# Energy consumption, waste heat utilisation and pollution control in ferro alloy industry

**UMASHANKAR AGRAWAL***

Ferro Alloy Industry forms the backbone of the Iron & Steel Industry in the World. Since energy crisis crept in during the last decade, considerable efforts have been made for decreasing the energy requirements in the production of Ferro Alloys and these efforts have resulted in new innovations for energy saving coupled with abatement of pollution. Large amount of investments have been made for developing several innovations but due to the peculiar nature of the dust pollutants and the high temperature involved, these are being constantly improved upon for smoother performance. Since India is poised for further growth in the Iron & Steel Industry, it is now the appropriate time for adopting energy conservation measures and to select the best suited technology for recovering the waste heat energy in the production of ferro alloys. The paper deals with the various aspects of energy usage, analysis of the areas where nett energy consumption can be reduced, modifications necessary in existing plants that can accomplish these objectives and finally scope for waste heat recovery from gases obtained from electric smelting furnaces. Pollution control and recovery of energy from waste gases should be considered as the two sides of the same coin and accordingly appropriate approach should be made.

Ferro Alloys are said to be the pepper and salt in the making of Iron & Steel and therefore very essential in the manufacture of all grades of Mild Steel, Alloy, Tool, Stainless and other special steels. Their extraction from the oxide ores involves considerable consumption of energy since their oxides are very stable with high value of free energy of formation, and reactions for their reduction are highly endothermic. Due to thermodynamic considerations, not only a higher heat energy is required, but this heat energy should be supplied in an intense form as is available in an electric arc furnace. Therefore all tonnage ferro alloys utilising carbon as reductant are smelted in electric furnaces. However Micro-alloying ferro alloys like Ferro Titanium, Ferro Vanadium, Ferro Molybdenum, Ferro Tungsten etc. are produced by metallo-thermic reactions using Aluminium and Ferro Silicon powder which also give the required intensive heat. But Aluminium and Ferro Silicon in turn are produced by electric furnace processes. The total energy consumption in ferro alloy production can be enumerated as for achieving the requisite temperature for reduction and to melt and separate the associated gangue in the form of slag as well as for super-heating of metal and slag for requisite fluidity to enable their being flown out of the furnace. The power consumption per metric ton for various ferro alloys can be indicated as follows :

| | | Kwh/Tonne |
|---|---|---|
| High Carbon Ferro Manganese | .... | 2800—3200 |
| Silico Manganese | ... | 4500—5800 |
| Ferro Silicon 70-75% Si content | .... | 8700—9500 |
| High Carbon Ferro Chrome | ... | 4000—4500 |
| Charge Chrome | .... | 2800—3800 |

*Umashankar Agrawal, Managing Director,
Ferro Alloys Corporation Limited,
Shreeramnagar, A. P.

| | | Kwh/Tonne |
|---|---|---|
| Low Carbon Ferro Chrome | — | 12000—14000 |
| Silico Chrome | — | 7800—8600 |
| Silicon Metal | — | 13800—15000 |
| Fe-Mo, Fe-Ti, Fe-W | — | Uses Al and/or Fe-Si Powder. The intensive heat energy for reduction of metal oxide being provided by exothermic oxidation reaction of Al and Silicon. |

It will be evident that the production of ferro alloys require higher power consumption as compared to that required for the production of Pig Iron or Steel in an electric furnace. Also, another salient feature that can be noted is that while in the reduction of Iron Oxide with carbon, the carbon is able to take part in the reaction with two atoms of oxygen to form $CO_2$,

$$FeO + C \longrightarrow CO$$

$$FeO + CO \longrightarrow Fe + CO_2$$

$$CO_2 + C \xrightarrow{1050^\circ C} 2\,CO$$

in the production of tonnage ferro alloys like high carbon ferro manganese, Ferro Silicon, High Carbon Ferro Chrome etc., Carbon Dioxide is unstable in presence of carbon at the high temperature involved. The oxides of Mn, Cr and Si cannot be reduced at temperatures below 1050°C by Carbon Monoxide. Therefore the carbon is utilised only upto the first stage of carbon monoxide formation. Thus the carbon monoxide generated leaves the furnace system unutilised except for a slight reduction of Iron Oxides in the ores. Thus there are two important characteristics in the ferro alloys production, namely it requires intensive heat energy for reduction and secondly that only a part of the carbon is utilised and the balance is available with potential heat in the form of carbon monoxide.

