ALTERNATIVE RAW MATERIALS FOR MANUFACTURING FLAT PRODUCTS BY E.A.F. ROUTE

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Abstract

The production of strip and sheets by E.A.F. route has shown a very rapid increase in the last years, through the utilization of thin slabs technology. Such development depends mainly on drastic reduction in investment costs, energy saving and lower manpower requirement. Recently, thin slabs technology has been implemented also for production of high quality steels, like extra deep drawing grade.

However to obtain these products it is necessary to limit the content in liquid steel of residual elements, such as Cu, Sn, Ni, Mo, which cannot be removed during refining. Therefore it is not possible to produce high quality flat products utilizing only purchased scrap, which is rich in tramp elements. The problem can be overcome with the diluition of scrap in charge with other raw materials.

This paper analyses, from the technical and economical point of view, the possible alternatives using various charge mixing: scrap, prereduced iron, solid pig iron and eventually also hot metal.

The comparison is carried out, with reference to a typical layout of an integrated minimill, taking into account the cost of production of steel in electric furnace, but also the availability of the materials and the flexibility of the plant.

Introduction

The charge of E.A.F. was selected, until few years ago, only on the basis of the production cost of liquid steel, obtained adding the price of the raw materials (generally scrap and D.R.I.) to the transformation cost (electric energy, electrodes, oxygen and so on). In such a way the conditions of an advantageous utilization of prereduced iron were well defined (low price of natural gas or carbon and availability of iron ore).

For long products, such as rebar, small section, wire rod, except for particular cases, high quality steel does not need. The success of minimill was based on small plants, which could produce at low prices, starting practically from any kind of scrap.

Now the situation is greatly changed : the minimills have extended their production to more sophisticated products and are now going into the market of flat products, also for high quality steel, like extra deep drawing, H.S.L.A. and so on.

In this case the quality of steel, in terms of composition, metallurgical properties and surface characteristics must be taken under control and the relevant requirements influence both plant design and operating practices. In particular the content of residual element, like Cu, Sn, Ni, Cr, Mo and As, must be controlled. Such elements cannot be removed (or can be removed only partially) during refining and their presence affects the properties of finished product.

The maximum allowable content of residual elements depend on sheet steel grade; for Cu, which represents the most heavy problem, the percentage in liquid steel must be less than 0.005 % for special applications, less than 0.01% for extra deep drawing and less than 0.1 for deep drawing and stainless steel. The content of Cu in scrap covers a very wide range, from 0.05% in heavy demolition to 0.6 in bundles of low quality. Then it is necessary to select the scrap to be charged in E.A.F. and for some type of products to reduce or to eliminate the purchased scrap.

The dilution of scrap must be performed by using raw materials deriving directly from iron ore, that is D.R.I. (or H.B.I. or iron carbide or similar) , solid pig iron and hot metal.

The type and amount of raw materials to be used for dilution depend, firstly, on the availability and price of high quality scrap and of "virgin" materials. But also the transformation costs are quite different for the various raw materials and the charge optimization must be made taking into account this value. Finally different charges affect the productivity too and this last item cannot be overlooked.

All these comparison parameters must be calculated considering the new technology utilized in the E.A.F. , whose operating practices have been deeply modified in the last years. Now the productivity of the electric steelmaking has reached the same level of the oxygen steelmaking and such level of productivity is necessary, in case of coils production, to feed the thin slab continuous casting machine in a suitable way.

Such aspects condition the decisions regarding the policy of raw materials supplying for a flat products minimill.

LAYOUT OF AN INTEGRATRD MINIMILL FOR FLAT PRODUCTS

At present many companies are carrying out or have planned the realization of a minimill for flat products. Then it is possible to define a typical layout for such a plant, also in case of production of high quality steels.

The comparison among different raw materials charges will be made on the basis of this layout; of course, different solutions can be adopted in function of the local conditions and of the specific technology and equipments selected.

