Materials and Processes Forum:

Sand Additives—Coal-dust Replacement

By J. Beale

This paper is the seventh to be presented at the very successful "Materials and Processes Forum" held last year in Birmingham. The author commenced his contribution with an examination of the three main theories as to the way volatiles evolved from coal-dust prevented burn-on of sand in iron castings. Also examined was the effect of coal-dust in inhibiting expansion defects, and on the green properties of moulding sand. Finally, Mr. Beale described how a coal-dust replacement system had been developed. The article also records the subsequent discussion.

In introducing his paper, Mr. Beale observed that the problem of environmental pollution had existed for a considerable time, particularly in the working environment in foundries. The Kearney Report indicated that foundry emissions generated from sand conditioning alone amounted to more than 40 lb per ton of metal melted. The Report further stated that controls on emissions would result in 350-400 foundries closing down and costs to meet these controls would vary between 1.5% and 4% of sales. Any material which could be utilized that had good casting efficiency, together with a lower pollution level would reduce pollution control costs.

The basic concept of proprietary volatile producers sprang from the requirement to replace coal-dust in foundry moulding sands. Coal-dust had many disadvantages—it was dusty, dirty, variable and was a fire hazard. Its effect on green sand was considerable and any product replacing coal-dust had to take account of these effects. The best approach was therefore considered to be that of a composite sand conditioner which would be physically, a dust-free, clean, consistent product with negligible fire hazard; the product would be required to do the job of coal dust and also maintain or improve the moulding and casting properties of the green sand system. In this study the author would consider the actual effect of coal-dust in moulding sands, this being then correlated to the activity of coal-dust replacements. Coal-dust and bitumen compounds were widely used in the iron foundry industry to improve surface finish. There were three main theories as to the mode of action of the evolved volatiles in these materials in preventing burn-on of sand on to iron castings.

Reducing Atmosphere Theory

Initially, burn-on was caused by the reaction between iron oxide on the surface of the metal with the silica of the mould which produced a fusible iron silicate—fayalite—which promoted adhesion of the sand to the metal.

The reducing atmosphere theory assumed that a reducing atmosphere was produced in the mould cavity which could inhibit the oxidation of iron to iron oxide. Possible conclusions as to the viability of this theory could be drawn from thermodynamic studies of the mould atmospheres. These indicated that the atmosphere in the mould would not be reducing until the partial pressure of the oxygen was as low as 10⁻¹⁴ atmospheres at a temperature of 1,600°C (1,327°C). This conclusion did not take into account speed of reaction but was only the condition existing at equilibrium.

Further, and probably more importantly, the theory would indicate that any reducing atmosphere would have a similar effect on surface finish. In fact, there was a wide variation in performance between materials having similar reduction potentials.

Carbon Theory

Mr. Beale said that test sand mixes had been produced which on castings showed a shiny black coherent layer of carbon at the metal mould interface. X-ray diffraction patterns of this layer showed it to be carbon with a number of faint lines corresponding to graphite, although not all the graphite lines have been observed. If an interfacing layer of graphite was laid down, then the sand was not
SAND ADDITIVES—COAL-DUST REPLACEMENT

wetted by the metal and iron silicate formation was was not possible due to this physical barrier and a very smooth casting finish was thereby produced. The formation of this lustrous carbon film would appear to be dependent on three main factors:

1. The nature of hydrocarbon volatiles present;
2. Temperature, and
3. Presence and nature of catalyst.

The formation of lustrous carbon from volatile hydrocarbons took place by a cracking process at temperatures in excess of 400°C in the presence of catalysts. This followed a carbonium, i.e., positive ion, mechanism. The first stage of the reaction was the acquisition of a positive charge by the hydrocarbon. Acidic surfaces, such as sand and alumino-silicate could act as catalysts and, in fact, until the production of more selective synthetic catalysts became possible, all refractories used natural clays, particularly of the montmorillonite type on catalytic crackers.