Efforts are being made to decrease the consumption of power required in the production of ferro alloys and also to recover the sensible and potential heat of the furnace gases. It can be observed from the energy balance in the production of tonnage ferro alloys like High Carbon Ferro Manganese, Ferro-Silicon, High Carbon Ferro Chrome that almost an equal magnitude of energy as that supplied in the form of electric power is leaving the furnace as potential recoverable energy. For example in the case of ferro silicon, about 7.740 million Kilocalories per ton of ferro silicon or 9000 Kwh/ton of ferro silicon is available as recoverable energy in the furnace gas.

For the smelting of various ferro alloys, due to the nature of raw materials and smelting characteristics, high carbon ferro manganese and Ferro Chrome are produced in closed furnaces while Ferro Silicon, Silico Chrome, Calcium Silicide are produced in open furnaces. In closed furnaces the furnace gas contains CO to an extent of 65 to 85% and thus has a high calorific value which can be obtained on its combustion. However Silicon alloys operation require stoking of charge materials. The open furnaces facilitate the frequent stoking of the charge mix required for the smooth descent of the charge in the furnaces.

In open furnaces air infiltration takes place and the carbon monoxide gas issuing from the furnance immediately gets oxidised to $CO_2$ on the charge surface and leaves the furnace through chimney under natural or induced draft. It is estimated that the furnace gas gets diluted with almost 50 times its volume with air and consequently the temperature of the out-going gas is brought down to about 150—250°C.

The furnace gases carry with them all the fine particles of charge mix consisting of ore particles, coal and coke particles and oxide fumes of vapourised metals. With the stringent pollution abatement laws enforced in advanced countries, endeavours have been made to contain the dusts and this has led to the concept of closing the hoods to decrease the volume of gas so that the gas treatment cost can be brought down. Closing the hood requires consequently greater preparation of raw materials with uniform size, shape and smelting character of the ores to be smelted. The recent developments on the use of chrome ore pellets in the production of charge chrome and manganese ore sinter in the production of Silico-manganese are aimed towards this direction. These developments afford to operate the furnaces with closed hoods. The gas can be treated more efficiently with less investment in smaller capacity gas cleaning plants and also the recovered gas can be utilised for other processes like drying pre-heating or steam raising. The concept of closing or semi-closing to afford stoking of the charge as and when required can be considered as primary step in the energy conservation measure.

The control of air infiltration and thus the burning of the gas by closing or semi-closing the hood of the furnace, not only decreases the volume of gas to be treated but also the temperature of the off-gas which can be altered to suit the requirement of dust collection equipments. In ferro-silicon furnaces making them semi-closed and closed, the following characteristics are reported.

| | | Open | Semi-Closed | Closed |
|---|---|---|---|---|
| Volume of gas | $Nm^3$/Kwh | 10-15 | 5—7 | 0 3—3 |
| Temperature | °C | 150-300° | 350-500° | 700-900° |

It can be observed that the semi-closed furnaces can be adopted for ferro silicon operation and high carbon ferro-chrome operation and from the hot gas the sensible heat can be recovered by waste heat boilers for steam generation. In view of the decreased amount of gas, the cost of collecting dust will be less. Recently a few plants have come up with generation of electric power from such closable hood systems such as at Bjolfossen, Norway and Japan Metals & Chemicals Co. Ltd. About 5 MW of Electric Power is generated from furnace gas on furnaces operating at 20MW.

Another area of possibility of recovering heat energy will be from the sensible heat content of slag and metal. In the production of ferro alloys like High Carbon Ferro Manganese and High Carbon Ferro Chrome nearly 800 kg. to 1200 kg of slag is produced per ton of ferro alloy and are tapped at temperatures of 1450—1750°C. In the production of Low Carbon Ferro Chrome upto about 4.5 tons of slag is produced for each ton of L C Ferro Chrome at about 1850°C. With a heat capacity of 350 to 400 Kilocalories per kg at these high temperatures, the sensible heat of the slag will amount to 400—600 Kwh per tonne of High Carbon Ferro Manganese and High Carbon Ferro Chrome production and about 1800 Kwh per ton of L C Ferro Chrome production. By adopting granulation processes either by water or air, the sensible heat can be recovered in the form of steam or hot air which then can be utilised for other purposes or electric power generation. Some of the processes used for blast furnace slag can be adopted for the slags obtained in ferro alloy production. Heat is also available in the form of furnace cooling water which is circulated on furnace shells, contact clamps etc. Along with heat recovery system of furnace gas, the heat recovered from the slag and cooling water can be suitably combined for optimum utilisation. Recently developments have taken place in Japan for utilisation of even low temperature cooling water for power generation by use of Freon Turbines instead of the conventional steam turbines.

