PART 2: CLEANER PRODUCTION IDEAS

List of Examples

Introduction

The ideas presented in this section have been chosen to demonstrate the wide range of Cleaner Production opportunities that exist in all areas of foundry operations. Cleaner Production is a way of bringing about operational improvement.

Cleaner Production is a process-oriented approach to environmental management. Rather than simply controlling the outcomes with end-of-pipe solutions such as waste treatment, which address only the results of inefficient and wasteful production processes, Cleaner Production encourages companies to look at production of waste and determine the best management strategy for each case.

Cleaner Production focuses on elimination or reduction of waste at source as the first priority.

The idea that improved environmental performance and business profitability are compatible is a powerful one, and it is changing the way business is done around the world.

While it is by no means an exhaustive list, the purpose of this document is to challenge industry and motivate practitioners to look for innovative ways to improve their operations. All the ideas described in this section are taken from demonstrated industry case studies. Although not every suggestion will be applicable to all foundries, readers should be able to find a number of ideas that are worth considering for their foundry. By reviewing all the concepts discussed in this report and thinking laterally about how they may be applied to the reader’s specific operation, it should be possible to identify ways of improving environmental performance and reducing costs.

In low-margin businesses, even minor cost savings can have a significant impact on business profitability. For example, if the company has a 10% margin, saving $100 dollars is equivalent to increasing sales by $1,000.

While this section focuses on positive benefits that can be achieved from Cleaner Production, it does not address the many real and imagined impediments to achieving Cleaner Production. The authors appreciate that production and resource constraints can act as major barriers to making process improvements. Nevertheless, companies need to find innovative ways to overcome these barriers if they are to ensure the future competitiveness of their operations.

Cleaner Production should be viewed as a strategic approach to operational improvement. While many of the ideas discussed could be implemented as stand-alone projects, the best results will be obtained by following a long-term strategic approach. This approach starts with an assessment of the operation to identify the sources and actual costs of waste and inefficiency. From this, an integrated strategy can be developed that increases the overall efficiency of the operation rather than simply optimising one part. General Guidelines to implementing a Cleaner Production project are provided in Part 7: Cleaner Production Implementation Guidelines.

The Cleaner Production ideas in this report have been grouped under the following headings:

- Improving Housekeeping Practices
- Selecting Alternative Inputs
- Improving Metal Yields
- Improving Energy Efficiency
- Minimising Foundry By-products
- Production Planning and Improvement.

1. Improving Housekeeping Practices

Key Points

Housekeeping refers to a range of activities that relate to keeping the workplace tidy, materials flowing smoothly and equipment working at optimal efficiency.

Good housekeeping depends on active staff participation and awareness. Training programs and awareness training in this area can lead to improvements throughout the entire operation and can help develop a participatory work culture. Top management support is critical to developing a Cleaner Production culture. Incentives and recognition of involvement can also help to drive the program.

Companies are likely to get the best results from Cleaner Production when it is an integral part of how the business is run, not something extra the company does. If it is used to drive change in the operation, Cleaner Production can lead to real improvements in operational costs and environmental performance which leads to long term competitiveness of the company.

Some of the key questions to ask in relation to housekeeping include:

- Is the state of general housekeeping affecting the flow of work or causing spills?
- Are materials and chemical supplies being stored appropriately to minimise the risk of damage or waste?
- Can just-in-time purchasing practices be implemented to reduce the cost of inventory management and avoid waste from out-of-date materials (e.g. resins, catalysts and paints)?
- Can preventive maintenance be use to optimise the efficiency of major equipment and ancillary systems (e.g. furnaces, natural gas leaks etc.)?
- Can we improve staff training programs to increase awareness about Cleaner Production or to provide skill that increase operator efficiency?
- Can we provide incentives (financial and non-financial) to increase participation in Cleaner Production?

Housekeeping improvements represent the simplest way to reduce pollution, often without significant capital expenditure. For many foundries, Cleaner Production programs that foster housekeeping and general staff awareness can help to minimise waste throughout the operation. Linked with safety and quality programs, these systems can also improve the quality of the working environment and reduce costs.

Housekeeping improvements can include general workshop tidiness, preventive maintenance and inventory control as well as simple process improvements. Improving housekeeping is highly dependent on the active participation of the foundry staff. Therefore, awareness-raising exercises along with effective incentive schemes can significantly increase and maintain the commitment of staff. Example 1 is a local example of this. Incentive programs can include the use of small prizes (e.g. casket tickets or vouchers). They can also include non-financial rewards such as awards and other ways of recognising achievements.

Example 1: Cleaner Production Incentive Schemes

Tyco Water, on Queensland's Gold Coast, has developed a monitoring and incentive program called an 'Improvement Share' program. This program measures improvement in a range of areas including hours labour per tonne of product, foundry waste, general waste, energy efficiency, safety and general housekeeping. All goals are measurable and can be improved by the staff. Improvements are measured on a quarterly basis, compared to the average performance of the previous year, and the staff are paid a bonus representing half the value of the improvement. The company believes that this approach has helped them become one of the best foundries in the world in terms of safety and environmental performance. This program has directly benefited the bottom line.

Source: Spokesperson from Tyco Water

1.1 Workshop Tidiness

An important aspect of good housekeeping involves keeping the workplace clean and free of clutter. This can reduce the risk of accidents and damage to stock and equipment. For example, keeping stock in a designated inventory area can reduce the risk of its becoming accidentally damaged by forklifts. In the case of hazardous products, this can prevent spills in non-bunded areas.

Keeping the workplace free of clutter can also help to maintain a smooth flow of work, which can increase the efficiency of the operation. Planning where materials are stored and used can make them easier to access when needed. Wastes also can be more easily segregated. It can be a good idea for teams or supervisors to routinely audit the general tidiness of the shop floor and to consider opportunities to improve work flow.

1.2 Preventive Maintenance

The efficiency of equipment depends largely on the effectiveness of the maintenance program. Preventive maintenance is typically more cost effective than reactive maintenance because it helps ensure that equipment is operating efficiently and therefore not wasting resources. It can help prevent costly production stoppages and avoid the need for emergency overtime. Preventive maintenance systems are typically more expensive in terms of purchasing parts and in servicing equipment more frequently. In a well-run system, however these costs can be less than the benefits

Preventive maintenance can help minimise leaks, spills and other potential losses of resources. A regular schedule for cleaning and maintenance, with inspection logs to follow up on repairs, is a good management option. Systems to encourage staff to identify and report maintenance problems are an important aspect of this program.

Computer packages are available that help schedule maintenance activities for tools, machines and other equipment. These systems typically provide functions such as equipment inventory, repair parts inventory, vendor and service contractor management, time in use and downtime analysis, and maintenance costs tracking. These packages can help to control manufacturing costs, reduce scrap and rework, and ensure on-time delivery.

1.2.1 Compressed Air

Leaks in pipes and equipment can add up to huge losses of resources. Compressed air loss is a major concern in many foundries as it costs more than water, electricity or steam. Therefore leaks in this area can add up to a major expense. An example of the extent of compressed air loss from leaking pipes is provided in Table 1.

Table 1: The Cost of Compressed Air loss from leaks (100 Psi)

Leak size (mm)	Air loss (m^3/year)	Cost/day	Cost/year
<1	27,494	$0.79	$289
1–3	139,196	$4.00	$1,462
3-5	508,343	$14.62	$5,338
>5	1,347,200	$38.76	$14,146

Note: Annual figures assume the loss is constant throughout the year. Electricity costs are calculated at $0.07/kW.h and 15kW.h/$m^3$ of compressed air.

Source: SEDA (1999)

AuditAir (1999), an energy efficiency group, estimate that losses as high as 20% to 40% of capacity are common in many operations. Many foundries report that, excluding the melting operations, compressed air is the largest source of energy wastage (FTJ, 1999i). To put it into perspective, a 6 mm leak in a compressed air line, while relatively easy to ignore, is equivalent to 300 60-watt light bulbs left on (SEDA, 1999). Example 2 describes the experience of one company in reducing the cost of compressed air.

Ancillary services, such as motors and drives, compressed air, lighting and boiler plant, are typically responsible for up to half of total energy consumption in foundry operations (ETSU, 1995). These are key areas for maintenance and inspection.

Example 2: Improved Air Compressor Management

An energy audit of a UK foundry identified several opportunities to improve air compressor management. The company reduced the operating pressure of the compressed air supply from 7 bar to 6.5 bar. A control system, costing £7,000 (A$17,500) was installed to ensure a consistent supply. The system was also programmed to operate at 5 bar during scheduled breaks and to shut-off during predetermined non-production times. This reduced power consumption by around 26 kW.h.

One of the major uses for compressed air was to ‘blow-off’ mould cavities to ensure cast cleanliness. The air guns on each of the three lines were reprogrammed to be effective for 10 seconds per mould. This change resulted in a 19.4% saving in compressed air usage.

Source: *The Foundryman* (1998a)

1.2.2 Natural Gas

The efficiency of natural gas use in a foundry is typically about 20%. Natural gas use efficiency can be improved by the following:

a) Distribution. Eliminate the leaks that may exist in the natural gas distribution system.

b) Combustion. Ensure that all burners operate at the correct air-to-fuel ratio across the complete range of firing rates.

c) Excess air. Eliminate air infiltration to the furnace and provide combustion air through the burner such that excess air approaches 0%.

d) Radiation losses. Put covers of refractory or ceramic fibre blankets over all surfaces that are at elevated temperatures and generate radiation losses, such as molten metal in ladles and launders.

e) Conduction losses. Minimise the heat flow between the hot surface of the refractory and the cold surface, by inserting ceramic fibre or fibre-type sleeves between the working refractory and the furnace wall.

f) Heat sink losses. Replace refractories of high density and high heat content, such that significant thermal energy is not expended just to bring the refractory up to working temperatures.

g) Waste heat. Potential uses of waste heat include: preheating combustion air in foundry processes; heating of building make-up air; heating of foundry building.

1.2.3 Water

Because it is often a relatively minor cost, water efficiency may be overlooked in many foundries. The Environmental Technology Best Practice Program in the UK reported that the cost of water waste in the sector averages around 1% of annual turnover and that around half of this is relatively easily to avoid (ETBPP, 1995c). Therefore, although it is not as important as other issues, there may still be some benefits in improving water efficiency in the operation. There are also many relatively low-cost options for reducing water loss that may generate a cost benefit to the company (see Example 3).

Table 2 shows some typical rates of water loss for equipment used in foundries. These figures, which do not include the cost of wastewater, indicated that even small drips can add up over time.

Table 2: Typical rates of water loss.

Potential source	Rate of loss (litres/hour)	Annual loss (kL)	Annual cost (water only @ 80c/kL)
Dripping union or flange (1 drop/second)	0.5	4.7	$3.76
Leaking valve	6	53	$42.40
Leaking pump shaft seal	0–240	0–2,100	$1,680
Open ball valve (12.5 mm)	420–480	3,680–7,360	$2,944–5,888
Running hose (25 mm)	1,800–4,000	15,770–34,690	$12,616–27,752
Broken pipe (50 mm)	4,200	367,920	$29,434

Note: Based on a constant flow over the year (i.e. 24 hours/day for 365 days).

Source: Adapted from FTJ (1998l)

There may be numerous opportunities to increase the efficiency of water use throughout the plant. To avoid spending too much money fixing problems that yield little financial return, the company should undertake a survey of water use. This will help identify the main areas where water is wasted, and the potential economic value of addressing the problem.

Example 3: Reducing water consumption

R.H. Sheppard Company, Inc. in Hanover, Pennsylvania used large quantities of fresh water for cooling metal parts during grinding operations. The company installed a 60 kL closed loop cooling system with temperature and bacteria controls, which saved 13 ML of water per year and improved the grinding process. From its reduced coolant disposal costs and savings in water costs, R.H. Sheppard Company expects a two- to three-year payback period on its $US540,000 (A$830,000) investment.

In response to calls from the local water board to implement water conservation during a major drought, Hopkinsons, a valve manufacturer in the UK, halved its water consumption. Prior to the campaign, water use was generally overlooked and averaged around 500 kL per week. Over two years, this figure was reduced to around 220 kL per week.

The major changes that were implemented included the use of closed-circuit cooling systems, electronic sensors for flushing urinals, tighter control of evaporative cooling systems and staff awareness campaigns. Annual savings from these measures were estimated to be £18,000 (A$45,000).

Sources: UNEP (1997) and FTJ (1996l)

1.3 Inventory Control

‘Just-in-time’ purchasing and manufacturing systems are widely used in the foundry industry and have been adopted by many Queensland companies. These systems can greatly reduce inventory and warehouse costs and also reduce the volumes of hazardous materials stored on site at any one time. This reduces the risk and liability associated with accidental spills and the need to dispose of out-of-date materials.

To control the distribution of hazardous and expensive chemical additives, companies should consider locking stores and having a system where workers can exchange empty containers for new supplies only on a one-for-one basis. This will help avoid stockpiling or misuse of products and provide the possibility of returning containers.

The control of both incoming and outgoing materials may also be an area where cost savings can be made. An engine manufacturer in the UK redesigned its packaging system to use returnable and collapsible packing frames. This system allowed the company to increase the number of units that could be shipped per truckload from 30 to 44. Fewer than half the return journeys were needed to return the packaging to the site. Overall transport costs for these products were cut by around 10% (The *Foundryman*, 1999b). It may be possible to work with suppliers to find ways to reduce or eliminate packaging, for example by using returnable bulk bags or trays.

1.4 Staff Training

The benefits of a well-trained workforce can be an overlooked part of the company's Cleaner Production program. Training can benefit the company in three ways:

- Improving operator skills reduces operational costs by increasing productivity and reducing errors and waste.
- Training that is targeted at increasing general awareness of waste and its implications can improve staff acceptance of waste minimisation techniques. For example, a training company in the UK claims that the productivity of shotblasting equipment can be increased by 80% through basic training about the 'do's and 'don'ts' of shotblasting (The *Foundryman*, 1999a).
- An effective training program can empower workers and makes them feel more valued by their company.

The best way to reduce spills is to train staff in the proper handling of materials. There should be clearly established procedures for mixing chemicals, and the responsibility for handling and mixing chemicals should be limited to a small number of staff who are trained in the procedures. As well as reducing spills, this will also improve the consistency of formulations.

2. Selecting Alternative Inputs

Key Points

Selecting alternative inputs provides a means of eliminating waste or improving the efficiency of the operation ‘at source’. Foundries should carefully consider each type of resource used in the process and calculate the true cost of the material to the company in terms of the purchase costs, the disposal and handling costs and the costs associated with quality problems (e.g. increased scrap caused by inferior sand) and environmental problems (e.g. compliance costs in managing odour from binders). Once the company knows the full costs of each input and how it impacts on each stage of the operation, the company will be able to set priorities for which inputs should be changed.

Some of the key questions to ask in relation to assessing the suitability of alternative inputs include:

- Can we work with scrap suppliers to improve the quality of the charge material to avoid contamination?
- Can we alter the metals and alloys that we use to improve casting quality?
- Can we improve our materials testing procedures to improve product quality and reduce waste?
- Can we improve sand quality to improve the dimensional accuracy of the cast?
- Can we change the type of binders and other additives to improve cast quality, increase reuse options, improve environmental performance etc?
- Can we change the type of refractory material used in the process?
- Can we change from solvent based coating systems to water-based systems?
- Can we alter the pattern or die materials to improve process performance?
- Are there any new consumables (e.g. risers, sleeves etc.) that will improve casting efficiency?
- Can we change the type of energy used in the process to improve efficiency and environmental performance (e.g. natural gas etc.)?

This section describes a number of alternative inputs that foundries are using to reduce the environmental impact of their processes, and to improve casting quality or efficiency. In addition to the ideas that are described in detail, companies may wish to explore some of the following avenues to identify other opportunities:

1. Purchase higher-quality moulding materials (e.g. sand with a low dust and/or impurity content).
2. Alter the metals or alloys that are used, to improve casting quality.
3. Improve materials testing procedures, to:
   - improve product quality and/or reduce waste;
   - improve the acceptability of liquid metal prior to casting;
   - develop non-destructive, in-line, fast, reliable and accurate methods for quantifying casting defects;
   - develop evaluation methods for ingot and as-cast chemistries and properties (particularly for ferrous casting);
   - identify the presence of undesirable elements (e.g. antimony, phosphorus, sulfur) and inclusions.
4. For ferrous foundries — explore the feasibility of working with steel scrap suppliers to develop reliable sources of high-grade scrap (Environment Canada, 1997).

2.1 Alternative Mould Coatings

Paints are used as the base for the refractory coatings on sand moulds and cores to improve the surface finish by minimising sand contamination. The environmental and operational problems associated with paint solvents are prompting many companies to look at replacing these materials with non-solvent alternatives.

Solvent systems such as alcohol, acetone and trichloroethylene offer a number of advantages including: rapid drying by air or flaming; low gas levels after drying; and minimal effect on the mould or core substrate. Problems associated with solvent systems, however, include the generation of hazardous fumes, occupational issues resulting in the use of flammable materials, and the environmental costs and risks associated with handling and disposing of the materials (The *Foundryman*, 1996a).

The two alternatives that companies can consider are water-based systems or powder (dry) systems.

2.1.1 Water-based systems

Water-based coatings are being developed to better compete with alcohol systems. Some of the problems that need to be overcome are high gas levels, soft bond strength and longer drying times. Unlike solvent-based coatings, water-based coatings generate moisture, which is absorbed into the mould or core. The surface of the paint becomes impermeable, making efficient drying even more difficult. Modern coatings are continually being developed that have reduced moisture ingress and faster drying times. Up to 50% reductions in drying time over conventional acrylic paints have been reported. The four common drying methods are forced air, microwave, infrared (see Example 4) and dehumidification, with dehumidification being the slowest of these.

Example 4: Infrared Drying

Decatur Foundry, a small-run jobbing foundry in the United States, specialises in iron castings for electric-motor frames and parts as well as pump components. A change form quick-drying, solvent-based coatings to slow-drying, environmentally safer water-based coatings, created a bottleneck in the production process.

The company installed an infrared/forced air unit as a replacement for the conventional electric-resistance ovens. This resulted in an 85% decrease in drying time. The new system heats the surface directly rather than heating the air, so the system requires no warm-up time and does not waste energy heating the air. Precision instrumentation allows more control in the drying process.

Achievements:

- Replacement of the first production line cost US$12,000 (A$18,400) and reduced annual energy consumption by 120 MW.h, equivalent to US$9,000 (A$13,800) .
- Organic solvents were eliminated.
- New units freed up floor space.
- Eliminating the drying bottle neck reduced labour costs and increased productivity, allowing Decatur to offer a very competitive turnaround time.
- Enhanced efficiency and productivity allowed Decatur to add two new lines (including infrared units), increase employment by 13%, and increase sales from US$5.9 million to US$10 million.

