OPTIMISING SAND USE IN FOUNDRIES

GOOD PRACTICE: Proven technology and techniques for profitable environmental improvement
OPTIMISING SAND USE IN FOUNDRIES

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Until recently, UK foundries did not consider the disposal of waste sand to be a major problem. However, the increasing cost and scarcity of good quality virgin sand and escalating landfill costs have forced foundries to pay closer attention to sand management and reclamation.

This Good Practice Guide provides practical advice on the management and reclamation of:

- chemically bonded sand based on the following binder systems:
  - furan;
  - alkaline phenolic;
  - phenolic urethane;
  - resin shell;
  - sodium silicate;
- greensand.

The factors affecting the choice of reclamation technique are discussed and the options available for the reclamation of each type of sand system summarised in comparative tables.

The cost benefits of sand reclamation are emphasised and examples of the cost savings achievable with primary and secondary reclamation are described. Action plans applicable to all foundries seeking to reduce sand use and costs are given.

To remain competitive, foundries are urged to:

- evaluate primary reclamation techniques (if not already adopted);
- optimise primary reclamation;
- consider secondary reclamation where primary reclamation is already used;
- examine options for beneficial re-use of residual waste sand when both primary and secondary reclamation have been optimised.
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In the foundry industry, sand is a valuable commodity. It can be reclaimed for return to the sand system, reducing the need to buy new sand and to pay ever-increasing waste disposal costs. Many foundries in the UK are reducing their operating costs by improved sand management and increased use of reclaimed sand.

To give some idea of the scale of the problem, the UK foundry industry currently spends nearly £35 million/year on purchasing over one million tonnes of new sand and disposing of a considerable proportion of this (as used sand) to landfill.

Foundry-quality sand will become more difficult to obtain and therefore more expensive to buy as UK stocks of sand diminish. The post-quarrying costs of improving the mineral to meet foundry acceptance criteria also increase the price of virgin sand. Other factors are also affecting raw material costs. Because of the high capital cost of extraction, some quarries have closed prematurely without all the raw material being extracted. This has tended to increase delivery costs because the sand has to be transported further. Controls on sand excavation, eg post-closure landscaping requirements, have also led to increased costs for quarry operators.

Until recently, the disposal of waste sand was not considered a major problem. However, there are now fewer licensed landfill sites available for the disposal of controlled wastes. Waste sand therefore has to be transported greater distances for disposal, resulting in increased haulage costs. Moreover, tighter legislative controls on wastes and waste disposal sites have led to a rapid escalation in disposal costs. The landfill tax\(^1\) has also increased the cost of sending waste sand to landfill sites.

Paying more attention to sand management and increasing sand reclamation will enable foundries to increase their profits and remain competitive. Table 1 summarises the advantages and disadvantages of sand reclamation.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced purchases of new sand</td>
<td>Some binder systems are not fully reclaimable</td>
</tr>
<tr>
<td>Lower waste disposal costs</td>
<td>Capital outlay required</td>
</tr>
<tr>
<td>Decreased binder/catalyst costs</td>
<td>More technical controls required</td>
</tr>
<tr>
<td>Improved casting quality</td>
<td>Additional costs for pollution control, storage,</td>
</tr>
<tr>
<td>Foundries’ impact on the environment reduced</td>
<td>distribution and blending</td>
</tr>
<tr>
<td></td>
<td>May require the use of more expensive binders</td>
</tr>
</tbody>
</table>

Table 1 Advantages and disadvantages of sand reclamation

This Guide describes practical measures to improve sand management and reclamation for foundries using chemically bonded sand (furan, alkaline phenolic, phenolic urethane, resin shell and sodium silicate) and greensand. Practical measures to improve the management of chemical binder systems are described in Good Practice Guide (GG104) Cost-effective Management of Chemical Binders in Foundries, available free of charge through the Environmental Helpline on 0800 585794.

**1.1 SAND RECLAMATION TECHNIQUES**

All dry reclamation systems can be divided into three main operations (see Fig 1):

- pre-treatment of knockout sand;

\(^1\) The 1997 rate for inactive wastes is £2.00/tonne.
binder abrasion through sand-to-sand contact;
- post-treatment of the abraded sand.

Reclamation techniques are classified as either primary or secondary processes.
1.1.1 Primary reclamation

Primary reclamation, also known as attrition or particulation, involves breaking down the sand from moulds or cores to its original grain size. This includes screening the sand, removing tramp metal, and separating and removing fines and over-sized agglomerates. The sand is then cooled before being sent for storage, returned to the sand system or blended with new sand.

At this stage, the sand grains are likely to retain a partial coating of spent binder. This affects the amount of reclaimed sand that can be used to make moulds and, more particularly, cores. New sand therefore has to be added to ensure that the sand mix produces adequate mould and core strength and subsequent casting quality. Primary reclaimed sand is not generally of sufficient quality to be used for coremaking without further processing to remove residual binder materials and is therefore used principally for moulds.

The main primary reclamation techniques are:

- shot blast;
- rotating drum;
- vibration.

1.1.2 Secondary reclamation

Secondary reclamation involves further processing of the previously particulated sand to remove residual binder. The sand is returned to a quality similar to, or better than, that of new sand. Foundries using secondary reclamation have, in some cases, virtually eliminated the need for new sand.

To remove residual binder, more aggressive techniques are required than for primary reclamation. The main secondary reclamation techniques are:

- high energy attrition, either:
  - pneumatic;
  - mechanical;
  - centrifugal;
- wet scrubbing;
- thermal treatment, usually in a fluidised bed.

Further details of the different reclamation techniques are given in Environmental Performance Guide (EG4) *Chemically Bonded Sand: Use and Reclamation*, available free of charge through the Environmental Helpline on 0800 585794. Equipment manufacturers will also be able to provide information.

Section 3 indicates the reclamation techniques suitable for use with the six main sand systems.

1.2 THE SAND BALANCE DIAGRAM

There is a considerable difference between the use of 100% reclaimed sand to produce moulds and cores and the achievement of 100% sand reclamation. For a number of reasons, eg sand losses due to inefficiencies in the sand system, burn-on and the need to remove dust and fines, 100% sand reclamation cannot be achieved. Even with thermal reclamation, dust losses of 5 - 8% can be expected.

Preparation of a sand balance diagram helps to determine a foundry's true reclamation rate and potential for cost savings.
1.2.1 Mechanical reclamation only

Fig 2 is an example of a sand balance diagram for a foundry using a blend of 70% mechanically reclaimed sand and 30% new sand for moulding. The system contains 100 tonnes of sand.

To obtain the necessary core properties, core production requires 10 tonnes of new sand. This leaves a requirement for 90 tonnes of blended sand for moulding purposes.

Fig 2 shows that to achieve a balance, the blended sand for moulding will comprise 63 tonnes of reclaimed sand and 27 tonnes of new sand. Although mould production uses 70% reclaimed sand, the true reclamation rate is only 63%.

![Fig 2 Mechanical reclamation sand balance diagram](image)

1.2.2 The effect of using new sand for coremaking

Large amounts of new sand entering the sand system, eg in the coreshop, have a significant effect on the true reclamation rate. Fig 2 shows that, although a foundry may use a high proportion of reclaimed sand, a large contribution of new sand in the form of cores means that the reclamation rate may be quite low.

For a given mixer blend, the higher the core sand content, the lower the true reclamation rate (see Fig 3).

![Fig 3 Impact of core sand ratio on the true reclamation rate](image)
1.2.3 Thermal/mechanical reclamation

The open loop shown in Fig 2 can be closed by introducing a secondary reclamation process to reclaim the proportion of sand that is currently thrown away. However, to close the loop fully, this secondary process must meet the following criteria:

- no degradation of the sand grain size;
- contamination stabilised to a level at which casting quality will not be adversely affected.

Following the example shown in Fig 2, the introduction of a thermal reclamation unit allows most of the sand previously discarded from the mechanical reclamation process to be diverted back into the system (see Fig 4).

The secondary reclamation unit controls organic contamination of the reclaimed sand. The amount of inorganic contamination is usually extremely low and, in normal circumstances, the amount of new sand needed for its control rarely exceeds degradation and other losses.

