η_1 = (sinter + return fines + hearth layer materials) / (new feed + fuel + return fines + hearth layer materials) x 100

η_2 = Sinter/(sinter + return fines + hearth layer materials) x 100

$= \frac{65.6 - 50.7}{50.7} \times 100 = 29.4\% \ (35.2\%)$ ... Improvement in productivity

The return fines consumption varies from 714.7 kg/t to 1,226.2 kg/t in this 3-month period. Conservatively, a 15% of improvement in productivity is to be expected.

(5) Improvement in availability

The availability of the sinter plant shall be increased to 90% through intensified maintenance. To achieve this goal, not only intensified maintenance of the sintering plant but various measures to eliminate or reduce external causes of plant shut-down (e.g. shut downs due to blast furnace shut-down, under-supply of cooling water and accidents at the raw materials handling facilities) are needed.

In view of troubles frequently taking place due to attack by chlorine and alkali, it is necessary to study the possibility of installing the third sintering machine for safety considerations even if the sinter requirement could be satisfied by a mere modification of the existing installations.

(6) Production goal

Productivity improvement from:

1% addition of burnt lime	5%
Use of slit bars	5%
Increased suction pressure	14%
Improved yield	15%
Total	39%

Using the average productivity 0.755 t/hr·m^2 from November, 1975 to October, 1976 as a base productivity, the projected productivity when these measures are taken will be 1.049 t/hr.m^2 (0.755 x 1.39).

Though contributions to the productivity improvement can be expected to come also from the reduced addition of coke and decreased air leak through intensified equipment maintenance, they cannot be incorporated in the estimate since the former contribution cannot be made clear before pot testing and the current level of air leakage is not grasped quantitatively as yet.

Estimated production 1.049 t/hr·m^2 x 24 hrs. x 50 m^2 x 2 strands

= 2,518 t/d (daily)

2,518 t/d x 0.9 = 2,266 t/d (average)

(Note)

The information received from Helwan Works before sending the mission says that Helwan sinter plant is operated intentionally at 60% of the capacity. A definite answer as to whether this is true was not obtained. If it is really so, it may well be expected to realize a productivity: $0.755 \text{ t/hr}\cdot\text{m}^2 \times \frac{1}{0.60} = 1.258 \text{ t/hr}\cdot\text{m}^2$, and what is left unsolved involves only the availability of the plant.

1.2 Improvement of facilities

1.2.1 Individual specifications

(1) Replacement of exhauster

1) Air suction

The unit air suction rate is 100 $m^3/min/m^2$ as indicated by the operational results at Helwan Works. (3,600 Nm^3/min x - 600 mmAq x 125°C).

Therefore, the new suction rate will be 50 m^2 x 100 $m^3/min/m^2$ = 5,000 m^3/min.

2) Suction pressure

-1,200 mmAq for the reason described in 1.1.4, (3)

3) Others

Temperature: 150°C Motor: about 1,600 kw

(2) Modification of screening equipment

a) The cold screen currently in use shall be replaced.

b) A secondary screen of a double-deck type shall be newly installed and part of the oversieve sinter shall be used as hearth layer materials.

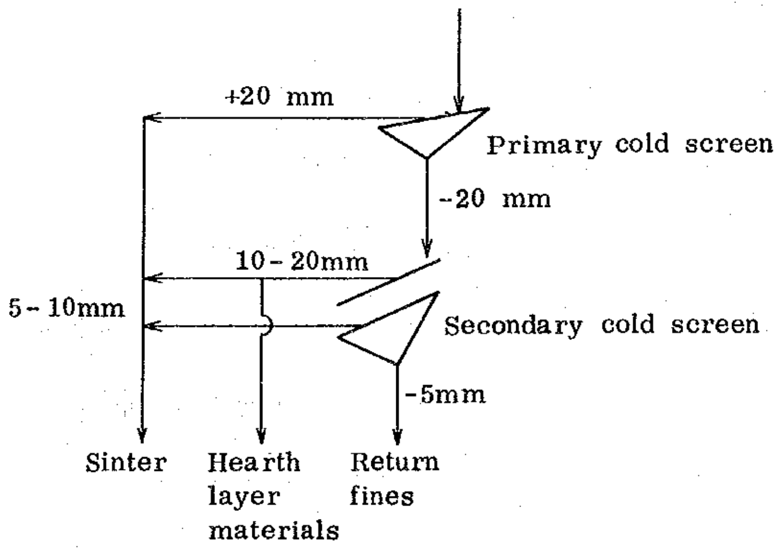


Fig. I.12 Screening equipment flow

Table I.3 Estimated size composition

	Sinter	Return fines	Screen feed
+20 mm	35% (350 kg)		21 % (350 kg) → 20%
20 - 10	45 (450)	10% (70 kg)	31 (520) → 30
10 - 5	15 (150)	45 (315)	27 (465) → 27
-5	5 (50)	45 (315)	21 (365) → 23
Total	100 (1,000)	100 (700)	100 (1,700)

20% of the design capacity of the sintering machine, 1.1 t/hr·m², shall be taken as an allowance.

$$1.1\ t/hr\cdot m^2 \times 100\ m^2 \times 1.20 = \overset{\text{product}}{132\ t/hr} \ \ldots\ \overset{\text{sinter cake}}{193\ t/hr} \longrightarrow 200\ t/hr$$

Product sinter	Hearth layer materials	Return fines	Total
1,000 kg	130 kg	330 kg	1,460kg

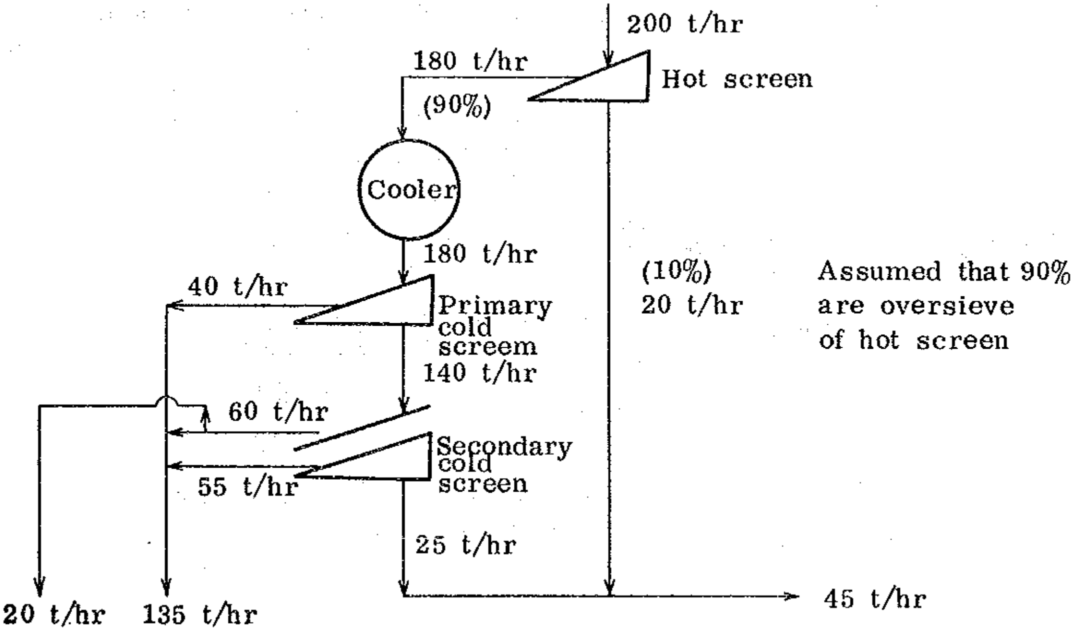


Fig. I.13 Estimated flow balance of sinter screening

3) Size of each cold screen

. Primary cold screen

Capacity: 180 t/hr

Size of screening machine: 6' x 10' , 5.7 m^2
(1,830mm) (3,100mm)