Progress Casting Group, in the United States, replaced its TCA solvent-based paint with water-based coatings in 1994. The company used 13 tonnes of TCA at a cost of US$59,000 (A$91,000). This was replaced with an equivalent amount of water-based coating at a cost of US$14,500 (A$22,000), resulting in a net materials saving of US$44,500 (A$68,500). The company gained additional savings in reduced compliance and disposal costs. The biggest obstacle was to develop an appropriate drying system. The company evaluated high-intensity lights, drying tunnels, infrared and microwave systems. Microwave and infrared were found to be most efficient, but the non-selective heat of the microwave system caused structural damage to the cores.

Sources: ACEEE (1999) and MNTAP (1994)

To date powder systems have been developed by Foseco, a major supplier of foundry materials, for greensand systems and are based on the use of a resin-coated powder (e.g. zircon). This material is tribostatically charged by blowing the powder down a plastic rod. The charged material then seeks a conductive medium (i.e. moist greensand) to earth the charge. These forces create a sufficient bond to form a coating. During pouring, the heat from the metal causes the resin to fuse together to give a fully bonded coating layer. This technology is relatively new but, in the future, experience from other powder coating practices may help to improve these systems further (The *Foundryman*, 1996a).

2.2 Water-based Shell for Investment Casting

Many investment casting operations (see Part 5) have successfully changed from solvent-based shell mould systems to acrylic systems. Example 5 describes the experiences of one precision casting company.

Example 5: Water-based Investment Shell

A UK-based investment casting operation, MBC Precision Casting, achieved significant savings by converting from an alcohol-based ceramic shell production system to a modern water-based system.

The technology cost £17,200 (A$43,000) and at the end of the first year the accumulated savings were £98,000 (A$245,000). The company also avoided over £100,000 (A$250,000) in new VOC abatement technology. The savings came from a number of sources including reduced slurry evaporation losses, reduced scrap, shorter knockout times, lower rework and virtual elimination of wax pattern relief. Poured weight capacity was also improved, as was dimensional accuracy and control. There was also a marked improvement in the shell shop working environment since alcohol fumes were eliminated.

The company reported that the make-up costs for water-based slurry were more than double those of alcohol-based coatings by weight. However, the average number of coats required was reduced by around 18%. Slurry costs per unit of metal poured, therefore, increased only from £0.29 per kg (A$0.73) for ethyl silicate to £0.33 per kg (A$0.83) for the water-based material. Also, the shell-to-metal ratio improved from 0.57:1 to 0.44:1 because heavier castings could be produced (up from 40 kg to 60 kg).

Sources: FTJ, 1998o and FTJ (1996h)

2.3 Improved Pattern Materials

Another avenue for investigation may be to consider changing the type of pattern and mould materials used. Specialist coatings for moulds may improve performance. For example, electroless nickel coatings on shell mould patterns are reported to improve surface quality and increase the life of the pattern by 250–300%. The natural lubricity of the surface finish aids in cast release and improves surface quality. The patterns are also reportedly easier to clean, thus increasing cycle time (FTJ, 1996n).

2.4 Improved Riser Materials

Risers are used in cast designs to provide the extra metal necessary to feed the casting cavity, to compensate for shrinkage during solidification. Riser sleeves, made from refractory materials, are designed to maintain the temperature of the metal in the riser and to reduce the size of the riser cavity. New sleeve technology may provide opportunities to improve cast design and to improve metal yield. The most common type of riser used in foundries today is made from fibrous refractory material. Non-fibrous, non-sand-based sleeves have been developed and have been in use since 1996. These are reported to provide greater dimensional accuracy and strength, low gas evolution and more uniform insulating or exothermic properties (Metal, 1998a).

2.5 Alternative Energy Sources

Alternative fuels for melting are often less expensive and cleaner may be available. Natural gas is typically a better option can fuel oils from a reliable source is available. If fuel oils are used, lower grade oils may be available. Petroleum distillated will result in lower particulate emissions than heavier grade fuels. Chose a low-sulfur or low-nitrogen fuel, natural gas reduce air emissions further. Proper maintenance of furnaces will also help reduce emissions (USEPA, 1998).

3. Improving Metal Yields

Key Points

Improving metal yield offers many foundries a significant potential to increase the efficiency of their operations, particularly in terms of energy use. Conventional sand casting operations have the most potential to increase metal yield. These improvements can increase efficiency in a number of ways including tonnes of usable castings per melt; per tonne of sand; and per hour of labour. The time required for handling reject and scrap material and for recycling operations can also improve as can emissions from the foundry. Foundries should consider the potential costs and benefits of improving metal yields as fully as possible.

Some of the key questions to ask in relation to improving metal yields include:

- How many tonnes of metal do we melt for each tonne of usable castings? What are the major areas of loss (e.g. melt losses, spilt metal, pigged metal, runners and risers, reject castings, or grinding losses)?
- Can any of these areas of metal loss be reduced by:
  - minimising metal spills, over- or under pours thorough precision pouring techniques?
  - redesigning the gating system to make it more efficient?
  - using casting simulation technology to improve cast design and solidification properties?
  - working with our customers to redesign the casting to reduce it's weight or improve its casting characteristics?
  - minimising grinding losses or even eliminate some fettling operations from the foundry?
  - using metal filtering, direct pouring techniques or other methods to minimise inclusions in the metal?
- Can we redesign, optimise or change the casting process used to increase the metal yield?

High integrity small to medium-sized grey iron engineering castings, complicated or heavily cored design — mechanised, volume production	55–60
Medium-sized ductile iron castings, jobbing or small batch production	50–60
Small grey iron castings — mechanised, volume production	
Small ductile iron castings — mechanised, volume production	40–50

Source: DETR (1999)

Gating systems (i.e. runners, risers and sprues) are often large, and sometimes larger than the actual product cavity. Wall thicknesses are sometimes over-specified to compensate for porosity and other metal quality problems. The number of units produced is often over-specified to compensate for reject products and customer returns. All this means that, for every tonne of metal sold, around 2 tonnes are melted (FTJ, 1997d).

While the bulk of this excess metal is collected and remelted, it represents a significant cost to the foundry in the following ways:

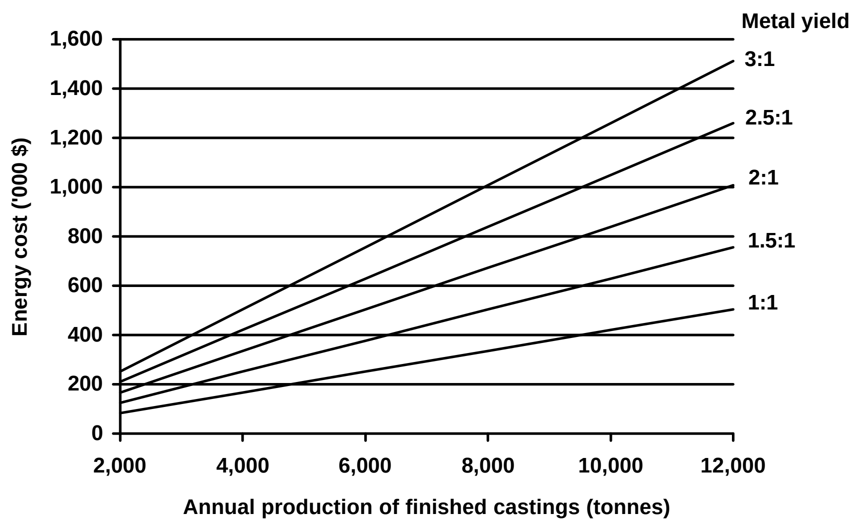
- energy used in melting and holding the metal;
- capital costs for unnecessary metal handling capacity;

- increased fettling costs;
- unnecessary metal collection and sorting time;
- increased maintenance of equipment;
- lost time that could be used for value adding activities; and
- customer relations issues.

Many foundries underestimate the true cost because they do not account for all of these sources of cost. Even so, the direct costs of energy are often sufficient to generate interest in making improvements in this area. Typical iron foundries using electric induction furnaces use between 500 and 800 kW.h of electricity for each tonne of metal melted, depending on the scale of operation and the melting and holding practices employed (FTJ, 1997e). At an average of 7 cents per kW.h in Australia, this equates to between $35 and $56 per tonne.

The Queensland casting industry produces over 80000 tonnes of castings each year. Assuming an average melt efficiency of 600 kW.h per tonne ($42 per tonne @ $0.07 per kW.h) and a metal yield of 50%, the industry is spending in excess of $3.3 million melting metal that does not end up in the final product. For an average foundry, producing 7000 tonnes of castings in a year, this would equate to nearly $300,000. The melting costs over a range of production rates and metal yields are shown in Figure 1.

Figure 1: Melting Costs of Iron Foundries using Induction Furnaces



Note: This figure shows the costs of melting in an iron foundry using an induction furnace. The ranges of annual production and metal yields shown are typical for Queensland foundries. This analysis assumes a melting efficiency of 600 kW.h per tonne of metal melted and an electricity cost of $0.07 per kW.h.

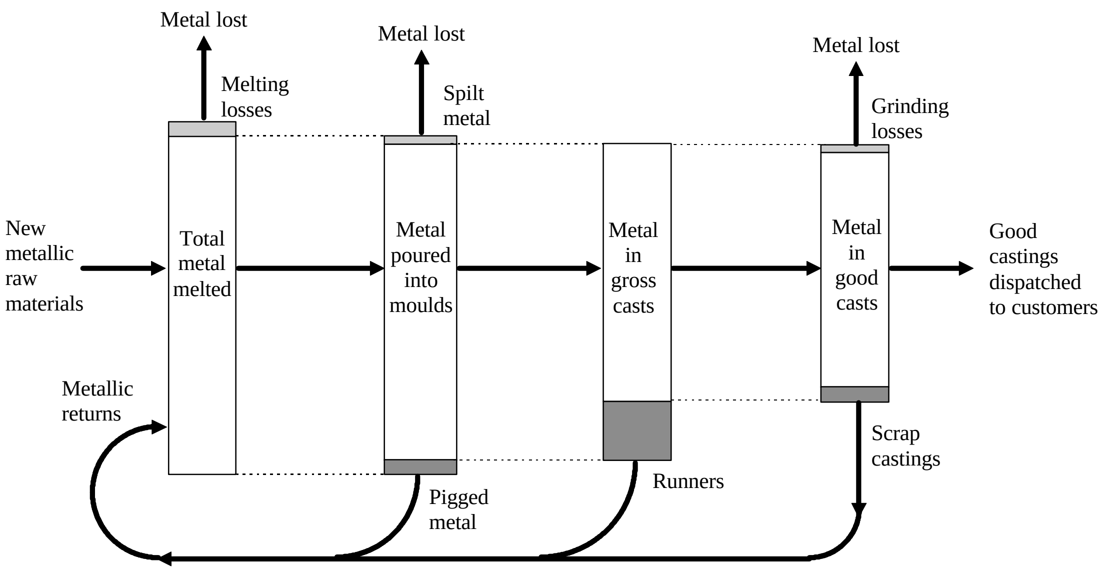
A realistic target for Queensland foundries may be to improve metal yield by around 20% (Metal (1997b) and FTJ (1997d)). This could mean a saving of over $600,000 for the Queensland industry and $60,000 for a 7000 tonne foundry.

Metal yields may be reduced in a number of areas in the foundry process. The benefits that could be gained by implementing improvements will vary between foundries. Therefore it is important for companies to undertake their own mass balance for metal, to identify the true cost of metal loss to the company and the key sources that can be addressed most effectively.

Improving metal yield often requires an integrated approach to ensure that improvements in one area lead to an overall improvement in operational efficiency. Companies wanting to improve yield should analyse the whole process to identify the main causes of waste and develop an integrated improvement strategy.

The Energy Efficiency Best Practice Program in the UK has prepared a publication titled *Achieving High Yields in Iron Foundries (DETR, 1999)*. Figure 2 is derived from this publication, and provides a simplified model of the foundry process, showing the major areas of metal loss. Using a mass balance approach to account for metal yields and metal loss is an essential first step in identifying the key opportunities for improvement.

Figure 2: Metal Mass Balance of a Typical Foundry



Source: DETR (1999)

3.1.1 Minimising Melting Losses

Melting losses as high as 3% have been reported by practising foundries (FTJ, 1997g). These losses are mainly a result of oxidation, slag removal and sampling operations. Minimising this loss may be achieved by:

- minimising contamination in the charge;
- accurate charge make-up and weight;
- optimising stirring practices to minimising slag formation;
- minimising unnecessary superheating; and
- selecting and maintaining appropriate refractory linings (DETR, 1999).

In some cases it may be possible to recover metal from slag, either in the foundry operation or in another process. One company's experience in metal recovery from slag is descried in Example 6.

Example 6: Metal Recovery from Slag

J. McIntyre Aluminum Ltd, in the UK, has dramatically increased metal recovery from its aluminium slag by installing two skimming, pressing and cooling systems. The company produces 30000 tonnes of castings annually and generates 6000 tonnes of slag each year. The system, known as a 'Tardis' (thermal aluminium recovery from dross in situ), achieves 48% recovery of the metal from the slag. Before the development of this system the company used a conventional cooling and cold processing route to recover metal from the slag. This system produced a 28% return to sow; thus the new system achieved a 20% increase in recovery. The company claims that similar results could be achieved with all types of aluminium slag.

Source: FTJ (1996e)

3.1.2 Minimising Spilt and Pigged Metal

Metal can be spilt during transfer to the melting furnace, the holding furnace, the pouring ladle and finally the flask. These losses can be minimised through better training, improved procedures and automation of the pouring process.

Excess or poor-quality metal is typically pigged at the end of the run. Although it will be remelted this represents a loss in terms of energy, labour and a minor amount of metal. In some cases it may be possible to return molten metal left in the ladle to the furnace, rather than pigging it out. This will reduce some of the energy loss.

To ensure metal quality, and to ensure that end production is not held up, most foundries melt more metal than is required for a particular production run to compensate for losses.

The amount of excess metal can be reduced by better matching metal demand and supply. Improving the efficiency and consistency of the pouring process will allow greater predictability of metal demand. Reducing holding times by better timing the melts to coincide with production can reduce energy use and reduce the risk of metal cooling to a point where it is unusable (DETR, 1999).

Precision or automatic pouring systems (see Example 7) improve metal yields by delivering an appropriate and consistent volume of metal to each mould at an optimal flow rate. The pouring location, in relation to the sprue, can also be controlled to improve the fill-out consistency. By doing so, over-pours and short-pours are eliminated, slag and other inclusions are reduced and casting quality is enhanced (FTJ, 1998h). Cycle time can also be significantly reduced, which is an important consideration for repetition foundries.

Example 7: Precision Pouring

The *LaserPour* system from Selcom Inc has been demonstrated to be cost effective in some iron foundries. Selcom claims that a typical iron foundry, with an average mould weight of 22.7 kg, 350 moulds per hour and 350000 tonnes of metal melted annually, can save over US$225,000 (A$346,200) in remelt costs annually and US$125,000 (A$192,000) annually in other savings including labour, increased profit in added output and reduced downtime. The company claims a further 15% improvement above this with its latest LaserPour IV system.

Chrysler Foundry, a supplier of engine blocks, installed four LaserPour systems to replace the previous teach-in pouring method. After overcoming some additional installation problems, which cost in the order of US$15,000–20,000 (A$23,000–31,000), the foundry experienced a significant increase in pouring consistency. This reduced the gross weight of the casting by around 3.2 kg per sprue cup poured, and reduced the overall scrap rate by around 510 tonnes. The monetary savings were approximately US$1 million (A$1.5 million) during the foundry's 1994–95 fiscal year.

Auburn Foundry, in the United States, pours up to 1600 tons of grey iron a day at its two plants. The company installed a LaserPour laser-controlled molten-metal-pouring system. The installation of new systems resulted in cycle-time reduction and generated a 6–8%production increase at one plant. Depending on the weight of the job, cycle time was between 7 and 12 seconds per mould. This was reduced by between 0.5 and 1.7 seconds. At 6000 to 8000 moulds per day for each line, and multiple lines at both plants, this amounts to a high potential for savings.

Sources: FTJ (1998h); Quality (1996); and Quality (1998)

3.1.3 Minimising the Weight of Castings

The gross and net weight of castings are often over-specified to compensate for metal quality problems, and due to uncertainties in the pouring and solidification process. This means that more metal is melted and poured that necessary.

Efficient casting design is an important component of increasing metal yield. Careful design of castings and gating systems can significantly reduce both the gross and net weight of the casting, thereby increasing metal yields. Cast redesign also has an important impact on the following:

a) Box yield — the ratio of net weight of castings to gross weight of metal poured. Increasing the number of units per box typically allows the relative size of the gating system to be reduced. Casting design studies indicate that adding an extra unit to the box can increase box yield by between 50% and 60%.

b) Box design — the size and shape of the box used. This can also reduce the volume of sand per casting.

c) Sand yield. Increasing the volume of metal in the box reduces the amount of sand that is required per tonne of product (DETR, 1999).

The major concern about reducing the size of the gating system is the risk of reducing product quality as a result of poor fill-out and shrinkage. The use of casting simulation software can help in redesigning the gating system while maintaining good casting quality (see Example 8). Industry experience shows that, depending on the current geometry and gating system used, cast weight can be reduced by as much as 30% without affecting cast quality. Reducing the size and complexity of gating systems can also reduce fettling time and the handling of metal for recycling (FTJ, 1997i).

Improved metal quality, direct pouring and casting simulation can all help to reduce the net weight of the actual casting. The increased confidence that these systems provide can allow the designers to specify lighter sections (e.g. reduce wall size). Some foundries use simulation techniques to identify opportunities to reduce dramatic changes in section size. Such changes can lead to quality problems and require far larger gating systems. Changing casting design requires a close relationship with customers, and is typically harder for jobbing foundries to organise than for captured foundries (DETR, 1999). There can be flow-on benefits to the customer in terms of a cheaper, higher-quality product. Further benefits can also flow to downstream users (e.g. lighter equipment, which costs less to operate) (The *Foundryman*, 1997a).

Example 8: Reducing Casting Weight Using Simulation Technology

Fishercast Ltd, a producer of steel valves, in the UK, has been using traditional design techniques based on modulus techniques (i.e. the use of standard engineering rules and formulas to calculate the appropriate size of the casting). The company invested in casting simulation software, MAGMASOFT, to evaluate the potential to redesign its castings to reduce their gross weight.

The company identified the products where they thought the major savings could be made. One steel valve body that was selected had a pour weight of 2330 kg. After using simulation software, they were able to produce a sound casting with a pour weight of 1880 kg, nearly a 20% reduction in metal use. Fettling time was reduced from 10.5 hours to 4.3 hours and total production costs were reduced by 12%.

Source: FTJ (1997i)

3.1.4 Minimising Grinding Losses

Fettling is probable the least favoured job in most foundries and, as a result, foundries often report difficulties in maintaining good-quality staff in this area. Fettling can account for as much as 20–30% of the total direct costs, particularly for iron foundries. Added to this are the costs of time lost to injuries, recruitment and organisation problems, which can greatly increase the actual cost of these activities (FTJ, 1998n). Fettling is also a significant source of metal loss, which can be difficult to recover cost-effectively. See Example 9 which discusses one company's experiences in minimising grinding in its operation.

Example 9: Rapid Grinding Systems Minimise Grinding Waste

A.W. Bell, a precision investment casting foundry in Australia, has developed a rapid grinding systems, the RGS430, in response to a perceived lack of appropriate technology to minimise waste from their fettling area.