In Fig 4, the introduction of secondary reclamation means that 29 tonnes of thermally reclaimed sand can be introduced to the system, instead of 29 tonnes of new sand. The total amount of reclaimed sand in the system is 92 tonnes (63 + 29), giving a true reclamation rate of 92%. This compares with 63% from mechanical reclamation alone. Much less new sand is needed and much less waste sand is produced, ie only 8 tonnes of new sand (8%) balanced out by 8 tonnes of waste sand - compared with 37 tonnes in Fig 2. Moulding and coreshop sand requirements are the same in both Fig 2 and Fig 4.

The only way that 90% reclamation can be consistently achieved in a primary mechanical reclamation system is through natural thermal reclamation taking place during pouring and cooling. This will only happen with low sand-to-metal ratios, and use of certain chemical binder systems. However, typical foundry sand-to-metal ratios do not permit total binder burn-out from the mould and cores.

*Fig 4 Sand balance diagram for a thermal/mechanical reclamation system*
2.1 RAW MATERIAL PURCHASE AND DISPOSAL

A foundry’s annual consumption of sand and binders can be calculated from its suppliers’ invoices. The amount of waste sand may be more difficult to determine as many foundries handle all wastes in the same way. Segregating waste streams and avoiding the contamination of inactive wastes by general refuse (charged at the higher rate of landfill tax) or hazardous materials classified as special waste, will facilitate reclamation and reduce landfill costs.

Sand is generally purchased to replace a similar quantity of sand disposed of as waste. However, the waste sand also has a potential for reclamation.

It is essential to examine when and how waste sand is generated. Not only will this help you to identify opportunities to minimise waste, but will also allow you to manage the waste sand properly. In the ideal case, the foundry produces moulds continuously and at the same rate as they are being knocked out. The system is therefore in equilibrium. In the worst case, eg where large castings are produced, it can take several days to assemble and cast the mould. At knockout, a surge of sand is produced which requires storage.

Arrangements should also be made to allow the new sand needed to make up losses to enter the cycle without affecting the reclamation system and potentially displacing sand to waste.

2.2 SAND-TO-METAL RATIOS

Sand-to-liquid metal ratios are a further parameter that can be controlled to optimise sand use and reduce operating costs.

The amount of sand mixed per tonne of metal poured varies for different types of metal and different sizes and shapes of castings. In each case, the amount of sand must be sufficient to ensure adequate mould strength. Once an adequate mould strength has been achieved, there is no additional benefit in using more sand to create a larger mould.

Although foundries may feel more confident with over-sized moulds, using more sand than is necessary only increases production costs. Optimising mixed sand (ie sand and binder) consumption has many advantages:

- increased productivity;
- less sand is required, leading to reduced sand costs;
- binder costs are reduced because less binder-coated sand is used per casting;
- emissions to atmosphere from mixing and casting operations are reduced because less sand is mixed for each casting;
- natural reclamation is higher in thermally-degradable binder systems because the proportion of burnt out sand is greater (see Section 2.6);
- burn-out makes particulation easier;
- burn-out results in lower residual binder levels in the reclaimed sand, which allows greater amounts of sand to be re-used.

Any foundry operating with a sand-to-liquid metal ratio in excess of those listed in Table 2 should review its production methods, as there may be scope to reduce sand consumption.
<table>
<thead>
<tr>
<th>Alloy sector</th>
<th>Sand-to-liquid metal ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron</td>
<td>up to 4:1</td>
</tr>
<tr>
<td>Steel</td>
<td>up to 5:1</td>
</tr>
<tr>
<td>Copper</td>
<td>up to 4:1</td>
</tr>
<tr>
<td>Aluminium</td>
<td>up to 12:1</td>
</tr>
</tbody>
</table>

Table 2 Typical sand-to-liquid metal ratios in UK foundries

Further details about sand-to-metal ratios are given in Environmental Performance Guide (EG4) *Chemically Bonded Sand: Use and Reclamation* and Environmental Performance Guide (EG5) *Foundry Greensand: Use and Reclamation*. Both Guides are available free of charge through the Environmental Helpline on 0800 585794.

### 2.3 CHOICE OF BINDER SYSTEMS

Many foundries use more than one type of binder. Undertaking a review can lead to the use of fewer binder systems. This could increase the potential for reclamation, and reduce:

- the capital tied up in stock;
- the need for different handling requirements;
- the need for training in the use of multiple binder systems;
- labour costs;
- administrative effort.

The following factors should also be considered:

- the choice of binder system affects the amount of sand that can be reclaimed;
- some binder systems are incompatible with others;
- the base sand used for different binder systems may be of different sieve gradings;
- the presence of heavy sands, eg chromite tends to segregate in fluidised beds and hoppers.

Good Practice Guide (GG104) *Cost-effective Management of Chemical Binders in Foundries* describes how foundries can achieve significant cost and other benefits by improving the management of their chemical binder systems.

### 2.4 METAL YIELD

Metal yield - the ratio of the amount of metal melted to the weight of the finished castings - does not have a direct effect on sand use. However, an increase in yield may result in fewer moulds being produced, which means that less sand is used. Five main factors affect metal yield:

- quality requirements;
- choice of mould-box size;
- the extent of runner and feeder systems;
- metal shrinkage;
- scrap casting rate.

Lower metal yields are generally associated with higher integrity products where superior quality standards may be required, necessitating a more extensive feeding system. Lower yields, however, may also be indicative of higher scrap rates and excessive feeding systems. In these circumstances, foundries should review process control and mould production methods.
The average metal yields for the main alloy sectors are given in Table 3 which shows that all foundries could benefit from considering metal yield if this leads to the production of fewer moulds. Binder and new sand purchases - together with the amount of sand processed - provide a check on actual binder addition levels (as distinct from nominal addition levels). Given the high cost of binders, this can result in significant savings.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Average metal yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chemically bonded sand</td>
</tr>
<tr>
<td>Iron:</td>
<td></td>
</tr>
<tr>
<td>grey</td>
<td>69%</td>
</tr>
<tr>
<td>spheroidal graphite (SG)</td>
<td>64%</td>
</tr>
<tr>
<td>Steel</td>
<td>51%</td>
</tr>
<tr>
<td>Aluminium</td>
<td>71%</td>
</tr>
<tr>
<td>Copper</td>
<td>63%</td>
</tr>
</tbody>
</table>

*Table 3 Average metal yields in the main alloy sectors*

The range of yields in different foundry sectors are considered in Environmental Performance Guide (EG4) *Chemically Bonded Sand: Use and Reclamation* and Environmental Performance Guide (EG5) *Foundry Greensand: Use and Reclamation*.

### 2.5 CORES

Cores are a critical part of a mould since they become virtually surrounded by liquid metal. As such, they require high-quality materials. Most foundries therefore use new sand for coremaking.

If a foundry produces only a small quantity of cores, this may provide a cost-effective entry point for the new sand needed to keep the sand system full.

If a foundry uses large quantities of cores or it operates a facing sand practice, primary reclamation alone may lead to a build-up of reclaimed sand that cannot be used. It may therefore be advantageous to install a secondary reclamation unit to return the waste sand to a quality suitable for coremaking.

### 2.6 FACTORS AFFECTING RECLAMATION

A number of factors affect sand reclamation and thus influence the quality of the castings produced with reclaimed sand. These factors are described below in no particular order of priority.

#### 2.6.1 Type of binder and catalyst

Organic materials are volatilised by the heat generated during casting. For primary reclamation, a measure of the amount of organic binder remaining in the sand can be obtained by determining the amount of combustible material present. This is obtained in the form of the loss on ignition (LOI) value for the sand. A high LOI indicates a high residual level of binder which, in turn, suggests a low level of binder degradation on casting. The LOI value is controlled by using less binder and diluting the reclaimed sand with new sand. Although effective, dilution uses increasingly expensive raw materials.

The chemical composition of the binder system is also important because it may contain elements associated with casting defects. Accumulation of elements such as nitrogen, phosphorus, sodium and sulphur in a reclaimed sand - over a number of cycles - may ultimately exceed acceptable levels and lead to a fall in compression strength.
2.6.2   Sand grain shape and sieve grading

The more angular the sand grain, the greater the surface area and hence the greater the quantity of residual binder that will adhere to it. Attrition can reduce the overall surface area of the sand grains, as the abrasion between individual sand grains makes them more rounded.

