The Production of Ferrosilicon Powder for Heavy-medium Separation

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SYNOPSIS

The heavy-medium separation process is gaining in importance. So that a closer and more effective control of the process can be achieved, higher demands are being made on the medium. The paper reviews the production processes for ferrosilicon of 15 per cent silicon, and makes special mention of the application of the medium, the importance of raw materials, and relative manufacturing costs.

INTRODUCTION

Ferrosilicon for heavy-medium separation is an alloy with a silicon content between 14 and 16 per cent. The process of mineral beneficiation by heavy-medium separation involves the separation of mineral particles by virtue of their difference in specific gravity. The medium consists of a suspension of ferrosilicon powder (15 per cent silicon content) in water. The density of the medium is between that of the sink and that of the float material.

Ferrosilicon (15 per cent silicon) is very well suited to heavy-medium separation because of its high corrosion resistance and its good magnetic properties. Because the ferrosilicon particles are small, the specific surface area is large, and, as corrosion is a surface phenomenon, a high corrosion resistance is needed. For the recovery of ferrosilicon from the separated float and sink material, magnetic separation is the easiest and cheapest way if the medium has good magnetic properties.

PRODUCTION METHODS FOR 15 PER CENT FERROSILICON

The cheapest and commonest production method is the melting of steel scrap, quartz, and reducing agent in a submerged-arc furnace. The three raw materials are weighed, mixed well, and fed into the furnace. At the Metalloys plant of Amcor, a 7,5 MVA furnace is used for the production of 15 per cent ferrosilicon. The characteristics of this furnace are as follows:

Shell diameter	6400 mm
Hearth diameter	4000 mm
Electrode diameter	890 mm
Secondary voltage	90 to 110 V
Resistance	0,85 mΩ
Reactance	1,0 mΩ

The power consumption 'including auxiliaries' for 1 tonne of 15 per cent ferrosilicon amounts to 2100 kWh. The manufacturing process has several specific prob-

