cmp TECHCOMMENTARY

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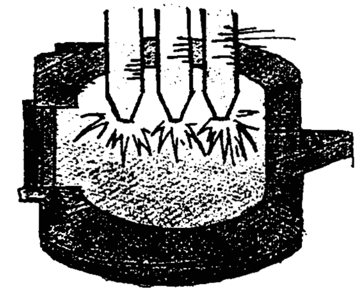
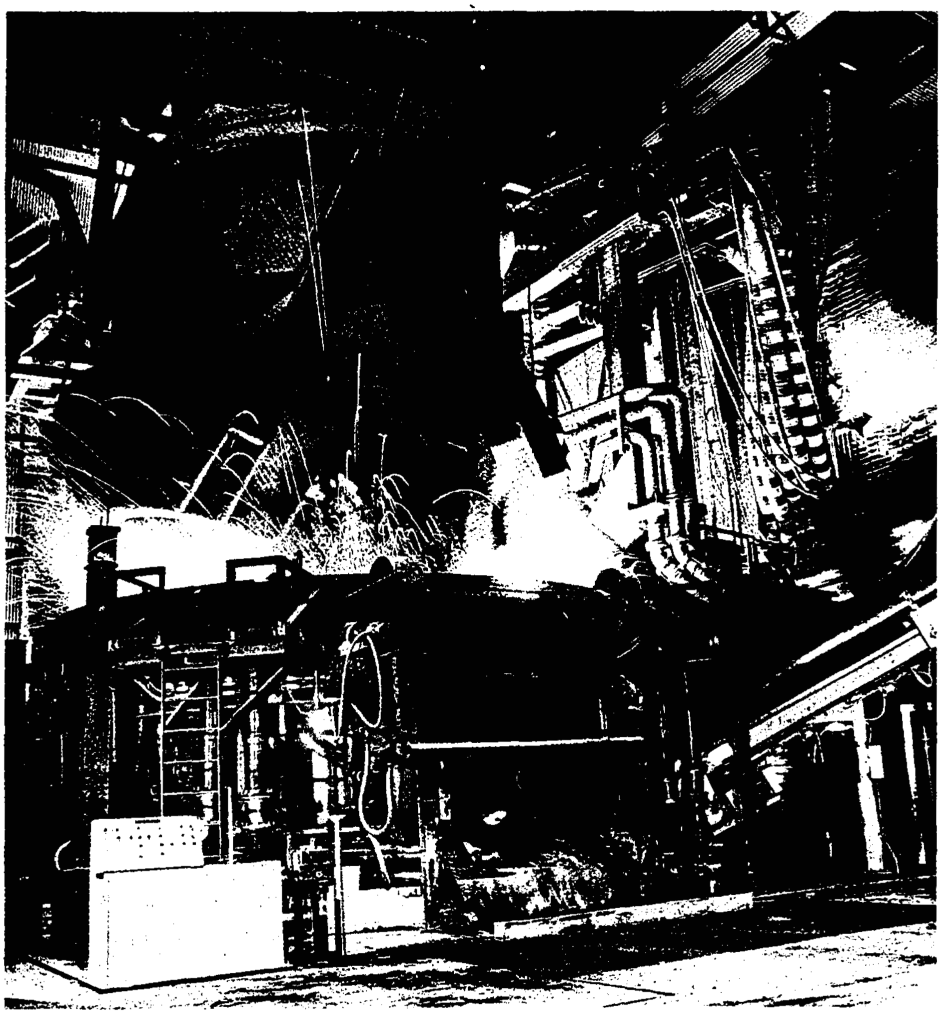
Electric Arc Furnace Steelmaking ... *The Energy Efficient Way to Melt Steel*



Introduction

Electric arc furnaces produce a large and increasing portion of the raw steel produced in the U.S. In 1984, approximately 34% of the total of 92 million tons of steel was made in electric arc furnaces with the balance produced by basic oxygen furnaces, 57%, and open hearth furnaces, 9%.

There are significant differences between these steelmaking processes. For example, basic oxygen furnaces use a metallic charge consisting of 60 to 70% blast furnace liquid iron, and 30 to 40% scrap. Electric furnaces use essentially a 100% scrap steel charge.