Most reclamation units incorporate an attrition stage to break down any sand lumps. Grain shape is thus progressively changed over a number of reclamation cycles. The production of more spherical grains reduces the amount of residual binder in the sand, which lowers the amount of combustible material in the sand, and reduces the level of fresh binder required which reduces operating costs.

Sieve grading indicates the distribution of grain sizes. To avoid the casting problems associated with large lumps of sand and fine sand grains (ie less than 70 µm), reclamation plants contain crushing, sieving and classifying units to produce a sand with the required screen distribution. Reclamation thus removes tramp metal, dust and most of the residual binder, and restores the sand to its original grain size.

2.6.3   Type of metal poured

The pouring temperature affects the quantity of heat transferred to the sand and thus the amount of binder burnt away. There is less self-reclamation with lower melting point metals such as aluminium, than with iron or steel.

2.6.4   Sand-to-metal ratios and section thickness

The sand-to-metal ratio has a major influence on the average sand temperature developed in the mould after pouring. The lower the ratio, the hotter the sand and the more effective the burn-out of binder. Fig 5 shows the effects of the sand-to-metal ratio on binder loss.

![Fig 5 The effects of sand-to-metal ratio on binder loss during casting](image)
The surface area of the casting and its section thickness also influences the extent of binder removal. The larger the surface area of the casting, the more sand will be brought into contact with hot metal, and the greater the amount of burn-out of the binder.

### 2.6.5 Time between metal pouring and shakeout

The longer the delay between pouring and shakeout, the further the heat from the metal can penetrate into the sand mass. This destroys more of the binder and thus helps to reduce the level of residual binder to be removed by reclamation.

### 2.6.6 Sand temperature

Good control of sand temperature is essential for optimum results and consistent performance. Where sand is reclaimed, a cooler classifier should be used to ensure that the temperature of the return sand is acceptable. Good Practice Guide (GG104) *Cost-effective Management of Chemical Binders in Foundries* explains the benefits of controlling sand temperature.

### 2.7 CONTROL TESTS FOR RECLAIMED SAND

The properties of the reclaimed sand have a significant influence on the resulting moulds and cores. Regular control testing of the reclaimed sand and/or reclaimed/new sand mix is therefore essential. There are six main control tests for reclaimed sand:

- mechanical analysis or sieve grading of the reclaimed sand;
- moisture content of the new sand;
- loss on ignition (LOI);
- sand temperature and foundry humidity levels;
- acidity/alkalinity of the reclaimed sand;
- specific chemical analysis.
There are a number of options available for reclaiming greensand and the different types of chemically bonded sand. These choices - together with their advantages and disadvantages - are described in this Section.

The price of reclamation equipment depends on the throughput and complexity of the system. Each type of equipment is available in a range of prices starting from £21 000 for a 1 tonne/hour vibration system (1997 prices). Section 4 explains how to evaluate the cost benefits of reclamation and gives example cost savings.

The Environmental Helpline on 0800 585794 can provide contact details for suppliers of different types of reclamation equipment, from whom detailed information on capital and operating costs can be obtained.

When selecting reclamation equipment, remember to confirm with the manufacturer that you will continue to achieve the emission limits specified in your process authorisation.
3.1 FURAN BONDED SAND

3.1.1 Primary reclamation
This binder system is almost totally organic and thus destroyed by heat. Many foundries reclaim furan bonded sand using a simple, low-energy attrition or particulation process, while also taking advantage of the thermal reclamation that occurs during casting. This mechanical process typically achieves 60 - 90% reclamation (average 80%).

Primary reclamation is limited by the build-up of residual resin and catalyst on the sand grains. This causes variations in the loss on ignition (LOI) value, acid demand value, and residual levels of sulphur, nitrogen and dust. In turn, these can lead to casting defects and/or excessive fumes during pouring.

As total binder removal is not achieved, binder addition levels can be reduced by typically 0.15 - 0.20% on rebonding. There is also a proportionate reduction in the amount of catalyst needed. This benefit is also partly due to the general improvement in grain shape, caused by a rounding of the sand grains.

3.1.2 Secondary reclamation
There is still considerable potential in the UK foundry industry for the use of secondary reclamation to return the sand to its original state.

Thermal reclamation is the preferred option, unless the binder has been catalysed by phosphoric acid, which cannot be removed by thermal processing. At the optimum operating temperature of approximately 800°C, the sand becomes ‘as new’. Exhaust emissions are within the limits specified in the relevant Secretary of State’s Process Guidance Notes. The only solid waste is a small amount of inert silica dust.

Wet reclamation is not generally feasible as the furan binder contains only a small amount of water-soluble catalyst.

Table 4 summarises the options available for the reclamation of furan bonded sand.

<table>
<thead>
<tr>
<th></th>
<th>Primary reclamation</th>
<th>Secondary reclamation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry attrition</td>
<td>High-intensity attrition</td>
</tr>
<tr>
<td>Technical compatibility</td>
<td>⬤⬤⬤⬤⬤</td>
<td>x</td>
</tr>
<tr>
<td>Capital cost</td>
<td>⬤⬤⬤⬤⬤</td>
<td></td>
</tr>
<tr>
<td>Operating costs</td>
<td>⬤⬤⬤⬤⬤</td>
<td></td>
</tr>
<tr>
<td>Economic viability</td>
<td>⬤⬤⬤⬤⬤</td>
<td></td>
</tr>
<tr>
<td>Sand quality</td>
<td>Usable for mould production</td>
<td></td>
</tr>
<tr>
<td>Waste generated</td>
<td>Dry dust</td>
<td></td>
</tr>
</tbody>
</table>

Key: ⬤⬤⬤⬤⬤ = Most favourable; ⬤ = Least favourable

*Table 4 Reclamation techniques for furan bonded sand*
3.2 ALKALINE PHENOLIC BONDED SAND

The controlling factor in the reclamation of this type of chemically bonded sand is the residual potassium content in the reclaimed sand. The reduction in strength of the rebonded sand is minimal up to 0.15% residual potassium, but falls rapidly above this level. New sand additions are essential to ensure acceptable levels of potassium.

In terms of primary reclamation, simple vibratory attrition is now capable of achieving 80 - 85% reclamation.

Secondary reclamation using attrition or dry scrubbing does not offer any additional benefits to the foundry; more heat and dust are generated and the reduction in residual binder levels is not significant.

Until recently, thermal reclamation was problematic as potassium salt residues tended to melt and frit in the fluidised bed, producing an agglomerated mass. However, use of a proprietary additive - based on china clay or a sugar derivative - with previously attrited sand has overcome this problem. The additive converts potassium salts to a thermally stable form and reduces the level of residual potassium to an amount that does not affect the bond strength. A further benefit is that the reclaimed sand is suitable for use with other binder systems, eg phenolic urethane.

Although use of an additive has cost implications, these are not significant. Thermal reclamation of alkaline phenolic bonded sand now offers a technically and economically feasible route to increasing the use of reclaimed sand.

Table 5 summarises the options available for the reclamation of alkaline phenolic bonded sand.

<table>
<thead>
<tr>
<th></th>
<th>Primary reclamation</th>
<th>Secondary reclamation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry attrition</td>
<td>High-intensity attrition</td>
</tr>
<tr>
<td>Technical compatibility</td>
<td>5/5</td>
<td>x</td>
</tr>
<tr>
<td>Capital cost</td>
<td>4/5</td>
<td></td>
</tr>
<tr>
<td>Operating costs</td>
<td>5/5</td>
<td></td>
</tr>
<tr>
<td>Economic viability</td>
<td>5/5</td>
<td></td>
</tr>
<tr>
<td>Sand quality</td>
<td>Usable for mould production</td>
<td>As new</td>
</tr>
<tr>
<td>Waste generated</td>
<td>Dry dust</td>
<td></td>
</tr>
</tbody>
</table>

Key: 5/5 = Most favourable; 1/1 = Least favourable

*Table 5 Reclamation techniques for alkaline phenolic bonded sand*
3.3 PHENOLIC URETHANE BONDED SAND

This totally organic binder system poses no major problems for reclamation. The binder decomposes on exposure to heat, so a certain amount of thermal reclamation occurs during casting. Low-energy attrition or particulation is capable of achieving approximately 80% reclamation. This upper limit is due to the build-up of volatiles in the sand, which requires dilution with new sand.

