Note: Melting techniques in the iron foundry

by J. T. DAVIES*

INTRODUCTION

The selection of melting equipment for use in an iron foundry has for several years been the subject of numerous discussions, papers, and conferences. The controversy that has raged throughout the world has been brought about by the following factors:

(a) the increasing demand for a consistent product of high quality, which has necessitated better control of iron,
(b) the introduction of legislation governing the pollution of the environment, and
(c) the fluctuating availability and increased cost of the various raw materials and fuels required for the production of molten iron.

In the majority of cases, the choice has been between electric and cupola melting. The need for a duplex operation with holding and superheating facilities has been dictated largely by the choice of the prime melting equipment. The criteria on which the choice is to be made vary so widely from one foundry to another and the variety of combinations is so large that it is impossible to make a choice that would be the 'best' for all foundries. The most that can be achieved is to find the best, from a short- and a long-term point of view, of the several alternative choices that suit a given foundry.

Many of the economic and technical considerations that normally determine the choice have been evaluated elsewhere[1]. This note endeavours to deal with some of the more practical aspects of the various types of melting equipment with which the author has been associated, particularly the aspects considered to be unique to the South African iron-founding industry. It also briefly discusses a few of the developments and new melting concepts being applied in the iron-founding industry today.

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REQUIREMENTS OF A MELTING PLANT

In a production iron foundry, the melting equipment should comply with the following requirements irrespective of its nature or type.

(1) *Quantity.* It must be able to produce metal in sufficient quantity to meet the demand of the production line. It is often forgotten that operations such as deslagging, botting, alloying, superheating, and tapping can reduce the capacity of the plant. Continuous tapping is an advantage in mechanized or automated production plants.
(2) *Flexibility.* Ideally, it should be fully flexible to cope with a fluctuating metal demand and any unscheduled stoppages on the production line without sacrificing any of the other requirements.
(3) *Metallurgical Quality.* It must produce iron of a consistently high metallurgical quality and be of such a nature that the metallurgical specification is easily attained. Metal temperature is also of importance, and the plant should be able to produce metal that can be poured within the closely defined temperature ranges that are applicable to the castings being produced.
(4) *Utilization of Raw Materials.* It should be able to utilize the available raw materials to produce iron of the lowest cost per tonne at the furnace spout.
(5) *Labour.* The plant should be of such a design that the labour available on the South African labour market is able to operate and maintain it.

Before the various types of furnace are discussed, it is worth while to have a look at two of the most important factors affecting a melting plant: the metallic raw materials and the energy sources available in South Africa. In an analysis of the operating costs of an iron-melting operation, these two factors usually contribute more than 60 per cent of the total operating costs. The relative capital cost of the various types of melting equipment available can therefore be considered to be of secondary importance when taken over the useful life of the melting plant.

RAW MATERIALS

The metallic raw materials available at present are steel scrap, pig iron, cast-iron scrap, and sponge iron.

Steel Scrap

The future availability of steel scrap is difficult to forecast, but the present fluctuating availability and escalating price render it suspect as a long-term raw material for iron melting. The prices have not risen as steeply as that of pig iron, and at present savings can be made by the replacement of pig iron with steel where practicable.

Swarf, borings, and turnings will become increasingly important sources of metallic raw materials. The use of baled scrap is also a means of reducing costs, but purity and quality must be improved. The contamination of steel scrap, particularly by lead, aluminium, and high-chromium steels, remains a problem to the iron-founding industry.

Pig Iron

This is the traditional raw material for iron melting but, again, availability and steeply rising prices are elements that warrant careful consideration in the long term. Rationalization of the grades of pig iron produced for foundry use could improve both these elements.

Cast-iron Scrap

Where available, this material can be used to advantage. The quality is of importance, however, and foundries should be highly selective when considering its use.

Sponge Iron

Sponge iron is not being used at present in the production of iron, but in the long term could be used to supplement the raw materials charged to direct-arc furnaces.

ENERGY

The two major sources of energy available in this country are coke and electricity. The former, unfortunately, is of relatively low quality, with high sulphur and ash contents and low strength. It has also risen sharply in price in recent years and, unless supplemented with other fuels, cannot be regarded as a contender in the long term. Electricity prices vary depending on locality but appear to be relatively more stable. Reducing the maximum demand charges by melting during off-peak periods and not holding metal over weekends are common methods of reducing electricity costs.

PRICE ESCALATION

Table I indicates the relative price escalation of steel scrap, pig iron, and coke in recent years.