Throughput: 32 $t/hr/m^2$

. Secondary cold screen

Capacity: 140 t/hr

Size of screening machine: 6' x 16' , 9 m^2
(1,830mm) (4,960mm)

Throughput: 15.4 $t/hr/m^2$

4) Belt conveyor: 1 set

(3) Burnt lime mixing equipment

The equipment shall be capable of mixing burnt lime in amounts up to 2% of the mixture.

2,518 t/d x $\overset{\text{O.R.}}{1.285}$ x 0.02 = 65 t/d ... 2.7 t/hr

Capacity of hopper:

The hopper shall have a capacity sufficient to store one day supply of burnt lime with a bulk density of 1.0 t/m^3.

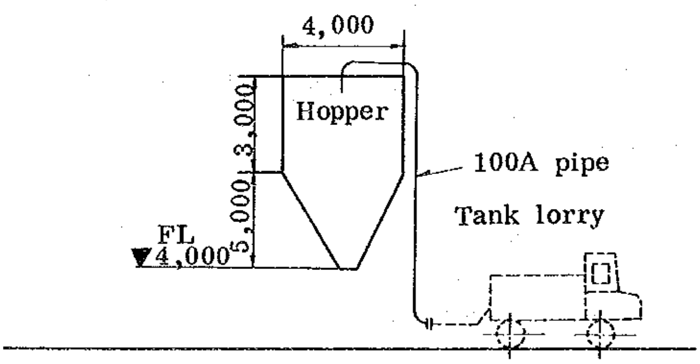


Fig. I.14 Conceptual drawing of burnt lime receiving equipment

Feeder: Screw feeder

Weigher: 0 - 2.7 t/hr

Tank lorry: 1 unit (10 m^3) with a compressor (10 Nm^3/min) mounted on it

(4) Sinter storage facilities

Sinter shall be stored in amounts equivalent to 1-day output of the plant. The required volume of the storage facilities is, therefore,

$2,260 \text{ t/d} \div 1.8 \text{ t/m}^3 = 1,255 \text{ m}^3$.

The stacking facility shall be a stationary one from which sinter shall be carried by bulldozers or shovel-dozers, and a re-screening equipment shall also be provided.

Undersieve fines shall be handled by shovel-dozers.

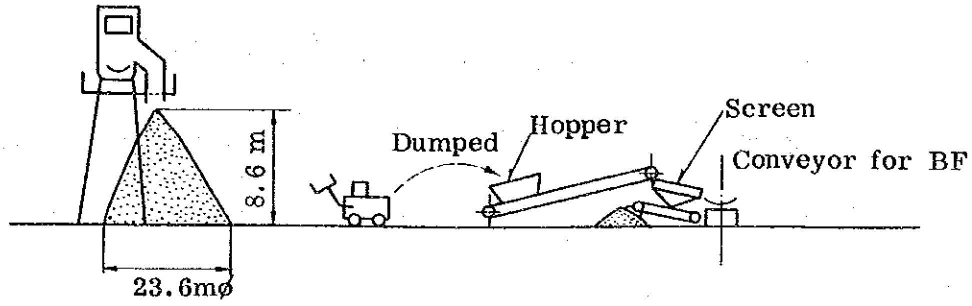


Fig. I.15 Conceptual drawing of product sinter storage facilities

1.2.2 Table of major equipment specifications

Table I.4 Comparison table of current and proposed specifications

Item	Current specifications	Proposed specifications
Storage hopper		
Iron ores	8 x 103 m^3 CF: 100 t/hr	Same as left
Limestone	3 x 103 25 t/hr	
Mill scale	1 x 103 12.5 t/hr	
Return fines	1 x 144 (hot) 1 x 25 (cold).	
Coke	3 x 103 12.5 t/hr	
Mixer		
Primary	Capacity: 112 - 225 t/hr, 2.8mø x 6mL	Same as left
Secondary	Capacity: 112 - 225 t/hr, 2.8mø x 6mL	
Surge hopper	20 m^3, 130 t/hr feeder	Same as left
Ignition furnace	6,941mmL x 2,200mmH, 10 burners	Same as left
Sintering machine	50 m^2, 2mW x 25mL, 70 pallets Pallet speed: 1.1 - 4.46 m/min Standard: 3.0m/min Pallet: 2mW x 1mL x 300mmH	Same as left + hopper for hearth layer materials
Exhauster	3,500 Nm^3/min at - 760 mmAq, 150°C	5,000 m^3/min at -1,200 mmAq, 150°C
Hot crusher	125 t/hr, 1 mø	Same as left
Hot screen	2mW x 5mL Mesh: 6 mm	Same as left
Cooler	60 m^3	Same as left
Cold screen	1.5mW x 3.0mL, Mesh: 8 mm	Primary: 180 t/hr; 1.83mW x 3.1 mL Mesh: 20 mm Secondary: 140 t/hr; 1.83mW x 4.96mL Upper mesh: 10mm Lower mesh: 5mm
Dust collector		To be replaced because of increased negative pressure
Rod mill	25 t/hr x 1, 2.1mø x 3mL 16 t/hr x 1, 0.9mø x 1.0mL	Same as left
Burnt lime receiving equipment		Hopper: 65m^3 x 1 Tank lorry with a compressor
Sinter storage facilities	- -	Tripper: 1 unit Screen: 1 unit

1.3 Future raw materials processing system

If the present sintering practice which uses the raw Baharia ore is left unammended, mechanical troubles due to attack by chlorine and alkali cannot be avoided and the equipment maintenance cost required to repair such troubles will be enormous. It would be better to introduce one additional strand and operate two strands with the remaining one maintained as a stand-by unit, even if the operation on two strands is sufficient in capacity to meet the sinter reaquirement.

If appropriate preparation of iron ores is carried out magnetizing roasting or high-intensity magnetic separation, it seems likely that a question will come out whether or not sintering itself is an appropriate succeeding process.

What is required most urgently is, therefore, to study into the possible means of raw materials preparation and, then, the necessity for the planned modification of the sinter plant should be determined.