Even though liquid iron (hot metal) is used in both the basic oxygen and open hearth furnaces, the overall energy required to produce steel by those methods is considerably greater than with electric furnaces using a solid scrap charge. This is because of the larger quantity of energy required in the blast furnace process to reduce iron ore to liquid iron. The electrical energy required to make 1 ton of liquid steel in an electric furnace at 500 kWh or 1.7 million Btu is only a small fraction of the 16 to 20 million Btu required using the blast furnace/basic oxygen furnace route.

The blast furnace is provided with energy in the form of coke which is mixed with iron ore pellets/sinter and limestone to constitute a furnace charge or burden. Liquid iron, containing approximately 4% dissolved carbon is tapped from the bottom of the furnace into hot-metal cars and transferred to steelmaking furnaces.

Steel is an iron-based alloy containing some manganese, varying amounts of carbon (generally less than 0.5%) and other alloying

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Introduction

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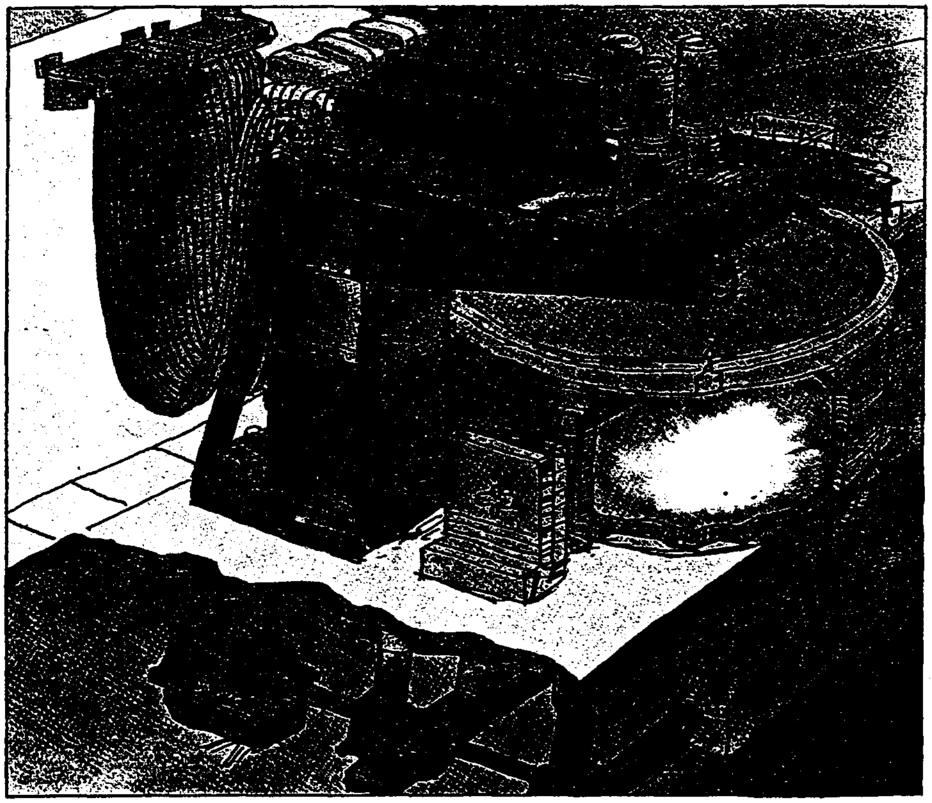
elements. Thus, the primary function of the basic oxygen or open hearth furnace is to refine the liquid iron by reducing carbon to a prescribed level, as well as removing impurities such as silicon, sulfur and phosphorus. In a basic oxygen furnace, this is accomplished by the injection of oxygen and the addition of fluxes. On the other hand, the primary function of the electric arc furnace is to serve as a scrap melter. Frequently, steel is further refined in a ladle metallurgy unit to improve cleanliness and provide additional temperature and/or composition control.

Liquid steel is solidified in either continuous casting machines or ingot molds. Continuous casting machines produce semi-finished sections, i.e., billets, blooms and slabs. Ingots require an additional rolling operation to produce the semi-finished shapes. Final steel products, strip, sheets, bars, rods, plates, tubes, etc., are manufactured from the semi-finished sections using a variety of rolling mills and processes.