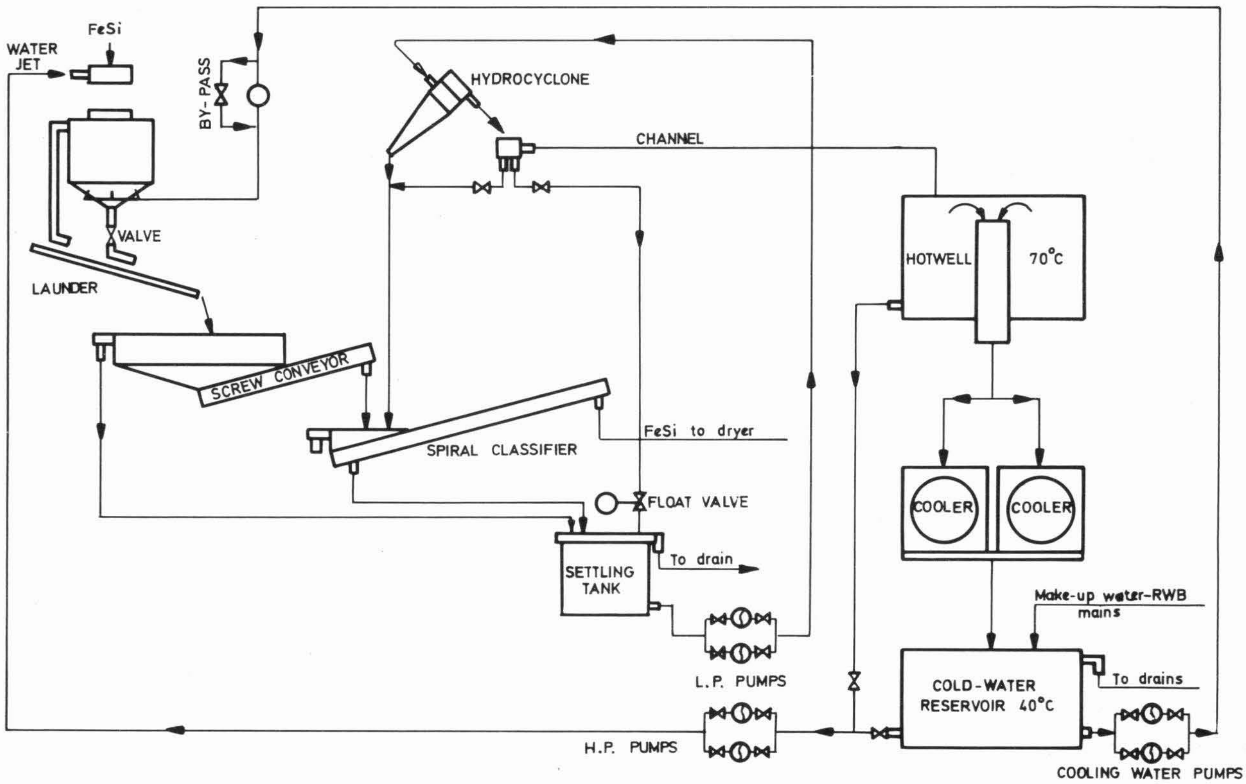

Figure 1
Flowsheet for the production of ferrosilicon

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lems, some of which are mentioned below.

(1) The handling of large amounts of steel scrap, which does not flow easily, is difficult.

(2) The low resistance affects the operation adversely if sufficient caution is not exercised.

(3) The silicon content of the alloy must be kept to between 14 and 16 per cent. This problem may lead to considerable amounts of off-grade product, which cannot be used for any purpose other than remelting in the furnace.

The furnace is usually tapped every two hours. The standard practice for the handling of the tapped metal was to cast the liquid ferrosilicon in sandbeds in layers of about 50 mm, cool it, break it up into lumps, crush it in two stages, and feed it to a ball mill for grinding. This cumbersome practice was abandoned when the 7,5 MVA furnace was commissioned, because the large tonnage of ferrosilicon that had to be handled made it economically unattractive. Instead, a granulating plant was built from an Iscor design. In the granulation process for liquid ferrosilicon, the melt is solidified by a high-pressure stream of water into small particles. The complete flowsheet is shown in Figure 1. The granulation process for ferrosilicon has several advantages over the 'old' handling method, the first being that the material is in a size range between 2 and 0,05 mm, which makes subsequent grinding of the material much easier than when crushed material is used. The second advantage of this rapid-quenching technique is that the material cannot segregate during solidifying, and consequently a homogeneous material is obtained.

The final powder is obtained by the grinding of the granulated 15 per cent ferrosilicon in a ball mill. Powders of different fineness can be produced by adjustment of the air-classifying equipment. A magnified picture of milled ferrosilicon is shown in Figure 2. The most important variable of the milled ferrosilicon is its corrosion resistance, which, according to Robinson and Du Plessis[1], can be increased by additions of chromium and/or other metals. However, when chromium was added on a trial basis, the results were inconclusive, and further testwork is being carried out. Another method for the production of 15 per cent ferrosilicon is the melting of high-grade ferrosilicon and the dilution of this melt with steel scrap until the melt has a silicon content of 15 per cent. The melt from an induction furnace has a slightly different chemical composition from that of the 15 per cent ferrosilicon produced in a submerged-arc furnace. This difference in chemical composition makes it possible for spherical material to be obtained from the atomization of the melt with steam. The flowsheet of the atomizing process is shown in Figure 3.

Figure 2
Milled ferrosilicon

The main purpose of this production method is to give particles that are more or less spherical (see Figure 4). Spherical material has several advantages over non-spherical material. With spherical material, losses during heavy-medium separation are lower as a result of reduced adhesion losses, and the medium is washed off the sink and float product more easily. Losses of the medium due to corrosion are considerably lower with atomized ferrosilicon than with milled ferrosilicon because of the low specific area of the atomized material. In addition, higher pulp densities can be obtained in heavy-medium separation with atomized ferrosilicon — a pulp density of up to 3,85 kg/l, compared with 3,1 kg/l for milled ferrosilicon.

