand flows into the cavities of patterns has been devised (Fig. 10).

The definitive version of the method takes the following form: a bucket (A) is filled to the brim with sand. A thin-walled hollow penetrator (B) with a suitably shaped orifice and vertically guided is rested on the surface of the sand. It is first preloaded with a small bedding weight (D) and the position of the graduated rod is read at the level of the guide bush (C). Weights are then added to bring the load to a suitable final value depending on the shape of the penetrator (e.g. 50 N, as in the drawing) and the depth reached is read off the rod. The difference between the two readings (e.g. in millimetres) gives a parameter directly related to the flowability of the sand. Experiments have shown, in fact, that the values it provides for different types of sand are reasonably repetitive and in biunivocal correspondence with grain size.

This method is closer to what actually happens in practice than the usual laboratory test, since the sand is made to flow upwards into a cavity. Its flow into the cavities of a given pattern is simulated as closely as possible by choosing the most suitable shape for the penetrator.

As can be seen in fig. 10, the sand spreads out after passing the orifice as the penetrator goes deeper in the same way as it would in the container.

## Conclusions

Electroformation of the inserts used to make the polystyrene patterns has greatly reduced the tooling costs for casting with the Policast process, both during regular manufacturing and in the setting up of prototype castings. This innovation also brings the process more within the reach of foundries with only average or small runs of a given casting. Spheroidization with the "spherocaster" offers the quality benefits conferred by the in-mould process, i.e. constant spheroidization over the production run, low shrinkage and freedom from primary and intercellular carbides, with minimal plant complications. Instrumental checking of vibration and its effect on sand compaction enables this critical stage of the Policast process to be kept under close, continuous control. Furthermore, when new castings are being worked out, the same methods lead to more rational identification of the best operating parameter values. These three innovations will thus serve to make the

Policast process less expensive and more reliable, and hence promote its development and wider employment.

#### REFERENCES

(1) Di Bari, G.A. Electroforming. *Metal Finishing*, 47th Guidebook-Directory, **77 (13)** (1979), 432.

(2) Goria, C.A., G. Del Gaudio, G. Caironi, G. Silva, and M. Selli. Moulding of iron castings with evaporative polystyrene foam patterns immersed in loose sand: prospects and problems. **Metallurgical** *Science and Technology*, **1** (1983), 14-31.

(3) Goria, C.A., G. Serramoglia, G. Caironi, and G. Tosi. Coating permeability: a critical parameter of the evaporative pattern process. **90th American Foundrymen's Society Congress**, Minneapolis, May 11th-15th 1986, Paper 86-101.

(4) Remondino, M., F. Pilastro, E. Natale, P. Costa, and G. Peretti. Inoculation and spheroidizing treatments directly inside the mold. American Foundrymen's Society Transactions, 82 (1974).