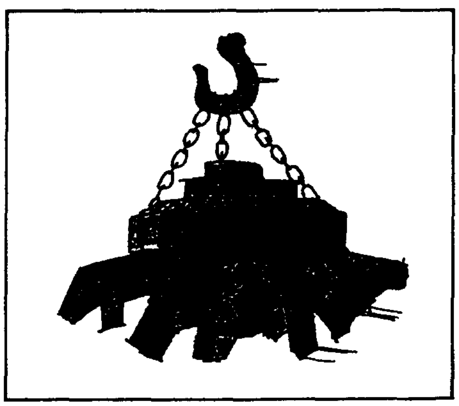
The Electric Arc Furnace



This cutaway drawing shows an electric furnace with carbon electrodes attached to support arms and electrical cables. Molten steel and the rocker mounting on which the furnace may be tilted is also shown.

The first commercial electric arc furnace in the U.S., a 4-ton unit, was placed in operation in 1906 by the Holcomb Steel Co. at Syracuse, N.Y. Production increased significantly during World War II, and again after 1960 with the advent of mini steel mills. It increased steadily from 8.4 million tons in 1960 to a record of 34.1 million tons in 1981, an increase of more than 300%. The proportion of steel made in electric furnaces has continued to increase from 28% in 1981 to 34% in 1984. Production within the next ten years is expected to reach 40 million tons, representing 40 to 42% of total steel production.

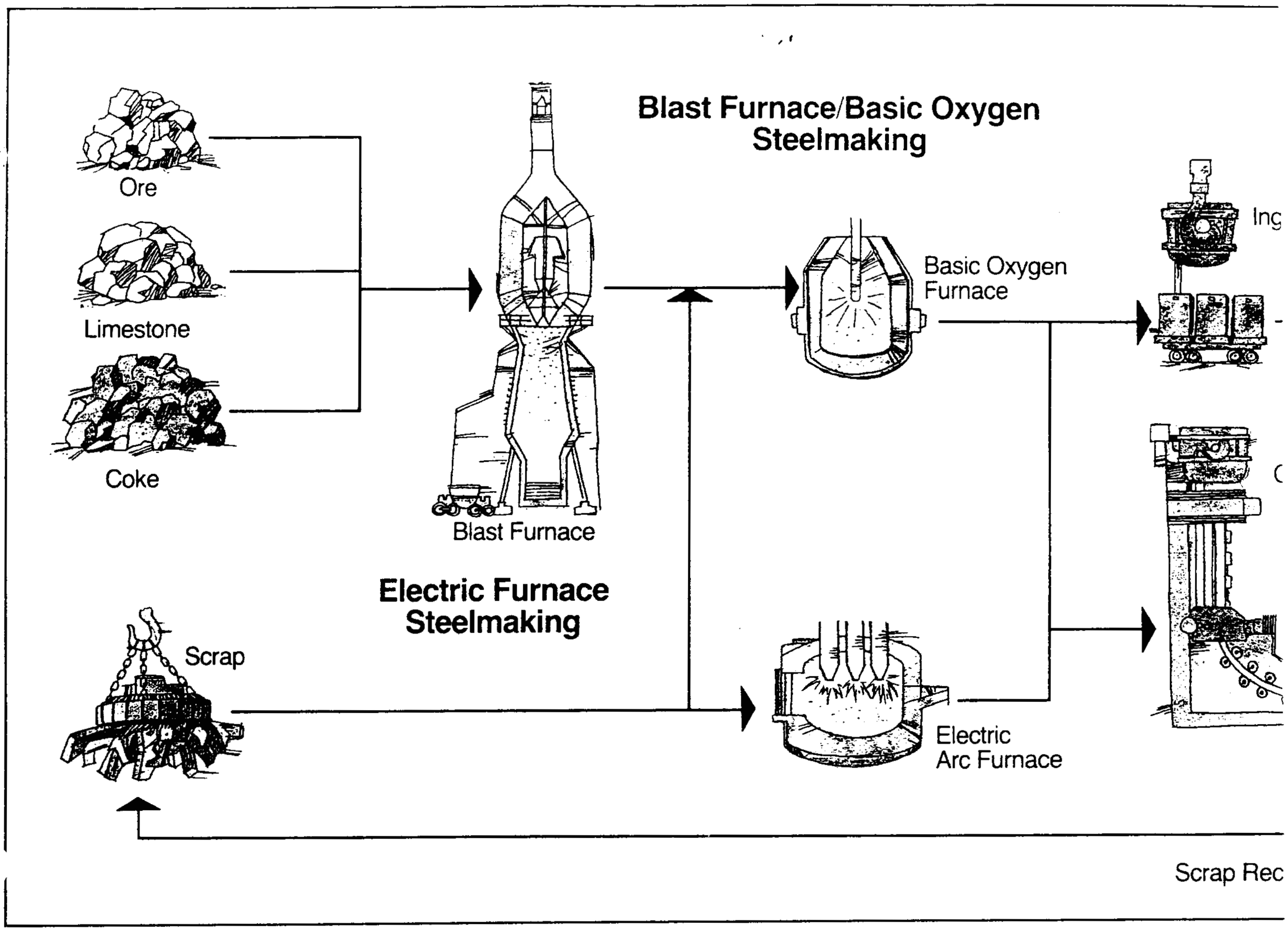
The rapid growth in electric furnace steel is due to a number of factors including relatively low investment costs, improved technology which has reduced production costs, and the appreciably lower price of steel scrap in comparison with blast furnace hot metal. Investment per annual ton (1982 dollars) is approximately $235 for coke oven/blast furnace/basic oxygen furnace production vs. $77 for electric furnaces.[11]