Annual production

The production level which allows to couple, in the best way, the productivity of E.A.F. and continuous casting is about one million of liquid steel for year.

This production corresponds to a tap-to-tap and a casting time of about 50 minutes for a ladle of 120 t, that is 8,350 heats for year. That means not more than 7,000 hours of actual operating time, which is a very reasonable value, taking into account the indirect operating time (failures, delays and accidents) and the no-working time (holidays, annual and weekly maintenance).

Anyway this production level can be easily overcome: it is possible to reduce the E.A.F. tap-to-tap and the casting time (especially in case of wide strip) and to increase the direct operating time and so to reach a productivity 30-40% higher.

The solution here discussed is completely modular, in fact with the addition of a second electric furnace, a second continuous caster and a second equalization furnace, it is possible to double the production, utilizing the same rolling mill, to reach from 2,000,000 to 2,500,000 t/y.

Electric furnace

According to the last technological development the basis design of E.A.F. has been chosen with the primary aim of reducing energy consumption and environment pollution, keeping a very high productivity.

For this reason it has been adopted the twin shell solution, which allows to lessen the power-off time, avoiding dead time due to tapping, furnace preparation and charging of the first bucket. The time saving is about 10-15 % with a correspondent increasing in productivity and an energy saving of about 3%.

Drawings 1 and 2 show the plan view and the cross section of a possible twin shell layout with TAGLIAFERRI technology.

The twin shell arrangement also allows the exploitation of the exhaust fumes, coming out from melting shell, to preheat scrap or alternative raw material, charged in the other shell. Such preheating involves an energy saving of about 10%.

From the ecological point of view, if D.R.I or solid pig iron is charged there is no any problem of pollution. In case of scrap charging, the utilization of burners also in the second shell, during the phase of preheating, allows to control the temperature and the composition of the fumes going out to atmosphere and then the presence of undesired compounds. On the contrary, with the traditional

preheating, it is necessary to select the scrap quality and to limit the temperature to avoid the emission of dangerous gases.

Table 1

MAIN TECHNICAL CHARACTERISTICS OF E.A.F.	
Type	Twin Shell
Capacity (without hot heel)	120 tons
Power rating	110 MVA
Burners power	36 MVA
Oxygen by supersonic lance	5000 Nm^3/h
post combustion oxygen	3000 Nm^3/h
Oxygen consumption (in both shells)	48 Nm^3/ton
Natural gas consumption (in both shells)	10 Nm^3/ton
Raw material preheating	Yes

The E.A.F. is equipped with burners, in both shells, supersonic oxygen lance and utilizes also the post-combustion; this technique is always advantageous if the furnace operates with a large amount of oxygen, because it allows to obtain the highest yield from the combustion enthalpy of carbon.

Continuous casting and rolling mill

To produce high quality strip it is necessary to design an integrated line which allows to obtain optimum internal structure and surface quality, very good control of profile and flatness and a very tight tolerance in temperature.

The choice of the slab thickness, caster design, furnace type and rolling process must take into consideration all these requirements. Furthermore the design has to give high flexibility in production mix and to permit eventual discontinuities between casting machine and finishing mill, due to production change or minor failure and delay.

ANALYSIS OF THE ALTERNATIVE RAW MATERIALS

The raw materials taken into consideration to dilute or to substitute scrap are: prereduced iron, solid pig iron and hot metal. It is convenient to consider also, at least, an internal scrap of 10%

Prereduced iron

The reference composition of D.R.I.(or equivalent) for the following calculation is reported in Table 2.

The addition of coal is calculated in order to keep constant the oxygen consumption at a value of about 48 Nm^3/t (including post-combustion and burners in both shells).

Table 2

D.R.I. COMPOSITION	
Total Fe	91.8%
Fe met.	86.0%
Metallization	94.0%
Carbon	2.5%
Total gangue	4.0%

The carbon content has been chosen in order to limit the oxygen blowing at high percentage of D.R.T.. When this percentage reaches 90% (the maximum quantity allowable, considering internal scrap), the oxygen demand increases up to 55 Nm^3/t, but this value is still acceptable, because of increasing in tap-to-tap time.