Wet attrition is not feasible because the binder is insoluble.

Thermal reclamation is viable, provided that any iron oxide present is first removed by magnetic separation. Iron oxide is sometimes added to this binder system to reduce casting defects. Failure to remove iron oxide can result in the production of large quantities of low-melting point materials during reclamation. This leads to a loss of refractoriness in the reclaimed sand, causing poor mould quality.

New sand additions can generally be limited to approximately 8%.

Table 6 summarises the options available for the reclamation of phenolic urethane bonded sand.

<table>
<thead>
<tr>
<th></th>
<th>Primary reclamation</th>
<th>Secondary reclamation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry attrition</td>
<td>High-intensity</td>
</tr>
<tr>
<td>compatibility</td>
<td></td>
<td></td>
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<tr>
<td></td>
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<tr>
<td></td>
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</tr>
<tr>
<td>Sand quality</td>
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<tr>
<td></td>
<td>mould production</td>
<td></td>
</tr>
<tr>
<td>Waste generated</td>
<td>Dry dust</td>
<td></td>
</tr>
</tbody>
</table>

Key: 4/4/4/4 = Most favourable; 3 = Least favourable

*Table 6 Reclamation techniques for phenolic urethane bonded sand*
3.4 RESIN SHELL SAND

Foundries using small quantities of resin shell sand can return the used sand to the main sand system without any major problems. This is because the thin section shells tend to self-reclaim during casting because of degradation of the chemical bond on heating. Despite this, most UK foundries using resin shell moulds based on silica sand do not reclaim this material. However, this sand could be reclaimed by a thermal process and subsequently recoated with resin either in-house or at a central recoating facility. The reclamation of zircon sand, which is more expensive than silica sand, offers greater economic benefits. Not only is it more thermally stable and refractory than silica sand, but supplies of zircon sand are often difficult to obtain.

Thermal reclamation - combined with recoating - is the only viable method for the recovery of resin shell sands (see Table 7).

<table>
<thead>
<tr>
<th></th>
<th>Primary reclamation</th>
<th>Secondary reclamation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry attrition</td>
<td>High-intensity attrition</td>
</tr>
<tr>
<td>Technical compatibility</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Capital cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economic viability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste generated</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key: / / / / / = Most favourable; ✓ = Least favourable

Table 7 Reclamation techniques for resin shell sand
3.5 SODIUM SILICATE BONDED SAND

Reclamation of sodium silicate bonded sands tends to be unpopular due to high capital and operating costs. The binder does not degrade thermally during casting and only 10% is removed during particulation. New sand (typically 20 - 25%) has to be added to the reclaimed sand to control the level of sodium oxide and thus avoid its embrittling effect on the rebonded material.

At mould face temperatures above 600°C, the binder forms a glass on the sand grains leading to a loss of refractoriness in the reclaimed sand. In addition, the residual binder present on the sand grains dehydrates new binder additions and thus reduces the setting time. As the binder does not degrade with temperature, thermal reclamation alone is not a viable option. However, the glassy substance that forms around the grains on heating is easy to subsequently remove by attrition.

Likewise, use of attrition alone requires the sand to be pre-dried. However, the additional cost of firing to a higher temperature (above 120 - 130°C) may be offset by the increased removal of the binder (as a glass) and higher recovery rates (typically 80%).

Wet reclamation has been used successfully to remove all of the sodium silicate from bonded sand. This eliminates the problem of dehydrating the new bond and allows a higher level of reclamation (about 90%) to be achieved. However, the reclaimed sand has to be dried before use. In addition to the high capital and operating costs, the waste streams produced by wet reclamation - a wet sludge and an alkaline liquor - require careful handling and disposal.

Table 8 summarises the options available for the reclamation of sodium silicate bonded sand.

<table>
<thead>
<tr>
<th></th>
<th>Primary reclamation</th>
<th>Secondary reclamation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-drying and dry attrition</td>
<td>High-intensity attrition</td>
</tr>
<tr>
<td>Technical compatibility</td>
<td>⚫⚫⚫</td>
<td>x</td>
</tr>
<tr>
<td>Capital cost</td>
<td>⚫⚫⚫</td>
<td></td>
</tr>
<tr>
<td>Operating costs</td>
<td>⚫⚫⚫</td>
<td></td>
</tr>
<tr>
<td>Economic viability</td>
<td>⚫⚫⚫</td>
<td></td>
</tr>
<tr>
<td>Sand quality</td>
<td>Usable for mould production</td>
<td></td>
</tr>
<tr>
<td>Waste generated</td>
<td>Dry dust</td>
<td></td>
</tr>
</tbody>
</table>

Key: ⚫⚫⚫⚫⚫ = Most favourable; ⚫ = Least favourable

Table 8 Reclamation techniques for sodium silicate bonded sand
3.6 GREENSAND

3.6.1 Primary reclamation

Most greensand foundries have traditionally carried out primary reclamation using batch or continuous mills, magnetic separators, rotary screens, etc. However, new sand must be added to the reclaimed sand to counteract the build-up of ‘dead’ materials (clay and spent carbonaceous materials), contaminants and fines in the system. Furthermore, the addition of spent sand from cores results in an excess of primary reclaimed sand requiring storage.

To increase the use of reclaimed sand and minimise the purchase of new sand, it is possible to use secondary reclamation to return the sand to a quality as good as, or better than, new sand. The reclaimed sand can then be used for coremaking. The reclamation process must also be able to deal with residual chemical binders from the cores (frequently a considerable percentage of the total spent sand).

3.6.2 Secondary reclamation

The main options available for the secondary reclamation of greensand are high-intensity dry attrition (often combined with fluidised bed calciners) or wet reclamation techniques.

Simple dry attrition is not a suitable method of secondary reclamation for greensand as it is not sufficiently intensive to remove the ‘dead’ clay and coal-dust present in the spent sand.

Wet reclamation is an efficient method of removing ‘live’ clay, coal-dust, coal-dust substitutes and alkaline materials, eg those left over from alkaline phenolic cores. Combining wet reclamation with a calcining treatment at 775°C improves efficiency, but additives are sometimes necessary to deactivate any residual ‘live’ clay and make it easier to remove. In addition to the process's high capital and operating costs, the effluent and clay/coal-dust sludge generated have to be monitored and controlled.

More aggressive attrition processes, eg high-intensity or rotary mechanical scrubbers, are now available. High-intensity attrition tends to leave a residue of clay (up to 0.7%) on the sand grains, thus making them unsuitable for coremaking. However, ways of improving clay removal are being developed. Rotary mechanical processes and pneumatic attrition are successful in mechanically stripping the coal-dust, clay and chemical binders from the sand grains. Such reclaimers are often preceded by a fluidised bed calciner operating at 750 - 800°C; this has the advantage of rendering the clay inactive and removing any residual organic binders from entrained core materials. Subsequent mechanical scrubbing requires less energy and is more efficient. This mechanical cleaning can be carried out in fluidised beds that also operate as sand coolers.

When the spent sand contains alkaline phenolic core materials, it may be necessary to use additives in the fluidised bed to prevent fritting of the sand grains. Unless the quantity of fritted particles is large, this is not a major problem as the particles should be removed in the classification process. However, fritting increases the pH of the sand, which can affect the subsequent bond strength and bench life of the rebonded core sand.

Any thermal reclamation process must be able to take into account variations in the LOI value of the sand mix.

Table 9 summarises available techniques for greensand reclamation.
<table>
<thead>
<tr>
<th></th>
<th>Primary reclamation</th>
<th>Secondary reclamation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Continuous or batch milling</td>
<td>High-intensity attrition</td>
</tr>
<tr>
<td>Technical compatibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital cost</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economic viability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand quality</td>
<td>Usable as greensand</td>
<td>Usable as greensand</td>
</tr>
<tr>
<td>Waste generated</td>
<td>Excess system sand Fine dust Sludge</td>
<td>Dry dust</td>
</tr>
</tbody>
</table>

Key: 55555 = Most favourable; 1 = Least favourable

*Table 9 Reclamation techniques for greensand*
The primary objective of every foundry is to produce consistently good-quality castings for least cost. The main reason for optimising sand management and installing reclamation equipment is usually to reduce operating costs. If the cost benefits of reclamation are significant, any minor technical complications associated with controlling and using the reclaimed sand are generally acceptable.