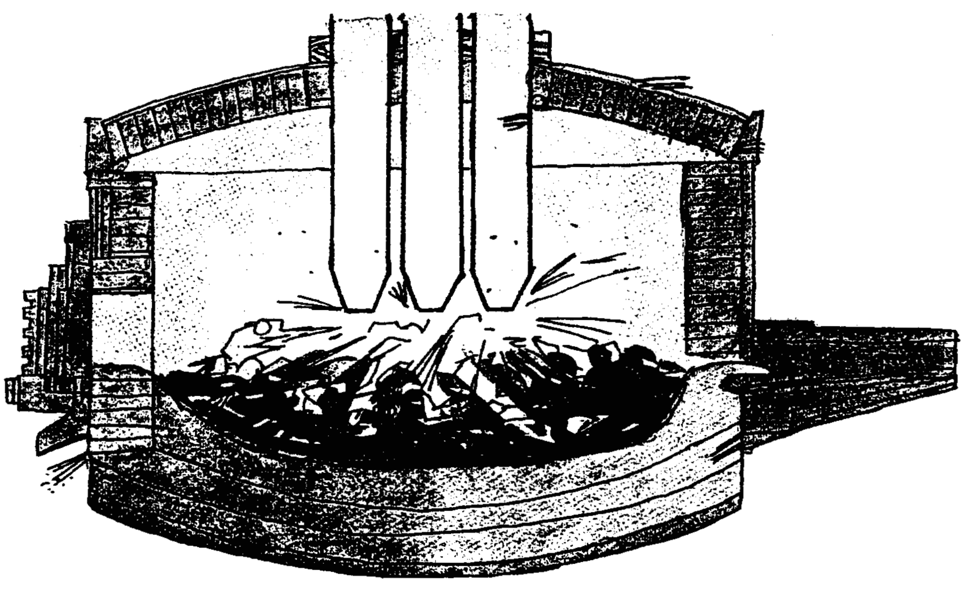


Scrap Steel

Approximately 300 electric arc furnaces, ranging in capacity from less than 10 to 400 tons, have been installed in the U.S. by integrated, specialty and mini mill producers.

Electric furnaces also are used in foundry operations with their use doubling since 1957. In general, furnace capacities here are smaller, one to 50 tons, than in basic steel operations. Steel foundries are the principal users of electric arc furnaces. There are approximately 350 foundries with electric arc furnaces in the United States.