2. Blast Furnace

2.1 Study of blast furnace productivity

2.1.1 Burden calculation

(1) Chemical analysis values of charging materials*

Table I.5 Chemical analysis of raw materials

Raw material	Fe	SiO_2	CaO	MgO	Al_2O_3	MnO	P	S	I.L.
Sinter (base)	49.21	11.22	10.94	1.03	2.15	1.14	0.21	0.09	-
Sinter ** (basicity = 1.00)	49.06	11.20	11.20	1.03	2.15	1.14	0.21	0.09	-
Limestone	1.00	2.42	52.57	0.87	1.14	-	0.08	0.06	42.49
Coke	1.34	4.94	0.45	0.26	2.84	-	0.02	1.23	-

* Mean values during the period Nov. '75 - Oct. '76.

** Values obtained by adjusting mean values during the period Nov. '75 - Oct. '76 ($CaO/SiO_2 = 0.975$) with limestone to obtain the basicity (CaO/SiO_2) of 1.00.

(2) Preconditions of calculation

. Required Fe	970 kg/t-pig
. Yield rate of Mn in pig iron	65%
. Yield rate of P in pig iron	100%
. Slag basicity of blast furnace slag	$CaO/SiO_2 = 1.20$

. Slag volume = $(\Sigma SiO_2 + \Sigma CaO + \Sigma MgO + \Sigma Al_2O_3)$ in slag x $\frac{1}{0.95}$

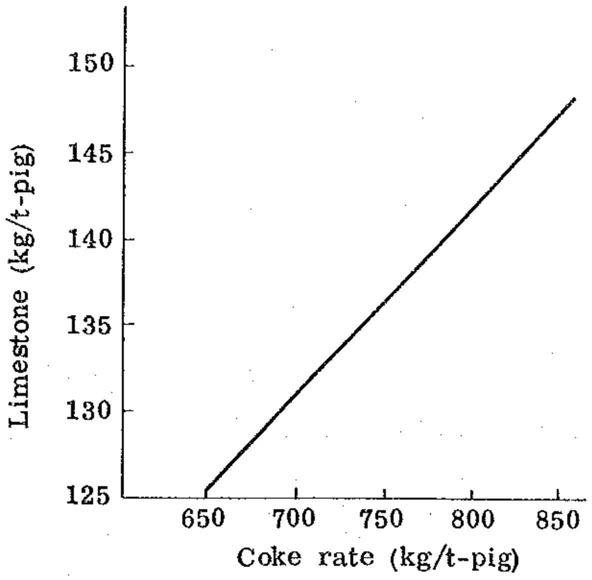
. Si in pig 0.7%

(3) Burden calculation

1) Raw material consumption

Sinter 1,977 kg/t-pig

Limestone & coke



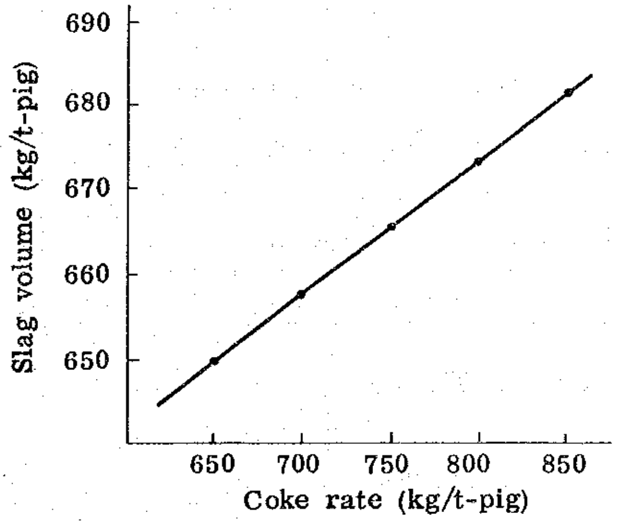
Limestone consumption at each coke rate is shown in Fig. I.16.

Fig. I.16 Limestone consumption at each coke rate

2) Chemical components in pig iron

C	4.00%
Si	0.70%
Mn	1.16%
P	0.44%

3) Slag volume and its chemical analysis



Slag volume at each coke rate is shown in Fig. I.17. Slag analysis at coke rate of 750 kg/t-pig is as follows.

SiO_2	37.15%
CaO	44.58%
MgO	3.53%
Al_2O_3	9.82%

Fig. I.17 Slag volume at each coke rate

* The data offered by Helwan Works indicate that the Al_2O_3 contained in slag is disproportionately higher than that contained in charging materials. This is attributable to the fact that the measured value of Al_2O_3% in the chemical analysis of raw materials tends to be rather lower than the actual value. The chemical analysis value of Al_2O_3 used in this burden calculation may also have been lower than the actual value, so the actual value of Al_2O_3 in slag is probably higher than 9.8%.

2.1.2 Fuel rate

(1) Based on the actual results in Helwan Works

Table I.6 Target operating conditions and coke rate

Operating factor	Base condition*	Target condition	Coke rate reduction per unit volume of each operating factor	Total coke rate reduction
Sinter ratio (%)	81.3	100	-0.8kg/+1%	-15.0kg
Scrap (kg/t-pig)	122.3	0	-0.3kg/+1 kg	+36.7
Limestone (kg/t-pig)	129	136	+19.2kg/+100kg	+1.3
Dolomite (kg/t-pig)	75	0	+18.0kg/+100kg	-13.5
Coke ash (%)	11.2	11.0	+10kg/+1%	-2.0
Si (%)	0.68	0.70	+70kg/+1%	+1.4
P (%)	2.04	0.44	+28kg/+1%	-44.8
Blast temperature (°C)	692	1,000	<950°C -20kg/+100°C 950-1,050°C -15kg/+100°C	-59.1
Moisture in blast (g/Nm^3)	9.8	10.9	+0.8 kg/+1 g	+0.9
Slag volume (kg/t-pig)	933	665	+25kg/+100kg	-67
Oil rate (kg/t-pig)	66	80	-1.2kg/+1kg	-16.8
Coke rate (kg/t-pig)	921	743	(Total)	(-178)

* Actual results of Nos. 1 and 2 blast furnaces during the period Dec. '75 - Sept. '76.

(2) Based on Nippon Steel's standard practice

Fuel rate (kg/t-pig) = 499 + 0.2 (70 - Oil rate) - (kc x Blast temp. - K_T)*
- 0.8 (13.5 - Moisture in blast) + 0.8 (80
- Sinter ratio) - 0.25 (300 - Slag volume)
- 0.3 x Scrap - 10 (11.5 - Coke ash)
+ 70 (Si - 0.5) - 28 (0.1 - P) - 0.192 (10
- Limestone) = 630

Blast temperature	kc	K_T
$\leq 950^{\circ}C$	0.20	215
$950^{\circ}C \sim 1,050^{\circ}C$	0.15	167.5
$1,050^{\circ}C \sim 1,150^{\circ}C$	0.10	115.0
$1,150^{\circ}C <$	0.08	92.0

It is estimated that the difference between fuel rate of 823 (743 + 80) kg/t-pig based on the actual results in Helwan Works and fuel rate of 630 kg/t-pig based on Nippon Steel's standard practice is mainly due to

- the difference in CO gas utilization rate due to the difference in gas permeability,
- the difference in reducibility of ore (low reducibility of high FeO sinter), and
- the difference in efficiency of oil injection (low flame temp.).