Sand reclamation produces cost savings for foundries through:

- reduced purchases of new sand;
- reduced disposal of spent sand.

These savings have to be offset by the costs of:

- providing the necessary capital investment;
- operating the reclamation plant;
- plant maintenance and repair;
- any process modifications, eg sand quality, grain size or changing to a different binder system with a greater potential for reclamation - these costs are generally low.

To be economically viable, the reclamation process must produce significant savings in annual operating costs and an acceptable payback on capital investment. For most foundries, the savings on new sand purchase and waste disposal are so large as to outweigh other considerations.

Upgraded binder system produces extra savings

Having installed a mechanical reclamation plant, J Youle & Co Ltd worked in partnership with its binder supplier to gradually increase the level of sand reclamation. A detailed analysis of the sand quality was carried out and resin/hardener rates adjusted to produce optimum performance. A 70% reclamation level was successfully achieved while reducing resin addition rates from 1.65% to 1.5%. Towards the end of the planned programme, the Company upgraded its alkaline phenolic binder system to one specifically designed for high reclamation levels. The type of virgin silica sand was also changed to maintain sand strength. These changes enabled the foundry to increase its reclamation level to 80% while maintaining mould quality.

The additional costs (new binder system, equipment operation and finance costs) of over £3 500/year were more than offset by cost savings of nearly £25 000/year from a reduced need for virgin sand and lower disposal costs. The net annual cost savings gave a payback on the Company's investment of around 18 months.

For more details, see Good Practice Case Study (GC99) *Small Foundry Benefits from Investment in Sand Reclamation*, available free of charge through the Environmental Helpline on 0800 585794.
4.1 HOW MUCH COULD YOUR FOUNDRY SAVE WITH PRIMARY RECLAMATION?

In 1994, a survey\(^2\) carried out for the Environmental Technology Best Practice Programme found that about half of the UK foundries using chemically bonded sand practised primary reclamation. These foundries achieved, on average, substantial cost benefits initially of over £15/tonne, rising to £27/tonne after repayment of capital (see Table 10).

If your foundry does not already reclaim its sand, enter your foundry’s details in the right-hand column of Table 10. This will allow you to estimate the savings your foundry could achieve for each tonne of sand through primary reclamation.

<table>
<thead>
<tr>
<th></th>
<th>Cost/tonne of sand</th>
<th>Your foundry’s details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of silica sand</td>
<td>£20.40</td>
<td>£........................</td>
</tr>
<tr>
<td>Cost of waste sand disposal (including landfill tax @ £2/tonne(^\ast))</td>
<td>£11.10</td>
<td>£........................</td>
</tr>
<tr>
<td>Total cost of sand purchase and disposal (A)</td>
<td>£31.50</td>
<td>£........................</td>
</tr>
<tr>
<td>Estimated depreciation cost to recoup equipment expenditure in one year (B)</td>
<td>£11.40</td>
<td>£11.40</td>
</tr>
<tr>
<td>Operating costs(^\ast) (C)</td>
<td>£4.85</td>
<td>£4.85</td>
</tr>
<tr>
<td>Anticipated cost saving in first year</td>
<td>A – (B + C)</td>
<td>£15.25</td>
</tr>
<tr>
<td>Anticipated cost saving in subsequent years</td>
<td>A – C</td>
<td>£26.65</td>
</tr>
</tbody>
</table>

\(^{\ast}\) Average figures obtained from data supplied by survey respondents.

\(^{\ast\ast}\) 1997 rate

Table 10 Cost benefits of primary reclamation

4.2 EVALUATING THE COST BENEFITS OF SAND RECLAMATION

The cost of sand reclamation depends on a number of factors, including:

- the type of reclamation plant chosen;
- the cost of new sand;
- the cost of operating the reclamation plant;
- the cost of disposing of waste sand (in the absence of a reclamation facility);
- the cost of disposing of waste(s) from the reclamation plant;
- the method by which the capital cost of the plant is to be financed;
- the cost of any loans needed to fund equipment purchases.

All of these factors need to be considered as part of the assessment of the potential benefits of sand reclamation.

Each foundry’s circumstances are unique. Before embarking on a sand reclamation project, collect data on all the costs and benefits and carry out a financial appraisal of the project.

Good Practice Guide (GG82) *Investing to Increase Profits and Reduce Wastes* explains how to use investment appraisal techniques to select the option with the most financial benefit. The Guide, which includes a simple worked example and Industry Examples, is available free of charge through the Environmental Helpline on 0800 585794.

\(^2\) The survey results are reported in Environmental Performance Guide (EG4) *Chemically Bonded Sand: Use and Reclamation*. This survey is being repeated during 1998.
4.3 EXAMPLE COST SAVINGS

The two examples below show the cost savings and payback achieved by two UK foundries. Their applicability to other foundries will, of course, depend on the technical requirements and the level of reclamation achievable. The examples use the average cost of silica sand and waste sand disposal given in Table 10, and assume a landfill tax rate of £2/tonne.

4.3.1 Primary reclamation

A foundry using alkaline phenolic bonded sand investigated the cost benefits of installing a primary attrition unit costing £30 000. The foundry operates for eight hours/day, five days/week for 46 weeks/year, ie 1 840 hours/year. Plant operating costs are average costs taken from Environmental Performance Guide (EG4). Table 11 shows that the net annual savings would be over £147 108/year, giving a payback of only 2.5 months.

Hillsyde Foundry decides the time is right to invest in thermal reclamation

Although Hillsyde Foundry in Staffordshire had decided in 1990 that the payback period on installing a thermal reclamation unit was too long, the foundry was aware that secondary reclamation could become viable if sand disposal costs increased significantly. The foundry therefore kept abreast of developments in thermal reclamation.

In February 1995, Hillsyde faced a doubling of its disposal costs for waste sand from £9/tonne to £17.75/tonne and the introduction of the landfill tax. When the increase in disposal costs was incorporated into the investment appraisal for a thermal reclamation unit, the payback period dropped significantly. In February 1996, Hillsyde therefore installed a 3 tonnes/hour thermal reclamation unit at a cost of £215 000. With a throughput of 100 tonnes/week of sand, thermal reclamation allowed the foundry to save £134 550/year, giving a payback period of 1.6 years. When the additional cost of the landfill tax (£2/tonne) was included in the investment appraisal in October 1996, the payback period fell slightly to 1.5 years. However, had the higher rate of landfill tax (£7/tonne) been imposed, then the payback period would have been 1.3 years.

For further details, see Industry Example 2 from Good Practice Guide (GG82) Investing to Increase Profits and Reduce Wastes.

### Table 11 Example cost savings from installing a primary attrition unit

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant throughput</td>
<td>3 tonnes/hour</td>
</tr>
<tr>
<td>Sand use</td>
<td>5 520 tonnes/year</td>
</tr>
<tr>
<td>Cost of silica sand</td>
<td>£20.40/tonne</td>
</tr>
<tr>
<td>Cost of waste sand disposal</td>
<td>£11.10/tonne</td>
</tr>
<tr>
<td>Total cost of sand purchase and disposal</td>
<td>£31.50/tonne</td>
</tr>
<tr>
<td>Plant operating costs:</td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>£0.98/tonne</td>
</tr>
<tr>
<td>Labour</td>
<td>£2.80/tonne</td>
</tr>
<tr>
<td>Maintenance</td>
<td>£1.07/tonne</td>
</tr>
<tr>
<td>Total operating costs</td>
<td>£4.85/tonne</td>
</tr>
<tr>
<td>Net cost saving</td>
<td>5 520 x (31.50 - 4.85) = £147 108/year</td>
</tr>
<tr>
<td>Capital cost</td>
<td>£30 000</td>
</tr>
<tr>
<td>Payback</td>
<td>2.5 months</td>
</tr>
</tbody>
</table>
4.3.2 Secondary reclamation

A foundry using furan bonded sand investigated the cost benefits of installing a thermal reclamation unit costing £105 000. The foundry, which operates for 46 weeks/year, already has a primary reclamation unit. Of the sand in the system, 5% is deemed unacceptable for further processing and is disposed of as waste. Operating costs for the thermal reclamation unit are assumed to be those indicated in the plant specification supplied by the equipment manufacturer. Labour requirements are assumed to be negligible, while annual maintenance is not included in the calculation.