The belt finishing machine incorporates an indexable feed table attached to a swing arm. Parts are mounted into the grinding fixture to achieve consistent, repeatable grinding. The movement of the arm and grinding pressure are preset for the part and type of alloy being processed. The benefits of this change are numerous:

- The operator's role has changed from being the actual grinder to being a part loader and unloader, since the machine does all the grinding work.
- Operators tend to use grinding belts unevenly. The grinding machine uses all the parts of the grinding belt equally, ensuring even wear and maximum belt life.
- Studies have also shown that, because operators are unable to apply consistent pressure on the grinding face, the abrasive material tends to go dull. The consistent pressure applied by the machine keeps the abrasive material sharp, which also increases belt life.
- The automated system ensures consistent grinding and eliminates operator issues such as over-grinding and grinding errors. Scrap rates are greatly reduced.
- Safety is significantly improved because operators are no longer directly doing the grinding, thus reducing the risk of repetitive injury. The working environment is also improved.

Tests comparing the efficiency of the machine against a skilled operator showed impressive improvements — a 438% improvement in productivity over the shift and a 75% reduction in belt usage. In an 8-hour shift the operator used six belts to finish 800 parts, whereas the machine used the same number of belts but finished 3500 parts in the shift.

Source: Metal (1996a)

Another concern about the fettling process is that it is largely a non-value-adding activity. With the increasing need to reduce costs in the industry, many foundries are looking at ways to reduce or even eliminate the fettling stage. Some have found that this can be achieved by improving both upstream and downstream processes in the following ways:

a) Improving the casting process may reduce the need to fettle.

Casting processes such as lost foam or investment casting, which achieve ‘near-net’ or ‘as-net’ castings (i.e. close to the size of the final product so that it requires less fettling and cleaning), can greatly reduce the need to fettle. Conventional casting techniques are also constantly being improved to achieve similar benefits. Gating systems can also be redesigned, as discussed in the previous section.

b) Some fettling processes can be combined into the machining stage.

In some cases, fettling may be unnecessary. Often parts are over-fettled by operators who want to do a good job. Some burs may be purely cosmetic and be effectively removed in the machining process. Improvements in these areas have been found to reduce fettling time by around 20% without affecting product quality or increasing machining costs (FTJ, 1998n). Changes to procedures, including quality control, would be required to develop appropriate standards and coordinate the actions of operators in each process. Machining tools are being developed that are more tolerant of unfettled parts, so the line between fettling and machining is becoming increasingly blurred.

c) Many of the remaining fettling processes can be automated.

Robotic fettling cells have been developed that can automate some fettling functions. These systems can reduce the space needed for the fettling area and create a more continuous flow of product through the area. Robotic systems can use heavier grinding equipment which can reduce grinding times. The systems can be enclosed so that noise and emissions can be more effectively controlled and higher levels of metal recovery can be achieved. Experience in companies suggests that cycling times can be reduced by 50–75%. With most castings, manual fettling is typically not eliminated entirely and the systems are most suitable for repetition foundries (FTJ, 1996g).

Used in concert, these three strategies may eventually ‘squeeze out’ manual fettling processes from many casting operations (see Example 10).

Example 10: Eliminating Fettling from the Foundry Process

The Swedish Foundry Association has been working to eliminate fettling from the foundry process. The two companies discussed below have successfully incorporated fettling into the machining process. Osterby Steel Foundry AB produces fully finished castings. The company identified a range of flexible machine tools, multi-operation machines and lathes. For example, a five-spindle milling machine was purchased for milling pump wheels. Initially the fettling of pump wheels required 120 hours of hand grinding.

Fettling time has been reduced to 35 hours of automatic grinding, with an additional 25 hours for hand milling. Across the product range, fettling time has been reduced by between 2 and 28 hours per unit. The company reported that most of the barriers to this improvement were organisational rather than technical. Communication problems between departments, wage issues, departmental under-utilisation, and scepticism among staff are cited as key barriers.

ITT Flygy AB, a manufacturer of iron and chromium submersible pumps, has increased production by 60% while maintaining the same number of fettling staff. As well as implementing job rotation to reduce fettling accidents and to retain staff, the company has implemented a range of changes designed to eliminate fettling. These include:

- improved pattern design and equipment;
- incorporating a parting rib, which does not require fettling, instead of a parting flash in cast sections (where no structural problems would result). Where a parting flash cannot be eliminated it is transferred to surfaces that will be machined automatically;
- standardising the angle of the parting burr to simplify fettling and allow automation;
- changing core design to eliminate gluing, which can create a mismatch and require fettling;
- changing the gating systems (to the Connor gating system) to incorporate long, thin in-gates that are easier to knock off and machine.

The benefits that have been gained include:

- a reduction of fettling cells from nine to four with greater total output;
- improved product quality, shorter machining times and lower manufacturing costs;
- reduction of the need to reassign staff due to repetitive injuries from an average of six staff per year to zero.

  In addition:

- The majority of castings no longer need fettling. Fettling time for the remaining casting has been reduced, often by more than 70%.
- Fettling has been eliminated in the design of all new castings.

Source: FTJ (1998n)

3.1.5 Minimising Scrap

Reject product or scrap can be very costly to the foundry operation in terms of reduced production efficiency and, in some cases, loss of reputation if production schedules are held up or faulty product is shipped.

Scrap should be 'designed out' of the process wherever practical. More efficient melting practices can reduce inclusions and porosity in the metal, reducing the need to reject poor-quality product, thereby reducing waste at source. It can also reduce the need to compensate for poor metal quality in the casting design for higher box yields to be achieved (FTJ, 1997i).

Good inspection processes should be maintained to remove reject product from the process as soon as possible to avoid further processing. All incidents of scrap should be recorded, measured and investigated to identify and address problems. All reject product should be carefully segregated to ensure that it is not shipped to customers by mistake and is properly recycled.

Reducing the reject rate can also lead to significant savings in a range of areas. If a foundry that produces 5000 tonnes of good product reduces its reject rate from 6% to 5%, it would result in a reduced demand of 137 tonnes of molten metal. In turn, this would lead to:

- a reduced metal charge of 141 tonnes (assuming a 3% melt loss);
- a reduction of around 85 MW.h of electricity (at 600 kW.h per tonne) for an electric induction furnace, saving over $5,900 (at $0.07 per kW.h); and
- a reduced slag production of 5.6 tonnes (assuming 4% slag) (FTJ, 1997g).

There will also be benefits in other areas — most prominently, reductions in labour, sand use, reclamation and dust generation (DETR, 1999).

3.1.6 Casting Simulation

Casting simulation technology is an emerging technology that is being used to increase the efficiency of casting design processes (i.e. gating design). Traditional foundry practices in this area range from simple adaptations of standard designs to using engineering methods to estimate the appropriate dimensions of the cast and gating system.

Simulating metal flow and solidification can improve casting design and help demonstrate the cost effectiveness of different design variables. This can be achieved prior to the casting and can significantly reduce lead times.

> *Being able to make a detailed prediction about casting quality, given a specific process design, prior to the actual production of the casting, provides benefits which should be obvious to any operating foundry person*
>
> Metal Asia (1998d)

All foundries, to some extent, experience problems with the casting design process. These include quality issues (e.g. porosity, shrinkage and strength), which result in some level of scrap, and commercial issues such as lost business resulting from poor quality, long lead times or inability to make early predictions and guarantees of quality. Some of the design improvements that can be achieved using casting simulation systems include:

- optimisation of gating systems;
- reductions in high-velocity melt erosion;
- optimisation of filling times;
- adequate venting in die castings;
- reductions in slag entrapment;
- optimal use of filters;
- optimisation of casting method;
- optimisation of feeder size and position;
- optimisation of casting removal times;
- improved box yield;
- effective use of chills; and
- reduction in heat impact to cores (MAGMA, 1999).

In summary, the above improvements lead to reduced scrap rates, higher quality and greater predictability. This can also impact on the efficiency of the process in terms of metal yield, energy use, process flow, product quality and reduced fettling time.

To date, casting simulation technology has been adopted only by around 10% of the foundries in the developed world. There is some level of scepticism about the potential of this branch of engineering. This is largely due to a number of technical, economic and perceived barriers to using the systems. The cost of the technology is relatively high and many foundries do not have the knowledge necessary to choose the most appropriate system (FTJ, 1998k). The quality of the prediction depends on the quality of the input data and the judgment of the engineer to be able to select the most important criteria. In practising foundries, a balance is needed between undertaking a detailed analysis and making a timely commercial decision (Metal Asia, 1998d).

There are also some unrealistic expectations as to what the technology can do. The models are still based on an incomplete knowledge of the microprocesses that occur during the pouring and solidification process. It is not currently possible, therefore, to eliminate all quality problems from the casting process. Fortunately two of the major quality issues, porosity and shrinkage, are relatively amenable to prediction (Metal Asia, 1998d).

The technology is complex and will not be a ‘magic potion’ for the foundry industry but, when used appropriately, it has been shown to create significant net benefits.

Experience from the industry indicates that the cost of implementing the technology can often be justified on the basis of reduced scrap alone. For companies that experience high reject and scrap levels on major product lines, the cost of modelling can often be justified after only one job (Metal Asia, 1998d). If problems are being experienced on just a few high-value lines, or the company is too small to justify developing an in-house capability, the company could consider outsourcing or entering a joint research and design project with a professional modelling group.

3.1.7 Metal Filtering

In an effort to improve metal quality, increase productivity and move towards zero defects, many foundries are using filters to remove dross, slag and other impurities from the melt. This improves the metallurgical properties of the casts, improves surface finish, achieves greater yields and reduces operating costs.

Metal filtration technology has improved greatly in recent times (see Example 11). They are becoming more refractory, less prone to breakage, more tolerant of thermal shock and extreme pouring temperatures and less expensive.

Example 11: Filtering Metal

Auto Alloys Foundries, in the UK, have achieved major savings in the cost of the metal alloys used. These savings have come from increased metal yields, achieved by redesigning the runner system. As an example, one nickel/chromium alloy fan head casting, with a net weight of 29.5 kg as cast, originally required 58 kg of liquid metal. The company now pours directly into the central boss through a ceramic filter, allowing riser size to be reduced. This has reduced metal demand to 39 kg — a 32% reduction. The reject rate was also reduced by 5%. The savings have been estimated to be £14.66 per unit (A$37). The company has also reduced design time without loss of quality for many of their products. Overall, the company’s reject rate has been reduced from 6% to 1%.

Swan foundry, an iron foundry, also in the UK, has also reported reasonable savings. The ability to simplify the runner system has allowed the company to fit more castings in a box for many of its products. This has greatly increased metal yield. For one of its products, a 12000 unit per year 10.8 kg ductile iron housing, the company estimates that the unit savings for increasing the number of units in the box from one to two is in the order of £2.20 (A$5.50 per unit or A$66,000 per year).

Source: FTJ (1997j)

3.1.8 Direct Pouring Techniques

Direct pouring of metal into sand moulds has been practised throughout the history of casting. This technique, however, leads to sand erosion and carryover of slag into the casting. In order to overcome this problem, many sand casting operations use sprue cups to reduce the metal contact with the sand. Complex runner systems have also been designed, including pouring brushes, downsprues, runner bars and in-gates, to reduce turbulence and impede the flow of inclusions into the mould cavity (Metal Asia, 1999b).

In the past five years, direct pouring techniques have improved to the point where the sprue cups can be eliminated and runner designs can be greatly simplified. In many cases pouring brushes, runners, filter prints and in-gates can be eliminated without compromising cast quality. The new direct pour devices, supplied by Foseco, are a combination insulating sleeve and metal filter that replaces a traditional pouring cup and acts as a feeder (Metal Asia, 1999b).

The major benefits of these techniques include the following:

- **Quality improvements** result from filtering, which more effectively removes external inclusions than gating system flotation, and a reduction in turbulence. Faster filling rates can be achieved leading to reduced thermal gradients, reduction of cold metal defects and more directional solidification.
- **Yield improvements**, resulting from simplified runner design, can greatly reduce the poured weight. Light-weighting (i.e. reducing the net weight of the actual product) the product may also be achieved due to improved metal quality. The simplified runner system can allow more units to be included in a single box and more units to be produced in a single melt. These changes all tend to reduce energy use. Better mould utilisation can also lead to reduced sand use.
- **Productivity improvements** through faster pour rates lead to greater throughput. Rejects and rework can be significantly reduced and labour costs for mould handling, knockout, fettling, and sand handling can also be reduced.
- **Reduced fettling**, through better surface finish and fewer gating marks, reduce the need for grinding and welding repairs (Metal Asia, 1999b).

Australian foundries (see Example 12) report that by using these techniques they are achieving, on average, a 20% yield improvement, a rejects rate of less that 1% and minimal repair work (Metal, 1997b).

Example 12: Direct Pouring

An Australian foundry, owned by Foseco Pty Ltd, produces a conveyer casting in an aluminium alloy (RH Si_7 Mg. While it is only 3.5 kg, it must be able to withstand a high load (1.2 tonnes). In order to guarantee the loading specification, the company has to ensure equal distribution of molten metal and directional solidification of the casting. This meant that the company used a complex runner system, including two downsprues and six in-gates and a series of risers. The reject rate was high — around 8% — due to inclusions created from the turbulent flow.

By using foam filters, a non-turbulent flow could be achieved and oxides and inclusions could be trapped more effectively. This allowed the gating system to be greatly simplified. The use of an insulating sleeve ensures that the metal remains in a liquid state long enough to allow sufficient feeding into the cast cavity. The reject rate was reduced to 1% and the cost per unit was reduced from $82 to $67 — an 18% improvement.

By using direct pour techniques, the gross weight of another product (with a net weight of 53 kg) was reduced from 82 kg to 69 kg. This reduced metal costs from $296 to $249. Sand use was also reduced somewhat, from 169 kg to 159 kg per unit, reducing the cost of sand from $18.77 to $17.05 per unit. Cost for consumables (i.e the filter and sleeve) increased from $19.11 to $28.54 per unit. In total, the company saved over $39 per casting or 11% over the original method. This estimate did not include savings in fettling time and rework, which were also considered to be significant.

Source: Metal Asia (1999b)

4. Improving Energy Efficiency

Key Points

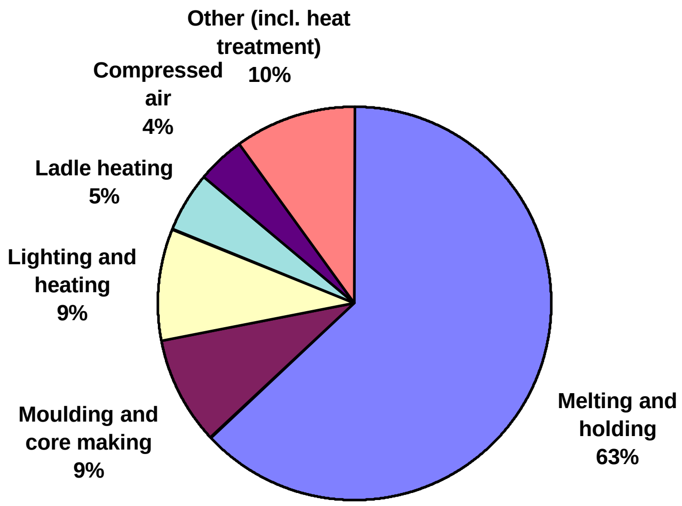
There are many opportunities for improving energy efficiency in most foundries. Some of these, such as optimising the efficiency of ancillary services can be achieved at minimal cost and make a valuable improvement to the bottom line. Reports from many foundries suggest that energy efficiency is one of the most significant Cleaner Production options still to be addressed in the industry. Foundries should undertake an audit to establish the full cost of energy to the company and the major demands on energy in the process. This will help prioritise improvement strategies.

Some of the key questions to ask in relation to energy efficiency include:

- Have we undertaken a recent detailed assessment of energy efficiency in the foundry?
- Can we benefit from implementing an energy monitoring program to manage energy use for either the whole foundry or for major equipment such as furnaces?
- Can we optimise the efficiency of our metal melting and holding processes (e.g. · change technology, better insulation, use protective covers over the melt; put a cover on the pouring ladle)?
- Can we optimise the efficiency of the ancillary services in the operation?
- Can we benefit from investing in automatic energy control systems to shut down equipment when not in use?
- Can we develop greater staff awareness of energy efficiency and run an effective ‘switch-off’ program?
- Can we improve the ladles and refractory materials used in the furnaces and to improve energy efficiency?
- Can we recover energy from any sources for reuse elsewhere in the foundry?
- Can we benefit from investing in energy efficient equipment and up-grading old equipment (e.g. lighting, ladle preheating, sand reclamation, furnaces etc.)?

Energy is a major cost for all foundries, typically accounting for around 10% of the total operating costs (FTJ, 1997e). Furnaces use a significant proportion of the energy consumed in foundries, around 60% for typical iron foundries. Figure 3 shows typical energy demands for an iron foundry as reported in a survey undertaken by the ETSU (FTJ, 1997b).

Figure 3: Typical Energy Demand — Iron Foundry



Source: FTJ (1997b)

The survey reported that, in 1994, the UK ferrous foundry industry used 10.5 GJ per tonne of saleable product which was a reduction from 12.2 GJ per tonne in 1991. Mixed metal non-ferrous foundries were found to have higher average energy consumption per tonne of product and also a greater range between the best and worst practice — between 32 GJ per tonne and 131 GJ per tonne. This means that the companies with lower energy efficiency were at a tremendous cost disadvantage in relation to their competitors (FTJ, 1997b). Melting and holding were found to be key targets, due to the high energy demand in these areas.

The energy consumed in the melting process is largely proportional to the amount of metal melted (DETR, 1999). Therefore improving metal yield (see section 3) is a key strategy in reducing overall energy consumption.

Non-melting functions in non-ferrous foundries were typically found to be higher than for ferrous foundries — around 50% of total energy demand as opposed to around 33% for ferrous foundries. Sand reclamation is becoming an increasing source of energy demand (FTJ, 1997b).

Energy cost savings may come from increasing the efficiency of equipment (e.g. furnaces, compressors), from improving the efficiency of production processes (e.g. increasing metal yields and reducing sand demand) or by reducing the cost of energy (changing energy source, changing tariff or timing of energy consumption).

The area of energy efficiency improvements is a good candidate for Cleaner Production efforts since significant gains can be made, often with relatively minor capital expenditure. The potential savings may, in fact, be sufficient to warrant dedicating a staff member or forming a team to investigate energy efficiency throughout the operation.

4.1.1 Energy Auditing and Monitoring

Energy monitoring can help identify areas of inefficiency and reduce the overall cost of energy (see Example 13). Monitoring, generally in the form of an energy audit, is an essential first step to improving the energy efficiency of the operation. It is important know the true costs of the current practices at the outset in order to be able to assess the viability of improvement options.

Monitoring systems can be used to measure energy use by major equipment such as furnaces, and can also be used to control energy use on a site-wide, ongoing basis. A well-designed energy-monitoring system can help pinpoint the underlying causes of inefficiency and help determine the potential cost savings. This will allow the company to evaluate the cost effectiveness of different management practices. For example, companies that use scrap from a range of sources can evaluate which materials achieve the highest melt efficiencies (The *Foundryman*, 1997d).