The speaker said that the lower limit for carbon deposition in the presence of such catalysts was in the region of 400°C. The fact that substances evolving large amounts of volatiles at temperatures below 400°C tended to flame and were inefficient in their action might well be dependent on this temperature limit. This, of course, should be fully considered in any formulated product.

Gas Cushion Theory

Mr. Beale said that the basis of this theory was that gas was evolved from coal-dust or other additives and that it tended to produce a gas cushion between the walls of the mould and the molten metal. Taken in conjunction with the reducing atmosphere theory this was then said to inhibit the oxidation of the metal and any contact of the molten metal with mould face. Again, the problem with this idea was that taken on its own, the efficiency of any additive should be a function simply of the amount of volatiles produced and be independent of the type of hydrocarbon evolved. This, in fact, was shown to be untrue, nevertheless it was a fact that a pressure build-up occurred at the interface when a mould was poured and this could serve the function of delaying contact of metal and mould until the sand grains became enveloped and linked by a protective carbon layer.

It was probable that all, or parts of the three theories referred to would combine to form the mechanism by which sand burn-on was inhibited during the casting of iron.

Effect of Coal-dust

In addition to reducing sand adhesion, coal-dust was useful for the purpose of inhibiting expansion defects and although it was not as effective as some other materials it was still worthwhile in small thin-section castings. Prolonged heating however could harden the coal-dust and expansion defects could sometimes be aggravated in larger castings.

The study of coal-dust would be incomplete without noting the considerable effect it had on the green properties of moulding sand. Most important was the increase in optimum moisture requirement; variation of other properties were related to this.

Green Strength

The green strength moisture curve was moved to the higher moisture range by the addition of coal-dust (fig. 4). There was a greater displacement for synthetic sand but the actual effect of coal-dust on peak strength value was not certain.

Shatter Index or Deformation

The influence of coal-dust additions on shatter index closely followed that of green strength in that there

Coal-dust:

Mr. Beale referred to the fact that the coal-dust properties were most compatible...
depend on the grading of the coal-dust; the finer the coal-dust the higher the moisture requirement. However, permeability was most affected by grading; if the coal-dust was as coarse or coarser than the sand then this property would not be significantly affected, but if the coal-dust was substantially finer as was normal then the water requirement would be increased, permeability would be lowered and the dry strength would be increased. (fig. 3).

Coal-dust Replacement System

Mr. Beale said that all these properties he had referred to had been examined and the formulation of the coal-dust replacement system was such that these properties should be maintained or improved and, most importantly, the system should be entirely compatible with the one it was replacing. This latter changes in properties would be also much smaller, i.e., more uniform sand properties (fig. 4).

Because of this greater thermal durability, the build-up of dead clay will be decreased in this system, thus lowering the moisture requirement of the sand. This, in turn, brought in its wake improved permeabilities (as in the reference made to the effect of coal-dust) less likelihood of blowing defects and better surface finish (higher water contents in iron foundry sands promoted burn-on). Together with these advancements, a less brittle sand was produced which meant better mouldability, improved lifts, and less mould breakage. This effect was further enhanced by lowering of coke fines.

In general, sodium bentonites took longer to develop their bond than other clays. This had been catered for in the product by the use of specific dispersion agents. These agents reacted with the clays causing
SAND ADDITIVES—COAL-DUST REPLACEMENT

rapid spreading and development of the bond which meant a shorter milling cycle—or alternatively where milling cycles were necessarily short because of production requirements, then the properties were more uniform (fig. 5).

The speaker said that the major criticism of sodium bentonite in iron foundries was, of course, the high dry strength. This problem had been the subject of much research by the lecturer's company. With the addition of special chemicals, they had been able to control the dry strength of coal-dust replacement systems to that normally required in iron foundries. Thus, problems of poor shake-out, excessive sand loss and hot-tearing were obviated. Average dry strength in a coal-dust replacement system sand would be approximately 60-70 lb., per sq. in. whereas, with a straight sodium-bentonite strength would be 30-40 lb. per sq. in. in excess of this figure.