Table 12 shows that the net annual savings would be over £94 000/year, giving a payback of less than 14 months.

With the help of a bank loan secured with a detailed business plan based on this information, the Company bought a vibratory attrition unit at a cost of £32 390 and now reclaims 80% of the 1 000 tonnes of sand used annually. Despite having to repay the bank loan at 9.5%, the project realised cash benefits for the Company during each year of the loan. The reduced need for virgin sand and lower disposal costs saved the foundry £14 400/year and £10 060/year respectively (1996 prices). Operating and other costs of £3 560/year reduced the net cost saving to £20 900/year, giving a payback of less than 19 months.

For more details, see Good Practice Case Study (GC99) Small Foundry Benefits from Investment in Sand Reclamation. This publication is available free of charge through the Environmental Helpline on 0800 585794.

Thermal reclamation virtually eliminates sand purchase and disposal

Triplex Alloys Ltd uses phenolic urethane binder systems on its two moulding lines and in the coreshop. Although the foundry practised primary reclamation, it still required 75 tonnes/week of new sand, costing £58 000/year and spent £24 500/year on disposing of used sand to landfill. Prompted by increasing sand purchase and waste disposal costs, the foundry decided, in 1994, to invest in a prototype thermal reclamation unit costing £30 000.

Extensive testing showed that the thermally reclaimed sand was technically acceptable and of a similar quality to new sand in terms of performance in moulding and casting operations. Although thermal reclamation cost £3.96/tonne (£13 700/year), the net cost saving for the foundry's requirement of 75 tonnes/week of sand was £68 000/year (1994 prices). The payback period for the prototype unit was less than six months. However, it is estimated that, at 1994 prices, a production unit installed at a site similar to Triplex Alloys would cost about £48 000 and have a payback period of less than nine months.

For more details, see Good Practice Case Study (GC3) Sand Costs Reduced by Thermal Reclamation, available free of charge through the Environmental Helpline on 0800 585794.
<table>
<thead>
<tr>
<th>Plant throughput</th>
<th>1 tonne/hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand use</td>
<td>3,680 tonnes/year</td>
</tr>
<tr>
<td>Weight of sand processed</td>
<td>3,496 tonnes/year</td>
</tr>
<tr>
<td>Cost of silica sand</td>
<td>£20.40/tonne</td>
</tr>
<tr>
<td>Cost of waste sand disposal</td>
<td>£11.10/tonne</td>
</tr>
<tr>
<td>Total cost of sand purchase and disposal</td>
<td>£31.50/tonne</td>
</tr>
<tr>
<td><strong>Total cost savings through avoided sand purchase and disposal</strong></td>
<td><strong>£110,124/year</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plant operating costs:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas (293 kWh/tonne @ 1.02 pence/kWh)</td>
<td>£1.76/tonne</td>
</tr>
<tr>
<td>Electricity (40 kWh/tonne @ 4 pence/kWh)</td>
<td>£1.60/tonne</td>
</tr>
<tr>
<td><strong>Total plant operating costs</strong></td>
<td><strong>£3.36/tonne</strong></td>
</tr>
<tr>
<td>(3,496 tonnes/year)</td>
<td></td>
</tr>
<tr>
<td><strong>Total operating costs (energy and sand)</strong></td>
<td><strong>£17,543/year</strong></td>
</tr>
<tr>
<td><strong>Net annual savings</strong></td>
<td><strong>£92,581</strong></td>
</tr>
<tr>
<td><strong>Capital cost</strong></td>
<td>£105,000</td>
</tr>
<tr>
<td><strong>Payback</strong></td>
<td>13.6 months</td>
</tr>
</tbody>
</table>

*Table 12 Example cost savings from installing thermal reclamation*
5.1 ACTIONS TO REDUCE SAND COSTS

5.1.1 General
- Review contracts for the purchase of sand, binders and additives.
- Review delivery/transport arrangements.
- Train operators to keep strike-off sand to a minimum.
- Minimise sand-to-liquid metal ratios.
- Increase metal yield by improved methoding.
- Wherever possible rationalise on binder systems.

5.1.2 Chemically bonded sand
- For sand mixes, introduce:
  - a regular calibration regime or, preferably, positive monitoring and control over binder system component delivery;
  - lockable controls to prevent unauthorised adjustment.
- For gas-cured systems:
  - introduce gas flow controls;
  - ensure gas tightness of equipment.
- Consider facing sand/backing sand arrangements.

5.1.3 Greensand
- Examine new sand addition rates and reduce as much as possible, preferably to less than 2%.
- Consider using a unit sand system to reduce the consumption of new sand.
- For sand mixes, introduce a regular calibration regime for additive mixing equipment, supplemented by a regular sand testing programme.

5.2 ACTIONS TO REDUCE SAND USE

Cost savings can be achieved by a reduction in sand use per tonne of castings produced. Every effort should therefore be made to reduce sand-to-liquid metal ratios. As several of the measures suggested in the action list below will reduce mould strength, **it is important to evaluate fully any proposed changes before they are implemented.**

5.2.1 General
- Ensure that mixer types/capacities equate with mixed sand demand.
- Train operators to keep strike-off sand to a minimum.
- Increase metal yield by improved methoding. This will allow better use of moulding box space, provide more efficient feeding systems and reduce scrap and waste sand levels.
5.2.2 Chemically bonded sand

Minimise sand-to-liquid metal ratios by:
- Using shaped boxes that follow casting contours more closely.
- Blocking-in box corners (where appropriate) to reduce the amount of sand required.
- The judicious use of ‘loose pieces’ and inserts to hollow out the mould in non-critical areas.
- Reviewing wall thickness and, in particular, the amount of sand beneath the casting. The use of reinforcing wires or bars may be preferable to excessively thick walls.
- Incorporating lumps of waste sand as a backing material to fill space and reduce binder consumption. An alternative is to use metal spheres cast with metal that would normally be pigged. These spheres must, however, be confined to sand away from the pattern face.

5.2.3 Greensand

Consider changing to a unit sand system as this uses less new sand than a facing sand/backing sand approach. However, steel foundries should review casting quality as well as mixed sand properties.

Use any additives in the most cost-effective manner as additive costs are significant, even in the relatively small quantities used.

Check the quality of sand at the greensand mixer regularly, either manually in small operations or using automatic sensors to check each mix in continuous operations.

5.3 ACTIONS TO IMPROVE WASTE SAND MANAGEMENT

Evaluate primary reclamation techniques (if not already adopted).

Optimise primary reclamation.

Consider secondary reclamation where primary reclamation is already used.

Use the highest amount of reclaimed sand possible in the sand mix.

Ensure hopper capacity is sufficient to enable the maximum use of reclaimed sand.

When both primary and secondary reclamation have been optimised, examine options for beneficial re-use of the waste sand (see Section 6).

Ensure there is a convenient way to remove waste from the sand system.

Segregate waste sand classified as inactive for the purposes of the landfill tax from general waste such as wood, paper and packaging that attracts the higher rate of tax. Any mixed loads of unsegregated wastes will also be charged at the higher rate.

Review waste handling to ensure that materials classified as inactive do not become contaminated with hazardous materials, e.g., many binder chemicals. All of such waste will then have to be disposed of - at a much higher cost - as special waste.

5.4 PRACTICAL STEPS FOR BEST PRACTICE IN SAND MANAGEMENT AND RECLAMATION

Keep foreign objects and other contaminants out of the sand system as they will ultimately clog the distribution system, leading to downtime.