Once a monitoring system has been established, it will also help the company to track improvements and measure the impact of changes within the foundry on energy efficiency over time.

Example 13: Energy Monitoring

Lucy Castings, in the UK, which melts 20000 tonnes of metal annually, implemented energy-monitoring technology that provides a minute-by-minute analysis of power consumption in the foundry. The company has formed an agreement with its electricity supplier to receive a low tariff if it remains within an agreed energy limit. As well as involving load management to ensure the company does not exceed this limit, the system has helped identify opportunities to improve energy efficiencies. The company's energy bill has been reduced by around 30% from £1,000,000 (A$2.5 million).

Sandwell Castings, another UK company, installed a dedicated power-monitoring unit on its electric induction furnace to measure the specific energy consumption (SEC) which, it was believed, was worse than industry benchmarks. The company conducted a trail using the meter to monitor energy use on a minute-by-minute basis. This analysis uncovered a number of inefficient practices, including:

- failures to operate the furnace under high power;
- lengthy holding times while waiting for compositional checks and alloying additions;
- lengthy holding periods while waiting for transfer to the launder or transport ladle;
- raising of melt temperatures to unnecessarily high levels.

The company reduced the average melt SEC by 57 kW.h per tonne, saving the company around £7,000 per year (A$17,500). The equipment paid for itself in around 6 months.

The G. Clancy Limited foundry in the West Midlands, UK, implemented an integrated monitoring and scheduling system to identify batch melting costs and allow comparisons between furnace charging and scheduling methods. This has helped optimise charging procedures, slagging practices, cold start routines and relining procedures. The capital investment was £30,000 (A$75,000) and the resulting energy savings paid for the equipment in less than 6 months. As an example of the improvements, energy input to one of the 10-tonne furnaces was reduced from 654 kW.h per tonne to 553 kW.h per tonne —a 15.4% improvement.

Sources: FTJ (1998f); The *Foundryman* (1997d); and FTJ (1997c)

4.1.2 Improvement Opportunities

Many foundry operations, like other industrial operations, assume that there are few options to minimise energy use in the process other than investing in expensive new technology. However, many case studies from the foundry industry suggest that most companies can achieve significant savings in this area by optimising existing systems and by making minor system upgrades. An extensive study of furnace efficiency by the ETSU in the UK has found that surprisingly few of the foundries had optimised their furnace processes. They concluded that most companies could reduce their total energy bills by between 10% and 30%, reducing total operational costs by between 1% and 3%. Other flow-on benefits are often achieved as a consequence, such as higher metal yields, improved metal quality, reduced labour and maintenance costs and better environmental performance (FTJ, 1997e).

While there are gains to be made in most foundries, they are not necessarily easy to achieve. As with any technology, foundries try to optimise the efficiency of melting practices by balancing a wide range of interrelated factors such as fuel and operating costs, metal production demands, environmental performance and costs, legislation and other operational, managerial or political considerations (FTJ, 1998a). Therefore, making a change in one area may have an adverse impact on other areas.

This indicates that the best approach to improving energy efficiency is to consider the issue of energy use as broadly as possible to help identify the real cause of the problem. This will help avoid spending money tackling the symptoms. ETSU has developed troubleshooting guidelines for furnaces, listing common symptoms and potential causes. These are reproduced in Table 4 (FTJ, 1998a).

Table 4: Checklist for Optimising Furnace Efficiency

Problem	Check:
Low temperature of metal output	• satisfactory operating instructions have been given and are being followed; • supervision is adequate; • the temperatures, quantities, sizes, weights and moisture contents of all materials charged are as specified; • refractories and insulation are suitable and in good repair; • burner control settings are correct, fuel calorific value for the burner is as anticipated, burner fuel-flow is correct and combustion air flow is satisfactory; • electric heating controls are properly set and functioning.

Low metal output rate	• output temperatures are not unnecessarily high; • form, temperature, moisture content and rate of charging of input materials are as specified; • materials handling into and out of the furnace are carried out speedily; • lining or insulation damage is not resulting in excessive heat loss; • fuel and air flows to burners are properly controlled; • oxygen flow rates are as specified; • doors are not over-sized or left open for excessive lengths of time; • exhaust rates are not excessive.
Unsatisfactory composition of metal output	• composition, proportions in the charge, size, cleanliness and moisture content of all input materials; • order of charging; • rate of heating; • temperatures and times of holding; • composition of the furnace atmosphere.
Low yields (in metal melting furnace)	• inputs and outputs are weighed; • the charge is as specified in respect of amounts, form, size, cleanliness and moisture of all charging materials; • highly oxidising conditions do not exist; • excessive superheating temperatures are not employed; • good separation of slag and metal occurs; • excessive turbulence does not occur in induction furnaces.
High energy costs	• electricity tariffs suitable for present operations; • competitive prices for fossil fuels; • furnace management — including output temperatures specified and achieved, scheduling of inputs and outputs, holding times at high temperatures, doors open periods, amounts of furnace 'furniture' used; • door sizes for loading, unloading and slag removal; • refractories and insulation, for damage, loss or deterioration; • burner controls, settings, air:fuel ratios; • oxygen flow rates; • the economic case for the use of a waste heat recovery system — e.g. involving recuperative or regenerative burners, simple stock drying or preheating by exhaust gases.
High input material costs	• current inputs — materials, costs, proportions in the charge, yields obtained, technical considerations; • possible alternatives — costs, proportions necessary, yields anticipated, possible new technical or quality problems or additional costs likely to be incurred elsewhere in the process.
High labour costs	• personnel — numbers, division of labour, versatility, number of furnaces served, shift patterns, pay rates, supervision; • input materials — types, forms, methods of delivery; • operations — scheduling, loading, unloading, handling within the furnace where necessary, control methods.

Source: FTJ (1998a)

Direct energy reduction measures that have had a proven payback include the following (Environment Canada (1997); USEPA (1992) and FTJ (1997b)):

- **Switching off unnecessary cooling fans and other ancillary equipment**

  If tools and ancillary equipment are routinely left running when not in use, this could, over time, be adding up to a significant period of non-productive running time. One option to reduce this may be to run a 'switch-off' campaign to raise awareness among staff about the need to turn off equipment. It may also be possible to automate the switch-off process. Interlocking control circuits may be able to be installed to automatically switch off ancillary equipment such as fans, pumps and conveyors when the equipment they serve is not in use (FTJ, 1998b). It may also be possible to reprogram major equipment to power-down or switch off during known breaks or after a time delay.

- **Installation of energy efficient lighting systems**

  Modern lighting systems can reduce running costs by as much as 25% while achieving the same light output and extended lamp life. There is a wide range of commercially available lights to suit a range of conditions (i.e. internal and external lighting). 'Intelligent' control systems can be installed to alter light output to adapt to ambient light conditions and production schedules. Even keeping light globes and reflectors free of dust can increase their efficiency; dirt on lights can reduce the light that reaches the workspace by 20% (FTJ, 1998b).

- **Improve ladle heating technology**

  Many foundries use inefficient preheating practices such as using gas torches. Efficient ladle preheating systems are available that can dramatically reduce energy use (see Example 14) and simple modifications such as installing lids or turning ladles upside down have been show to increase energy efficiency in this area.

- **Installation of variable speed drives** (e.g. ventilation fans, baghouse extractors etc.)

  Specifying the high-efficiency option when replacing motors could reduce the ongoing running costs by 3–5%.

- **Changing technology**

  Furnace technology is constantly improving to become more energy efficient, to burn more cleanly and to produce lower environmental impacts. Regenerative systems that utilise waste heat are becoming more common and increasingly available for smaller foundries (FTJ, 1999b). Regenerative furnaces that use natural gas have been shown to reduce energy costs by between 30% and 50% compared with electric systems. These system recover around 90% of the waste heat, so that a furnace with an operating temperature of 1200oC would produce flue gas with a temperature of only

100o–100oC. This also helps improve the quality of the working environment (FTJ, 1999c).

Many foundry furnaces are less than 35% energy efficient. The efficiency of reverberatory furnaces or crucible furnaces may be improved by upgrading the combustion system, which also reduces stack emissions. The efficiency of cupola furnaces can be increased by elevating the oxygen levels in the air feed. Induction furnaces are about 75–80% energy efficient. They emit about 75% less dust and fumes than electric arc or cupola furnaces because of the absence of combustion gases or excessive metal temperatures. If relatively clean scrap metal is used, the environmental controls can be greatly minimised.

Upgrading furnaces is clearly an expensive exercise, but it is an area that can significantly increase the cost effectiveness of the operation. Most of the foundries in Queensland have converted from cupola furnaces to electric furnaces in the past decade (see Example 15).

Example 14: Energy Savings from Electric Ladle Preheating

Kaye (Presteigne) Ltd., an aluminium diecaster in the UK that melts around 6000 tonnes of metal each year, installed a 18 kW electric radiant ladle heater. Prior to this the company preheated its ladles using a hand-held gas torch that was dropped into the ladle. This created significant quantities of waste heat and generated fumes, which was an OH&S issue. The naked flame also created aluminium oxide on the lining of the ladle which impacted on product quality.

The new system cost £6,000 (A$15,000). The system included an insulated cover that lowered over the ladle to increase heat transfer efficiency. Energy costs were reduced by £4,860 (A$12,150) annually. This change allowed for a new style of ladle to be used which had better insulation properties. The company also experimented with new types of refractory linings. One was identified that had more uniform heat transfer and a prolonged life — 18 months instead of the previous 6 months — saving an additional £1,166 (A$2,900) annually. These changes were estimated to pay for themselves in around 13 months.

The new system means that the ladle only needs to be preheated at the beginning of the week rather than at the beginning of each day, which will generate additional energy savings. Safety is improved due to the absence of the naked flame and the fact that the ladle is exposed only during metal transportation. The working environment has been improved by the reduction of odour and waste heat. Due to the success of the project, the company is considering installing a second unit.

Source: FTJ (1996a)

A future trend in the foundry industry that will improve energy efficiency will be the move towards immediate melting and pouring of metal. The aim will be to reduce holding times as much as possible, with a view to eliminating metal holding altogether (The *Foundryman*, 1997a). There is an opportunity for the industry to develop processes that enable in-situ melting and pouring (like plastics moulding) to improve metal integrity, and overcome problems with metal cleanliness and quality associated with conveying and pouring processes.

Energy reductions can also be achieved indirectly by optimising other processes such as metal yield and sand yield through;

- improved mould and casting design and casting simulation technology (see section 3.1.6);
- precision pouring and increased product quality (see section 3.1.8);

- optimising sand use (see section 5.3).

Some semi-solid casting techniques (see Part 5) have been shown to significantly reduce energy requirements. These systems heat the metal only enough to achieve the semi-solid state, rather than the super-heating that takes place in conventional casting applications.

Example 15: Converting from Cupola to Electric Furnaces

Most of Queensland's major foundries have replaced their cupola furnaces with electric furnaces over the past decade. In 1997, Bundaberg Metal Industries, a Queensland foundry, upgraded from a cupola furnace to an electric induction furnace. The foundry is relatively small, melting around 650–700 tonnes of metal per year, comprising ductile and grey iron and some gunmetal. This change has reduced costs and led to a number of benefits.

Using a cupola furnace meant the company melted around 15–16 tonnes of metal every four days. A large number of castings would be prepared over a 3-day period, to be poured on the fourth. This batch process required significant space for storing moulds in process, and the time required for fettling would hold up production of the next batch of moulds. Melting can now be done daily, with around 3–4 tonnes of metal melted in a day. This change has allowed the company to develop a more continuous process, with product moving through the facility. The large stockpiles of coke and lime have also been eliminated, further increasing space availability. Production capacity has increased and improvements in emissions and the quality of the working environment have also been noted.

Source: Spokespersons from Bundaberg Metal Industries

5. Minimising Foundry By-Products

Key Points

Most conventional foundries generate significant quantities of by-products from the casting process. These include sand, dusts, slags, refractories, and general foundry and office wastes. Beneficial reuse is currently an important issue in Queensland and can help to reduce the cost of managing many of the major by-product streams. Cleaner Production is different from beneficial reuse as it seeks to stop the material being generated in the first place leading to greater cost savings. As well as reducing the cost of disposal, savings can also be made by reducing the need to purchase new materials, by reducing unnecessary processing of materials and handling of by-products and by reducing compliance and environmental control costs.

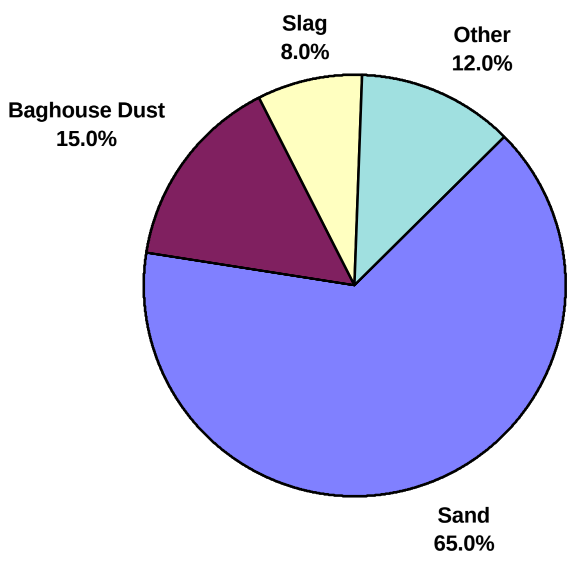
Some of the key questions to ask in relation to foundry by-products include:

- Have we calculated the full cost of by-products to the company (including purchasing, processing, disposing and compliance costs)?
- Do we effectively segregate our by-product streams to improve internal and external reuse options and reduce the cost of disposal?
- Do we have an effective strategy in place to minimise each major waste stream?
- Can we improve the casting design process to minimise sand use (e.g. better flask utilisation)?
- Are there other areas of the operation we can improve to minimise sand waste (e.g. minimise spills)?
- Can we implement computer aided sand mixing systems to minimise sand and binder use?
- Do we regularly investigate and trial new binder systems?
- Can we improve the efficiency of our sand reclamation system?
- Can we minimise other foundry by-products or reduce the demand for consumables?
- Once by-products have been minimised as much as possible, are there any beneficial reuse options that minimise the cost of managing the material?

All foundries generate by-products from their processes. In Queensland, only a few foundries segregate their by-products to any great extent. Most foundries still tend to mix their foundry waste streams (i.e. sand, baghouse dust and slag) and send them to landfill. Segregation in general waste streams is more common, with some companies separating recyclable material such as paper, cardboard and steel drums. Because most companies do not segregate their foundry by-products, this means that the volume of each needs to be estimated.

Sand is still the most significant by-product generated, accounting for around 65% of the total volume of materials generated. Baghouse dust probably accounts for up to 15% of the total, although the amount that is currently recorded separately in Queensland is around 7%. Dust generation is increasing as more companies undertake greater sand reclamation and implement stricter environmental controls. Slag accounts for an additional 5-10% and other materials such as refractories and general waste account for the remaining 10-12%.

Figure 4: Breakdown of By-Product Streams in a Typical Queensland Ferrous Foundry



In the face of rising disposal costs, many foundries have started investigating beneficial reuse strategies to reduce costs. While beneficial reuse can reduce some costs, more substantial savings can be made by stopping waste at source.

5.1 Segregation

Segregation is the key to successful management of foundry by-products. For example, achieving maximum internal reuse of sand requires systems that minimise contamination. Contamination of sand by excess metal fines, shotblast or even chemical binders can limit the potential for reuse.

Even in situations where internal reuse is not practicable, segregation can help open up opportunities for beneficial reuse to reduce the cost of waste disposal. A large volume of non-hazardous waste contaminated by a small volume of hazardous waste becomes a large volume of expensive hazardous waste. Shotblast dust contamination, for example, is often responsible for sand being classified as hazardous (Environment Canada, 1997).

Some options for improving segregation at foundries include:

- installing dedicated baghouses for the different dust generating processes (e.g. shotblast dust, furnace dust and sand dust) to segregate potentially contaminating material;
- installing magnetic separators on baghouses, reclamation units and other transport systems to remove ferrous metals. This improves the reuse options for both the sand and the metal fines;
- investing in technologies that have built-in segregation (e.g. shotblast machines - see Example 16);
- keeping sand from the core sand knock-out area separate from the other sand streams;
- establishing a separate collection system for resin-containing sands that are wasted before firing, to avoid high levels of binders contaminating the main sand stream;
- providing separate bins and bays to collect different by-product streams, including general waste (see Example 17);
- providing incentives to staff for maintaining good segregation practices (e.g. casket tickets, bonuses etc. - see Example 18)

Example 16: Self-segregating Shotblast Units

RMC, a Brisbane-based foundry, has replaced its shotblast units with two new systems that segregate the shot, sand, dust and gunmetal into four separate streams. This allows the shot to be recirculated and the gunmetal to be returned to the furnace. Now that shot contamination has been removed from this sand stream, the company is able to reclaim 100% of its sand. It is estimated that there will be less than 5% loss of material to the baghouse and other areas.

Source: Spokesperson from RMC

Example 17: Segregation reduces the cost of general waste

Ashley Forge, Foundry Division, in the UK, implemented a simple waste segregation program for solid waste. While minor in terms of total operating costs, managing solid waste can lead to significant savings through little additional effort. The change at Ashley Forge was brought about by a 50% increasing in landfill costs. Waste segregation involved separating solid and swarfe waste. Timber pallets and other recyclable materials are separated for return to the supplier or to recyclers. The immediate savings have been £1,750 (A$4,380) per year. Additional costs of segregation are minimal.

Source: WMC (1999)

Example 18: Achieving Segregation

The Toowoomba Foundry, in Queensland, has realised that there are many benefits to be gained by segregating its by-products. Up until two years ago, most waste materials were simply dumped in bulk bins or bays and periodically disposed to landfill. The company now has separate bins for most of its by-product streams and is looking at cost-effective opportunities to increase segregation further. Now easily recyclable material such as paper, cardboard and metal drums are also kept separate and reused.

By avoiding contamination of the foundry sand, the company has been able to send the material to a local compost operator, achieving one of the first examples of beneficial reuse in Queensland. While the company still incurs some costs for segregating and screening the material, the overall costs to the company have been significantly reduced. Segregation of the baghouse dust has led to the development of a value-added product. The dust is sintered into a small bead that appears to have excellent water filtering properties. This product is currently being trialled for a range of applications.

To help achieve and maintain its segregation goals, the company has implemented a simple incentive program. If the production teams meet their segregation targets for a given period the group raffles a gift voucher. Other incentive programs used in the company include BBQs and dinners. The program more than pays for itself and is funded using a portion of the money that is made or saved from the segregation of recyclable material which is either sold or taken away at no costs (e.g. scrap steel, cardboard, drums, swarf etc). Some of the service providers also contribute to the prize pool.