In India, the ferro alloys industry has been well estiblished to meet the demand of user industries and recently several large capacity furnaces for charge chrome production are being commissioned. The total production capacity is presently about 2,32,000 tons of Manganese Alloys, 90,000 tons for silicon alloys and 20,000 tons for chrome alloys which include High Carbon Ferro Chrome and Low Carbon Ferro Chrome and also 1,50,000 tons for charge chrome mainly for export. In terms of MW installation it will amount to about 144 MW for Manganese alloys, 154 MW for silicon alloys, 40 MW for H C Fe Cr / L C Fe Cr alloys and 105 MW for Charge Chrome totalling to about 443 MW.

As explained above, an equal magnitude of 410 MW of energy is possible to be recovered from the furnace gases and if waste heat boilers and turbo generators are used, about 100 MW of electric power can easily be generated or the waste heat can be utilised for drying, preheating and pre-reduction of raw material to bring down the power input.

While abroad some of the major hurdles in collection of flue dusts and pollution control have been surmounted and recent developments have established the recovery of waste heat or electric power generation from gases on industrial scale, the adoption of the same to furnaces in India which mostly are of smaller size will require considerable in depth study involving, techno-economic viability and investment of heavy capital expenditure.

The recovery of energy cannot be considered as an isolated concept but should be considered in the total system. If the energy is to be recovered the furnace is to be made closable or semi-closable and for this the preparation of raw materials with respect to fines and moisture content particularly of carbon reductants should be carried out. Similarly the dust emission should be characterised with reference to its quantity of generation, particle size, chemical and physical properties like abrasion and settling characteristics since the carbon reductants and the ores are different as compared to other countries. The collection of data on several of these furnaces in itself will consume considerable time and cost since suitable instruments and monitoring are to be established. Similarly the use of gas for drying, pre-heating and pre-reduction and the know-how for adopting these techniques are to be evolved for the various processes. All the above factors are to be considered in the total system and efforts need be made now.

It has been reported that the pollution control and energy recovery system will involve an equal amount of capital investement as that for establishing a new ferro alloy unit of the same capacity.

World Steel Production has grown from 304.3 million tonnes in 1959 to 746.6 million tonnes in 1979, but it has suffered a severe set back since 1980, ( which can be seen from Table—1 ). The production has gone down to 696.2 million tonnes in 1982.

**TABLE — 1**

*World steel production ( 1959—1982 )*

(Millions of Metric Tonnes)

| REGION | 1959 | 1969 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|
| Western Europe | 93.5 | 156.6 | 155.5 | 163.9 | 174.0 | 161.3 | 158.9 | 143.7 |
| Eastern Europe | 78.8 | 147.6 | 204.2 | 210.9 | 209.5 | 209.2 | 206.1 | 204.0 |
| North America | 90·2 | 137.6 | 127.3 | 138.9 | 139.4 | 117.4 | 124.4 | 77.6 |
| Latin America | 3.4 | 12.2 | 22.0 | 24.3 | 27.5 | 29.1 | 27.4 | 27.4 |
| Africa & Middle East | 1.9 | 5.7 | 9.7 | 10.9 | 13.2 | 13.4 | 13.4 | 12.8 |
| Asia & Far East | 36.6 | 115.2 | 155 9 | 167.5 | 183.0 | 165.8 | 177.5 | 179.6 |
| WORLD TOTAL | 304.3 | 574.9 | 674.6 | 716,4 | 746.6 | 696.2 | 707.7 | 645.1 |
| INDIA | 2.5 | 6.6 | 10.0 | 10.1 | 10.1 | 9.5 | 10.8 | 11.0 |

TABLE — 2

*World ferro alloy production*

*( Exclusive of communist countries )*

(Production in '000 Tonnes)

| PARTICULARS | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|
| High Carbon Ferro-Manganese | 3438.9 | 3482.2 | 3345.0 | 3272.7 | 3809.3 | 3438.3 | 3152.4 | 2748.5 |
| Silico Manganese | 1182.7 | 1194.4 | 1082.3 | 1154.4 | 1357.3 | 1308.1 | 1050.0 | 910.0 |
| Ferro Silicon | 2220·0 | 2312.6 | 2322.9 | 2302.3 | 2663.5 | 2303 5 | 2909.9 | 1692.1 |
| Ferro Chrome | 1639.4 | 1762.9 | 1702 3 | 1712.2 | 2142.3 | 2174 3 | 1274.7 | 1055.6 |
| TOTAL | 8481.0 | 8752.1 | 8452.5 | 8441.6 | 9972.4 | 9224.2 | 8387.0 | 6406.2 |

