Basic Electric Furnace Practice for Low Alloy Steels

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THE low alloy steels generally find application in the construction of automobiles, locomotives, bridges, machinery and machine tools and many other equipment. These steels are used in "as forged" or "as rolled" condition or as castings after suitable heat-treatment, to develop the properties desired.

The chief alloying elements in low alloy steels are Ni, Cr, Mn, Mo, V, Si, and Cu. These elements are used either singly or very often in combination with others in various proportions; the total of the alloying elements generally does not exceed 8 per cent. The usual range of the various elements in alloy steels is as given below:

C =0·12 to 0·65%
Mn=0·50 to 2·0 %
Cr =0·35 to 2·0 %
Ni =0·25 to 5·0 %
V =0·10 to 0·50%
Mo =0·15 to 1·00%
Cu =0·15 to 1·00%

The production of alloy steels requires good control of melting technique so that they must be uniform and homogeneous with respect to both composition and grain growth characteristic, be reasonably clean and free from inclusion, and contain the minimum amount of sulphur, phosphorus and dissolved gases.

The basic practice of making a low alloy steel in electric furnace is very similar to that of making plain carbon steel so far as slag making is concerned. The selection of scrap is important and should be well balanced to avoid the presence of undesirable alloying elements.

Charge

The charge is prepared from plain carbon steel or partly from alloy steels and the balance from ordinary steels. The carbon content of the charge is generally kept 0·15 to 0·30 per cent higher than desired, for which pig iron, graphitic carbon or coke is incorporated with the charge. It is preferable to keep the phosphorus and sulphur content of the charge below 0·05%, otherwise prolonged oxidation of the bath will be required resulting in longer duration of heat.

The addition of alloying elements is goverened by the ease of their oxidation with reference to iron, thus Ni, Cu, Mo may be added with the charge because these are not oxidised in the melting process or towards the end of the heat as in the case of Cr and V which are heavily oxidised. The method of making the necessary alloy additions, however, varies in different works making the same grade of steel. Limestone, lime, fluorspar and iron oxide are generally added with the charge.

Oxidising period

After the melting down, vigorous boiling of the bath is necessary for the elimination of dissolved hydrogen and nitrogen. To ensure good boiling, which is employed either by lancing oxygen or by the addition of iron ore to the molten bath, a minimum of 20 parts carbon drop at a rapid rate is desirable. It is imperative that during the oxidising period both slow boiling and over boiling of the bath should be avoided. The method of adjusting the carbon to the desired carbon level of the finished steel consists in either catching the carbon during the boiling down period within the limits of the specification or reducing the carbon 5 to 10 points below and then raising the carbon by the addition of recarburiser such as pig iron, coke, etc.

Reducing period

After the slag off, the heat is blocked by the addition of any one of the following ferro-alloys viz. ferro-manganese, silico-manganese and ferro-silicon.

Now a slag forming material consisting of a mixture of lime, coke, fluorspar and a small amount of powder ferro-silicon is shovelled over the bath. Carbon and lime react to form calcium carbide and this slag is white in colour and reduces oxides of iron, silicon and manganese which is in contact with the slag metal interface. Since the metal at this stage is not thoroughly deoxidised, addition of good recarburiser is necessary prior to the tapping of heat.

The time to hold the metal under white slag has an important bearing upon the hydrogen and nitrogen content of the finished steel. This time should be kept as low as possible; yet it will

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allow desulphurisation and final adjustment of the bath composition.

Finishing period

This period is occupied by the final adjustment of the composition and the temperature of the steel. The exact composition of the bath is generally analysed by the time this period is reached. The addition will consist of carbon, ferro-alloys and the different alloying elements.

Carbon: It is adjusted by the addition of special low sulphur, low phosphorus pig iron and high carbon ferro-manganese.

Manganese: As high carbon ferro-manganese, silico-manganese and low carbon ferro-manganese.

Nickel: Electrolytic nickel plates or Ni-shots.

Chromium: High carbon ferro-chrome.

Molybdenum: As ferro-molybdenum and calcium molybdate Cr and Mo may be added in two stages; in the first stage, rough addition being made immediately after a reducing slag is made and finally towards the end of the heat.

Vanadium: As ferro-vanadium about 5 to 10 minutes before the tapping of heat.