Reduce binder additions to the optimum level, making use of supporting frames if necessary. Computer-controlled binder systems allow foundries to operate at lower binder levels, while maintaining adequate mould strength.
If the moulds are large enough, consider facing with a relatively high binder content sand and backing with a sand with a lower binder level. In this way, the two-thirds of the sand that receives the least heat input contains less binder to remove during reclamation. This approach works best when a zero retention mixer is used.

Consider reducing the overall amount of binder used per mould by filling space well away from the pattern face with lower quality material, eg:

- Place lumps of waste sand (up to 5 cm across) from previous moulds in the corners of the moulding box.
- Gather up core butts and other ‘lumps’ from a mechanical attrition unit or even the shakeout and throw this material into the box as the bonded sand is applied.
- Put 3.5 - 7.5 cm steel spheres (cast with surplus metal or pig metal) in the mould. In a vibratory shakeout unit, these spheres help break the mould apart and also act as ‘hammers’ in breaking up sand lumps on the vibrating deck. Lump reduction is speeded up and the spheres can be recycled. However, care should be taken not to ‘over-vibrate’ during compaction or the spheres will sink to the parting line.

Reduce sand-to-metal ratios by removing unnecessary sand. This may include:

- ‘cutting corners’, using loose pieces, not moulding the cope to the full height of the box, or using inserts to hollow out the mould in non-critical areas;
- using wires and rods for judicious reinforcement rather than thicker walls created by adding thicker sand sections;
- reviewing the thickness of the bottom mould to avoid the use of deeper drags than necessary.

When implementing these practices, be sure to add generous radii; sharp corners will concentrate stresses - both thermally induced and from handling - causing the mould to crack, sometimes prematurely.

Delay shakeout for as long as practicable to achieve maximum burn-out of the binder; self-reclamation is the most effective of all reclamation techniques.

Consider breaking the moulds in a conveyor, leaving the castings on top of the sand to cool and thus release heat into the sand below. This minimises shakeout damage and helps burn out more binder. However, a way of recovering the ‘burnt’ sand and adequate sand cooling capacity in the reclamation plant are required.

Do not overload the reclamation unit as all reclamation systems work within a reasonably tight loading range. Use load cells or measure motor current to sense when to add more sand, and then add it incrementally. If necessary, use surge hoppers.

Do not overlook the need for anti-segregation devices in the sand system to maintain both the sand grain size distribution and minimum binder additions.

Pay particular attention to the classification and de-dusting of sand in the reclamation process. Ensure optimum performance by:

- Using a dedicated and properly maintained dust collector.
- Monitoring pressure drops and air flow rates.
- Using control charts to record the waste removed from the dust collector in terms of weight of dust/tonne of sand processed. Fluctuations and/or trends will reflect operational changes and allow corrective action to be taken before a major problem arises.

If you require a reclamation plant with a throughput of more than 5 tonnes/hour, consider installing two or more smaller units, running in parallel, rather than one larger one. In addition to possible cost advantages, this will allow production to continue in the event of a shutdown in one of the units. It also allows for the operation of a single unit during periods when the foundry is operating at less than full capacity.
Pay attention to plant design and installation, eg:
- Install large bolt doors to allow access to the ductwork.
- Ensure that there are aisles that can accommodate the containers needed if the unit has to be emptied.
- Monitor areas of potential sand build-up in the ductwork, eg low pressure points. These can fill with sand, sometimes causing them to collapse.

Move sand around the foundry carefully, eg:
- use air slides instead of elevators, and pneumatic transporters rather than conveyor belts;
- use dense phase pneumatic sand transporters that do not degrade the sand significantly as it is moved from the reclamation plant to its point of use;
- design units with fool-proof transfer points to keep sand in the system and off the floor;
- enclose the system to prevent losses and keep work areas clean - in the long run this is cheaper than using brooms and shovels.

5.5 ACTIONS TO IMPROVE SAND STORAGE

Correct storage of sand is important to ensure that the sand supplied to the mixers is of a consistent quality.

5.5.1 General
- Keep silos sealed and waterproof to prevent ingress of water. Excessive moisture in sand can result in delayed strip times, mould distortion on stripping and, in extreme cases, prevention of curing. Phenolic urethane systems are particularly sensitive to these effects.
- Protect storage facilities, including internal hoppers, from contamination by foreign objects that may obstruct the flow. Any delay in detecting contamination can lead to a production run of sub-standard moulds or cores.
- Check the effectiveness of the dust removal system by measuring the quantity collected. Delivered sand contains about 0.5% dust, so about 5 kg of dust should be collected for each tonne supplied.

5.5.2 Measures to minimise segregation

Whenever sand is moved or handled, there is the potential for segregation to occur. The wider the grain size distribution within the sand, the more pronounced will be the effect. This is one of the reasons why a narrow spread in grain size is recommended.

Where segregation does occur, the effect on mould and core quality can be considerable. Because the sand discharged from the silo will vary in particle size distribution, the effectiveness of binder additions will change. Finer sands require higher addition rates. Coarse sand is more prone to penetration and erosion by molten metal.

The greatest segregation problems occur where small volumes of sand are discharged, as is the case with continuous mixers and small batch mixers. With a batch mixer, the result will be the production of an occasional bad batch of sand. With continuous mixers, the result will be a striated mould or core, containing layers of strong and weak sand.

Filters are often positioned on top of silos to enable the collected dust to be discharged directly back into the silo, eliminating the need for handling and disposal. However, this practice creates a major segregation problem as a layer of fines is deposited in the silo every time the filter is shaken down. To avoid segregation, filters should either be positioned below the silo or be designed to permit discharge to a dust waste collection bin.
**Hopper design**

Any segregation effects in the hopper will be directly reflected in the sand discharged by the mixer. Segregation can be minimised by good hopper design (see Fig 6) and by observing the following guidelines.

- Use tall, narrow hoppers with an acutely angled conical base (see Fig 6a).
- Ensure that the discharge opening is as large as possible, permitting discharge on a ‘first in, first out’ basis.
- For existing squat hoppers, minimise segregation during charging by using more than one feed point. In this way, the top surface of the sand will remain reasonably level.
- Where space constraints allow only a single feed, position the inlet in the centre. Use a conical distributor below the inlet to spread the incoming sand (see Fig 6b) or use a tangential feed from a blowing system.
- Ensure unrestricted flow by avoiding internal projections and by using low-friction coatings.

![Fig 6 Storage hopper design](image)

For further advice on all aspects of sand management and reclamation, contact the Environmental Helpline on 0800 585794.

The Environmental Helpline can also:

- arrange for you to be sent other relevant Environmental Technology Best Practice Programme publications;
- tell you about relevant environmental and other regulations that could affect your operations;
- arrange for a specialist to contact your company free of charge if you employ fewer than 250 people.
Even after primary and secondary reclamation has been optimised, a foundry may still be left with some waste sand. However, the beneficial re-use of waste sand and other foundry by-products is attracting increasing interest in the UK.

Arrangements for beneficial re-use vary according to the foundry's location and circumstances, the particular by-product, availability, and the volume involved. The main types of arrangement are:

- one-to-one, ie an agreement between the foundry and a single local user;
- many-to-one, ie material is collected by a large end user from a number of foundries;
- all-for-one, ie co-operation between a group of foundries in an area with a high concentration of foundries, to supply one or more users.

The various applications for the re-use of waste sand are increasingly providing ways in which foundries - small as well as large - can reduce their waste disposal costs and achieve other benefits. Other foundry by-products, eg metallic slags and spent refractories, may also be suitable for beneficial re-use.

6.1 POSSIBLE APPLICATIONS FOR THE RE-USE OF WASTE SAND

6.1.1 Waste sand re-use in the manufacture of asphalt

Both chemically bonded sand and greensand can be used in the manufacture of hot rolled asphalt (HRA) and macadam. The following Case Study describes the savings made by a greensand foundry and an asphalt manufacturer in a recent collaborative venture.

**Waste sand sets scene for profitable partnership**

Precision Disc Castings Ltd (PDC), a greensand foundry producing brake discs for the automotive industry, uses recycled sand to make moulds. However, PDC still has to buy approximately 10 000 tonnes/year of virgin sand to make cores because the recycled sand is not of suitable quality. To maintain the balance of the sand system, an equivalent amount of used sand, fines and dust was sent to landfill, at a cost of around £100 000/year. However, when PDC examined the possibility of installing a sand reclamation system, it found that this option was not economic for its site.