In case of percentage of D.R.I. higher than 40%, a lot of prereduced iron is charged into the bucket to have a better recovery of energy in the preheating shell. This practice of preheating, as well as the massive oxygen blowing, allows to reduce the higher energy consumption due to the reduction of oxides present in D.R.I. and to enhance productivity.

Solid pig iron

The utilization of solid pig iron as raw material in electric steelmaking is not so usual, because it has not a market and is not easily available. Then solid pig iron is usually utilized only in very few electric steelmakings and it is not possible to program a systematic use of this material. Tab.3 shows the reference composition for solid pig iron and for liquid hot metal.

Table 3

PIG IRON COMPOSITION	
C	4.4%
Si	0.5%
Mn	0.6%
P	0.05%
S	0.03%
Hot metal temp.	1340° C

Nevertheless with the overcapacity of the blast furnace based iron and steel shops and with the diffusion of smelting reduction plants, there is not any reason which prevents a larger utilization of solid pig iron in E.A.F. charging.

From the point of view of charging practice, solid pig iron can be considered such as scrap and the adoption of "hot heel" eliminates any problem of melting

The high content of carbon limits the percentage of solid pig iron in charge, unless very high quantity of oxygen and, above all, tremendous blowing flowrate are utilized. For this reason it has been assumed as maximum percentage of solid pig iron in charge only 50%.

Hot metal

The utilization of hot metal in charge must be limited to 20-30%; in fact, with higher percentage, other processes can be utilized with more efficiency. Anyway the maximum value for which there is a consolidated experience is 20% and there fore this value has been considered as maximum one.

The effect of an addition of liquid hot metal is pratically the same in case of utilization of any solid charge, that is scrap, D.R.I. and solid pig iron, but the operating practices are a little different. The experience in charging hot metal in E.A.F. is not so large and would be interesting to reach a percentage in charge up to 30%, in order to avoid the necessity of two scrap buckets.

RESULTS AND DISCUSSION

The maximum productivity per hour for different alternative raw materials is reported in Fig. 1. In this figure the "zero value" corresponds to charge of 100% scrap; the effect of the combination of more than two types of material in charge can be calculated by addition of the single effects.

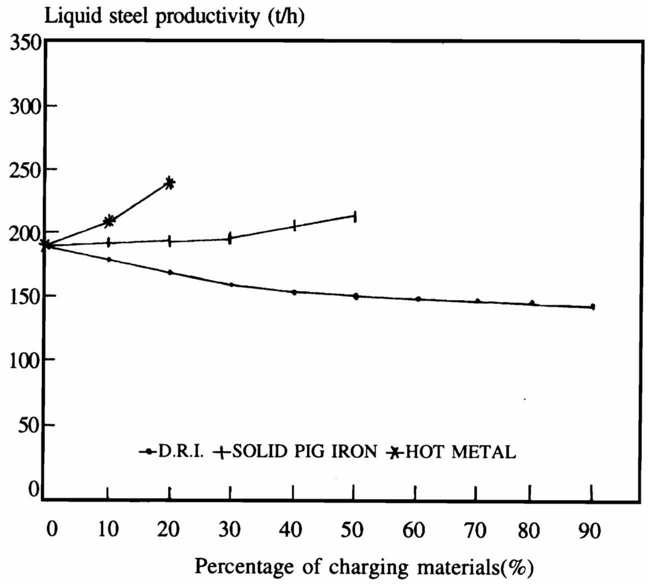


Fig. 1: Maximum productivity with different charging materials.

Of course, this is the top value reachable without any delay due to equipments before or after the furnace. The very high specific transformer power (almost 1 MVA for ton of capacity), the charge preheating and the twin shell solution takes to a tap-to-tap time which can be pratically considered as the minimum obtainable. It is likely that the productivity of the electric arc furnace is going to reach a maximum value, as it has happened, some years ago, for the oxygen converters.