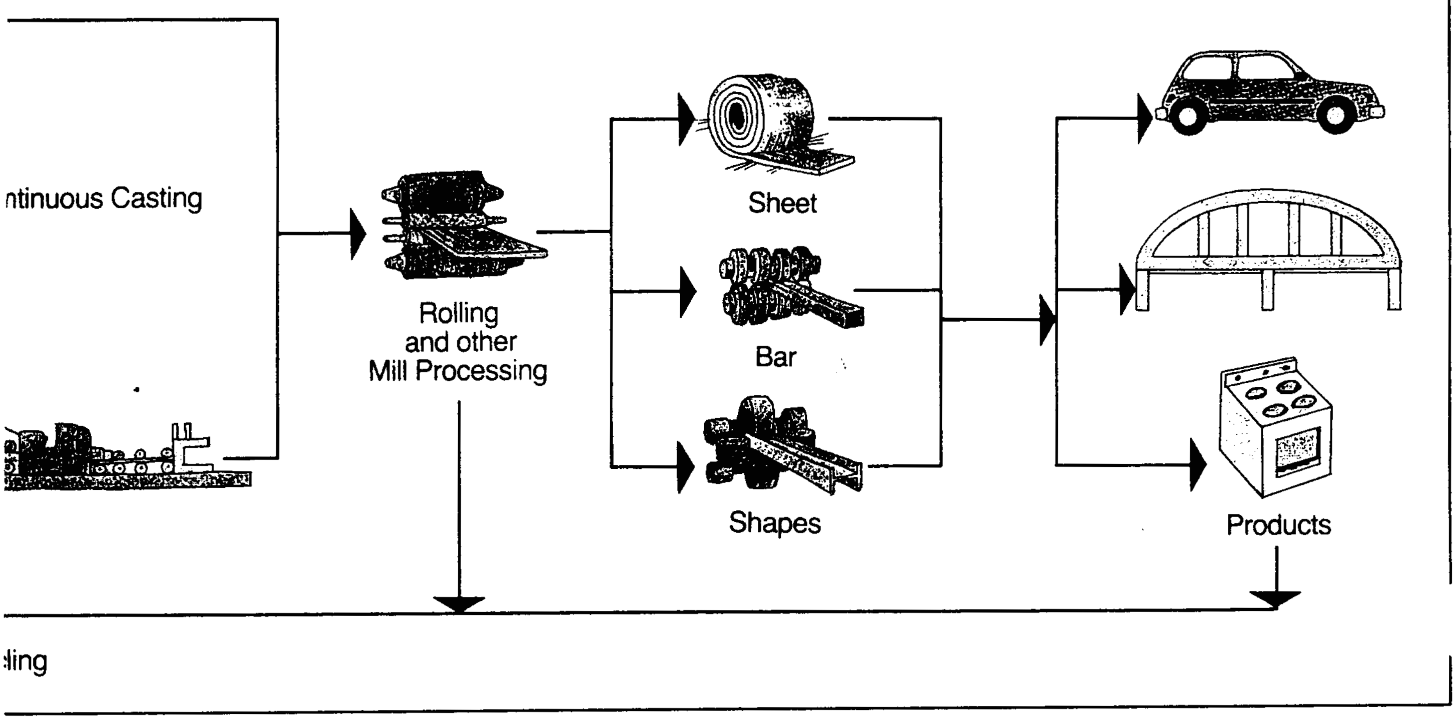


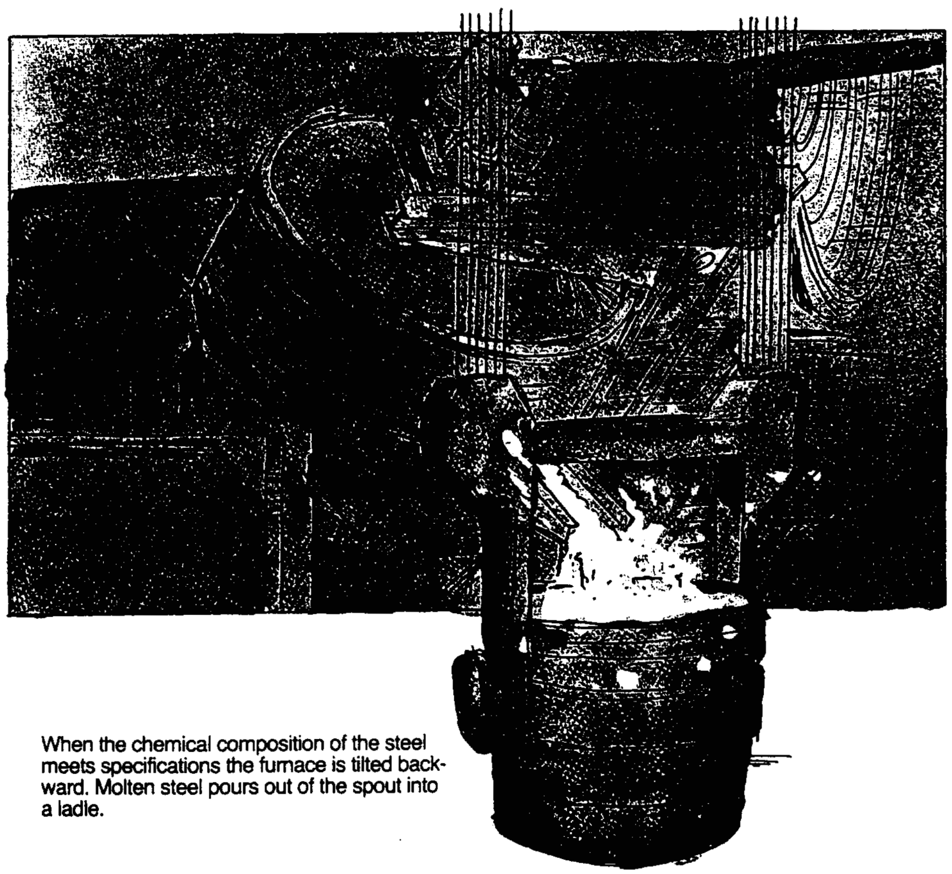


When the roof of the furnace is in place the three carbon electrodes are lowered until they approach the cold scrap. Electric arcs produce heat to melt the scrap.

Electric arc furnaces consist of a refractory-lined hearth, vertical cylindrical sidewalls and a removable roof. Three graphite electrodes, which pass through holes in the roof, are clamped to arms which move vertically on masts mounted to the furnace assembly. The electrodes and roof can be raised and swung to one side to permit furnace charging. In conventional furnaces, a horizontal tapping spout is built into the hearth structure with a working