TABLE I

RECENT PRICE ESCALATION

Material	Jan. 1974 R/t	Sep. 1975 R/t	Increase %
Steel scrap (Grade A)	29,10	42,50	46,0
Pig iron (No. 2 Fdy)	49,00	74,00	51,0
Coke (Large)	18,10	27,00	49,1

TYPES OF FURNACE

The types of furnace used in the production of iron include cupola, direct-arc, coreless induction, and channel-type furnaces.

Cupola

The cupola has been used since the late eighteenth century for the production of iron and, whilst there have been many changes in design and shape, it remains the principal melting furnace of the iron-founding industry throughout the world. Modern developments have included the use of preheated blast air, oxygen enrichment of the blast air and injection into the tuyères, the supplementary use of gas (culminating in the gas-fired cupola), and the divided-blast cupola.

The acid-lined cold-blast cupola consists essentially of a shaft furnace in which the burden is preheated by the ascending gases and finally melted by contact with the incandescent coke. Its main advantages over other types of furnaces are its simplicity of operation, low capital cost notwithstanding the cost of emission control, relatively high thermal efficiency, continuous melting, and low maintenance costs.

The practical difficulties associated with this type of cupola are as follows.

(1) Metallurgical consistency and metal temperature are difficult to achieve, particularly when the operation is intermittent. The pick-up of carbon and removal of sulphur are restricted, which mitigates against the use of high proportions of steel in the charge and results in increased raw-material costs if pig iron is used. The use of the low-quality coke available in this country gives rise to low metal temperatures, especially for the higher grades of cast iron, the thermal efficiency and melting rate being affected by the poor quality of the coke.
(2) Corrections to metal chemistry are made only with difficulty.
(3) Erosion of the refractory in the melting zone limits the operation to relatively short periods (two shifts) before repairs have to be carried out, usually in unpleasant working conditions.

The above difficulties can be overcome, or at least reduced, if a few basic rules of cupola operation are observed. These include the careful repair of the refractory with only high-quality materials, the adoption of the correct procedure for the preparation and ignition of the coke bed, the accurate weighing of all the materials making up the charge, the monitoring of the weight of blast air and, where possible, the maintenance of a constant weight of air throughout the campaign. Oxygen enrichment of the blast air provides an additional control of the chemistry and obviates low-temperature metal at the start up.

The many problems associated with the cold-blast cupola led to the development of the hot-blast cupola. The concept of preheating the blast air has been known since 1827, but development really began on an increased scale after 1920. The principal effect of the hot-blast air is the increased temperature attained in the combustion zone, and this increase depends on the temperature of the blast. The hot-blast cupola has many advantages.

(a) The temperature of the metal is increased, thus facilitating the casting of thin sections.
(b) The coke ratio can be decreased significantly for the same metal temperatures as achieved with cold blast.
(c) The reduction in the consumption of coke increases the melting rate.
(d) The oxidation losses of silicon, manganese, and iron are lower.
(e) The carbon pick-up is higher.
(f) The reduction of sulphur is increased owing to the reduction of coke and the increased activity of the slag at higher temperatures.
(g) The proportion of steel scrap in the burden can be increased, resulting in reduced costs.
(h) Hot-blast water-cooled furnaces can be lined with a neutral refractory so that either acid or basic melting conditions can be used.

The problems with the hot-blast cupola are mainly the inability to control the chemistry within close limits, and the exceptionally high cost of the emission control equipment as a result of the fine particle sizes in the fume and combustion products. The poor quality of South African coke reduces the real benefit to be gained from the use of the hot-blast cupola.

Direct-arc Furnaces

This is a furnace familiar to most iron and steel founders. The electrical energy is transmitted to the furnace charge by three graphite electrodes that pass through the furnace roof.

The charge is heated by direct contact of the metal with the arc, and by radiation from the arc and the furnace walls and roof. Some heating also occurs by the passage of electrical current through the metal.

This melting technique is used extensively in areas where cheap sources of electrical energy are available because its economic operation depends on the use of low maximum-demand tariffs. It can also be used as a holding furnace in a duplexing operation.

The principal advantages of direct-arc melting are as follows.