Fig. 2 shows the energy consumption for the same conditions of charging. Also in this case the reference value is very low, because of high consumption of oxygen and natural gas and of energy recovery. The trend not so regular of the curves depends on the increasing amount of oxygen blown for the highest percentage of D.R.I. and pig iron.

D.R.I. and pig iron have opposite effects and that suggests the possibility to combine these two raw materials to maintain the same level of productivity, when the scrap cannot be utilized; of course if availability and price allow such supplying policy.

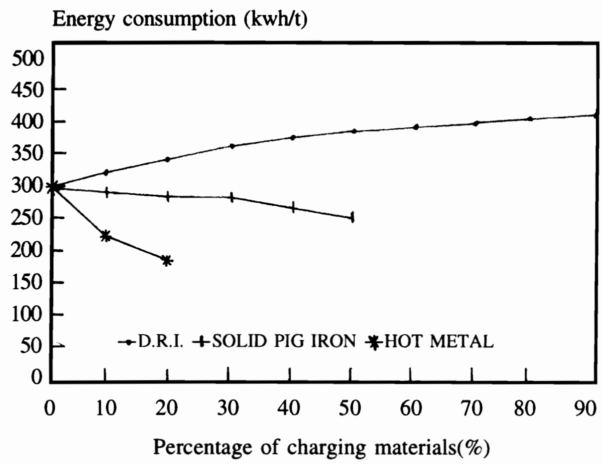


Fig. 2: Energy consumption with different charging materials.

Finally Fig. 3 presents the differences in transformation cost induced by use of alternative raw materials, always with reference to the conditions of 100% scrap. The prices utilized are reported int Tab. 4.

Table 4

MAIN INPUT PRICES	
Energy	.07 \$/kWh
Oxygen	.15 \$/Nm^3
Natural gas	.16 \$/Nm^3
Carbon (mean value)	.12 \$/kg
Electrode	2.5 \$/kg
Refractory (brick)	1.3 \$/kg
Refractory (gunning)	.5 \$/kg

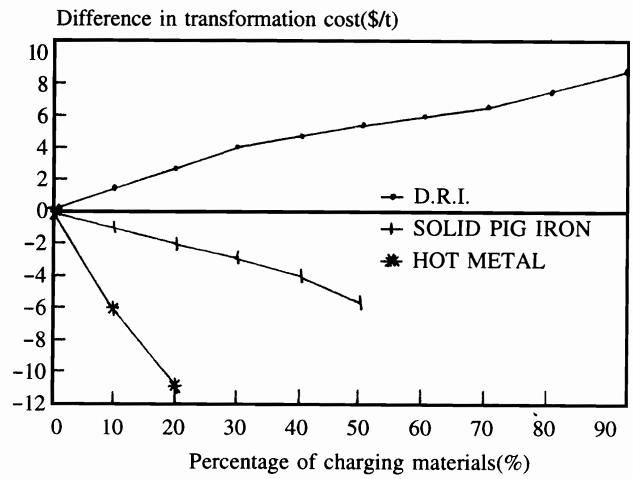


Fig. 3: Changes in transformation cost with different charging materials.