If the abovementioned items are improved, therefore, the fuel rate in Helwan Works will approach to that of Nippon Steel's standard practice, and will be further reduced. In the current high slag volume, high alkali burdening practice in Helwan Works, however, blast furnace operation is difficult, so improvement of raw material conditions (beneficiation of ore) is needed.

Note) When natural gas is injected instead of oil,

coke rate = 765 kg/t-pig
natural gas rate = 80 Nm^3/t-pig (67 kg/t-pig)

2.1.3 Pig iron production capacity

(1) Study results and measures to be taken for each equipment

After careful study of pig iron production capacity, taking into consideration the policy to use the existing equipment as far as possible, the following conclusion was reached.

1) Pig iron production capacity

P_M	(Maximum pig iron production)	600 t/d · BF
P	(Average pig iron production)*	540 t/d · BF

* At the operation rate (P/P_M) of 90%.

2) Measures to be taken for each equipment

a) Charging equipment:
- . The existing equipment shall be used. The maximum weighing frequency of scale car shall be more than 6.3 charge/hr through improvement of works.

b) Blast furnace:
- . The mantle shall be replaced, and the hearth diameter shall be enlarged to 5.7 m.

c) Hot blast stove:
- . Blast temperature shall be raised to 1,000 °C by employing three stoves.
- . Replacement of checkerwork.
- . Replacement of hot blast pipe line

d) Blower:
- . The existing equipment shall be used.
- . Shortage of blower capacity shall be made up for by oxygen enrichment (max. 2,200 Nm^3/hr · BF).

e) Gas cleaning equipment:
- . The existing equipment shall be used.

3) High top pressure operation

Although high top pressure operation remarkably increases production, it is not economical and cannot be recommended since practically all the equipment have to be replaced.

(2) Charging capacity

1) Capacity of each charging equipment

a) Scale car

Weighing capacity = 12 t/charge

Weighing frequency = 6 - 7 charges/hr

The present charging frequency is 6 charges/hr. According to DEMAG report "Reply to the Memorandum of the Egyptian Iron & Steel Company concerning Iron & Steel Works Helwan (dated May 8, '59, p.8)", equipment of the same type in Ruhr marked a record of 10 charges/hr (= 40 skips/hr) in the past, so 7 charges/hr can be achieved through work imporvement.

b) Coke weigher: 5 t/batch

c) Skip:	Maximum ore handling capacity	6 t/batch (= 12 t/charge)
	Maximum coke handling capacity	5 m^3 x 0.45 t/m^3 = 2.25 t/batch (= 4.5 t/charge)

2) Charging capacity

Charging capacity is determined by the weighing frequency of scale car and the capacity of skip. Charging frequency should have an allowance of min. 130% of P_M. Therefore, charging capacity in terms of t-pig/d is a tapping volume equivalent to 6 - 7 x 24/1.3 = 110 - 129 charges/d. Fig. I.18 shows the relation between coke rate and maximum production determined by charging capacity when ore consumption (sinter 1,977 kg/t-pig + limestone 143 kg/t-pig) is 2,120 kg/t-pig.

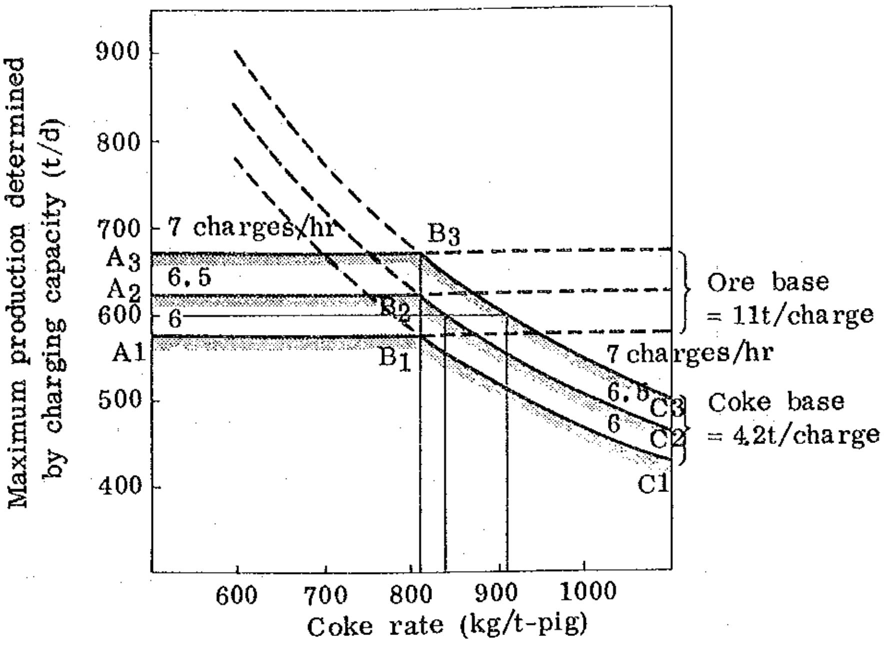


Fig. I.18 Maximum production determined by charging capacity

Calculation will be made assuming that normal ore base is 11 t/charge and normal coke base 4.2 t/charge, taking into consideration some variations in maximum ore base of 12 t/charge and maximum coke base of 4.5 t/charge. The curves $A_1B_1C_1$, $A_2B_2C_2$ and $A_3B_3C_3$ in Fig. I.18 represent the relation between coke rate and P_M equivalent to charging capacity for charging frequencies of 6, 6.5 and 7 charges/hr, respectively. At charging frequency of 6 charges/hr, P_M of 600 t/d cannot be satisfied. P_M reaches 600 t/d at the charging frequency of 6.3 charge/hr, and subsequently, the more charging frequency increases, the more increases charging capacity.

Fig. I.18 indicates that coke rate becomes a limiting factor to charging capacity when coke rate is 810 kg/t-pig or more, and ore rate (2,120 kg/t-pig) becomes a limiting factor when coke rate is less than 810 kg/t-pig. Therefore, charging capacity can be raised by beneficiating ore to lower SiO_2% and accordingly ore rate (to approximately 1,600 kg/t-pig in Nippon Steel). Moreover, as charging frequency is increased to attain P_M of 600 t/d, coke rate as a limiting factor is mitigated. For example,

when charging frequency is 6.3 charges/hr, allowable coke rate will be 810 kg/t-pig or less, and similarly allowable coke rate will be 910 kg/t-pig or less at 7 charges/hr.

