PINHOLE DEFECTS

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From the B.C.I.R.A. Lecture Course on Defects in Grey Iron Castings

In recent years the pinhole defect has become much more prevalent, particularly in mechanized foundries making medium to small grey iron castings, such as automobile parts. The prime cause of the defect is the presence of a trace of aluminium in the iron and some of the sources of this aluminium and some methods of minimizing the tendency for pinholing to occur will be outlined in this paper.

Identification of pinholes—For the benefit of the people who are lucky enough never to have seen pinholing, the defects are shown in Fig. 1. They are small, more or less round holes about \( \frac{1}{8} - \frac{1}{4} \) in dia. They lie just below the surface skin of the casting and, unfortunately, they are rarely found when the casting is knocked out and lightly shotblasted to remove the sand. If the casting is annealed and exposed to a second, heavier shotblasting process, then it is likely that the pinholes will be revealed at this stage. But, as more frequently happens, the castings appear sound when they leave the foundry and the pinholes are not found until the castings are machined by the customer (Fig. 2) some weeks or even months later. This usually results in a large number of castings being returned to the foundry, and the foundryman then spends a great deal of time breaking up current castings to ensure that he is not still producing defective castings.

Pinholes have a particular feature which makes them fairly easy to distinguish from other types of defect. This is the presence of a continuous layer of graphite which lines the inside surface of the majority of the holes in as-cast irons (Fig. 3). This thin skin can be peeled off the surface and often remains as a complete 'bag' in one half of a fractured pinhole, while the other half has a bright metallic silvery appearance. When a pinholed casting is machined, the inside of the pinhole has a shiny black finish, rather like an old-fashioned black-leaded grate.

The position and shape of the defects and the presence of the graphite film indicates three important points:

1. The rounded shape suggests that they are bubbles of some gas and not a form of shrinkage;
2. The graphite film shows that the gas must be of an inert or reducing nature in order not to oxidize away the graphite film. It has been shown in the laboratory that if a sample is either melted and solidified, or just annealed in a dry atmosphere of hydrogen, nitrogen or argon, or in vacuum, then a layer of graphite very similar to that found in pinholes will form over the surface of the sample;
3. The position of the defects just below the skin of the casting suggests that the gas is the result of a mould/metal reaction.

Cause of pinholing—The most likely mould constituent to react with molten metal is water vapour. A method of assessing the tendency to pick up gas from a sand mould has been developed at the Association and is illustrated in Fig. 4. To obtain a sample which retains the gas content of the liquid metal, the sample moulds are made of graphite. Metal is cast into the first graphite mould direct from the ladle, and this gives a measure of the gas content of the metal in the ladle. A second chill mould is cast by pouring the metal through the green sand mould into the graphite chill. The difference in gas content between the first sample and
Fig. 1
Casting with pinholes revealed by fracturing.

Fig. 2
Casting with pinholes revealed by machining.
the second is a measure of the metal's tendency to pick up gas from this particular mould. Obviously, the results obtained are only representative of this particular mould, as the shape of the cavity and area of sand traversed will affect the results. However, very useful information was obtained by comparison of the results from these moulds.

From these tests it was immediately obvious that the only gas picked up was hydrogen and that the amount picked up varied very markedly with the presence of certain minor elements in the iron. Table 1 shows typical results. The manganese and magnesium contents are specialized cases and are shown out of general interest. The most important figures are those due to the presence of a trace of aluminium. After making test castings it soon became clear that the presence of these small amounts of aluminium was essential for the production of pinholes and that the high hydrogen pick-up was always associated with pinholes.