Another aspect of the chemistry of iron/sand systems that had been investigated was the effect on clays of the acid gases given off by the volatile fraction of foundry sands. It had been shown that it was possible to re-activate clays affected in this manner and in order to obtain maximum utilization of the expensive clays in the coal-dust replacement product system, clay activators had been incorporated in the product.

With regard to the volatile fraction of the product, this had been a difficult development area and for best results it had been shown necessary to use a blend of several selected materials. The speaker said that the unit liquid approach had been examined several years ago and rejected as being inadequate and having a deleterious effect on the sand casting properties.

The special liquid component of the coal-dust replacement was nevertheless essential and after blending and atomization this created a dust free product. Also, because of adsorption on to the clay particles, volatilization was slowed down, hazy carbon deposition was made more effective, and smoke production was kept to a minimum. This in fact, was the basis of a Patent taken out by the speaker's company. Because of the concentrated form of the volatiles and also the synergistic effect of the blending, the product is equal to at least 1 to 1½ times its own weight of coal-dust.

More-flowable Sand

The loss of angular coke fines also led to a more flowable sand and had a subsidiary effect on actual bulk density; this could be seen in the rammed density graph (fig. 6). This resulted in denser moulds giving improved casting definition and increased dimensional stability.

Physically, the product was a light coloured virtually dust-free material with flow properties and bulk density similar to clay. An important side benefit of the formulation was that it was necessarily highly concentrated and storage space was generally less than half that required for conventional additions.

Ideally, the utilization area for coal-dust replacement was in green-sand recirculating systems where the inherent advantages of the types of clays and volatiles used could be seen. Furthermore these systems would be made up of synthetic or semi-synthetic sands where the amount of clay added was at least equal to, or more than, the amount of coal-dust.

Technically, the product had been shown to be viable in many foundries and the advantages with its use varied with the conditions pertaining in the individual foundries but uniformly all were cleaner, whilst the storerooms were safer.

Case Histories

In what proved to be an appendix to his paper, the speaker provided case histories of foundries which were now using coal-dust replacement:

**Foundry A**

This was a small mechanized foundry and the sand additions, prior to the coal-dust replacement trial, were as follows: 15 lb. coal-dust, and 15 lb. clay. The initial additions were: 15 lb. coal-dust replacement, and 6 lb. clay.

After three days, the clay addition was reduced to 3 lb., and further reductions were still to be made both to the total coal-dust replacement addition and also the clay. It should further be noted that these additions resulted in a considerable improvement of sand properties and also casting finish which was desired by the foundry.

**Foundry B**

This was a large highly-automated foundry making a variety of electric motor parts and pump parts etc. The basic requirement at this foundry was to improve the foundry environment and cut down dust. The sand was a unit system milled by continuous millers, dwell time in the mill being extremely short, of the order of 14 sec. and approximately 600 tons of sand was prepared per day. Sand temperatures varied between 33°C and 53°C at the mill. 10 tons of new sand and approximately 100 tons of core sand were added to the system per week.

*Continued on page 414*
Sand Additives—Coal Dust Replacement

Continued from page 412

Additions to the mill approximated to 0.1% of clay and 0.1% of coal dust replacement. This gave the following properties:

- Clay content: 6.5 – 7.5%
- Loss on ignition: 3.5 – 4.5%
- Green compression: 10.0 – 12.00 lb. per sq. in.
- Green permeability: 58.0 – 65.0
- Shatter: 70.0 – 75.0
- Moisture: 3.0 – 3.5%

The base sand was Buckland Fine and quality of castings was exceptionally good.

Discussion

The discussion on the paper presented by Mr. J. Beale (Fosco F.S.), Limited on “Sand Additives to replace Coal Dust” took place under the chairmanship of Mr. A. P. Lovat. Mr. Beale was joined by Mr. A. D. Morgan for the discussion period.