(3) Fuel consumption capacity of blast furnace

An analysis of operation results confirms the following equation between fuel consumption capacity of blast furnace and hearth diameter.

$$F \text{ (t-fuel/d)} = 9.06 \times \text{H.D.}^{2.32} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad \text{(I.1)}$$

Where F: fuel consumption capacity (t-fuel/d), H.D.: hearth diameter (m)

Needless to say, the fuel consumption capacity is not determined only by this equation, but it varies with the level of permeability and can be improved by oxygen enrichment and high top pressure operation. However, this equation is helpful as a measure for determining fuel comsumption capacity. According to this equation, the fuel consumption is approximately 400 t/d at the present hearth diameter of 5.1 m, as shown in Fig. I.19. On the other hand, operating results of Helwan Nos. 1 & 2 blast furnaces in the recent year indicate that the monthly average value of fuel consumption (adjusted for the operation rate of 100%) was 307 t/d - 409 t/d (the maximum value was recorded in No. 2 blast furnace in May '76). If the present hearth diameter is maintained, it is difficult to achieve the production of 600 t/d even at the maximum value of fuel consumption because the fuel rate has to be lowered to 680 kg/t-pig.

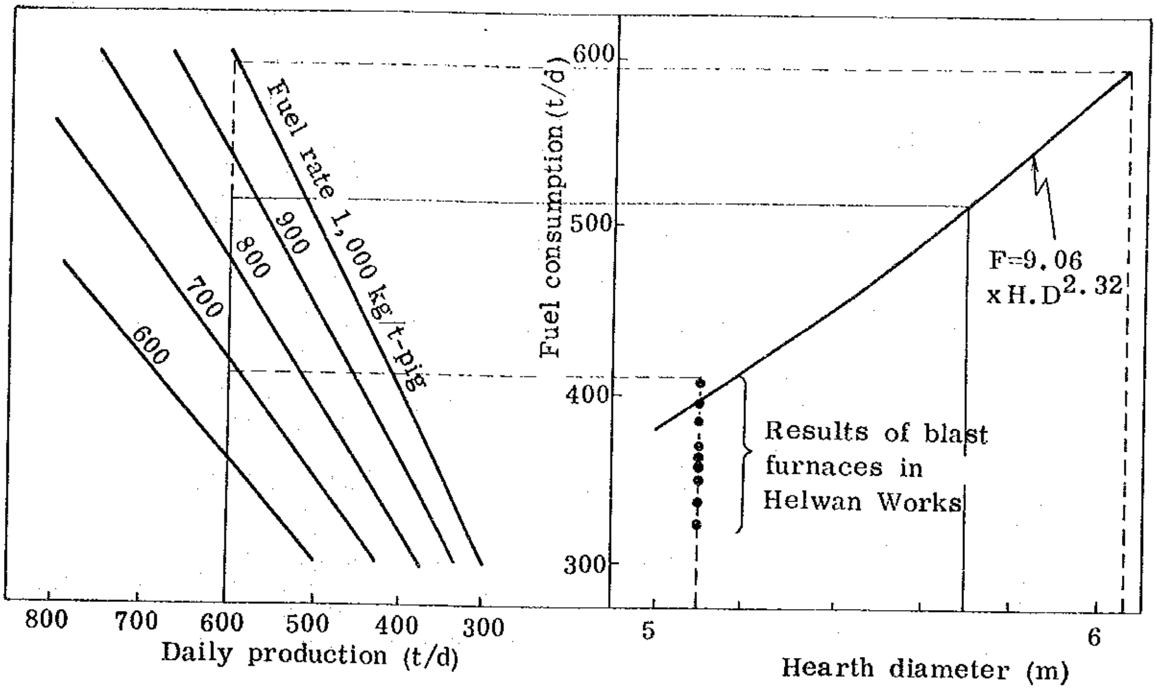


Fig. I.19 Relation between hearth diameter, fuel consumption capacity, fuel rate and daily production

It is sure that the fuel consumption can be raised by enlarging the hearth diameter. According to the equation (I.1), the hearth diameter must be enlarged to 6.06 m in order to achieve the daily production of 600 t/d at the present fuel rate (average 987 kg/t-pig). It is difficult, however, to enlarge the hearth diameter to 6.06 m due to the space limitation. In order to obtain 600 t/d of iron production, therefore, both fuel rate reduction and hearth diameter enlargement are required. Judging from the space near the blast furnace, the maximum limit of hearth diameter is estimated at 5.7 m, which require the fuel rate to be 850 kg/t-pig. Reduction of fuel rate to such a level can be achieved as described in 2.1.2

Oxygen enrichment has an effect in increasing fuel consumption by 30 - 40 t/d per 1,000 Nm^3/hr of oxygen to be injected. It is recommended to adopt oxygen enrichment since it is effective in improving theoretical flame temperature in front of tuyere, increasing the efficiency of fuel injection, supplementing the capacity of blower, etc.

(4) Blower capacity

1) Blast volume and oxygen volume

Assuming the required blast volume (without oxygen enrichment) per 1 ton of fuel at fuel rate (= coke rate + injected fuel rate) of 700 - 1,000 kg/t-pig is 2,800 Nm^3 based on the operating results in Japan, the blast volume and the enriched oxygen volume for P_M of 600 t/d at each fuel rate and oxygen enrichment level are shown in Fig. I.20.

$$\text{Blast volume } (\mathrm{Nm}^3/\mathrm{min}) = \frac{2,800\,(\mathrm{Nm}^3/\text{t-fuel}) \times \text{fuel rate (t/t-pig)} \times 600\,(\mathrm{t/d})}{1,440 \text{ min/d}}$$

$$\times \frac{1,659 - 21 \times O_2 \text{ enrichment ratio } (\%)}{1,659 + 79 \times O_2 \text{ enrichment ratio } (\%)} \times \frac{1}{0.9} \quad \cdots\cdots\cdots\cdots\cdots \quad (\mathrm{I}.2)$$

$$\text{Enriched oxygen volume } (\mathrm{Nm}^3/\mathrm{hr}) = \text{Blast volume } (\mathrm{Nm}^3/\mathrm{min})$$

$$\times \frac{O_2 \text{ enrichment ratio } (\%)}{79 - O_2 \text{ enrichment ratio} (\%)} \times 60 \text{ (min/hr)} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (\mathrm{I}.3)$$

(Although blast leak ratio is 15 - 40% at present, calculation was made on the assumption that it can be reduced to 10% through improvement.)