Source: Spokesperson from Toowoomba Foundry

5.2 Beneficial Reuse

'Beneficial reuse' is a term that is being used by a number of industries to refer to the use of a by-product generated in one operation in another process. This is an area that is receiving considerable interest in the Queensland foundry industry. The Australian Industries Group and the Queensland Environmental Protection Agency recently formed a beneficial reuse working party to produce an Environmental Guideline titled *Beneficial Reuse of Ferrous Foundry By-products.* A copy of this guideline is provided in the back of this manual as a summary of the potential for beneficial reuse in Queensland.

Companies are interested in exploring beneficial reuse opportunities due to a number of perceived benefits. These include reduced waste disposal costs, improved environmental performance and the potential for reduced liability. Beneficial reuse is also attractive to some foundries because it can be implemented without any impact on upstream foundry processes.

While beneficial reuse can play a role in the overall management of foundry by-products (see Example 19), this manual focuses on options that help foundry operations reduce waste at source. Beneficial reuse is an end-of-pipe strategy that does nothing to reduce the cost of producing the by-product in the first place. It is not, therefore, considered in detail in this manual.

As well as the cost of generating the by-product, beneficial reuse typically involves costs to the company. The company has to undertake some level of value-adding including segregation, screening and grading, and also make some guarantees in regard to the consistency of supply — both quality and quantity. Another concern about beneficial reuse is the potential continued environmental liability for the generator.

Example 19: Beneficial Reuse

Since late 1993, Viking Pump, Inc., of Cedar Falls, Iowa has been shipping spent sand to a Portland cement manufacturer for use as a raw material. This reduces the costs for the cement company, since it reduces the need for virgin sand. Landfill costs for the foundry have been reduced, creating a win–win situation for both companies.

When Viking piloted the use of foundry sand in cement manufacturing, the sand was loaded with an endloader into grain trucks and hauled to the cement plant. Once the cement company decided that the waste sand was compatible with its process, Viking invested in a sand silo for storage. The sand is now conveyed to the silo and gravity fed into trucks. This reduced handling time from around an hour to 6 minutes. Viking expects to send at least half of its spent foundry sand to the cement manufacturer and is continuing to look for alternative uses and greater utilisation.

Source: USEPA (1992)

Despite the challenges, beneficial reuse can and will play an important role in minimising foundry wastes in Queensland. Experience in other countries indicates that many of these options are becoming a reality. Early experience in Queensland is proving to be fairly positive but a number of issues need to addressed. Some of the major beneficial reuse options are listed in Table 5.

Table 5: Beneficial Reuse Options for Foundry By-products

Greensand
- flowable fill / aerated concrete
- cement manufacture
- brick / asphalt manufacture
- land-fill liner / cover
- construction fill
- soil improver

Alkaline phenolic sand
- smelting flux
- waste vitrification (stabilising hazardous waste)
- flowable fill / aerated concrete
- cement manufacture
- brick / asphalt manufacture
- road construction
- soil improver

Dust and sludges
- fertiliser fillers
- chemical and industrial applications
- soil modifiers
- landfill lining / capping
- artificial topsoil
- lightweight aggregate production

Sodium silicate sand
- Cement / mortar production
- insulating wool manufacture
- waste vitrification
- road base construction

Furane sand
- roofing felt
- insulating wool
- brick and blockmaking
- soil products (mixed with greensand)

Resin shell sand
- flowable fill / aerated concrete
- cement manufacture
- brick / block manufacture
- road / asphalt construction
- soil improver
- smelting flux
- waste vitrification (stabilising hazardous waste)

Investment casting shell
- coarse aggregate substitute
- absorbent media

Desulfurisation slag
- slaked lime replacement
- soil modification
- blast furnace cement

Water quenched cupola slag
- blockmaking
- abrasives
- soil modifiers

Induction melting slag
- road base construction
- abrasives

Electric arc furnace slag
- road base construction
- ballast

Air-cooled cupola slag
- Course aggregate substitute
- road base construction
- decorative ground farms
- brickmaking
- insulating wool
- asphalt
- ballast

Sources: BUIC (1999) and EPA (1999)

5.3 Optimising Sand and Binder Use

Improving sand yields, by minimising the amount used in the operation and through reclamation practices, not only reduces disposal costs but also reduces purchasing and production costs (e.g. new sand and sand handling).

Binders and catalysts are added to the sand to achieve sufficient hardness of the mould and, more importantly, cores. Chemical binders typically account for around 1–3% of the sand mix by weight. In terms of the total cost, however, binder can account for as much as 30–60% (FTJ, 1998i). A focus on volume rather than on cost, when identifying opportunities for improvement, can lead some foundries to disregard binders. However they can be an important source of savings.

5.3.1 Minimising Sand Use

Foundries can minimise the use of mixed sand in a number of ways. These include:

- improving cast design by adding more units to each box can improve the sand:metal ratio;
- using a range of flask sizes so that each casting is done in the most appropriate flask;
- inserting blocks or other material to fill voids in the flask so as to limit the need to use sand;
- using new sand for the sand/metal interface only and backfilling with non-reclaimed, non-mixed sand;
- minimising spillage as much as possible (Using bobcats to move sand, for example, is a major source of sand loss.);
- optimising the sand mixing system (see below).

Control of sand mixing (see Example 20) is an area where companies can achieve a number of benefits. As well as optimising the amount of binders and catalysts used, process control can increase the predictability of mould and core quality and set times. A problem experienced by foundries using chemical binder systems is the variability of sand temperatures, which affects the amount of resin and catalyst needed to achieve the desired quality and the time required for effective catalyst activation (FTJ, 1996m). This in turn can lead to downstream quality problems and higher than necessary emissions.

One Queensland company is investigating a simple process control system in its core shop. Temperature probes in the sand/binder mixer can be used to control a variable rate dispenser system for two catalysts, one a rapid ester catalyst and the other a slow ester catalyst. By varying the proportion of each of these catalysts, the system could achieve a constant set time regardless of sand and ambient temperatures. This would help achieve a more consistent core quality. This would also allow the throughput to be more streamlined, allowing better integration with upstream and downstream processes.

Example 20: Computer-aided Sand Control Systems

Beijing Jeep, a greensand foundry in China which produces 6000 tonnes of castings annually, reduced its reject rate due to sand quality problems by 46%. This was achieved by incorporating an online sand testing and intelligent control system on the sand mixer. Prior to the change, sand-related scrap was 4.8% of total product sold. Within 2 years, this was reduced to 3%. The sand control system also reduced the demand for inputs, most notably bentonite which was reduced by 378 tonnes per year. This represents a reduction of 63 tonnes of bentonite per 1000 tonnes of castings.

The online sampling system tests sand compactability and strength, then automatically controls addition of water which is the key variable for finetuning sand quality. Each batch requires one or two test cycles and water additions and, with total cycle times being less than 2 minutes, the system is suitable even for intensive mixers.

Prior to the implementation of the control system, compactability fluctuated widely from 22% to 50%. Improved control reduced the fluctuation to between 37% and 43%.

Source: FTJ (1998j)

5.3.2 Optimising Binder Use

Most companies seek to reduce the cost and environmental impact of binders by investigating alternative binders and by trying to optimise binder use. Methods that help minimise binder use include:

- minimising the use of mixed sand by improving the sand:metal ratio;
- minimising the loss of mixed, un-cast sand. Sand can be reclaimed but binders cannot. During the pouring stage, most binder is burned off the sand. Unfired sand contains higher levels of binder and thus creates additional environmental problems;
- mixing only the quantity of sand that is needed;
- increasing operator awareness about the need to minimise sand loss;
- monitoring binder levels in reclaimed sand so that less new binder is added;
- ensuring reclaimed sand has cooled prior to reuse to minimise binder burn-off during mixing;
- setting optimum binder levels;

- calibrating and maintaining mixing equipment carefully to achieve consistent binder levels;
- maintaining good inventory practices to avoid stock going out of date and to avoid stock damage or spillage;
- continually monitoring the development of new binders and undertaking trials to determine their potential benefits to the operation (FTJ, 1999d).

Binder performance is continually being improved (see Example 21). Increasingly, chemical companies are offering improved binder systems that reduce cost and environmental impact while maintaining or improving product quality and production rates. Companies should have a program to identify new binder systems and trial them on an ongoing basis (see Example 22).

The elimination of binders altogether is a significant benefit that can be achieved by changing part of all of the production system to an alternative casting process, such as the lost foam process or vacuum moulding systems (see Part 5).

Chemical binders typically have a limited usable life once they are prepared. After pouring, the heat from the metal burns off most of the resin, leaving only low levels of resin in the sand. Resin-coated sand that is wasted before firing can, however, have higher levels of resin and these can build up over time in recirculating systems. Further, in liquid form, many resins are classified as hazardous waste so must be treated with care. Waste resins have to be cured prior to disposal, which can lead to significant costs in terms of catalyst addition and labour to handle the material (FTJ, 1997h). This highlights the importance of effective storage and stock control to minimise waste in this area.

Regular monitoring and control of process variables, such as binder additions/ catalyst levels, reclaim to new sand ratio, loss on ignition, fines and dust loss, should be maintained to keep binder use to a optimum level (FTJ, 1997h).

Example 21: Reducing Binder Inputs

Rayne Foundry in Essex, UK, is a ferrous and non-ferrous jobbing foundry that uses furane no-bake binders. In the early 1990s, the company used a Supaset™ 53 system, which required the addition of a phosphoric xylene sulfonic acid catalyst at a rate of 44% of resin volume. Resin consumption was around 1.3% of sand volume.

The major environmental concern from this binder system was the generation of SO_2 emissions. To address this problem the company investigated alternative systems. In 1994, the company introduced the Pemacol™ system with a binder content reduced to 0.85% and also a reduced acid content, which resulted in a 50% reduction in emissions from the casting area.

The company then identified an opportunity to better control catalyst addition by installing a temperature-sensitive acid blending unit. This control helped ensure that the 50% reduction was maintained over the year regardless of temperature. The mixed sand costs were significantly reduced and phosphate was eliminated from the sand, allowing reclaimed sand to be used in the non-ferrous casting line. This increased on-site sand reclamation from 80% to 94%.

Hadleigh Castings in Suffolk had a similar experience. Prior to 1994, the company was using an alkaline phenolic binder system. Through a range of improvement programs they were able to reduce resin levels to between 1.4% and 2%, depending on the base sand used. The company installed a mechanical reclamation process to reduce the cost of sand, however they found that, due to the nature of the binder system, the core and mould strength of the reclaimed sand was lower than for new sand. Since the company's customers were increasingly demanding higher dimensional accuracy, the company had to purchase high-grade sand at significant expense and had to increase binder levels for reclaimed sand.

The company decided that it would be difficult and expensive to achieve further benefits from the current sand system, so they decided to change to a furane sand system. This helped the company achieve a number of improvements, including:

- a reduction in binder levels to 0.7–0.8%;
- increased sand reclamation to around 85%;
- greater dimensional accuracy; and
- a reduction in scrap from mismatch caused by the plastic nature of phenolic binders.

The company has more recently changed to the Permacol™ sulfur-free furane binder system to greatly reduce SO_2 emissions.

Sources: FTJ (1996d) and The *Foundryman* (1997c)

Example 22: Reducing Binder Inputs in Queensland

In an effort to reduce odour from the site, AustCast Australia, in Brisbane, implemented several improvements to reduce the amount of binder being used in the moulding process. The company changed their sand supply to reduce the shell and fines content, which allowed them to reduce binder inputs. By improving the binder:sand ratio and the sand:metal ratio, they reduced binder use by 0.6% (a saving of 96 tonnes of resin per year). This significantly reduced the cost of binders to the company.

Source: Spokesperson from AustCast Australia

5.3.3 Sand reclamation

Reclamation of sand can be undertaken using a number of techniques. Most pertinent for Queensland are mechanical reclamation, which is commonly practised in the State, and thermal reclamation, which has been undertaken by one company and is being investigated by several more. Note that internal sand reclamation is considered under a different heading to beneficial reuse which refers to reuse of by-products outside the foundry industry.

Many of the larger foundries in Queensland currently undertake manual sand reclamation. The reclamation rate is typically limited by two factors: the ability to cool the sand quickly enough and the quality requirements of the sand that dictated the ratio of new to reclaimed sand. The highest rate of manual reclamation is achieved by Bundaberg foundry (96%) and Walkers (90%). This is due to the fact that they produce large iron castings and quality can be achieved with a relatively small sand grain size. Therefore, losses from the system are predominantly spills and baghouse dust (typically less than 5%).

For most operations, manual reclamation is likely to be limited to around 70–80%. ANI Bradkin (Runcorn) currently achieves around 70% efficiency; Austcast currently achieves 30% but plans to increase this rate to around 65–75% with the installation of a sand cooling system. ANI Bradkin (Ipswich) is planning to install a mechanical reclamation plant that would be expected to achieve 70% recovery.

The average rate of sand reclamation across the foundry sites surveyed is currently 36%. This means that, while the industry buys 48700 tonnes of sand each year, recycling raises the total weight of sand used in castings in Queensland to approximately 177000 tonnes per year. Therefore, internal recycling currently reduces the volume of sand purchased by the industry by around 131000 tonnes per year.

As discussed, plans to commence or increase reclamation are being considered by ANI Bradkin (Ipswich) and Austcast. RMC plan achieve close to 100% reclamation by the end of 1999. If these three projects were implemented, this would increase the industry average internal recycling rate to 50%. Assuming no change in production, this would reduce spent sand generation by around 30% or 14200 tonnes per year.

Moving beyond this average internal recycling rate of 50% will be relatively difficult. A further 5% may be fairly easily gained if companies work to improve the efficiency of the current systems. Further gains will then need to come from shifting to thermal or other reclamation processes, by improving moulding techniques to reduce the sand:metal ratio, by changing the sand/resin systems and casting processes used, or by identifying cost-effective methods to reclaim sands at small foundries.

Sand reclamation plays an important role in the overall Cleaner Production strategy for the industry. Its use should be considered in conjunction with other components such as beneficial reuse and process improvements. A hypothetical Case Study is presented on the following pages (see Example 23). This discussion is intended to show how a typical Queensland foundry may integrate different approaches to minimise the cost and environmental impact of sand for the company.

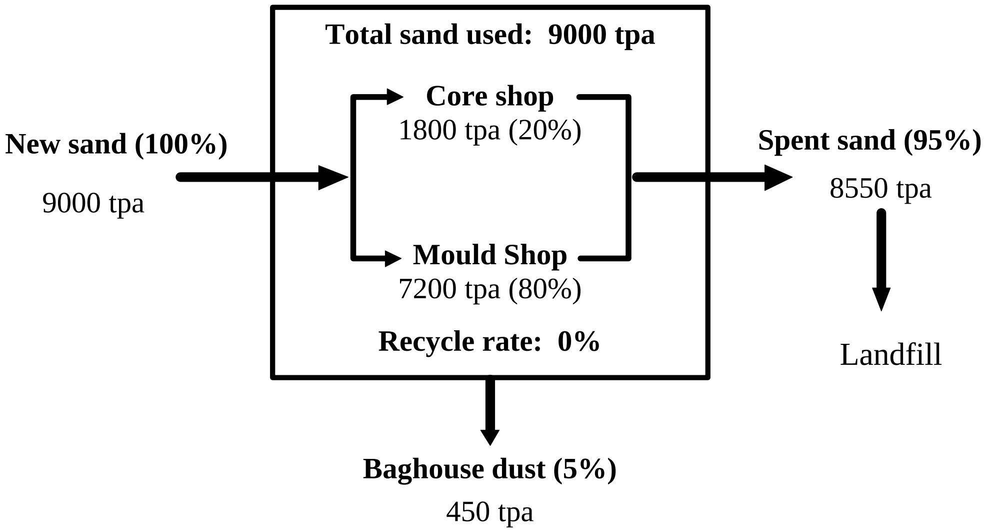
Example 23: Sand Optimisation - A Hypothetical Case Study

MetalCast Ltd is a hypothetical company that will be used as an example to demonstrate some of the concepts of Cleaner Production. Sand is one of the largest waste issues in the foundry industry, so this will be used as the focus of the example. The data used are indicative of typical volumes and costs for foundries operating in south-east Queensland, but do not specifically represent the costs or activities of any particular foundry.

Initial Situation

MetalCast Ltd is a medium-sized foundry operating in the Brisbane area. The company produces 3000 tonnes of ferrous castings annually. The process uses approximately 3 tonnes of sand for every tonne of product, thus the company uses 9000 tonnes of sand per year. The company does not reclaim any sand, so purchases the full 9000 tonnes of virgin sand annually. The baghouse removes around 5% of the sand as baghouse dust (see Figure 5).

Figure 5: Initial Situation



The company pays $25 per tonne for new sand (including transport) and $20 per tonne for disposal of both spent sand and baghouse dust. The total costs for this situation are shown in the Table 6

Table 6: Annual Costs Prior to Improvements

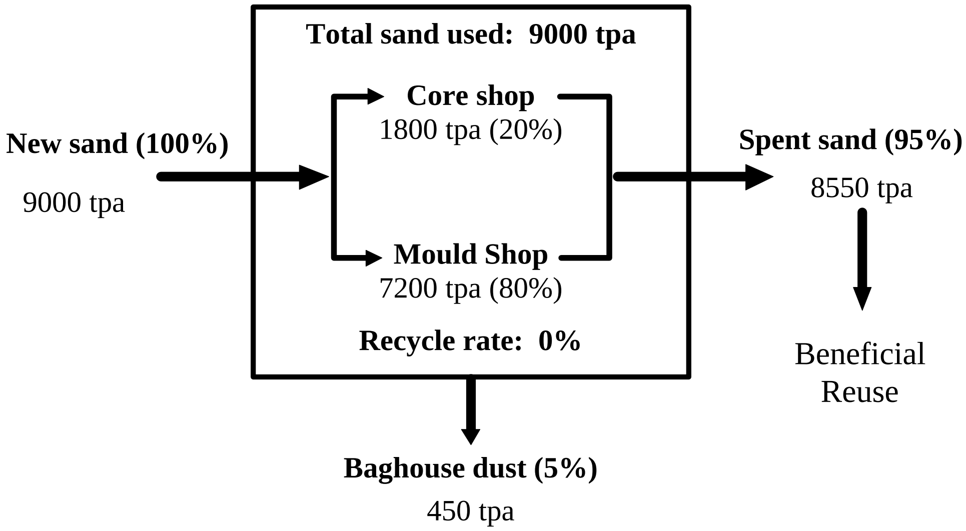
	Tonnes/year	Cost/tonne	Cost/year
Total sand used	9,000		
Total sand in	9,000	$25	$225,000
Total sand out	8,550	$20	$171,000
Total baghouse dust (5%)	450	$20	$9,000
Total cost:			**$405,000**

From this table it can be seen that the total cost of sand to the company is $405,000 per year.

Project 1: Beneficial Reuse

The company realised that the cost of its spent sand could be reduced if it could identify a beneficial reuse for the material outside the operation. This would save the company money and help the environment by stopping sand going to landfill. The company investigated a range of options and identified a cement manufacturer that was interested in taking the material. The company had to screen the material, to ensure it met the specification of the company, and pay part of the transport costs. The new situation is shown in Figure 6.

Figure 6: Situation After Beneficial Reuse



The total cost of these operations was $10 per tonne: half the disposal costs. The total costs after beneficial reuse are shown in the Table 7.