(1) The furnace is a robust piece of equipment that is simple to operate.
(2) Arc furnaces are extremely flexible in regard to the composition of the charge. Nearly all forms of the available raw materials can be utilized. Wet, oily, rusted, dirty scrap can be charged as turnings or bales, and even large, heavy sections can be melted.
(3) The furnace is frequently emptied, enabling inspection and repair of the refractory lining to be carried out. This feature makes this technique the safest of the electrical melting techniques.
(4) The thermal and metallic losses are small, thus improving the electrical efficiency of the furnace.
(5) Corrections to the metal chemistry can be made relatively easily in the furnace.
(6) High percentages (up to 100 per cent) of steel scrap can be used, rendering the production of low-sulphur irons easily attainable.
(7) The removal of slag is easier than with other furnaces.

The chief disadvantages of arc-furnace operation are the additional costs of the graphite electrodes, the availability and cost of basic refractories where a basic slag process is followed, and the poor mixing of the metal bath, resulting in a non-homogeneous melt. Although melting costs are comparatively low, holding and superheating costs are high. The furnace operation tends to be extremely noisy, and fume extraction and ventilation should be provided to reduce the high ambient temperatures. Capital costs are about the same as for a cupola but less than for coreless induction furnaces. Carburization of the melt can be achieved by the charging of electrode scrap or carbon granules, or by injection of graphite into the melt by means of a dispenser.

Coreless Induction Furnaces

Induction furnaces of the crucible type can be divided into three categories: those operating on mains frequency at 50 Hz, those operating on medium frequency at 150 to 800 Hz, and those operating on high frequency at 800 to 10 000 Hz.

The mains-frequency furnaces are used mainly in the melting of iron, and the other types have found application in special circumstances. Only the mains-frequency furnace will be discussed here.

The advantages of mains-frequency coreless furnaces are as follows.

(a) The melting rate is flexible and can be changed as required to suit the metal demand and the electrical economy.
(b) Temperature control and chemical reproducibility are easy to achieve.
(c) Various grades of iron can be produced, and correction of the analysis is easy.
(d) The furnace can operate as a melting or holding furnace.
(e) The metallic yield is high (98 per cent).
(f) Its operation satisfies the environmental-pollution requirements without additional equipment.

However, there are a number of disadvantages. The furnace, being less robust than arc furnaces, requires careful operation and maintenance. The removal of slag is a tedious operation, and careful operation is required if attack of acid linings by slag is to be avoided. The installation, maintenance, and monitoring of linings requires more care than in other furnaces. Although most furnaces are equipped with protective devices and instruments to detect the wear patterns of linings, the only method of obviating damage to the furnace coil is to measure the lining wear on a regular basis throughout each campaign.

The composition and size of the charge materials are limited, and materials containing oil, rust, and moisture should not be used. This problem can be overcome by preheating of the charge, which also improves the utilization of the furnace.

Starting up of the furnace from cold takes several hours and requires starter blocks or a high-density charge.

Holding metal in the furnace overnight and week-ends is costly and has the additional disadvantage of a reduction in the nucleation of the melt. Careful inoculation of the iron must subsequently be practised to ensure casting quality.

Reactions that are time and temperature dependent occur between the metal and the lining. The carbon in the metal reduces the acid lining as follows:

$$3C+SiO_2=SiC+2CO.$$

This occurs more readily when metal is held at high temperatures for long periods, resulting in rapid lining wear.

Channel Furnace

The channel furnace is mentioned here because, although it is best suited to applications in which holding and superheating have to be carried out, it can also be used as a melter or to supplement the melting capacity of a plant.

This furnace has been described as a large step-down transformer with a shorted secondary. The electrical energy is transferred to the metal through one or more inductors, which consist in principle of a transformer comprising a core, a primary coil, and a secondary winding. This secondary winding is the channel of metal that transfers heat to the bath with which it is in contact. The smaller furnaces (up to 50 tons) generally have a single inductor with power ratings of up to 1250 kW. These are normally used where a combination of cold melting and holding is required. Furnaces larger than 50 tons are powered by two or more inductors, which may have single or double loops. Furnaces have been installed with power levels of more than 5000 kW. The smaller furnaces are hemispherical or cylindrical in shape, while the larger furnaces are shaped like a horizontal drum. This latter type is used mainly for holding and superheating.

The advantages of the vertical type of channel furnace are as follows.

(a) The electrical efficiency is very high.
(b) The power-to-weight ratio is low and the capital cost relatively low.
(c) When installed in a duplex operation, the furnace is independent of the prime melters and can therefore be tapped continuously.
(d) The working environment is good.
(e) If used as a reservoir, it irons out fluctuations in analysis and can supply metal at constant temperature.
(f) Prime melters are able to operate during off-peak periods.
(g) It requires very little maintenance.
(h) The lining campaigns are usually a minimum of one year.
(i) The condition of the inductor lining can be fairly accurately ascertained from the electrical operating characteristics, whilst the vat lining can be gauged by inspection within the furnace or by measurement of the shell temperature.
(j) The inductors can be replaced without relining of the whole furnace.