door located diametrically opposite in the sidewall. The entire furnace unit can be tilted on rockers for tapping liquid steel into a ladle. Electric power is supplied from a 3-phase multi-voltage tap transformer. The electrodes are connected by

THE STEEL CYCLE





When the chemical composition of the steel meets specifications the furnace is tilted backward. Molten steel pours out of the spout into a ladle.

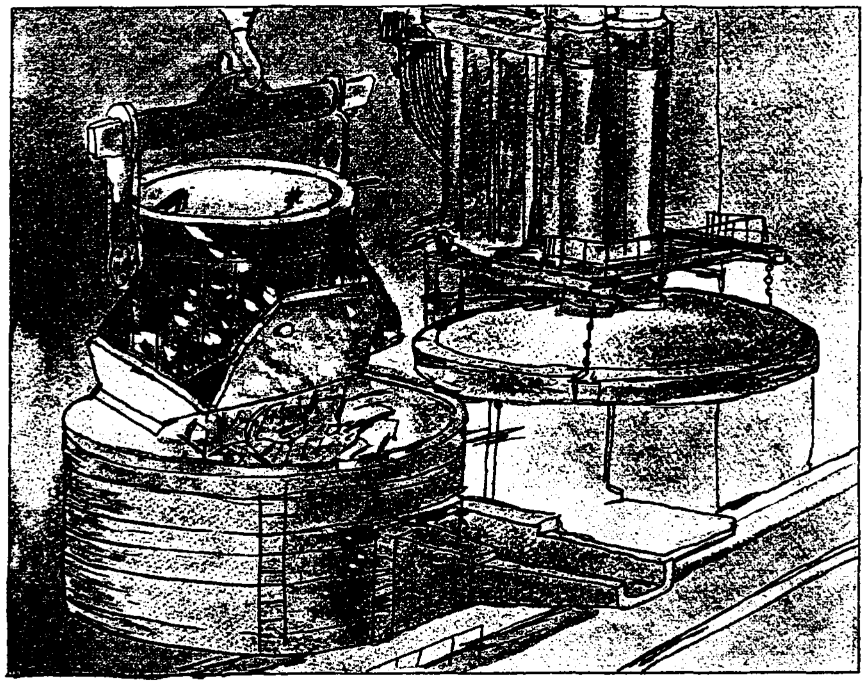
heavy flexible cables to the transformer which is located as close to the furnace as possible to avoid excessive transmission loss with the heavy currents employed. Many modern electric arc furnaces also are equipped with oxy-fuel burners.