Table 7: Annual Costs After Beneficial Reuse

	Tonnes/year	Cost/tonne	Cost/year
Total sand used	9,000		
Total sand in	9,000	$25	$225,000
Total sand out	8,550	$10	$85,500
Total baghouse dust (5%)	450	$20	$9,000
Total cost:			**$319,500**

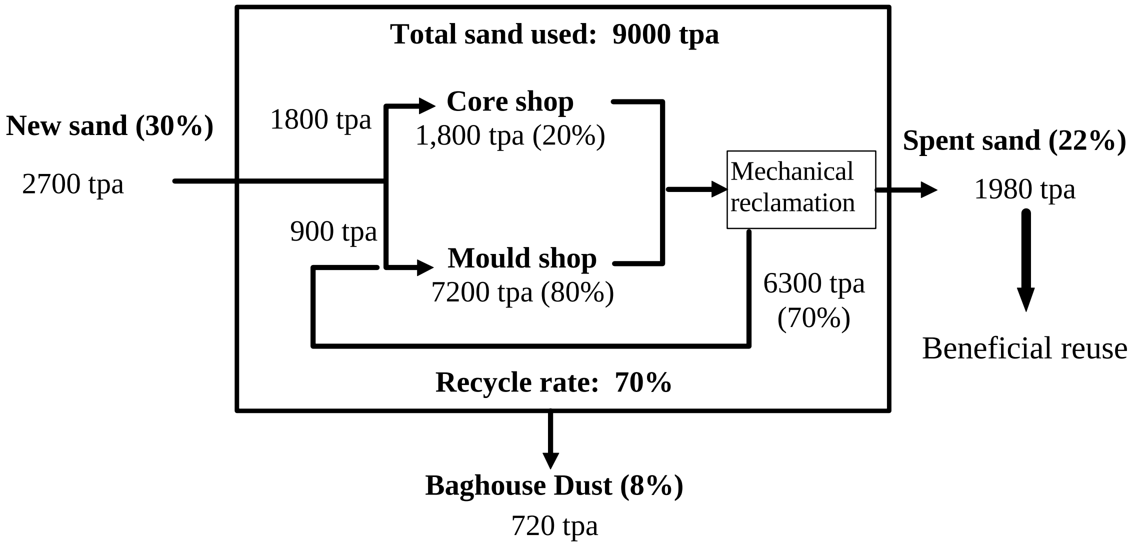
The total cost savings of this change were $85,000 per year.

Project 2: Mechanical Sand Reclamation

The company realised that, while they were now saving a significant proportion of their disposal costs, they still had to pay for the sand in the first place. Unless a better beneficial reuse option could be found, the cost of managing the by-product was still quitehigh.

The company decided to investigate options for internal reuse. The company identified a suitable mechanical sand reclamation system that could achieve a 70% reclamation rate. This rate was limited by the fact that new sand had to be used for the production of cores and to compensate for losses from the system such as baghouse dust and general spills. A second baghouse was installed on the reclamation unit and total dust generation was increased to around 8% of total sand processed annually. The new situation is shown in Figure 7.

Figure 7: Situation After Mechanical Sand Reclamation



The 70% reclamation rate reduced the volume of sand purchased to 2700 tonnes per year; 9000 tonnes was processed through the reclamation unit annually to maintain the rate of production. The volume of spent sand going to beneficial reuse was reduced to 1980 tonnes per year. The total sand costs to the company after it commenced mechanical reclamation are shown in Table 8.

Table 8: After Mechanical Sand Reclamation

	Tonnes/year	Cost/tonne	Cost/year
Total sand used	9,000		
Total sand in	2,700	$25	$67,500
Total sand out	1,980	$10	$19,800
Total baghouse dust (8%)	720	$20	$14,400
Total cost:			**$101,700**

The cost savings generated by this improvement were $217,800, bringing total savings up to $303,300 per year. The capital cost of the reclamation unit was, conservatively, $200,000. Operating costs were around $12 per tonne or $108,000 per year. Net annual benefits were therefore $109,800. This meant that the expected payback for the equipment was 1.82 years.

Project 3: Process Improvement

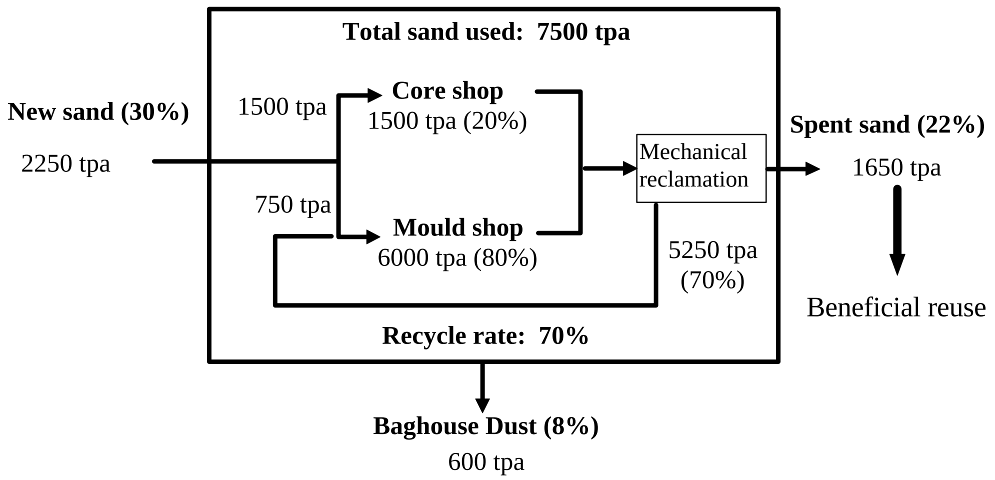
The improvements as described significantly reduced the cost of sand disposal and the cost of purchasing new sand. The company realised that the next challenge was to reduce the cost of unnecessarily processing sand. The company suspected that its sand: metal ratio, 3 tonnes of sand for every tonne of product made, was fairly high. The company believed that through process improvement they could reduce the total amount of sand needed in the process. This would further reduce the cost of sand purchase and disposal. It would also reduce the cost of mechanical reclamation and other activities such as sand mixing and handling.

The company investigated the process and identified a number of issues that increased the volume of sand use.

Problem	Solution
a) The sand mixer produced more sand than was needed in each shift. This sand had to be wasted.	a) Better process control on the mixer to reduce waste.
b) New sand was used to fill the entire mould when a large proportion of the sand did not have contact with the metal.	b) For larger castings, new sand was used for the sand/metal interface and the mould was then backfilled with spent, non-reclaimed sand. Concrete blocks were used to fill larger voids in the mould cavity.
c) Small castings took up only a very small proportion of the mould.	c) The company implemented a second smaller mould box size that was used for smaller castings.
d) Small amounts of sand were spilled throughout the process, particularly at the sand mixer.	d) A general Cleaner Production awareness program was developed which helped improve general housekeeping, resulting in less sand waste.

These changes reduced the sand:metal ratio by around 17%, from 3:1 to 2.5:1. This reduced the total amount of sand needed from 9000 tonnes to 7500 tonnes per year. This situation is shown in Figure 8.

Figure 8: Situation After Process Improvement



The total costs for this situation are shown in Table 9.

Table 9: After Process Improvement

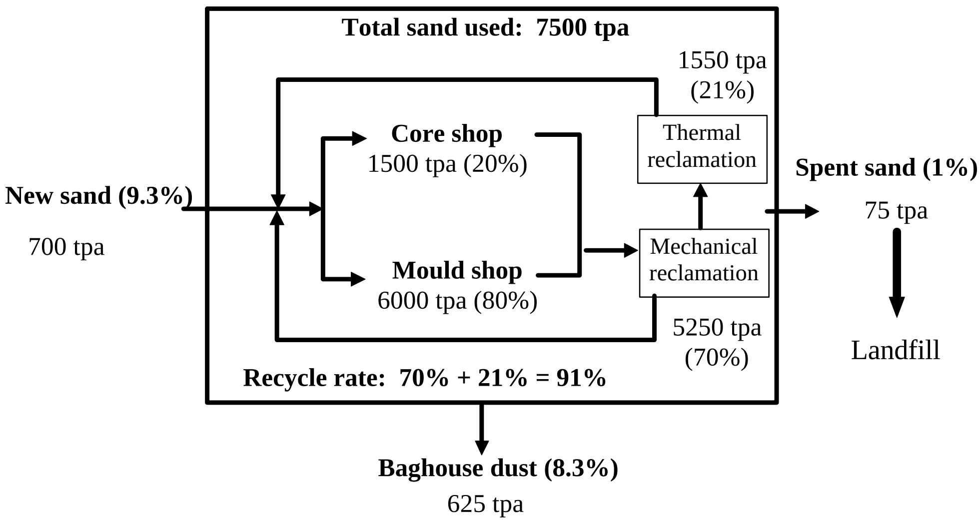
	Tonnes/year	Cost/tonne	Cost/year
Total sand used	7,500		
Total sand in	2,250	$25	$56,250
Total sand out	1,650	$10	$16,500
Total baghouse dust (8%)	600	$20	$12,000
Total cost:			**$84,750**

The cost savings generated by this improvement were $16,950, giving total savings of $320,250 per year.

Project 4: Core Sand Reclamation

The next major improvement the company wanted to tackle was to reclaim the remaining waste sand for use in the core shop. Around 20% of the sand — 1500 tonnes per year — was used in the core shop. Technically, a thermal reclamation unit could further process a portion of the mechanically reclaimed sand, which would return it to an 'as new' quality. This would allow the sand to be used in the core shop and would virtually 'close the loop' in terms of sand. This can be seen in Figure 9.

Figure 9: Situation After Core Sand Reclamation



The high cost of thermal reclamation was known to be high. The company had priced appropriate systems in the range of $250,000 to $500,000. The thermal reclamation unit could be expected to achieve about 95% reclamation of the sand processes through the system. In total, it would be designed to supply around 21% of the total sand used in the year. The total recycling rate for both reclamation units would therefore be around 89%. The new system would increase total baghouse dust generation to around 8.3% of the sand processed annually, or 625 tonnes. Only 75 tonnes of waste sand would be generated each year due to minor spills and other loses. This means that the company would no longer have sufficient quantity of sand to maintain their beneficial reuse arrangement. They would, therefore, have to send to landfill at the higher cost of $20/tonne. The total costs for this situation are shown in Table 10.

Table 10: After Core Sand Reclamation

	Tonnes/year	Cost/tonne	Cost/year
Total sand used	7,500		
Total sand in	700	$25	$17,500
Total sand out	75	$20	$1,500
Total baghouse dust (10%)	625	$20	$12,500
Total cost:			**$31,500**

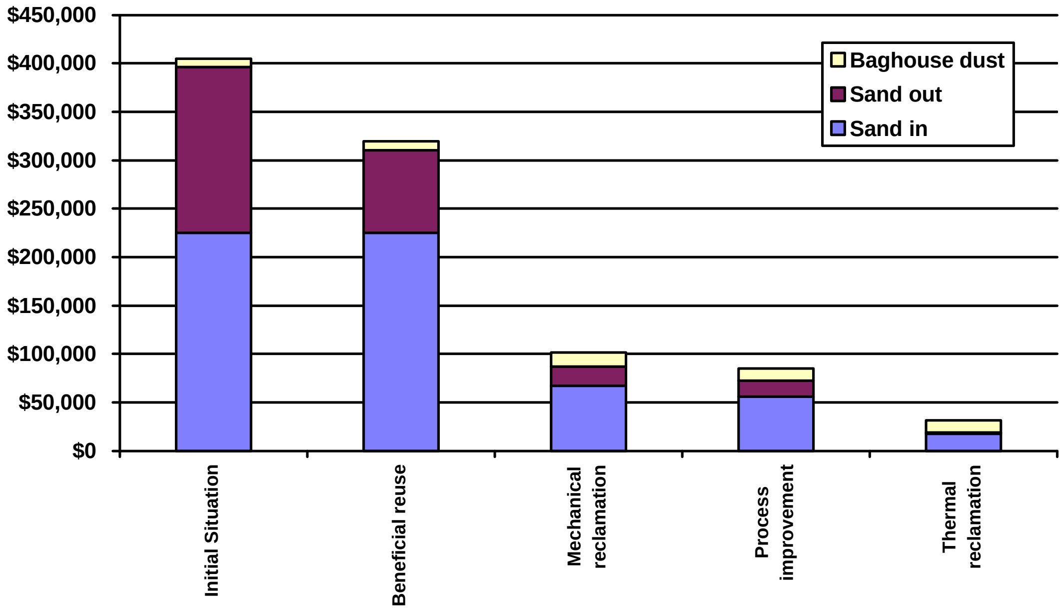
The potential cost savings generated by this improvement would be $70,200, achieving total annual savings of $373,500 per year.

Operating costs were expected to be less than $15/tonne or $24,750 per year. Net annual benefits would therefore be $45,450. Given the range of capital costs, the company could achieve a payback within 5.5–11 years. This timeframe was considered to be fairly long but, as the cost of new sand and landfilling were expected to rise significantly, the company felt that the options would become increasingly viable in the near future.

The Future

The four improvement projects discussed above reduced the company’s total sand costs by over 90%. The company summarised these cost improvements in Figure 10.

Figure 10: Summary of Cost Improvements at MetalCast Inc.



The company identified that the most significant improvements in cost were achieved when sand use was reduced at source. Beneficial reuse, while reducing the cost of the by-product management, did nothing to reduce the cost of generating the by-product in the first place.

By reducing sand at source, such as through reclamation or by improving process efficiency, the company saved money in a whole range of areas including:

- reduced input costs (e.g. energy and materials);
- reduced disposal costs;
- reduced processing and handling costs;
- reduced maintenance costs;
- reduced compliance costs.

Mechanical sand reclamation plants break the lumps down to grain size and remove resins and contaminants by attrition and dust extraction (see Example 24 and Example 25). The levels of resins and catalysts present in the sand are reduced during firing and reclamation but they are not entirely eliminated.

Binding level can often be reduced with reclaimed sand. Waterman foundry in the UK introduced mechanical reclamation and reduced new sand purchases by 75%. Binder and acid purchases were also reduced by around 35% as a result of using reclaimed sand (FTJ, 1997f). Reuse can cause binders and other contaminants to build up over time creating highly acidic or alkaline conditions, depending on the binder system used (FTJ, 1998i). Paints and glues used in the process can also present contamination problems.

Example 24: Mechanical Sand Reclamation

The Chicago Faucet Co., a red brass foundry in the United States, uses a ball mill to recycle the material that is generated from the sand screening system. All the furnace skims, floor spills, slags, core butts and tramp metal from the screening are dumped into a vibrator. The vibrator feeds a rotating ball mill, which pulverises all materials into very small particles. The material then passes through a vibrating screen and an impactor. Further, more than 90% metallic material can be returned to the furnace.

Source: USEPA (1992)

Example 25: Internal Reuse of Foundry Sand

KHD Humboldt Wedag installed a multistage process for regenerating used foundry sand. This process included iron removal by a magnetic separator, followed by reclamation in a fluidised-bed furnace consisting of a vertical, cylindrical brick-lined reaction chamber and a second reaction chamber to ensure the gases are completely burned

Heat is recovered for use in the foundry by counter-current water flow through the regenerated sand. The sand is further cleaned of impurities in a counter-current impact mill consisting of two gas jets, which clean the particles with application of friction. The system cost 5,480,000 DM (A$4.6 million). The operating costs for the systems regenerating 5 tonnes of sand per hour was 532,000 DM (A$444,000) per year. The sand disposal costs were 48 DM (A$40) per tonne.

The system reduced sand disposal by 75–80%. Stack emissions were also reduced. Heat recovery saved approximately 250,000 DM ($A209), reducing the operating costs of the recovery system to 282,000 DM ($A236) per year. Savings in disposal costs of approximately $60,000 DM (A$50,000) per year. Savings in new sand purchases were estimated to be around 12500 tonnes per year.

Source: ICPIC (1999)

Thermal reclamation is an alternative system that thermally drives off organic materials including binders (see Example 26 and Example 27). Assuming that contamination can be kept to a minimum during the casting process and other handling activities, the quality of reclaimed sand should not be significantly different from that of new sand (FTJ, 1998i). Thermal reclamation typically achieves very high rates of reuse: up to 98%. The only wastes generated are clean dust and air emissions that contain the organic materials burnt off (FTJ, 1998i).

Some companies report that thermally reclaimed sand is in fact of higher quality than virgin sand, because many of the organics that can be present in the original sand are removed during pouring and reclamation. Further, the thermal expansion properties are more predictable in subsequent pourings.

A further potential benefit of thermal reclamation systems is that baghouse dusts can be treated to render them inert. This can reduce the disposal cost of this material, particularly for non-ferrous foundries. If this practice is carried out, care needs to be taken to ensure that contaminants are not introduced into the sand.

Because of the high rate of recycling achieved in thermal systems, sand quality and testing become more important. For example, if binders with long strip times are used, high levels of impurities can neutralise the small amount of binder used, creating problems with incomplete core hardening (FTJ, 1998i). If maximum internal reuse is going to be considered, therefore, it is important to maximise the quality of the base sand, to minimise contamination and undertake regular on-the-spot sand testing. These precautions will help minimise the risk of system failure.

Thermal reclamation is typically considered too expensive for many Queensland foundries. Depending on the scale of the unit and the ancillary equipment used, capital costs that would be applicable to Queensland foundries range from $200,000 to $1 million.

Two potential solutions to this problem are the development of centralised thermal reclamation processes or smaller mobile units that can be shared between smaller foundries. This first approach is being developed in Queensland by a company, Resin Coated Sands, that has established a thermal reclamation operation at Eagle Farm in Brisbane. This was initially established to recover shell sand from one company (see Example 27), but the company plans to extend this service to other foundries. This option may not be suitable for smaller foundries or those that are located significant distances from the centralised operation.

An alternative may be to develop a mobile reclamation process that can be shared between facilities. At present, no mobile units are in operation in Queensland. In Germany, R+A Recycling and Anlagentechnik GmbH offer a door-to-door service that can be used to thermally reclaim many types of foundry sands (FTJ, 1996k).

Example 26: Overseas Examples of Thermal Reclamation Systems

Carondelet Foundry Company in Missouri, USA, installed a fluidised bed thermal sand reclamation unit and a mechanical reclaimer in 1994 to treat its phenolic urethane no-bake and phenolic urethane Isocure sand. Prior to this, the steel jobbing shop was disposing of an average of 150 tonnes per day of waste sand off-site for landfill disposal, at a cost of about US$29 per cubic yard (A$58 per cubic metre). In addition, new sand was costing approximately US$22 (A$34) per tonne.

The thermal system processes 125 tonnes per day and the mechanical system processes the remaining 25 tonnes. Only 5% of the foundry's sand is not reclaimed. The reclamation system is estimated to save the foundry over US$1 million (A$1.5million) per year and paid for itself in under a year. In addition, the foundry feels that the reclaimed sand is better than new sand and results in better castings.