Despite these advantages, the channel furnace has many disadvantages in South Africa. The furnace performs most effectively when used continuously to hold or melt the same grade of iron. There is sufficient bath stirring to provide a homogeneous melt but insufficient to enable a high level of alloying by furnace addition to be carried out. It is very difficult to alter the metal analysis in a channel furnace. Most foundries in this country melt various grades of iron and, very often, a number of different types (e.g., grey, nodular, malleable).

The refractories used are usually high-alumina or high-magnesia linings. The failure characteristics of these materials vary considerably, and alumina is preferred because its use avoids catastrophic lining failure. The relining of a channel furnace or an inductor is a delicate and important operation, and must be carried out under strict supervision. The drying out period is greater for alumina than for magnesia linings, and the complete operation for a medium-sized furnace takes three weeks before the furnace is operational. To enhance lining life, the furnace is best operated with an airtight cover, tea-pot spouts for inlets and outlets, and regular deslagging practice. Inductors wear out faster than the vats and can be replaced without damage to the vat lining, but the condition of the inductor lining should be continually monitored to ascertain the wear pattern and to prevent accidental failure. The furnace should not be left unattended for long periods since failure of the cooling system or the freezing of the furnace could seriously damage the inductor.

RECENT DEVELOPMENTS IN MELTING TECHNIQUES

The concept of a duplexing operation has become increasingly popular in iron foundries, and there are many factors that make this highly desirable. The most important one is the need to have metal of the correct analysis and temperature continuously available during the production shift. This applies particularly to high-production or automatic-moulding plants. The major disadvantages are the increased cost of plant for transferring metal and the additional personnel required to operate such a plant.

Oxygen enrichment of the blast air for cupolas has been practised for some years, but the injection of oxygen into the well of metal below the slag has proved to be more effective in most operations and is becoming more popular. Improved metal temperatures and carbon pick-up and better control generally have resulted.

The supplementary firing of cupolas with natural gas in order to reduce the consumption of coke is gaining popularity in the United Kingdom, where the price of coke has soared in recent years. This technique does not appear to have a future in South Africa owing to the paucity of inexpensive fuels.

The divided-blast cupola developed by the B.C.I.R.A. has proved to be highly successful in reducing the consumption of coke or improving temperatures and carbon pick-up. It can easily be adapted to cold- or hot-blast cupolas at reasonable capital cost.

Development in the electric melting field is directed mainly at improved efficiency, with furnaces becoming larger every year.

CONCLUSION

Cupolas, arc furnaces, and coreless and channel furnaces are proven systems that work efficiently. Combinations of these are also effective, and, in the selection of a melting plant, one should choose the system that meets the given requirements for the least possible cost of poured iron. Capital costs and factors such as reliability, ease of operation, and flexibility should also be considered in the final selection.

IFAC Symposium

The 2nd IFAC Symposium on Automation in Mining, Mineral and Metal Processing will be held from 13th to 17th September, 1976, at the Carlton Hotel, Johannesburg. Advance registration takes place on 12th September, 1976.

The technical programme covers the following topics, with papers delivered by the listed authors.

Environmental control
A. E. Hall and A. D. Unsted (South Africa); E. J. Magri and A. D. Unsted (South Africa); G. Nilsson and K. S. Nyström (Sweden).

Ball milling
J. H. Fewings, J. A. O'Shea, and P. Wickham (Australia); J. Ragot, M. Roesch, Prof. P. Degoul, and Y. Berube (France); U. Kortela and D. Niemi (Finland); J. Kolostori, R. Haber, L. Kericzky, and M. Hilger (Hungary).

Metal rolling
H. Moll, E. T. Craven, Dr J. A. Temple, and M. Narita (South Africa); Dr P. Fish, Dr J. Temple, and M. Wright (South Africa); T. Yamamoto, M. Tanaka, and M. Ota (Japan).

Materials handling
C. G. Beeforth (South Africa); Prof. F. L. Wilke and Dipl-Ing H. Klee (Germany); C. C. Crosson, M. J. H. Tonking, and W. G. Moffat (South Africa); J. A. Ryder (South Africa).