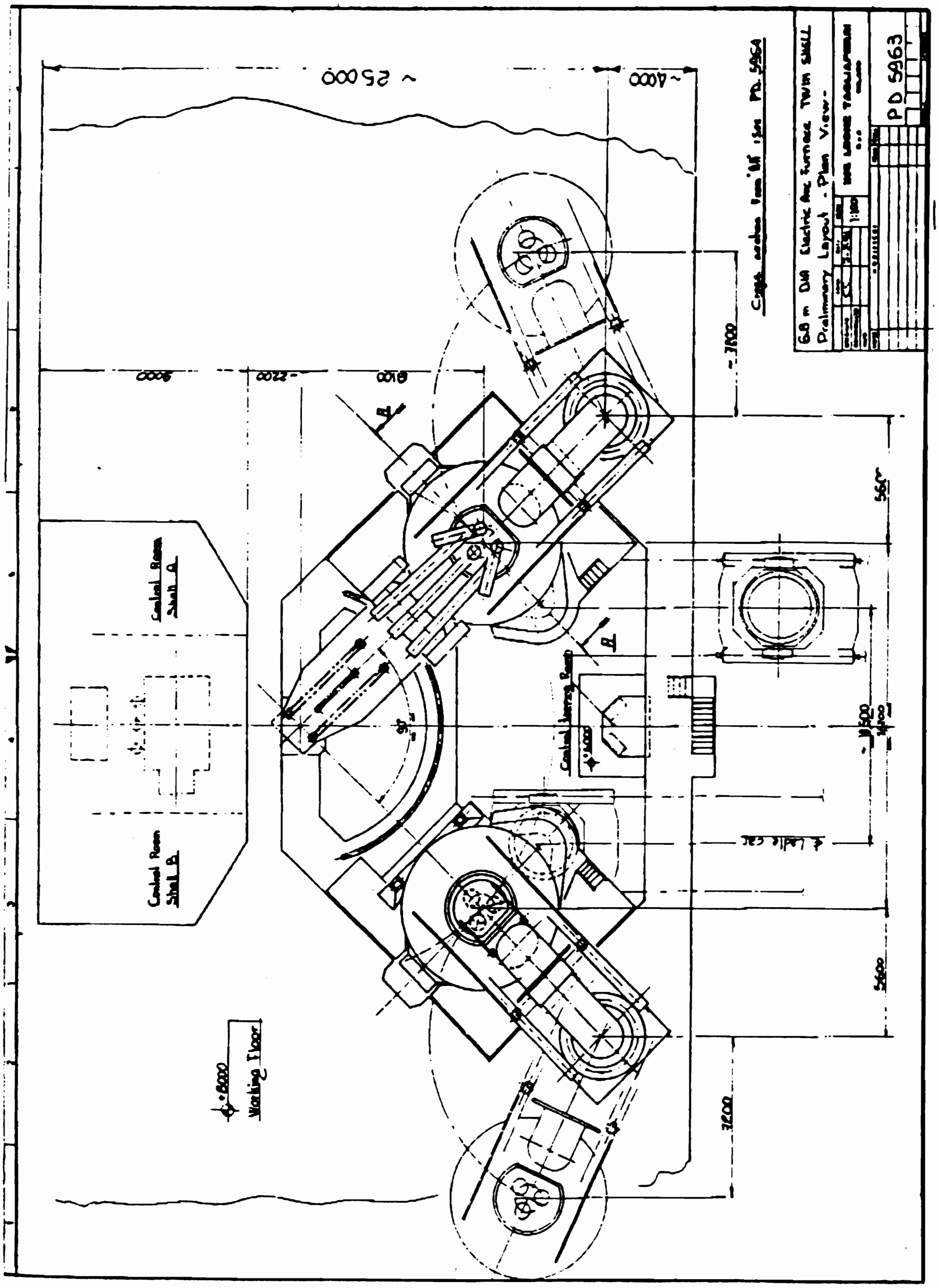
With the ratio between oxygen price and electric energy price here assumed the utilization of solid pig iron or hot metal allows to obtain very interesting money savings, which can be evaluated jointly with the raw materials prices.