PDC therefore approached a local company, Tarmac Quarry Products Ltd, with a proposal to replace part of the fine aggregate used in asphalt manufacture with spent greensand. Following a feasibility study and operational testing, full-scale production of asphalt using foundry greensand began in March 1997. Minor modifications were necessary at both plants. Tests have shown that the quality of Tarmac’s products is unaffected by using foundry greensand and that the products meet all relevant BSI standards.

Both companies have achieved significant net cost savings, with reduced waste sand disposal costs for PDC and reduced raw material costs for Tarmac. In addition, there are environmental benefits through a reduced need for quarrying, landfill and raw material transportation. Table 13 shows the savings, costs and payback achieved by PDC and Tarmac re-using 9 000 tonnes of greensand per year.
Table 13 Savings, costs and payback

<table>
<thead>
<tr>
<th>Precision Disc Castings Ltd</th>
<th>Tarmac Quarry Products Ltd</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual savings</strong></td>
<td></td>
</tr>
<tr>
<td>Greensand disposal costs</td>
<td>£90,450 (£10.05/tonne)</td>
</tr>
<tr>
<td>Fine aggregate purchase</td>
<td>£50,850 (£5.65/tonne)</td>
</tr>
<tr>
<td>Transport of sand</td>
<td>£31,500*</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Annual operating costs</strong></td>
<td></td>
</tr>
<tr>
<td>Transport of sand</td>
<td>£31,500**</td>
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<tr>
<td>Annual net savings</td>
<td>£58,950</td>
</tr>
<tr>
<td>Capital cost</td>
<td>£31,105</td>
</tr>
<tr>
<td>Payback</td>
<td>6.3 months</td>
</tr>
<tr>
<td></td>
<td>7.8 months</td>
</tr>
</tbody>
</table>

* Net annual savings from not paying for transport of fine aggregate from a quarry.
** Payable to Tarmac.

For more details, see New Practice Case Study (NC95) Waste Sand Sets Scene for Profitable Partnership.

6.1.2 Waste sand re-use in the manufacture of cement

Waste sand, particularly chemically bonded sand, has considerable potential as a substitute for quarried silica sand in cement manufacture. However, this requires some care as the presence of residual binder and other contaminants in the waste sand can give rise to environmental, processing or quality problems.

The increased risk of phenol releases to water is a particular concern. The waste sand therefore has to be stored carefully and process discharges monitored. Other critical factors include the presence of metals and the alkaline content of the waste sand. Settlement of metallised sand after grinding has been experienced with one chemically bonded sand, while the bentonite content of greensand can give rise to slurry thickening in wet manufacturing processes.

One UK cement works is already authorised to use up to 50% waste foundry sand, ie approximately 2.5% of its total raw material requirement. A covered storage facility prevents leachate and wind-blown sand, while phenol levels in the filtrate from the filter presses used to reduce the water content of the cement slurry are controlled by careful sand selection and testing.

Approval has also been given for another works using the semi-dry cement manufacturing process to use waste foundry sand. Here the main concern was the potential for releases to atmosphere, but emissions of phenol in the stack exhaust have been shown to be insignificant. The main factor affecting the suitability of waste foundry sand in this process is its alkaline content.

6.1.3 Waste sand re-use in the manufacture of clay bricks

Greensand screened to remove lumps and rubbish can be used to produce clay bricks. The sand must be free flowing and have a low metal content. Although the bentonite content of greensand can affect wet-to-dry shrinkage, bricks of acceptable quality can be produced with careful process control. Brick colour after firing is similar to that using quarried sand.

Waste foundry sand can also be used to produce mortar.
6.1.4 Waste sand re-use as aggregate in road construction

Use of waste foundry sand as a substitute for natural aggregate in road construction has a number of economic and environmental benefits. However, sand is not a conventional road pavement construction material and requires some treatment to achieve acceptable mechanical properties. Sand lacks the stiffness and strength of conventional crushed aggregate and, if it gets wet, will tend to become unstable (visible as rutting in the road pavement).

Strategies for using waste foundry sand in road pavement construction usually involve washing to remove fines and adding a small amount of binder, e.g., cement or cement kiln dust. Use of foundry sand tends to be restricted to lower pavement levels where the stress is less and to areas where sub-drainage can be provided. Contamination of surface water and groundwater from substances leached from the waste sand has been a concern although limited experience suggests that it is not a problem. Use of binders to reduce permeability as well as to increase mechanical strength is regarded as the optimum treatment method.

6.1.5 Waste sand re-use in ceramic tile production

Waste foundry sand is one of a range of industrial wastes suitable for use in a new ceramic tile technology developed in Italy. Savings in raw material costs of over 50% are claimed compared to the cost of conventional clay materials for ceramic tile production. Wear-resistant floor tiles with specifications equivalent to porcelain are now available.

6.1.6 Waste sand re-use in horticulture

Waste sand has a number of potential uses in horticultural applications, e.g., as a component of potting compost, as a top dressing to promote plant growth, and for landscaping.

The main barrier to the use of waste foundry sand in horticultural applications is concern about metals and other contaminants that could affect plant growth or enter the food chain. However, preliminary results from experiments in the UK suggest that use of greensand does not adversely affect the growth of five indicator crops, i.e., tomatoes, French beans, maize, barley and oilseed rape. The pH or contaminants present in the greensand may be responsible for the slightly slower germination rates and initial plant growth observed in these experiments compared to a control soil. The nutrient content (phosphorus, potassium, and magnesium) of waste sand proved beneficial to growth and levels of metals in these experiments were not regarded as a problem. Experiments are also being performed using furan bonded sand, resin shell sand, and alkaline phenolic bonded sand.

In the USA, waste sand has been successfully used as a plant growth media for nursery production of roses, trees, shrubs, and garden annuals. A mixture of 60% top soil, 30% foundry sand and 10% composted garden waste has reportedly produced better results than standard field soil. Research also found that greenhouse geraniums grow as well, or better, in potting mixtures containing waste foundry sand than in control mixtures. Tests indicate that better plant growth is obtained with mixtures of 50% soil and 50% foundry sand than with 100% foundry sand.

Landscaping applications generally use greensand. However, large volumes of waste sand - free from rubbish and metals - are required. Phenol and metal leaching are particular problem areas.

The demand for waste foundry sand for top dressing and other horticultural applications can be seasonal.
6.1.7 Waste sand re-use to improve soil drainage

Foundry greensand is currently being evaluated in the USA as a method of permanently modifying the surface texture of poorly drained agricultural soils. Excess surface water on poorly drained farmland with a high clay content often leads to delays in spring planting, with resulting problems at harvest time. The potential exists to use large amounts of spent foundry sand to reduce the clay content of such soils from 28 - 40% to about 25%. This would enable crop planting to start significantly earlier.

Crop yields and the metal content of plants grown on sample plots were similar to those from untreated control plots. Experiments to determine the optimum amount of sand that can be applied are currently being performed. Sand will be applied over a number of years to alter soil properties gradually.

Application to the fields can be carried out directly from flat-bed trucks and no prior processing of the waste sand is required.

6.1.8 Other opportunities to re-use waste foundry sand

These include:

- as hardcore or backfill;
- concrete blocks;
- landfill permanent lining and daily cover;
- roofing felt;
- glass wool production;
- waste vitrification.
The Environmental Technology Best Practice Programme is a joint Department of Trade and Industry and Department of the Environment, Transport and the Regions programme. It is managed by AEA Technology plc through ETSU and the National Environmental Technology Centre.

The Programme offers free advice and information for UK businesses and promotes environmental practices that:

- increase profits for UK industry and commerce;
- reduce waste and pollution at source.

To find out more about the Programme please call the Environmental Helpline on freephone 0800 585794. As well as giving information about the Programme, the Helpline has access to a wide range of environmental information. It offers free advice to UK businesses on technical matters, environmental legislation, conferences and promotional seminars. For smaller companies, a free counselling service may be offered at the discretion of the Helpline Manager.

FOR FURTHER INFORMATION, PLEASE CONTACT THE ENVIRONMENTAL HELPLINE

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world wide web: http://www.etsu.com/etbpp/