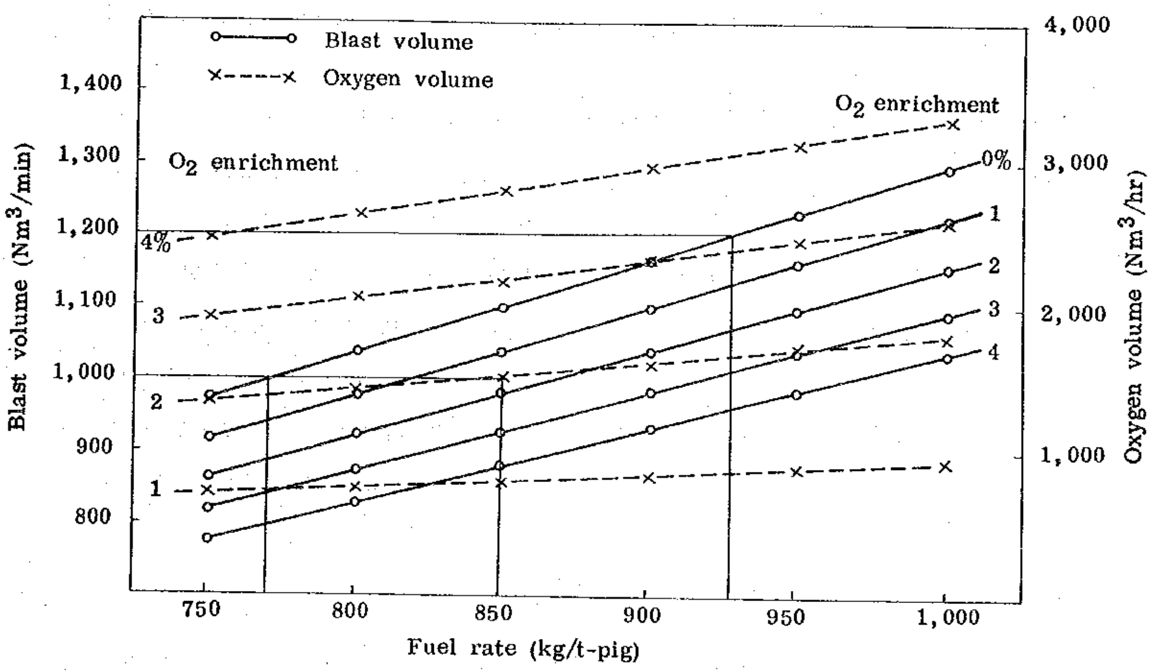


Fig. I.20 Blast volume & enriched oxygen volume at P_M of 600 t/d

Blast volume at fuel rate of 927 kg/t-pig or less is within the blower capacity range (1,200 Nm^3/min) without oxygen enrichment. However, when 200 Nm^3/min of blast is used for stove pressurization to prevent hot blast pressure from dropping during hot blast stove changeover, the limit of blast volume is 1,000 Nm^3/min. Without oxygen enrichment in such a case, the requirement becomes considerably stringent, since fuel rate is 770 kg/t-pig or less. When fuel rate is 850 kg/t-pig, well-balanced blast can be obtained by introducing approximately 2% of oxygen enrichment. It can be said, therefore, that oxygen enrichment would provide sufficient balst volume.

2) Blast pressure

Assuming blower discharge pressure is 1,200 g/cm^2, pressure drop between blower and hot blast stove 150 g/cm^2, and allowance for variations in hot blast pressure 150 g/cm^2, the requirement for hot blast pressure should be 900 g/cm^2 (1,200 - 150 - 150). According to the operating results of blast furnaces of inner volume of 1,000 m^3 or less, $\triangle P/V$; pressure loss in the furnace (g/cm^2)/ $\{$blast volume (Nm^3/min) + oxygen volume (Nm^3/min)$\}$, is 0.8 - 1.1. The relation between hot blast pressure, oxygen enrichment ratio and $\triangle P/V$ at P_M of 600 t/d and fuel rate of 850 kg/t-pig is shown in Fig. I.21. As is evident from the figure, without oxygen enrichment, the requirement becomes stringent since $\triangle P/V$ of 0.86 or less is required. When oxygen enrichment of 2% is employed, $\triangle P/V$ is 0.93, while $\triangle P/V$ is 0.98 or less in oxygen enrichment of 3%. In this way, the requirement is relieved as oxygen volume is increased. In any case, permeability is required to be improved because of less room in blast pressure.

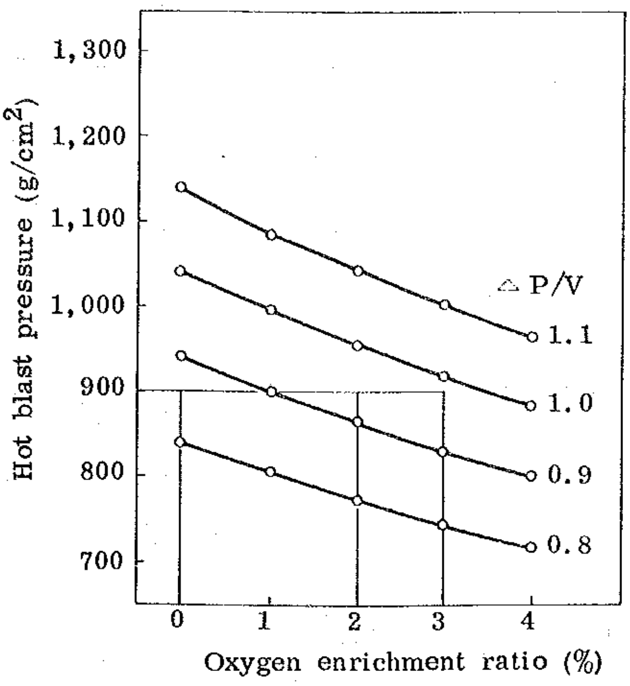


Fig. I.21 Hot blast pressure at production of 600 t/d and fuel rate of 850 kg/t-pig

(5) Capacity of gas cleaning equipment

1) Blast furnace gas generation and gas component

Table I.7 Blast furnace gas generation and gas component

Item	Case 1 (Oil injection)	Case 2 (N.G.injection)	Remarks
P_M (t/d)	600	600	Ave.600x0.9=540
Coke rate (kg/t-pig)	743	765	C% in coke = 86.77
Oil rate (kg/t-pig)	80	0	C% in oil = 83.5 H% in oil = 12.0
Natural gas rate (Nm^3/t-pig)	0	80(67kg/t-pig)	C% in natural gas = 71.57
Limestone (kg/t-pig)	136	138	H% in natural gas = 21.74
Blast volume (Nm^3/t-pig)	2,051	1,961	I.L. = 42.49%
Oxygen volume (Nm^3/t-pig)	53.3 (2% enrichment)	77.4 (3% enrichment)	
Blast humidity (g/Nm^3)	10.9	10.9	
C in pig (%)	0.7	0.7	
Flue dust (kg/t-pig)	60	60	C% in dust = 16.46
Reduction efficiency of H_2	0.45	0.45	
Reduction efficiency of CO*	0.306	0.301	
Blast furnace gas generation (Nm^3/hr)	76,300	75,400	
Blast furnace gas component			
CO_2 (%)	14.3	14.3	
CO (%)	30.2	30.8	
H_2 (%)	2.4	3.5	
N_2 (%)	53.1	51.4	
Calorie (Kcal/Nm^3)	978	1,025	

Blast furnace gas generation and gas component are shown in Table I.7. CO% and CO_2% were obtained by adjusting the reduction efficiency of CO obtained from Fig. I.22 with CO_2 generated from limestone.