CONCLUSION

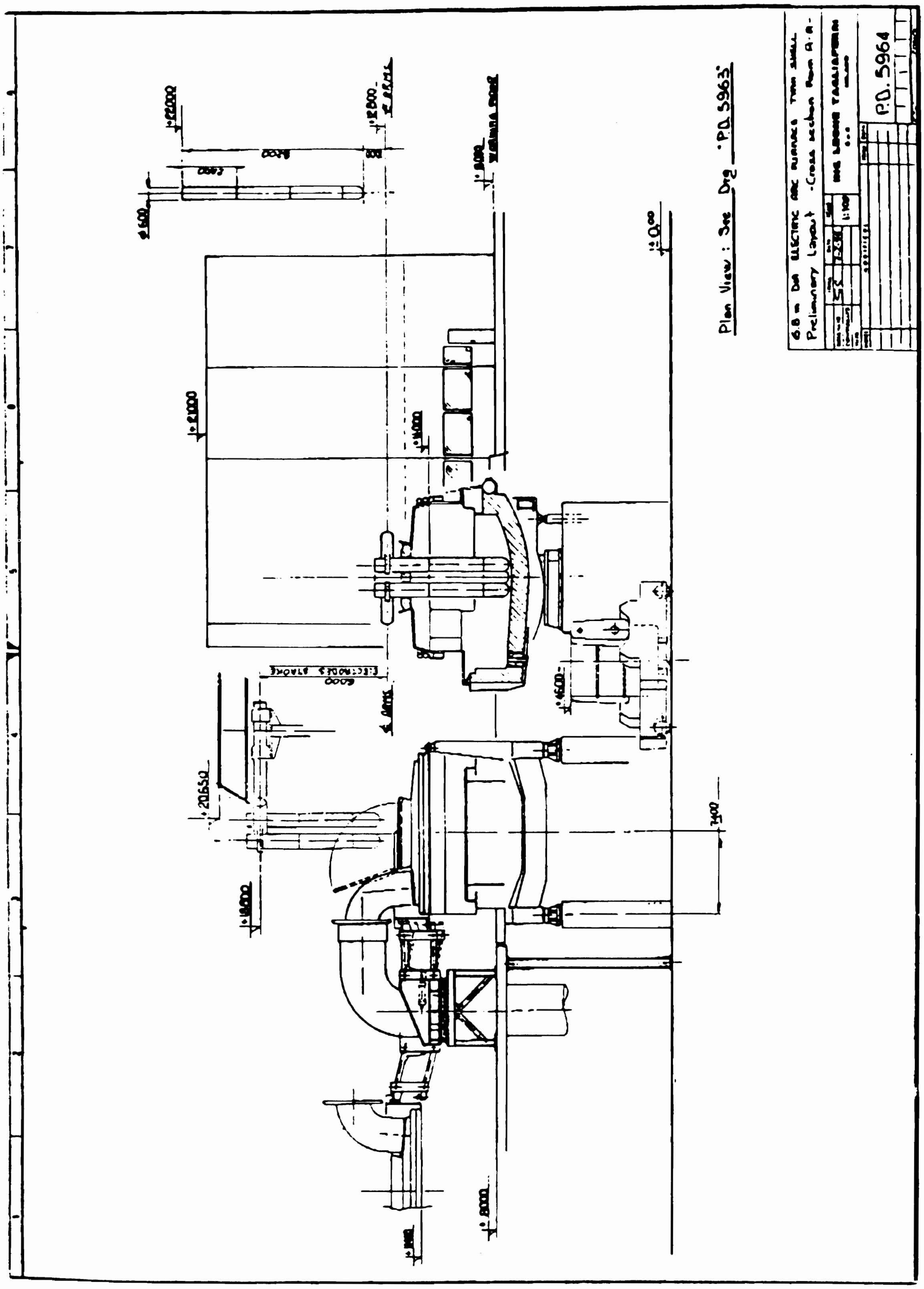
The choice of the charge composition for electric steelmaking depends on the following parameters:

- composition of liquid steel to be produced, with reference to the contents of residual elements;
- productivity, in terms of ton per hour, to be achieved;
- transformation and raw materials costs.

In the future more severe quality requirements and also different availability of alternative raw materials could modify very considerably the present market situation: the investment decisions must take into account all these aspects, because the "scenario" is quickly changing.



Drawing 1: Twin shell E.A.F. preliminary layout: plan view



Drawing 2: Twin shell E.A.F. preliminary layout: cross section