Copper: As metallic copper

Temperature adjustment: It is determined by the film test, pour test and also by immersion thermocouple. The temperature of the bath before tapping is generally maintained in the range of 1,550/1,600°C, depending upon the final product desired.

Tapping heat

The heat is finally deoxidised by the addition of aluminium, ferro-titanium, or Ca-Si-Mn, to the molten metal in the ladle.

Heat log

The progress of two typical low alloy heats are given below:

Medium carbon-manganese-nickel-chromium-molybdenum steel

The specification

% C	...	... 0·38-0·42
% Mn	...	... 1·35–1·45
% Si	...	... 0·35 (Max.)
% Ni	...	... 0·6 –0·7
% Cr	...	... 0·45–0·55
% Mo	...	... 0·18–0·22

Charge: The charge is made up as below:

Plain carbon steel	...	13,000 lb
Nickel alloy steel	...	2,000 lb
Ca-Mo ...	...	45 lb
Iron ore ...	...	200 lb
Lime ...	...	450 lb
Total charge	...	15,045 lb

5·00 a.m. Power on

7·00 a.m. Melting completed.

7.35 a.m. Oxygen lanced = 140 cft.

7·45 a.m. 1st bath sample { % C = 0·105; % Ni = 0·46; % Mn = 0·12; % Mo = 0·16 }

7·50 a.m. Slag off

8·05 a.m. Blocking of heat { Si-Mn = 60 lb; Ca-Mo = 15 lb }

8·15 a.m. 2nd Bath sample % C = 0·11

8·25 a.m. *Reducing period*: Reducing slag is made by the addition of 500 lb lime, 10 lb fluorspar and a mixture of 100 lb of lime, 30 lb of powdered coke.

8·50 a.m. *Rough addition*:

Ferro-silicon	...	46 lb
Ferro-manganese	...	190 lb
Pig iron ...	...	320 lb
High carbon ferro-chrome		53 lb

9·05 a.m. 3rd bath sample: { % C = 0·33, % Mn 1·12; % Ni = 0·46, % Cr = 0·50; % Mo = 0·22 }

9–45 a.m. Final addition to make up the desired composition:

Ferro-chrome	...	45 lb
Ferro-manganese	...	45 lb
Ni-plates	...	29 lb
Ferro-silicon	...	15 lb
Syn. Pig iron	...	112 lb

10–00 a.m. Tapped with aluminium in the ladle. Temperature—1,600°C.

Analysis of final ladle sample

C % = 0·385, % Mn = 1·15, % Si = 0·22,
P % = 0·013, % S = 0·016, % Ni = 0·66,
Cr % = 0·54
Mo % = 0·022

Low carbon-chromium-molybdenum steel

Specification

% C	...	0·18–0·22
% Mn	...	0·60–0·80
% Cr	...	0·90–1·10
% Mo	...	1·00–1·25

Charge

Alloy steel scrap	...	6,500 lb
Plain carbon steel	...	9,500 lb
Graphite ...	...	54 lb
Molybdenum oxide	...	80 lb
Limestone ...	...	400 lb
Fluorspar ...	...	50 lb

6·00 a.m. Power on

7·40 a.m. Melting completed

8·20 a.m. 1st bath analysis % C = 0·26 % Mo = 0·88
% Cr = 0·22

Vigorous ore boiling started with :

8·10 a.m.	120 lb addition of iron ore		
8·30 a.m.	2nd bath sample—% C 0·19		
8·46 a.m.	Slag off		
	Blocking of heat with 30 lb of		
8·53 a.m.	High carbon ferro-manganese		
8·55 a.m.	Lime	... ...	160 lb
	Fluorspar	... ...	20 lb

Reducing period

9·00 a.m.	Lime	... ...	90 lb
	Graphite	... ...	18 lb
	Ferro-chrome	...	133 lb
9·15 a.m.	3rd bath sample		
	Report of analysis :		
	C %	... ...	0·18
	Mn %	... ...	0·38
	S %	... ...	0·015
	Cr %	... ...	0·89
	Ni %	... ...	0·15

9·45 a.m.	Addition for final adjustments of the bath		
	High carbon ferro-manganese		32 lb
	Ferro-molybdenum	...	30 lb
	Low carbon ferro-manganese		32 lb
	Ferro-chromium	...	25 lb
	Ferro-silicon	... ...	144 lb
10·09 a.m.	Heat-tapped with 15 lb. Fe-Ti in ladle		
	Tapping temperature 1,590°C.		

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