### Controlling factors
Several factors have a controlling effect on the tendency of aluminium to produce pinholes. For instance, a small amount of titanium in the iron promotes pinhole formation without having much effect on the hydrogen pick-up. Elements such as manganese and magnesium, which themselves increase the hydrogen pick-up, have a strong promoting effect on

### Table 1

Effect of composition on hydrogen pick-up from sand moulds

<table>
<thead>
<tr>
<th>Manganese, per cent</th>
<th>Magnesium, per cent</th>
<th>Aluminium, per cent</th>
<th>Hydrogen pick-up, cm³/100 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>0·6</td>
<td>0·05</td>
<td>nil</td>
<td>0·4</td>
</tr>
<tr>
<td>2·2</td>
<td>...</td>
<td>0·09</td>
<td>2·8</td>
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<td>0·05</td>
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<td>6·0</td>
</tr>
<tr>
<td>nil</td>
<td>...</td>
<td>...</td>
<td>0·4</td>
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<tr>
<td>0·05</td>
<td>2·5</td>
<td>1·2</td>
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<td>0·01</td>
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<td>0·05</td>
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</tbody>
</table>
pinholing caused by aluminium, without actually producing pinholes themselves.

As the defect is the result of a mould/metal reaction, it is reasonable to assume that the composition of the moulding sand and the design of the mould layout are going to have some effect.

It is essential to maintain an adequate amount of volatile matter in the sand to minimize pinholing. Fig. 5 shows that the presence of coal dust in the sand markedly reduces pinholing, but does not completely overcome it. The same thing applies to pitch in the sand. It is important for the volatile materials to be fresh or 'live.' It is not sufficient for the sand just to appear black.

In one case investigated a foundry was suffering a severe outbreak of pinholing in castings which had been produced successfully for years. Examination of the metal showed that only the meager trace of aluminium was present and that it was unavoidable. The moulding sand appeared quite normal and black. Analysis of the sand showed that the blackness was mostly due to soot and that the useful coal dust content was about 1 per cent. Raising this to about 5 per cent completely overcame the problem in this instance.

Given that the metal picks up the gas from the mould, the farther the metal passes over the sand the more likely are pinholes to occur. This is the reason that many areas of pinholing are found in zones remote from the

![Fig. 5](image)

Coal dust reduces pinholing.

![Fig. 6](image)

Casting layout giving pinholes.

in the ferrosilicon inoculation and inoculant should required chill or iron produced. Potentiometric by addition should not be used to cause pinholing, but produce casting minimum quanta ferrosilicon is used to produce casting, paying attention to the mentioned earlier.

The second method of contaminating the engine is a soil. Many of these are put straight into engines that are fitted with other parts and do not arrive in the engine room. When this occurs, pinholing in the engine occurs.
in the ferrosilicon is sufficient to give good inoculation and the minimum addition of inoculant should be used to obtain the required chill reduction and properties in the iron produced. Major changes in composition by adding ferrosilicon to the ladle should not be undertaken as this is very likely to cause pinholing. If aluminium-free metal is produced from the furnace and only the minimum quantity of the right grade of ferrosilicon is used, it should be possible to produce castings free from pinholes by paying attention to the controlling factors mentioned earlier.

The second major source of aluminium is contaminated scrap. It is very common nowadays to use old internal combustion engines as a source of good quality scrap iron. Many of these are complete engines and are put straight into the furnace charge. Most engines are fitted with light alloy pistons and other parts and these all go into the furnace. When this occurs much of the aluminium arrives in the molten metal in the well of the furnace and when this metal is cast severe pinholing occurs. Many cases of intermittent outbreaks of pinholing have been traced to this source and, invariably, removing the light alloy scrap has overcome the problem. There are several foundries where a competent man is employed in the stockyard solely to collect all the non-ferrous parts he can find, and he is paid a bonus on the amount he can collect. All of these foundries are convinced that the saving in scrap castings more than justifies the expense of employing a man for the job.

Summing up, the prime cause of pinholing is the presence of traces of aluminium in the iron. This aluminium causes large amounts of hydrogen to be picked up from the sand mould, and it is this gas which causes pinholing. The tendency for pinholes to occur is minimized by the presence of coal dust in the sand, and all runner systems should be kept as short as possible. The most likely sources of aluminium are the use of too much ferrosilicon with too high an aluminium content, and the use of contaminated scrap iron. If there is an outbreak of pinholing, the first place to look is in the stockyard.