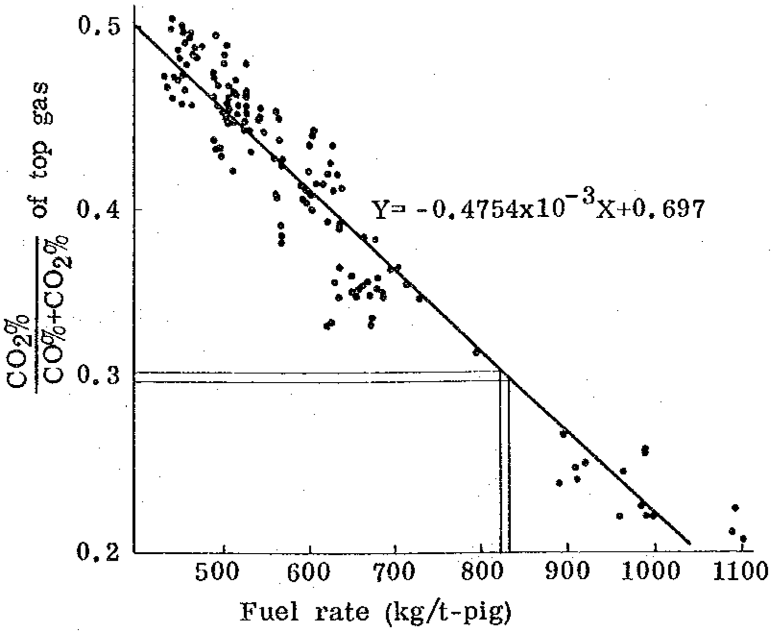


Fig. I.22 Relation between reduction efficiency of CO gas and fuel rate

2) Capacity of gas cleaning equipment

Table I.8 Dust content in cleaned gas

Month/ Year	Dust content in cleaned gas			Total gas volume (Nos. 1 & 2 BFs)	Aswan ore (Ave. of Nos.1&2)
	No.of samples	Average	σ		
Jan. '76	4	14.0mg/Nm^3	6.4mg/Nm^3	110,000Nm^3/hr	119 kg/t-pig
Feb. "	3	12.0	7.1	110,000	81
Mar. "	3	13.3	3.4	116,000	76
Apr. "	3	34.7	25.5	70,000	830
May "	3	28.7	16.1	69,000	840
June "	-	-	-	65,000	265
July "	1	29	-	105,000	101
Aug. "	2	28.0	3.0	115,000	275
Sept. "	3	11.3	1.2	60,000	170

Measurement results of the dust content in cleaned gas generated by Nos. 1 and 2 blast furnaces are shown in Table I.8. The table suggests that the dust content is affected more by the blend ratio of Aswan ore containing more fines than by gas volume. Reduction of flue dust volume and improvement of gas cleaning efficiency can be expected by reducing the blend ratio of Aswan ore and reinforcing the screening of sinter and coke. Meanwhile, total gas generation in Nos. 1 and 2 blast furnaces amounts to approximately 150,000 Nm^3/hr, exceeding the gas cleaning equipment capacity of 120,000 Nm^3/hr by approximately 25% to bring about an adverse effect on gas cleaning efficiency.

Since gas cleanness has a significant effect on blast furnace gas consuming plants, especially on the life of bricks, it is desired to be reduced to less than 5 mg/Nm^3, or 20 mg/Nm^3 at the worst. Therefore, the dust content should be properly controlled, and if it exceeds 20 mg/Nm^3 with an increase in production in the future, gas cleaning equipment (wet-type scrubber x 1, Theissen washer x 1, or electric precipitater x 1) should be added.

2.2 Improvement of raw materials properties

2.2.1 Sinter

(1) Required production of sinter

In the event of disuse of Thomas converter in the steelmaking plant, Aswan ore cannot be used because of the high P content, and operation has to be solely rely on sinter. Consequently, it is necessary to ensure stable supply of sinter in accordance with pig iron production in blast furnaces.

The required monthly production of sinter, when required sinter is 2,000 kg/t-pig, blast furnace operation rate (P/P_M) is 90%, is as follows.

Daily production (P_M)	Monghly production of sinter
400 t/d x 2 BFs	42,800 t/m
500 t/d x 2 BFs	53,500 t/m
600 t/d x 2 BFs	64,150 t/m
700 t/d x 2 BFs	74,850 t/m

(2) Basicity of sinter

As will be described later, use of limestone and dolomite may cause an increase in fuel rate and deterioration in permeability. Fig. I.23 shows the relation between basicity of sinter, coke rate (kg/t-pig) and limestone consumption (kg/t-pig) (in which dolomite is not used, and slag basicity was adjusted with limestone only.) As to the requirements for blast furnaces, it is desired to increase basicity of sinter to over 1.25 and to minimize the charging quantity of limestone. However, if the basicity of high SiO_2 sinter is increased, yield and productivity may be deteriorated, so CaO/SiO_2 has to be reduced to approximately 1.0 and 130 - 140 kg/t-pig of limestone has to be charged.