Autogeneous milling
Prof. P. Uronen, H. Aurasmaa, and K. Saarkelo (Finland); T. O. Olsen, H. Berstad, and S. Danielsen (Norway); A. H. Mokken and F. W. Volk (South Africa); K. Heiskanen (Finland).

Steel plants
I. D. Landau, L. Muller, G. Dolle, and G. Bianchi (France); E. J. Buckman (Australia).

Mineral processing systems
T. Buhtelin, P. Uronen, E. Timonen, and J. Jylha (Finland); I. J. Barker and Prof. R. P. King (South Africa); M. A. Schapper (South Africa).

Geological surveys by satellite
I. J. Longshaw, R. P. Viljoen, and M. C. Hodson (South Africa).

Control and stability theory
D. J. Bell (United Kingdom); G. A. Carter and D. Rutherford (United Kingdom); Dr M. Kohne (Germany).

Planning and mine design
Dr J. M. Rendu (South Africa); D. Rankin, K. B. McQuillan, and P. D. Dickson (South Africa); R. I. Naude (South Africa).

Minicomputers and microprocessors
M. G. Rodd and J. H. Potgieter (South Africa); D. C. Farquharson, C. Kuiper, and W. G. Warburton (South Africa); C. Rydell (Sweden); M. G. Rodd and C. C. Rabey (South Africa).

Nuclear and physical instrumentation
Dr R. Greenwood-Smith, P. D. Munro, and G. S. Stacey (Australia); G. J. Wenk, W. J. Howarth, and L. R. Wilkinson (Australia); R. Rolle, P. J. D. Lloyd, and A. L. Hinde (South Africa); A. R. Atkins and A. L. Hinde (South Africa).

Manpower and other controls in mining
R. H. King, R. L. Frantz, and H. L. Parkinson (U.S.A.); H. Eraly (Belgium); Dr-Ing. W. Blankmeister (Germany); R. Hermans and T. Vith (South Africa).

Experience in computer control of concentrators
A. Niemi, E. Nuotio and S. Häkkinen (Finland); R. D. Beck (South Africa); H. Pentilä and O. Mattila (Finland).

Electrochemical instrumentation
Dr A. W. Bryson (South Africa); G. T. W. Ormrod and G. Sommer (South Africa); B. F. van der Merwe (South Africa); A. P. Saunders, Dr H. I. Philip, and Dr J. P. Martin (South Africa).

Identification and modelling
Prof. H. Unbehauen and B. Göhring (Germany) A. R. Atkins, A. L. Hinde, Prof. R. P. King, P. J. D. Lloyd, and J. G. Mackey (South Africa); J. J. Kruger and J. D. van Wyk (South Africa).

Case studies of computer control systems
A. B. Stewart, P. D. Martin, and M. S. Rennie (South Africa); C. D. Franklin and A. R. Brimmer (South Africa); I. Djordjovic (Switzerland).

Metal rolling II
R. S. E. Alberts and A. A. Joubert (South Africa); W. J. Edwards (Australia).

Computer applications in mining
H. Eraly (Belgium); A. Whillier (South Africa); S. G. Bergdahl (Sweden).

Pyrometallurgy and iron ore smelting
L. K. Nenonen, U. Graefe, and M. Neimanis (Canada); P. E. Wellstead, N. Munro, and M. Cross (United Kingdom); E. Rose and I. Dash (United Kingdom).

Metal rolling III
J. Kotze and J. W. Duppen (South Africa); W. J. Edwards, P. W. Johnstone, and I. D. Phillips (Australia); E. J. Buckman (Australia).

Technical and other visits
1. Deep-level gold mine.
2. Iscor Steelworks, Vanderbijlpark.
3. Sasol oil-from-coal plant.
4. Chamber of Mines Research Laboratories.
5. National Institute for Metallurgy.
6. Council for Scientific and Industrial Research.
7. Krugersdorp Game Reserve and Sterkfontein Caves.
8. Electra and Mining Exhibition.

Post-symposium tours
1. Northern Transvaal and Kruger National Park.
2. Natal and North Coast.
3. Cape Peninsula and Kimberley.

Registration forms and full details of the Symposium are obtainable from The Secretariat, IFAC Symposium, CSIR Conference Division S 100, P.O. Box 395, Pretoria, 0001 South Africa. (Telephone: Pretoria (012) 74-6011 Ext. 2077.)

World phosphates

The Minerals Bureau of the Department of Mines has released the second publication in its series of reports on the economic aspects of minerals that are of particular importance to South Africa. The report is entitled 'An Economic Assessment of the World's Phosphate Industry, with Particular Emphasis on the South African Industry'.