Ferro Alloys are very important raw materials for the Steel Industry as they are used to give requisite characteristics to steel products. As such steel and ferro alloys are interdependant and the traumatic World recession in steel affected the ferro alloys industry as seen in Table—2. The World production of tonnage ferro alloys excluding Communistic Countries was 9 97 Million tonnes in 1979 and 6.41 million tonnes in 1982.

**Impact on ferro alloy industry**

The steel recession pushed the technological progress and led to new technologies such as Acid operation of Blast furnaces, Mixed blowing of molten steel with Oxygen plus inert gas, injection techniques in the ladle, continuous casting etc., thereby it is aimed to produce steel of a superior quality and to achieve cost reduction by minimising raw materials usage that is particularly the ferro alloy consumption. The adverse steel production and the new technical developments in steel technology have had a compounded effect in decreasing the demand for ferro alloys. This has made a tremendous impact on prices of Ferro Alloys which can be seen from table—3, and this has caused stiff competition in ferro alloy producers in the international market.

The world economical recession has the similar effects on ferro alloy industry as on steel industry. This has led to low capacity utilisation by operation of furnaces at low power inputs or by total shutdown of some of the furnaces, no capacity expansion and closure of the small and less efficient unviable production units. To operate with high productivity and to reduce costs, ferro alloy producers are adopting installation for large furnaces with computer control systems and waste heat energy recovery systems. In order to produce quality ferro alloys at reduced costs, this crisis has also motivated them to adopt new measures such as use of high purity raw material and low cost carbon reductants, use of beneficiated and agglomerated ores,

TABLE — 3

*Bulk ferro alloy prices*

(Figures : US $ per M.T.)

| PARTICULARS | 1978 | 1982 Aug. | 1983 Feb. |
|---|---|---|---|
| Ferro Manganese | 343.0 | 423.6 | 355.3 |
| Silico Manganese | 706.6 | 444.0 | 369.10 |
| Ferro Silicon | 777.7 | 837.7 | 735.8 |
| Ferro Chrome | 376 5 | 552.7 | 429.2 |

preheating and pre-reduction of materials, careful sizing and blending of furnace burden for lower energy utilisation. Also there has been introduction of Plasma Arc Smelting which permit direct use of fines of ores, improvements in furnace designs, development of new ferro alloys and complex ferro alloys, utilisation of by-products etc.

Looking to our domestic Ferro Alloys industry, it has been also affected to a great extent and is in a serious crisis. Instead of increase in production as expected for developing countries the production has gone down. The total installed capacity is 5,13,000 tons for all ferro alloys. The surplus capacity after meeting internal requirement is earmarked for exports. But the shortage of low phos. high grade manganese ore, non-availablity of low ash low phos reducing agents, high power costs, non-availability of power, increased rail freights and depressed international prices have totally cut down the export possibilities.

To the possible extent the domestic units producing ferro alloys have taken steps for optimal utilisation of raw materials, use of low cost carbonaceous reducing agents etc. but have not been able to adopt the vital measure for reduction of energy consumption. This is the appropriate time for adopting energy conservation measures by selecting suitable technology for recovering the waste heat energy and also by making necessary modifications in existing plant equipments which would facilitate them to produce quality ferro alloys at competitive prices. But the task is gigantic and unit rather small. Hence it would not be possible without the unstinted support and assistance of the State and Central Authorities in form of not only direct cash subsidies but also in adopting policies which would indirectly support the survival and growth of ferro alloys industry in India.

In view of the importance of conservation of ferro alloy minerals, and also energy while producing the ferro alloys, government fiscal concessions should be very liberal as to encourage to adopt these innovative concepts. Financial Institutions should encourage by providing loans on concessional terms for such investments. Investment allowance should be allowed at higher rates for setting up equipments and machineries for preparation of raw materials, for modifications or renovation of furnaces to make them semi-closed or totally closed and for establishment of dust collection equipments and energy recovery systems. These will help to attain a shorter pay back period for the overall investment made and to derive the benefits of new developments in technology in the production of energy intensive products like ferro-alloys.