Energy input consists of approximately 70% electrical and 30% chemical which is derived from oxy-fuel combustion, oxidation of carbon and other chemical reactions. Approximately 53% of the total energy is retained in the liquid steel; heat loss in the waste gases is 20%, cooling losses from walls and roof 17%, with 10% lost in the slag.

Operations and Costs

At the start of a heat cycle, with the electrodes and roof raised and swung to one side, a charge of steel scrap is dropped into the furnace from a clamshell bucket. The roof is replaced, electrodes lowered and an arc struck. Arc length is optimized to meet the changing conditions during the melting process by selecting the appropriate voltage tap. Two, and sometimes three buckets of scrap, are used in making a single heat of steel. After melting and refining are completed the heat is tapped into a ladle for casting.

A typical modern melt shop, containing one 19-ft. dia., 120-ton furnace with a 70-Mva transformer, would have an annual melting capacity of approximately 600,000 tons. Average heat times would be close to 2 hours. Power consumption for an efficient operation should be in the range of 450 to 500 kWh/ton. Thus, for a consumption of 475 kWh/ton, the monthly electrical consumption would be approximately 24 million kWh.


The roof of a furnace is pivoted aside so that a charging bucket of scrap may be lowered into position for bottom-dumping.

Total usage of electric power the 31 million tons produced in the U.S. in 1984 was approximately 14,725 billion kWh.

The cost of producing steel in electric furnaces varies considerably. The major component is raw materials, typically 63% followed by electric power 16%, labor 11%, electrodes 8%, and refractories 2%[10].

Special Features

Modern furnaces are equipped with a variety of features to increase production rates, reduce heat times and lower operating costs. They include:

- Ultra High Power (UHP) transformers. Power levels of 600 to 900 kva/ton are being installed.
- Water-cooled sidewalls and roofs to reduce refractory costs.
- Oxy-fuel burners to supplement heat input and improve melting efficiency.
- Oxygen injection for decarburization to reduce refining time.
- Lime injection to reduce processing time and heat loss.
- Foamy slags to shield sidewalls and roof from heat radiation from the arcs. This practice permits the use of maximum available secondary voltage through the use of long arcs with high power factors.
- Computer control to optimize electrical power programming, automatic tap changing based on furnace condition and power demand. More complex systems provide control of metallurgical parameters (tap temperature, timing of process events), data logging and least-cost charge calculations, etc.

Arc stability is an important factor in the operation of an electric furnace. At the beginning of the melting period, power input is limited by unstable arcs which can also cause flicker in the primary voltage line. Flicker is of mounting concern with increasing transformer power. Most new UHP meltshops are equipped with static VAR generators for this reason.

Additional state-of-the-art developments currently being introduced to improve furnace performance as well as steel quality include:

- Eccentric bottom tapping to reduce tap times, reduce temperature losses and avoid slag contamination in the ladle.
- Oxygen and carbon injection to provide additional source of heat from oxidation of carbon.
- Coated/water-cooled electrodes to reduce electrode consumption.
- Scrap preheating to recover energy from furnace waste gases.
- Single electrode d-c furnaces to reduce electrode consumption and noise.
- Continuous charging using preheated scrap.

In summary, modern electric furnace steelmaking is typified by:

- Productivity in excess of 60 tons/hr.
- Steel scrap as a raw material.
- Flexibility. Shop capacity can be increased in relatively small increments at one-third the cost of coke oven/blast furnace/basic oxygen furnace installations. Shut down and start-up costs to match market demands are relatively small.

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Other CMP Reports

This Tech Commentary is one of a continuing series of reports written to describe technology of interest to electric utilities and their customers. Reports presently available are:

84-1 Arc Furnace Power Delivery (1984, 145 pages)
A detailed analysis of the technical problems relating to large electric furnaces and utility power grids.

85-1 Ladle Refining Furnaces for the Steel Industry (1985, 32 pages)
A review of supplemental steel heating and refining units often used in conjunction with electric arc furnaces.

85-2 Electric Arc Furnace Dust Disposal (1985, 80 pages)
An analysis of dusts generated by electric furnaces and a review of methods for treatment and disposal.

Future topics for reports will include Plasma Applications, Arc Stability, Vacuum Melting and DC Furnaces.

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