The report discusses the importance of this important industry to South Africa and relates it to the World situation. Problems that could be encountered in the marketing of the commodity are discussed, and South African resources of phosphatic raw material are evaluated. Environmental problems relating to the use of phosphate in detergents are also dealt with.

In the past South Africa has produced sufficient phosphate for her local requirements and exported only minor amounts of phosphatic fertilizers to neighbouring countries.

Two large phosphoric acid plants, one at Phalaborwa and one at Richards Bay, are scheduled for completion early in 1977, when South Africa is destined to become a large exporter of phosphoric acid. These exports are expected to earn some R130 million in foreign exchange per annum.

In addition, Foskor is investigating a new mine and plant at Phalaborwa for the possible export of some 2,5 million tonnes of phosphate concentrate per annum. This could involve capital expenditure of R150 to R200 million and foreign exchange earnings of R150 million per annum from the early 1980s.

South Africa may thus become an important World supplier of phosphates, which, with nitrogen and potassium, constitute the essential raw materials for fertilizers.

The report may be obtained from The Director, Minerals Bureau, Private Bag 4, Braamfontein, 2017 South Africa. (Telephone: 725-3360.)

Company Affiliates

The following members have been admitted to the Institute as Company Affiliates.

AE & CI Limited.
Afrox/Dowson and Dobson Limited.
Amalgamated Collieries of S.A. Limited.
Apex Mines Limited.
Associated Manganese Mines of S.A. Limited.
Blackwood Hodge (S.A.) Limited.
Blyvooruitzicht G.M. Co. Ltd.
Boart International Limited
Bracken Mines Limited.
Buffelsfontein G.M. Co. Limited.
Cape Asbestos South Africa (Pty) Ltd.
Compair S.A. (Pty) Limited.
Consolidated Murchison (Tvl) Goldfields & Development Co. Limited.
Deelkraal Gold Mining Co. Ltd.
Doornfontein G.M. Co. Limited.
Durban Roodepoort Deep Limited.
East Driefontein G.M. Co. Limited.
East Rand Prop. Mines Limited.
Envirotech (Pty) Ltd.
Free State Saaiplaas G.M. Co. Limited.
Fraser & Chalmers S.A. (Pty) Limited.
Gardner-Denver Co. Africa (Pty) Ltd.
Goldfields of S.A. Limited.
The Grootvlei (Pty) Mines Limited.
Harmony Gold Mining Co. Limited.
Hartebeesfontein G.M. Co. Limited.
Highveld Steel and Vanadium Corporation Limited.
Hubert Davies Heavy Equipment (Pty) Ltd
Impala Platinum Limited.
Ingersoll Rand Co. S.A. (Pty) Ltd.
Kinross Mines Limited.
Kloof Gold Mining Co. Limited.
Lennings Holdings Limited.
Leslie G.M. Limited.
Libanon G.M. Co. Limited.
Lonrho S.A. Limited.
Loraine Gold Mines Limited.
Marievale Consolidated Mines Limited
Matte Smelters (Pty) Limited.
Northern Lime Co. Limited.
O'okiep Copper Company Limited.
Palabora Mining Co. Limited.
Placer Development S.A. (Pty) Ltd.
President Steyn G.M. Co. Limited.
Pretoria Portland Cement Co. Limited.
Prieska Copper Mines (Pty) Limited.
Rand Mines Limited.
Rooiberg Minerals Development Co. Limited.
Rustenburg Platinum Mines Limited (Union Section).
Rustenburg Platinum Mines Limited (Rustenburg Section).
St. Helena Gold Mines Limited.
Shaft Sinkers (Pty) Limited.
S.A. Land Exploration Co. Limited.
Stilfontein G.M. Co. Limited.
The Griqualand Exploration and Finance Co. Limited.
The Messina (Transvaal) Development Co. Limited.
The Steel Engineering Co. Ltd.
Trans-Natal Coal Corporation Limited.
Tvl Cons. Land & Exploration Co.
Tsumeb Corporation Limited.
Union Corporation Limited.
Vaal Reefs Exploration & Mining Co. Limited.
Venterspost G.M. Co. Limited.
Vergenoeg MiningCo. (Pty) Limited.
Vlakfontein G.M. Co. Limited.
Welkom Gold Mining Co. Limited.
West Driefontein G.M. Co. Limited.
Western Deep Levels Limited.
Western Holdings Limited.
Winkelhaak Mines Limited.