Mr. Morgan said that the theme of the morning’s work had been “Towards a cleaner foundry”, and although Mr. Beale had shown slides which indicated that the foundry undoubtedly looked cleaner, he wondered whether this was merely because the coal dust substitute was not black, and that a dust and handling problem still existed. It would appear that as long as silica sand and clay was in use, it was necessary to have some carbon present to get a good surface finish on iron castings, and this meant that the sand would become black.

Mr. Beale had demonstrated that the development of a coal dust substitute was a long-term project, because of the necessity to reutilize the sand under test for a long time, and this was best undertaken by the suppliers themselves. The development of new materials always brought problems in its wake. The speaker asked Mr. Beale how he controlled the quantity of these additives, in particular where the addition altered the green strength and volatile matter and shatter index of the sand.

Adding Small Amounts of Oil

Oils were quite difficult to control and add accurately. Had Mr. Beale any views on the methods of adding very small quantities of these substances? He expected to see some development in the handling and quality of coal dust itself. It might well be that coal dust could be improved to make it cleaner to handle.

Mr. Beale said that with regard to control of material going into the product, he agreed with Mr. Morgan entirely that, with a product that was a one-shot addition, this would indeed be very difficult to control. There was no doubt that most foundries would want to alter their additions regarding the type of work they had on. If it was going to be a heavier section casting they would want to put in a little more coal dust. If they did this with the one-shot addition which was providing 100% of the bond, this would, of course, mean that the bond strength would also go up as the volatile content increased. Because of this, they had taken due care to make sure that in any system that they operated, the product, and there were several which they used, accounted for all the volatiles going in, but only part of the clay. Therefore, all the volatiles were replaced and only some of the clay, so that there was a balance of clay to maintain flexibility in the system. This meant that if the foundry wished to increase the volatile fraction going into the sand, then it could do so and make a compensating reduction in the amount of clay going into the mix.

Blue Colouration

Of course, another aspect of this was that coal dust was rather weak in its activity in some ways, in that a large excess of coal dust could be added into the sand system and, unless estimated, being done consistently, this would not really be noticed. The only thing that would be seen would be that the surface finish was getting better and better and the castings were beginning to go blue. Eventually, if one continued on this course, a mapping defect, which was encountered in high coal dust conditions, would occur. If, however, a material was being added that contributed to green strength, this phenomenon could not take place because there would be a marked effect on green strength properties if additions were being made to excess. Furthermore, such a product was fairly expensive and people did not use an excessive amount. This was useful in that it meant that control on sand was that much better as the founder was much more conscious of what he was doing.

Drawbacks

The chairman said that liquid replacement for coal dust had been mentioned. He wondered whether Mr. Morgan or Mr. Beale would like to expound on that a little further, particularly in respect of any drawbacks there might be. He was aware that there had been a considerable swing towards a liquid coal dust replacement in Sweden and towards the latter part of the previous year some 40 Swedish foundries had changed to a liquid coal dust replacement. This total represented a substantial proportion of that country’s foundries.

Mr. W. L. S. Hatton (Fosco F.S.), Limited said that he had attended a lecture by Dr. Beckius where the figure of 40 had apparently been overheard. He had talked to Dr. Beckius afterwards and had since confirmed in Sweden that Dr. Beckius had said 14. There were about 100 foundries in Sweden.

Mr. Beale said that he thought the problem with liquid materials was their effect on the green properties of sands and their reaction whilst pouring was taking place. Almost every liquid he had examined reduced the scabbling resistance of the sand. Furthermore, there was something to be said for a carry-over of fines in the sand. The speaker had found that unless the sand was a very fine material and was consistently being replenished with fines, the water requirement of the sand was reduced until such a time as the mouldability span, i.e., the amount of water required in the sand to provide a...
Sand Additives—Coal-dust Replacement

Continued from page 414.

given mouldability, became very narrow indeed. This necessitated a very high degree of sand control. If the sand was slightly wet, it became “claggy” and there was sticking to the pattern. If the material was slightly dry, as often happened when the sand got hot, there were problems of the sand drying out with resultant sand inclusions.