In 1988, R.H. Sheppard Company, Inc. in Pennsylvania installed a thermal sand reclamation system to recover its 2200 tonnes per year of waste green sand. The foundry was spending over US$180,000 (A$277,000) per year on new sand purchases and disposal costs. Even considering the US$428,500 (A$660,000) capital investment and regular operation and maintenance costs, over the 20-year useful life of the equipment, the company estimates it will save about US$2 million (A$3 million). This does not include the intangible savings of reduced liability for waste sand disposal.

Triplex Alloys Ltd, Darlaston, UK produces 1500 tonnes per year of aluminium castings by gravity die-casting (66%) and chemically bonded boxless sand moulding (33%). The company uses phenolic urethane binder systems. The company used a mechanical attrition system to reclaim sand but the binders reduced the internal reuse ratio. The standard blend of old sand to new sand was 30:70. This led to new sand purchases of 75 tonnes per week, at a cost of £58,000 (A$145,000) per year and disposal cost of the same volume of £24,500 (A$63,750) per year. The company installed a thermal reclamation system which restored the sand to an 'as new' condition. This virtually eliminated the need to purchase new sand and pay for sand disposal. The system cost £48,000 (A$120,000) and the operating costs were £3.96 per tonne or £13,700 (A$34,250) per year. The total cost saving was £68,800 (A$172,000) year, which achieved a payback of 9 months.

Sources: UNEP (1997) and ICPIC (1999)

Example 27: Thermal Reclamation Systems In Queensland

RMC (Reliance Manufacturing Company) was the first Queensland foundry to undertake thermal reclamation of its waste shell sand. Waste sand from shell moulds cannot be reclaimed mechanically, so the company needed to look at thermal methods. The company did not have sufficient space to undertake the process on-site so they arranged to have their sand supplied by an innovative company, Resin Coated Sands (RCS), which was able to offer full reclamation services.

RCS established an operation at Eagle Farm in Brisbane, and commenced thermal reclamation of RMC's sand. For the first 6 months the operation achieved approximately 40% reclamation. Within the first year, 100% reclamation has been achieved. This required an improvement in RMC segregation practices to eliminate shot contamination (see Example 16). The reclaimed sand is reported to have better properties than new sand because it contains less organic material and exhibits less thermal expansion during the pouring process. This, along with beneficial reuse, should eliminate most of the waste from RMC's site.

Resin Coated Sands has indicated that, once the system has been optimised for RMC, they will increase their production capacity further to allow them to treat sands from other operations. Several companies have expressed interest in using this service and initial trial work has been conducted for some companies. Preliminary results suggest that the cost of the treated sand will be higher that the cost of new sand, but less than the total current costs including transport and disposal.

Source: Spokespersons from RMC and Resin Coated Sands

A novel strategy for further improving the cost effectiveness of thermal reclamation is to combine heat treatment and thermal sand reclamation processes into one system. Such a system has been developed by Consolidated Engineering Company under the trade name *Sand Lion.* While these systems are currently being implemented by large repetitive foundries, the principles may be applicable to smaller foundries in the future. In these systems, the moulds are sent directly from the pouring area to the specially designed heat treatment oven. Moulds and cores are thermally treated while being knocked out. The sand is reclaimed and returned via a cooler classifier to storage silos. Sand from other (i.e. jobbing) areas in the plant can also be reclaimed through the system.

These systems achieve high levels of energy efficiency, since moulds are transferred directly to the oven rather than being allowed to cool. The binders also provide additional fuel value to the process. Space requirements can be reduced because it is no longer necessary to maintain separate areas for heat treatment, knockout and reclamation (FTJ, 1996i).

5.4 Minimising Other By-Product Streams

5.4.1 Optimising other Refractory Material

The choice of refractory material used to line furnaces and ladles can play a role in the efficiency of the process. More furnace linings fail, however, due to poor operational practices rather than to poor refractory material (Metal, 1997a). Therefore, the selection of the refractory or combination of materials should be made after a consideration of the total process. Some of the factors that should be considered include the following:

- **Operating temperature** — the range of temperatures, particularly temperature excursions have a significant impact on refractory life. Improved control systems may increase refractory life while achieving energy and other operational improvements.
- **Type of charge** — the refractory should be compatible with the composition of the melt and the melting point.
- **Slag** — the composition of slag is unique for each melt, and the refractory needs to be selected to sustain chemical attack. Composition, basicity, turbulence and splash are important consideration when designing appropriate linings.
- **Furnace and ladle design** — the design and location of tap holes, the type of furnace and ladle used, the types of filters used and the furnace atmosphere (i.e. oxidising or reducing) all have an impact on refractory choice and life.
- **Melting practices** — superheating practices, holding times and the duration of non-operational periods are also important considerations (Metal, 1997a).

Keeping good records of refractory practices, measuring and documenting lining type and life, and reasons for failures will help build up a profile of major problems and allow refractory practices to be optimised.

Maximising refractory life can reduce materials and maintenance costs as well as achieving a number of Cleaner Production benefits. Refractory lining life is reduced by general wear and through chemical attacks from slags. Slags are formed during the melting process and contain a range of oxides. The exact composition depends on the dominant chemicals in the melt, so is unique to each furnace. A range of refractory materials are available which are designed to withstand attacks from certain oxides. Selecting the best lining material or combination of materials may help maximise lining life for a particular furnace. Additives that prevent oxide formation can be used to reduce slag formation.

Ladle design, and maintaining the quality of the refractory lining play important roles in casting quality. The performance of refractory material in ladles may be overlooked because the ladle is used only to transfer and pour the metal. Poor-quality or damaged material can significantly increase the levels of inclusions. Ladle design can also affect the ability to produce a clean cast due to turbulence and stream velocity (Metal Asia, 1998b).

5.4.2 Optimising Blast Media Use

The selection of blast media can have a commercial impact on product quality, process throughput and efficiency, media life and recycling opportunities. Shot suppliers can provide advice as to the best options. Many alternatives exist of each metal types and new media are continually being developed to help achieve increased efficiency and reduce waste and dust generation from the process (FTJ, 1998e).

5.4.3 Minimising General Waste

General waste, such as paper, cardboard and metal drums, can also be minimised or segregated to reduce costs to the foundry (see Example 28).

Example 28: Reducing the cost of general waste disposal

West Yorkshire Foundry, UK, halved the cost of general waste disposal by installing two roto-compactors. Formerly, skips were used to collect and remove waste at a cost of £20,000 (A$50,000) per year.

The compactors help contain the waste better and create a cleaner, more presentable site. There is also less disruption and hassle from waste contractors constantly coming on-site to remove skips.

Source: FTJ (1997a)

5.4.4 Reusing Swarf and Baghouse Dust

Bricketting systems are available for swarf and other metal chips. These systems compact the material, making it easier to handle, and add value to it by removing a significant proportion of the oil and other moisture (typically up to 95%). This may improve the options for on-site reuse and increase the value of the material to recycling markets (see Example 29). If material is segregated appropriately, there is the potential to separate the cutting fluids for direct on-site reuse, filtering or off-site reprocessing (FTJ, 1999f).

Cupola furnaces have the advantage of being fairly tolerant of oily and contaminated scrap. They will also scavenge metals from low-grade sources such as slag and some baghouse dusts. Most of the major Queensland foundries have shifted to electric furnaces, which need high-quality scrap, and this has reduced some reuse options.

As well as providing a potential use for recaptured heat, metal charge preheaters are being used to enable the reuse of oily swarf and metal chips (FTJ, 1999g). The environmental implications, as well as the potential cost benefits, need to be considered carefully. Another option is discussed in Example 30.

Example 29: Reducing Baghouse Dust Waste

ANI Bradkin, a Brisbane-based foundry, currently sends its furnace baghouse dust to secured landfill at a significantly higher cost than other foundry by-products. The company is currently undertaking bricketting trials that will allow the dust to be compacted into a form that can be handled more easily and allow it to be send to unlined landfill at a reduced cost, or potentially allow some form of beneficial reuse.

Another option being trialled is adding the material to the furnace. Baghouse dust cannot simply be added directly to the melt because the dust extraction system would remove it. It therefore needs to be pelletised or bricketted to allow it to sink. While some metal recovery may be achieved, the main purpose is to incorporate the material into the slag, which is more stable, easier to handle and has the potential to be used as a construction material. This could significantly reduce the cost of this by-product to the company. The company is currently looking for suitable and cost-effective equipment to achieve this outcome.

RMC (Reliance Manufacturing Company), a Brisbane-based foundry, is considering options to reclaim baghouse dust which consists predominantly of metal in oxide form. Tests indicate that dust from the fettling area is 83% copper, 6% zinc and 4% lead, similar to the composition of the original gunmetal. Dust from the furnace is 60% zinc and 5% copper. The company is investigating methods to reclaim the metal from the dust and return it to the furnace. To reclaim the metal, it would need to be reduced from its oxide form, perhaps using a sintering process. This would also pelletise the material allowing it to be returned to the furnace more easily. Metal reclamation is considered to be more viable in this operation than many others because the majority of metal melted is gunmetal with has a high value. Foundries that melt a wide range of metals may have more limited options in this area.

Source: Spokespersons from ANI Bradkin and RMC

Example 30: Recovery of Foundry Dust

A UK foundry that employs 400 people and produces 25000 tons of iron castings annually installed a wet scrubbing unit to capture fugitive dusts from the process. The system captures over 99% of the dust, resulting in minimal emissions. Annually the process captures 1600 tonnes of sludge, which is internally reused in the mould-making process. The capital investment was £19,000 (A$47,500) but resulted in annual savings of £84,000 (A$210,000) including £60,000 (A$150,000) for materials costs and £24,000 (A$60,000) for waste disposal.

Source: ICPIC (1999)

5.4.5 Minimising Investment Shell Slurry

Another example of input reduction for the investment casting industry is described in Example 31.

Example 31: Quality Control of Investment Shell Inputs

Finecast, an investment casting foundry in the UK, identified the need to improve the quality control of its casting shell slurry. Inconsistencies in the mix resulted in unexplained events of shell cracking during de-waxing, and breakdown and metal run-out during pouring. Initially only daily viscosity tests of the slurry were carried out. The company implemented a full quality-control regime, which reduced reject product attributed to shell problems by 90%. Slurry life was also extended significantly and productively improved.

The variables that were identified as being the key determinants of shell quality were viscosity, temperature, pH, specific gravity, binder percentage and bacteria counts. Appropriate tests were developed for each of these factors.

Source: FTJ (1999k)

6. Production Planning and Improvement

Key Points

Focusing on overall production planning and improvement can help to develop a systematic approach to Cleaner Production in the foundry. Foundry processes are continually being improved to achieve better economic and environmental outcomes. Computers, automation and control systems will continue to change the way foundries operate over the next 20 years. As well as many challenges, these technologies will create many opportunities for the industry.

Some of the key questions to ask in relation to production planning and improvement include:

- Do we have an effective Environmental Management System that is integrated with our other business systems?
- Can we improve the layout or streamline the process to improve the efficiency of the operation?
- Can we use production simulation technology to help redesign our processes?
- Can we utilise any computer aided technologies in the foundry (e.g. rapid prototyping, rapid tooling, casting simulation)?
- Can we benefit from undertaking a cost / benefit analyses of different casting systems for part of all of the products or for new markets (e.g. Investment, permanent mould, die, lost foam and vacuum casting)?
- Can we develop a capability in another casting process for some of our products (or for new markets)?
- Can we improve our communication systems (e.g. electronic data interchange, the Internet) to reduce our lead times, increase the efficiency of the process and offer better customer services?
- Can we improve scheduling and materials tracking systems?
- Can we develop / improve smart controls and sensors for automatic supervision?
- Can we use / improve computer aided design tools to integrate concept design, prototyping, pattern making and moulding?

6.1 Process Layout and Design

Improving the layout and design of processes within the foundry can improve the efficiency of the operation and thereby reduce the generation of waste. As well as achieving incremental improvements by implementing some of the ideas described in this manual, the company may benefit from taking a more holistic view to redesigning the process. It may be possible to 'design out' wasteful practices. If a company has been doing a process the same way for a number of years it may benefit from investigating redesign opportunities.

As well eliminating or minimising the generation of waste materials 'at source', improving process layout may minimise non-value-adding processes. This may include unnecessary movement of materials into and out of the process areas, time-consuming and wasteful processes such as over-fettling, and unnecessary space for inventory of consumables and work in progress.

Process simulations, visits to other sites, benchmarking, identifying key process problems and brainstorming solutions are all potential approaches to effective process redesign. A number of management and process approaches are discussed below and could be explored further to develop a suitable approach to process redesign and improvement (see Example 32 and Example 33).

Example 32: Redesigning the Foundry Process

Charter Casting Limited changed its casting operation from one that had a flow of product through different operation divisions, to a cellular working environment. Jobs have now been reassigned to form small multi-skilled teams working in purpose-built work areas.

The company has achieved a number of benefits from this change. Work in progress has been reduced greatly, leading to reduced space requirements. Direct labour costs have been reduced by around 10% due the reduced movement of work in progress. Lead times have been reduced and product quality has increased significantly. The reject rate has been reduced to 3.5%. Job satisfaction and morale have improved among team members. Teams are now responsible for production quality and output from the work and multi-skilling has led to greater work variety. Overall, the company has experienced a 25% growth in production due to its increased competitiveness.

Source: The *Foundryman* (1997b)

Example 33: Redesigning the Foundry Process (A Queensland Story)

Nu-Spray is a small non-ferrous jobbing foundry in Brisbane that supplies high-quality castings to the local market. It produces around 40 tonnes of casting per year and uses approximately 60 tonnes of sand per month. The company has been in operation for 5 years and has grown with limited capital input.

The owner identified that the major problem limiting capacity was the manual sand/binder mixing system, which was very labour intensive, took up a lot of space and produced high levels of waste. As part of the solution the company decided to install an automatic hopper and mixer system. The company located suitable second-hand equipment, which was installed during the second half of 1999. The expected benefits of the improvement are as follows:

- The time of the staff member who was responsible for mixing sand is now available to help increase production at the foundry.
- Sand and binder waste has been significantly reduced, resulting in environmental benefits and cost savings. Previously, sand had been stored in an area where stormwater would contaminate the stockpile and spillage of sand and binder from the manual system was high.
- Space was made available by elimination of the sand storage area. This also helped increase production: the extra space made it possible to redesign the process and increase the storage area for moulds.
- Production capacity will increase by at least 30%. The company expects to utilise this by capturing orders that they have previously been unable to accept due to production constraints.
- The changes, which cost less than $20,000, are expected to pay for themselves in less than 6 months.

The company is currently investigating further opportunities for process redesign to take advantage of the increased space. Second-hand conveyors have been located, and these will allow the company to create a continuous flow of production and reduce a significant amount of manual handling.

Source: Spokesperson from Nu-Spray Foundry

Production planning simulation techniques are being developed, with a view to streamlining production processes, making them more flexible and eliminating production errors (FTJ, 1998c) (FTJ, 1998m). Production simulation can be used for a range of decisions where the mistakes in real life would be costly. Potential uses include optimisation of existing processes, design of new process cells, lines or whole plants, and order scheduling (see Example 34).

Example 34: Production Simulation in Foundries

The Swedish Foundry Association is pioneering the use of production simulation techniques for use in smaller foundries. One of their clients was reported to have problems in keeping up with the demand for molten metal during peak pouring times. A pouring schedule was simulated, taking into account a range of factors including the melting capacities of the furnaces, the metal requirements for each mould, desired intervals between pourings etc. Simulations helped the operators identify opportunities to streamline the production process, thereby reducing the risk of metal shortage. As a result, the foundry's output increased by 15%. The simulations have also helped identify and remove bottlenecks in its coreshop.

Another company was considering the purchase of a robot that would service two shell-moulding lines. They needed to be sure that the machine would be able to handle the required capacity, how it would be affected by different mould combinations, and other factors such as whether the operator would be able to handle the workload. The initial process design was modelled and it was shown that the robot was likely to be a bottleneck. A number of alternatives were simulated and a new design was developed and implemented. As a result, the company estimated that the efficiency of the process was increased by 20% compared with the initial design. As well as optimising the use of the robot, other bottlenecks were identified and eliminated. Several expensive fixtures were found to be unnecessary, and overall capital costs were thus reduced.

Source: FTJ (1998c)

6.2 Rapid Prototyping and Pattern Making

Many companies are actively developing systems that improve the efficiency of the pattern-making process to reduce lead times and improve casting flexibility. These approaches include the use of automated computer-aided manufacture (CAM) tooling to produce patterns and to undertake rapid prototyping. While they are capital intensive, rapid tooling machines can achieve high levels of accuracy in pattern design.

The Castings Development Centre in the UK, for example, is developing technology that can machine moulds directly from compacted resin-coated sand, eliminating the need to produce and maintain patterns (FTJ, 1999j). This system is reported to achieve high rates of production and equivalent dimensional accuracy, and can be cost effective for developing prototypes or for single units or small production runs.

Prototypes are needed when testing must be carried out prior to full-scale production, using parts with properties that are the same as, or functionally similar to, those of the production parts. As computer-aided design (CAD) technology has become more common, this has led to the development of a range of techniques commonly called rapid prototyping. These systems effectively allow the designer to ‘print’ a three-dimensional solid model of their design from a CAD design. This prototype can then be used as a proof of concept and allow detailed form, fit and function testing to be undertaken without the necessity to develop expensive tooling. Among their many benefits, these techniques:

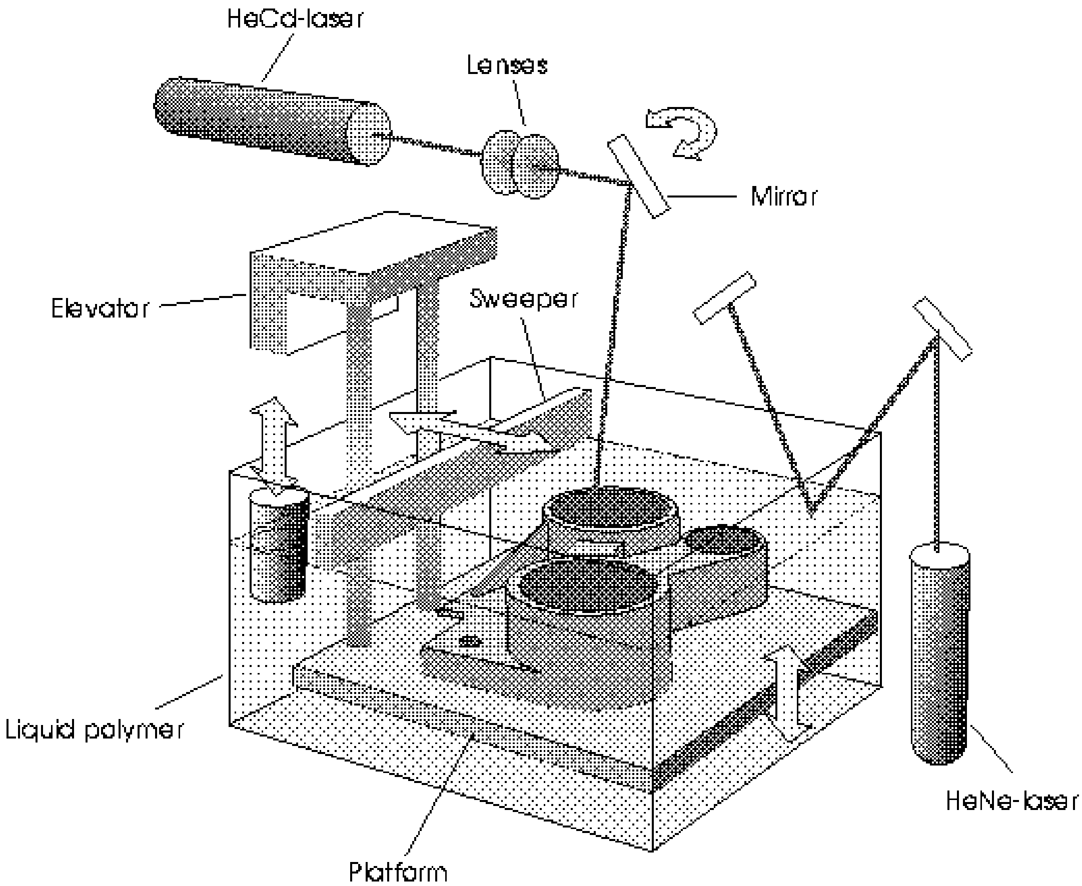
- reduce time and resources required to develop a new product;
- allow design problems to be identified early;
- can provide the master pattern for hard tooling systems or temporary patterns for single unit or limited production runs;
- significantly reduce lead times for product development. The system has been demonstrated to reduce prototype development to as little as 2–4 days and final part manufacture to 1–4 weeks (depending on part geometry). This is compared to 18–20 weeks for conventional methods (Solid Concepts, 1997).