Solid particles of rounded shape and smooth surface can also be produced by the flame-spheroidizing of ir-

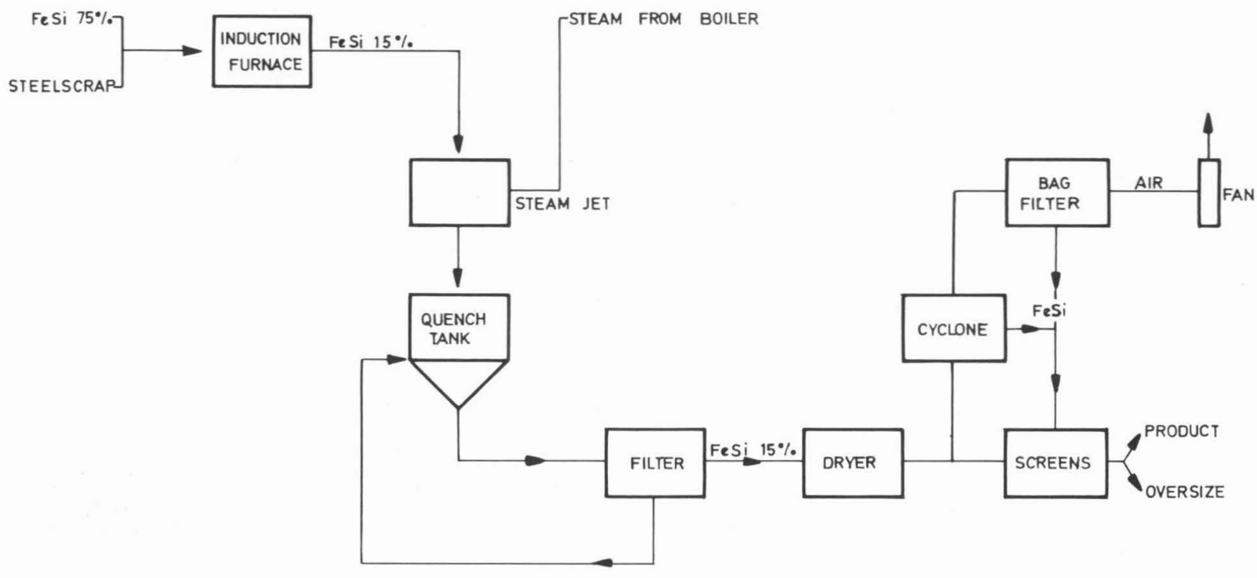

Figure 3
Flowsheet for the atomizing process

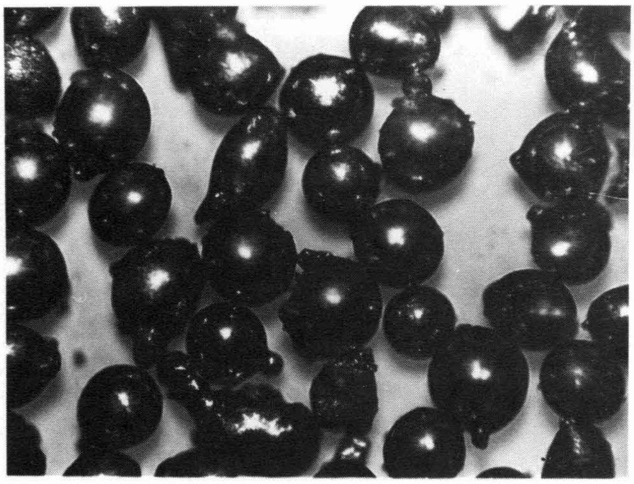

Figure 4
Particles of silicon

regularly shaped, solid particles. The particles are passed through a high-temperature flame or plasma so that they are melted at least on their surface. A problem with this method is that large particles do not melt completely on their surface and do not become round and smooth. For the flame-spheroidizing process, the fine ferrosilicon powder normally used yields a fine spherical product. For coarse spherical material, another method had to be found. This involved water-atomizing of a melt of 15 per cent ferrosilicon, but the particles produced in this way are spherical only if the chemical composition is well controlled. Many of these particles, however, are too coarse for use in heavy-medium separation and have to be screened out. This screened-out fraction is then milled and finally flame-spheroidized.