The speaker was aware of the use of these materials in Sweden although whether the founders who had tried them continued to use them was another matter. The problem was that some of these materials were, in fact, very effective for a short while. While there was coal dust and coal dust fines in the sand system there appeared to be quite a good performance. This state of affairs could continue for as long as three or four months before the system finally settled down and the true effects became apparent. Liquid replacements for coal dust also tended to give up their volatiles very rapidly and, in certain circumstances, could give rise to excessive fume production. This was because the body of the mould would reach 300 to 400°C which was sufficient to volatilize such material, but not the coal dust. Therefore, in certain circumstances, people might find themselves in difficulties if they were not very careful, with heavy fume production.

Crucial Test

Mr. Morgan said he would support everything Mr. Beale had said. The principal problem he had seen with these liquid materials was in the actual dispensing into the mill of such very small quantities of material, and the difficulty of control. Anything which was initially added to the sand as a replacement for coal dust seemed to work moderately well, but Mr. Beale had already brought out the absolute necessity to run these materials for several months, and this was the crucial test, because there might be problems which showed up only after prolonged circulation of the sand through the system. He felt sure there were suppliers of these liquid materials who might have comments to make.

Difficulties Overcome

The chairman said he would confirm one comment from Mr. Beale. It had been reported that those Swedish foundries that had changed to a liquid coal dust replacement had also needed to change from an AFS 50 to an AFS 60 sand after two or three months. He also knew that at least three foundries had been using the material for well over 12 months or so; presumably, any difficulties of this nature had been overcome.

Mr. J. D. Coleman (Richards Structural Steel Company, Limited) said that Mr. Morgan, in his opening address, had remarked that he did not like the appearance of greensand. This was probably brought about by the presence of coal dust which, even before decomposition, coloured the sand black. Had Mr. Beale or Mr. Morgan considered the use of expanded polystyrene, which in itself was white, as a substitute for coal dust?

Mr. Morgan replied that BCIRA had done a considerable amount of investigational work on the use of polystyrene as a sand additive. If completely synthetic new sand mixtures were being used, it worked extremely well. On recycling, there might be some difficulties arising, principally in that of control, and knowing how much material was present. It was not effective for very heavy section castings. The material burnt out too quickly. He did not consider at this stage that it was a satisfactory substitute for coal dust.

Major Problem

Mr. Beale said that his company had also had a look at polystyrene. The major problem was that it only catered for thin sections, and he thought that the casting of metal into a mould must be looked at as a dynamic situation. The carbon film that it was believed was being broken down or eroded away and reforming continuously must have something to continuously replace it—something which had a long evolution of volatiles—or the carbon film would be oxidised and burnt away. The conditions then would be ripe for the formation of iron oxide, slag, and consequent sand burn-in. It had been found that polystyrene gave rise to this problem, apart from the fact that it was 30 times dearer than coal dust.

Type of Polystyrene

Mr. M. L. Styles (Stanton and Staveley) said he was interested in the point about using polystyrene in moulding sands. Was this the form of polystyrene people were accustomed to seeing, i.e., expanded polystyrene? Any do-it-yourself people in the audience who had tried to cut this material would appreciate that polystyrene granules had a tremendous aptitude for picking up static. He could imagine that feeding it into a sand mill could present problems. On the question of cost, how did they stand with polystyrene in the final cost of sand mixtures?

Mr. Morgan replied that there were quite a lot of difficulties in the use of polystyrene. The polystyrene powdered material was, in fact, unexpanded, but it would still be very difficult to add to the sand. If polystyrene had been a satisfactory material to add, he would have suggested adding it as a dispersed material in water. He thought the cost of it would be about the same as that of Mr. Beale's additives.

Mr. Beale said that in the situation where a facing sand mix was used the actual amounts of polystyrene one could get away with on small castings was quite reasonable. Nevertheless, cost could be a problem in some circumstances.

This ended the discussion on Mr. Beale's paper.

(The detailed report on the Materials and Processes Forum is to be continued in future issues.)