The three most common systems that have been developed are:

- Stereolithography (SLA) process, developed by 3-D Systems, Inc.;
- Selective Laser Sintering (SLS) process developed by the DTM Corporation; and
- Laminated Object Manufacturing (LOM), developed by Helisys Inc.

The SLA and SLS processes both build up complex three-dimensional models by successively layering material using laser deposition. The SLA process (see Figure 11)uses a photopolymer liquid resin that is cured using a UV laser. The SLS process uses powdered metal which is fused (sintered) by heat generated from CO_2 laser (Durham and Grimm, 1996).

Figure 11: Schematic Drawing of Stereolithography Apparatus (SLA)

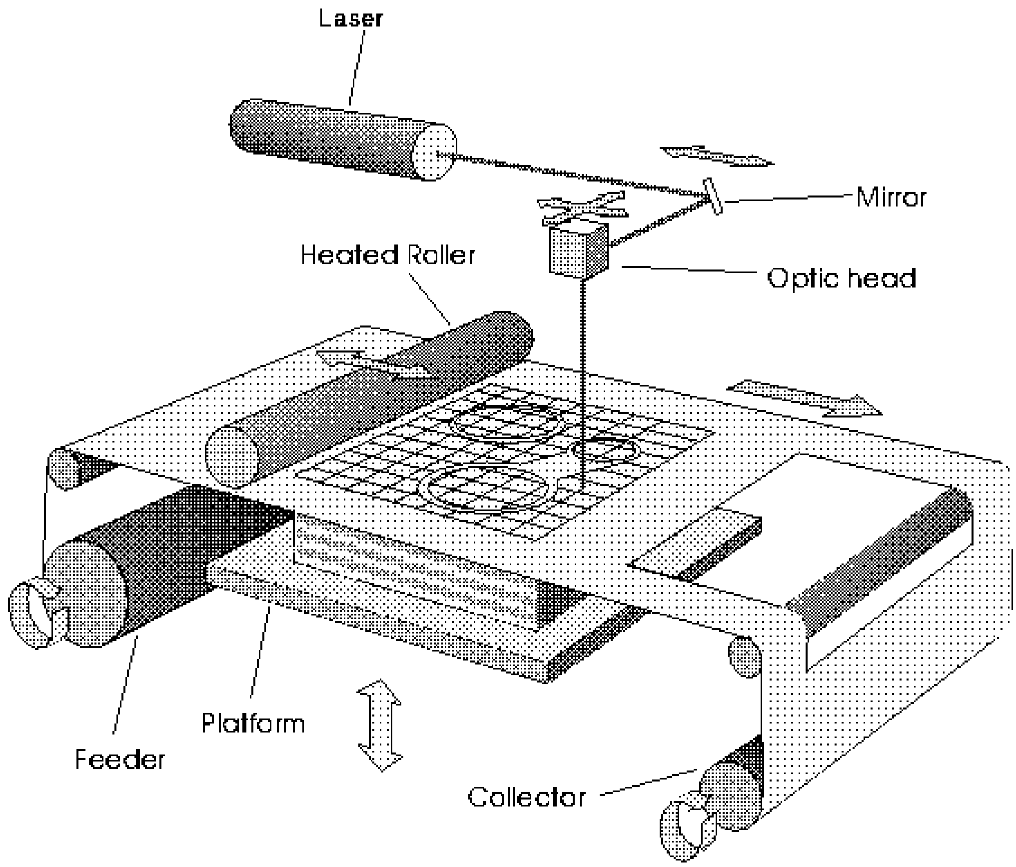


Source: Dolenc (1994)

The LOM process (see Figure 12) divides the 3-D model into thin 2-D layers. A laser is used to cut the shapes into thin sheets (i.e. paper, plastic, ceramic) which are laminated together to build up the model (BIBA, 1998).

Prototyping technology can also be used to produce final castings. The SLA process has been adapted so that prototypes can be used as patterns for investment casting processes. This can greatly reduce the cost of developing new investment products. For a single unit or for limited production runs, rapid tooling of patterns can bypass the expensive and time-consuming step of machining hard tooling.

Figure 12: Schematic Drawing of Laminated Object Manufacturing System (LOM)



Source: Dolenc (1994)

Rapid prototyping technology is currently being developed in Australia by a number of groups, including the Queensland Manufacturing Institute Ltd (QMI, 1998) and the CRC for Alloy and Solidification Technology (CAST, 1999).

Factors that should be considered when investigating the use of rapid prototyping include:

- **The availability of 3-D CAD modelling capabilities.** Companies are increasingly using these techniques for design or tooling, so it is becoming less of an issue.
- **Scale of the operation.** The relatively high cost of rapid prototyping tends to restrict smaller foundries from developing an in-house capability. Outsourcing may be an option, however, and there are a number of centres in Australia that offer rapid prototyping services.
- **Part complexity.** In general, the cost effectiveness of rapid prototyping improves as part complexity increases.

- **Part size.** Current systems are restricted to smaller parts.
- **The importance of short lead times.** Where timing is an important competitive consideration, rapid prototyping can be of significant economic benefit (Metal Asia, 1999a).

For more information about rapid prototyping and related technologies, visit the BIBA Internet List of Worldwide Rapid Prototyping Sites at:

http://www.biba.uni-bremen.de/groups/rp/rp_sites.html

6.3 Changing Casting Processes

Casting processes are continually being improved. This includes the optimisation of particular casting techniques for specific applications and the extension of casting techniques to other castings (i.e. larger or smaller scales, different metals, geometric complexity etc.). Companies can benefit from continually monitoring developments in innovative casting technologies and process improvements that could be applicable to their products.

Precision casting techniques, such as investment casting, lost foam and die casting, have high dimensional accuracy and can produce ‘as net’ castings that require almost no fettling or polishing. They can also significantly reduce the generation of by-products such as sand, and eliminate or reduce the use of inputs including binders and other consumables.

While it is clearly a strategic decision, companies could benefit from undertaking an analysis of how different casting systems could benefit their operations. This section briefly highlights a few innovative processes that have been adopted by foundries to achieve cost savings and environmental improvements. More detailed descriptions, including the major advantages and disadvantages, are provided in Part 5.

Vacuum moulding. This extension of conventional sand moulding eliminates binder use and virtually eliminates sand waste. The process also achieves significantly higher dimensional accuracy and metal yield than conventional processes. This process is applicable to all sizes of castings and most metals, and can be very economical and energy efficient (UNEP, 1997).

Lost foam casting. The major benefits of this process include the virtual elimination of waste sand, the looser packing of sand, the elimination of cores from the design process and the simplification of the production process. Because multiple parts are typically mounted on a single tree, significant economies can be achieved throughout the production process, particularly for complex castings (Environment Canada, 1997). One company has reportedly reduced fettling costs by 66% using this process (FTJ, 1998g).

Investment casting. This process typically achieves the highest dimensional accuracy and requires the least amount of fettling and cleaning. Metal and sand yields and melt efficiencies are relatively high. The Replicast process has successfully adapted these techniques to make it suitable for some larger castings.

Semi-solid metal casting. This process, which is an extension of die casting, combines many of the advantages of casting and forging. The major advantages include lower energy intensity, increased metal yield and structural integrity.

These and other techniques (described further in Part 5) should be reviewed by companies to assess their relative benefits for the products produced and markets served by the company. There is also the potential to undertake in-house research and development to develop a modified process which is optimised for the specific production requirements of the company.

A feasibility analysis of different casting techniques should consider all the major costs and benefits. As an example, Table 11 lists many of the different aspects that could be considered when comparing the costs and benefits of lost foam casting and convention sand casting.

Table 11: Comparing Costs and Benefits of Lost Foam and Conventional Sand

Materials

- Sand
- Binders
- Polystyrene — balls
- Polystyrene — blocks
- Paint
- Ceramic tubes
- Exothermic sleeves
- Plastic sheet
- Water
- Tooling

Labour

- Pattern making
- Tooling
- Moulding preparation
- Transport of moulds
- Pouring
- Knockout
- Fettling

Energy

- Pattern making
- Tooling
- Moulding preparation
- Transport of moulds
- Pouring
- Knockout
- Fettling

By-products

- Sand
- Slag
- Baghouse dust
- Shotblast
- Metal fines
- Foam cuttings
- Timber
- General foundry wastes

Occupational Health and Safety

- Lost time to injuries
- Training requirements
- Capital requirements

Rework and defects

Space

Environmental compliance

- Training requirements
- Capital requirements
- Maintenance

6.4 Communication Tools and Integrated Control Systems

Computer technology will have an increasing impact on the foundry industry in the future (see Example 35). A whole range of communication tools are continually being developed and, while they can create significant challenges, they also present incredible opportunities for developing innovative and efficient systems to deliver excellent customer service.

As well as computer-aided design and manufacture (CAD/CAM) and automated process control, communication systems are undergoing a massive transformation. All companies should maintain a close watch on these technologies and develop appropriate strategies to ensure their commercial competitiveness (Metal, 1997c). These technologies include electronic data interchange (EDI) and the Internet, as well as a range of improving systems in office and foundry management.

Example 35: A Vision for 2010 — Communication and Control Systems in a State-of-the-art Foundry

The following description of a customer order to MetalCast Ltd (a hypothetical company in the year 2010) provides a vision of how modern communication and control systems are likely to impact on the foundry industry in the near future. All the technologies discussed are currently available and will develop significantly and become more integrated over the next decade.

a) After conducting an Internet search, a customer finds the home page of MetalCast. Impressed by the valuable information and interactive design tools that are available online, the customer is able to develop an effective design and accurate specifications.

b) The customer sends specifications and detailed 3-D design data via e-mail (CAD files) to MetalCast. Using casting simulation software (see section 3.1.6), MetalCast estimates the cost and provides a quote by e-mail.

c) On confirmation of the order, the customer is given a unique order code that will allow them to track the progress of the order directly via the Internet. MetalCast designs an efficient gating system and recommends some design changes that reduce the net weight of the cast and improve the cast strength and quality.

d) On confirmation of the order, the automatic purchasing system sends electronic orders to the each of their suppliers to ensure just-in-time delivery of the necessary consumables.

e) After design approval, the CAD data is sent to the rapid prototype unit and a 3-D prototype is produced (see section 6.2). This is sent to the customer for proof-of-concept testing. After prototype approval, the order is placed in the production scheduling system.

f) The prototype is used to create a permanent pattern which is bar-coded for automated storage and retrieval for future orders. Bar codes are also used for each flash and later for individual units to track the product from the mould room and through pouring, finishing and dispatch.

g) When the order is ready to be processed, the work computer provides the job details (i.e. number of units, flasks and other special instruction). Work instructions and easy-to-follow demonstration videos are readily available on the system if staff need any additional information.

h) The pattern, flask and other consumables are delivered automatically by a series of overhead robotic cranes to the mould and core room. This eliminates the need for operators to spend time moving materials to and from the workspace, thus saving time and reducing the risk of accidents. Inventory records are altered accordingly.

i) The prepared flasks move to the pouring area where the metal has been prepared on a just-in-time basis to minimise holding times. Bar code scanners on the conveyors track progress and report on any bottlenecks. This helps identify opportunities for process improvements. Scales and sensors on the conveyors record the weight of the flasks at each stage to accurately calculate a range of efficiency measure including metal and sand yield. This helps identify key areas of waste and inefficiency.

j) After moving through the robotic fettling and cleaning area, the products are sent to dispatch for packaging. The customer is automatically e-mailed, to inform them that the order has reached the dispatch area and is scheduled to arrive at their premises the following morning. Invoices are automatically prepared and sent.

Electronic data interchange (EDI) is the basis of systems that share electronic information between customers and suppliers, and can greatly reduce the use of paper, reduce error and increase the speed of transactions. Information that can be exchanged electronically includes customer orders and specifications, supplies requisitions and design data such as CAD files (see Example 36).

Example 36: Signicast Corporation — Continuous Flow Manufacturing

Signicast Corporation, an advanced investment casting corporation in Wisconsin, USA, has redesigned its process from a jobbing shop to a continuous flow manufacturing (CFM) system. As a result, delivery times have been cut by 90% (1–2 weeks versus 8–12) while costs have been reduced and quality and flexibility improved. The two major objections that potential clients have about investment castings are lead times and price. As a result of these changes, sales have more than doubled sales, to over US$65 million (A$100 million).

CFM is an integration of production, material handling and information processing. The system, which was designed around a greenfield site, incorporated a number of elements:

- development of a just-in-time parts delivery system;
- development of stand-alone production modules that were each designed around standardised product range;
- standardisation of machinery and automation of processes where possible, which includes:
  - ♦ three automatic storage/retrieval systems. One handles the pick-up and delivery of dies, sprues and moulds on cluster pallets in the wax cell. The other two move totes containing moulds in production;
  - ♦ four robots to keep moulds in sequence and flowing continuously through the plant.

Signicast has achieved a product throughput of 4.3 days without heat treat and 6.3 days with heat treatment. Labour costs were reduced by 25%. The quality control and analysis process has shifted from lot traceability to mould traceability. Having a batch size of one means that problems are quickly identified and solved, eliminating rework loops. Automation has also removed much of the drudgery of the work and allowed operators more time to focus on producing quality products.

Source: Signicast (1999)

The Internet has developed rapidly over the last decade but will develop even more over the next. The potential to use this technology in the foundry industry is immense and is likely to revolutionise how all businesses interact with their customers, suppliers and other stakeholders (see Example 37). Some ideas that could be applied by the foundry industry and individual companies include the following:

- **Online casting information.** The industry or individual companies could develop information about the casting processes to help customers develop better designs and specifications. Tools could be developed to help customers work out which casting process would be most cost effective and to demonstrate the benefits of casting techniques over forging and machining.
- **Integrated ordering, production, product tracking and delivery systems.** Customers could use the Internet to submit electronic orders. This could include design information in the form of CAD files. When production scheduling is integrated into this system, there is the potential to offer product tracking information to customers (see Example 37). Foundry customers could potentially use this service or be sent notification by e-mail informing them of progress. This information would help them plan their own processes more effectively.
- **Purchasing and inventory management.** The Internet can also be used to integrate with suppliers and to develop more effective just-in-time inventory systems.
- **Intranets.** The technology can also be used to develop Intranets — information systems that are available only in-house or to an approved group of individuals. This can be used to protect commercially sensitive information or to develop in-house information systems. This could include online manuals for quality assurance and other management systems.
- **Training.** Training for quality management, environmental management, health and safety and other issues typically involves the development of complicated written procedures and work instructions. Internet/Intranet-based training could incorporate video files that present easy-to-follow demonstrations of how to undertake an activity. Companies are also beginning to use the Internet to disseminate corporate information to staff.
- **Process control.** It is likely that the Internet will increasingly incorporate and even replace the current process control systems. This has the potential to greatly reduce the cost of control and make it more accessible to non-technical staff. A range of shop-floor monitoring technology is being developed, including the use of bar codes on work orders to track progress.
- **Environmental management.** Increased process control and monitoring has the potential to greatly enhance the ability of companies to management their environmental aspects more effectively and efficiently. Cleaner Production benefits should flow from this increased control.

Example 37: Reducing Pattern Lead Time Through Integrated Communication

Independent Steel Castings Company (ISCCO), a precision investment casting company located in Michigan, USA, uses the Internet to increase the efficiency of the tooling and prototype stage. Customers can now send engineering data in the form of CAD files over the Internet. These are then sent to the toolmaker, who uses computer software that is capable of using the CAD data to develop tool-cutting information. This computer transcribes the data and sends it directly to a 'six axis cutting machine'. A prototype of the new pattern mould is then quickly roughed out using an aluminium plate. Only shrink allowances and polishing have to be added to the mould. This system has reduced tooling lead time to less than 3 weeks.

Other features of the company's communication system include: a quotation tracking system that enables them to respond to requests within 48 hours; order tracking facilities that schedule production, monitor backlogs, and guarantee delivery date; computer-aided design, production and quality management; preventive maintenance; general inventory and financial and office management functions. This integrated system has allowed the company to achieve turnaround times of as little as 5 weeks.

Another service that the company can provide, using its 3-D CAD technology, is an engineering comparison of its investment casting process with other options such as machining and welding. This helps the company demonstrate the potential cost savings and other production advantages that their customers can achieve from changing to the casting process.

Source: ISSCO (1999)

7. Conclusions

Cleaner Production can bring about financial savings, improve environmental performance, enhance compliance, and improve product quality. The case studies described in this section suggest that most foundries could significantly to improve their bottom line and reduce the impact of the operation on the environment. Even companies that have expended a major effort on process improvement should continually review emerging Cleaner Production.

As shown in this report, there are the gains to be made throughout the foundry and these improvements do not necessarily have to come at a great price. While there are a number of barriers to implementing Cleaner Production, the benefits are real.

More than simply listing opportunities for improvements, as in this report, companies should consider Cleaner Production strategically as a way of doing business. Companies that successfully implement any management or improvement system, such as quality management systems, environmental management systems, safety or hazard management systems achieve that success because senior management uses the system to better manage the business.

For the most successful companies, Cleaner Production is not something extra that they do when they take time out from managing the business. It becomes an integral part of how the business is run.

Part 6: Cleaner Production Implementation Guideline provides an overview for develop a strategic approach to Cleaner Production. By using Cleaner Production as a tool for managing their business, senior managers and foundry owners can use the approach to drive changes throughout their operation. By taking a strategic approach to minimising waste and maximising resource efficiency and productivity, Queensland foundries will be better able to compete in the increasingly competitive castings market.