The fraction of ferrosilicon particles from water-atomization that is suitable for heavy-medium separation is used together with the flame-spheroidized ferrosilicon. This combined material is of a superior quality to the steam-atomized product in the shape and specific gravity of the coarse fraction and the size distribution of the whole[2]. It can be used up to a pulp density of 4,0 kg/l without the heavy losses that occur with the steam-atomized product. The process was developed by Iscor and was used at the Metalloys plant of Amcor. However, there were changes in the conditions at the particular ore-beneficiation plant where the mixture of flame-spheroidized and water-granulated material was used, and lower pulp densities were permitted. Thus, the need for this superior quality of ferrosilicon disappeared, and its higher manufacturing cost compared with that of steam-atomized ferrosilicon did not warrant its continued production.

CONCLUSION

Milled 15 per cent ferrosilicon is the cheapest type of ferrosilicon powder to produce. However, its quality is not constant, and its use in heavy-medium plants results in erratic consumptions and difficult operation. Finer grading of the ferrosilicon powder increases the milling cost, while the higher specific area of the finer powder causes higher losses due to increased corrosion. The field of application of milled ferrosilicon is limited to a density of about 3,1 kg/l.

Atomized ferrosilicon is about twice the price of milled ferrosilicon, and its consumption is always lower than that of the milled material. The saving in consumption by the use of steam-atomized ferrosilicon can be as much as 80 per cent or as little as 10 per cent. Only a trial run will show what result will be obtained. The field of application is wider, and pulp densities of up to 3,85 kg/l can be obtained.

Flame-spheroidized ferrosilicon is as good as the steam-atomized material. When cheap milled ferrosilicon is used in the flame-spheroidizing process, the final cost of the spheroidized powder is about the same as that of steam-atomized ferrosilicon. Water-atomized ferrosilicon is very expensive, and its production is warranted only for special applications when steam-atomized ferrosilicon fails.

REFERENCES

1. ROBINSON, F.P.A., and DU PLESSIS, D.J. Polarisation and corrosion of ferrosilicon alloys for iron ore benefication media. *Corrosion*, vol. 22, no. 5. 1966. pp. 117-131.
2. HOFFMAN, D.J.N., and BEETON, T.B. Heavy separation media. *U.S. PAT. 3,312,543*, 1967.

DISCUSSION

Mr A. Grant:*

What are the practical applications of 14/16 ferrosilicon?

Mr Sciarone:

Iscor uses 15 per cent ferrosilicon for upgrading their iron ore. Ore with a high silicon content is float material, and the sink material is a high-grade iron ore. Amcor are upgrading their chromium ore at their Potgietersrus mine with 15 per cent ferrosilicon.

Nearly all diamond mines use heavy-medium separation to remove most of the gangue material, and at Groot Eylandt heavy-medium separation is used to split high- and low-silica manganese ores; the high-silica manganese ore is then used for the smelting of silicomanganese.

Professor G.T. van Rooyen†:

Please elaborate on the influence of chromium additions to 14/16 ferrosilicon on the corrosion resistance, magnetic properties, and specific gravity.

Mr Sciarone:

The chromium additions were made in the furnace to obtain complete mixing. A chromium addition of 2 per cent was the maximum level to which additions could be made without influencing the grindability. An improved resistance to corrosion could not be established because the results were too scattered.

No tests have been done on magnetic properties. Chromium additions did not show a noticeable effect on specific gravity. There was only a tendency to a slightly higher carbon content in the final alloy.

Dr R.E. Robinson‡:

How does the shape of the 14/16 ferrosilicon particle affect its properties?

Mr Sciarone:

The particle shape is very important. The particle must be smooth and solid. The smooth surface and near-spherical shape result in lower viscosity of the pulp and in a marked increase in corrosion resistance.

These properties make it possible to work at much higher bulk densities in the heavy-medium separation than with milled 15 per cent ferrosilicon.

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