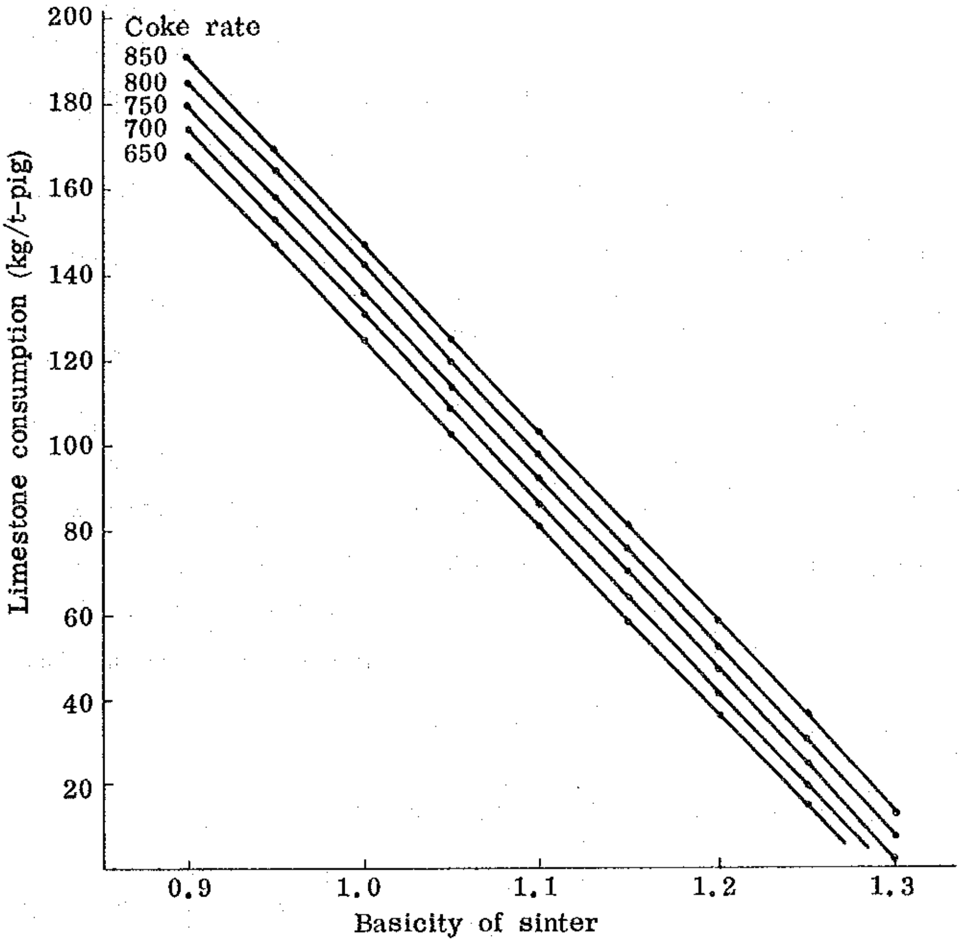


Fig. I.23 Limestone consumption in the blast furnace

(3) Size

Table I.9 shows the grain size distribution of sinter produced in No.1 sintering plant.

Table I.9 Size distrubution of sinter

	+20 mm	20-15	15-10	10-5	-5mm
February '76	51.0%	13.5	17.0	13.3	5.0
April '76	52.2	12.9	16.5	14.4	4.0

In view of the fact that sinter contains -5 mm fines as high as 4 - 5% after screened in the sintering plant and considerable amount of sinter is crushed during transportation or in the bin, and that underbin screens are not provided in Nos. 1 and 2 blast furnaces, it is estimated that 7 - 8% of harmful fines (-5 mm) is being charged in blast furnaces. The most effective methods of fines removal are increasing mechanical strength of sinter and screening under ore bin, but Nos. 1 and 2 blast furnaces have no space to install screens. Therefore, it is desirable to add cold screens in the sintering plant to reduce fines of -5 mm to be charged in blast furnaces to under 5%.

(4) Reducibility

In an operation solely using sinter, the reducibility of sinter has a significant influence on the fuel rate of blast furnaces. As shown in Fig. I.24, FeO% in sinter affects its reducibility. In Helwan Works, it is necessary to operate the sintering plant paying the attention to FeO % in sinter.

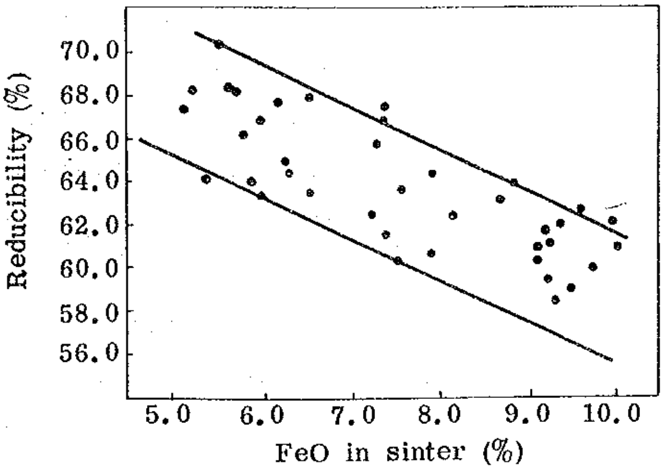


Fig. I.24 Influence of FeO% on reducibility of sinter

(5) Mechanical strength

As one of the methods to indicate the mechanical strength of sinter, shatter index (as indicated in the +10 mm fraction after dropping sample (size: +10 mm, weight: 20 kg) four times from the height of 2 m) is usually employed, and more than 82% in this index of mechanical strength is required.

2.2.2 Scrap

In your blast furnace operating practice over the past two years, scrap for No. 1 and No. 2 blast furnaces has been used at a rate of up to 200 kg/t-pig, and the scrap used included mold cast iron and other scrap of good quality.

Therefore, scrap should be used in the steelmaking plant as far as possible, and its use in blast furnace should be limited to that type of scrap which is not suitable for the steelmaking plant.

In the converter, scrap is melted by the heat of the hot metal and the heat of reaction generated during blowing, without consuming additional energy.

In the blast furnace, on the other hand, scrap charging leads to consumption of new energy sources, such as the heat of dissolution, the heats for reduction of silica and other elements and carbon

itself contained in the hot metal.

Generally speaking, whatever advantage derivable from scrap charging in the blast furnace operation is dependent on the supply/demand balance of scrap and hot metal. In other words, when basic oxygen steelmaking is the predominant process in a steelmaking shop, if hot metal supply is short and scrap is abundant, then scrap charging into a blast furnace can reasonably be expected to lead to reduced fuel rates (by 0.3 kg/t-pig/kg-scrap in Nippon Steel's past experience) and also increased output of pig iron. In such a case, scrap charging makes sense economically. However, when sufficient supplies of hot metal can be expected, there is no merit whatever in scrap charging because it would only serve to wastefully consume additional energy.

2.2.3 Limestone and dolomite

When limestone and dolomite are charged into a blast furnace, a large amount of heat is taken away and coke is consumed in separating CO_2.

That is, assuming that

$CaCO_3 = CaO + CO_2 - 767$ Kcal/kg-CaO,

$MgCO_3 = MgO + CO_2 - 690$ Kcal/kg-MgO,

$C + 1/2\ O_2 = CO + 2{,}450$ Kcal/kg-C,

C% in coke = 86.77,

CaO% in limestone = 52.57,

MgO% in limestone = 0.87,

CaO% in dolomite = 32.00,

MgO% in dolomite = 20.04

(operating results in Helwan Works during the period Nov. '75 - Oct. '76),

consumption of coke by limestone and dolomite is as follows.

Limestone: $(767 \times 0.5257 + 690 \times 0.0087) \times 100/2{,}450 \times 0.8677$

$= 19.2$ kg-coke/100 kg-limestone

Dolomite: $(767 \times 0.32 + 690 \times 0.2004) \times 100/2{,}450 \times 0.8677$

$= 18.0$ kg-coke/100 kg-dolomite

Therefore, use of limestone and dolomite in blast furnaces should be reduced to minimum.

Limestone charged into blast furnaces in Helwan Works contains relatively small amount of fines but a large quantity of coarse lumps of over 100 mm, which may hamper smooth slagging in the furnace, leading to lowered permeability. Therefore, crushing should be strengthened to reduce grain size down to approx. 30 mm. On the other hand, dolomite contains a considerable amount of fines, so fines should be removed.

2.2.4 Coke

(1) Coke balance

During the past two years, Nos. 1 and 2 blast furnaces have experienced a remarkable decrease in production due to shortage of coke. It goes without saying that stable supply of coke in accordance with the program is required to ensure planned pig iron production. Coke balance in Nos. 1 and 2 blast furnaces is shown in Fig. I.25.

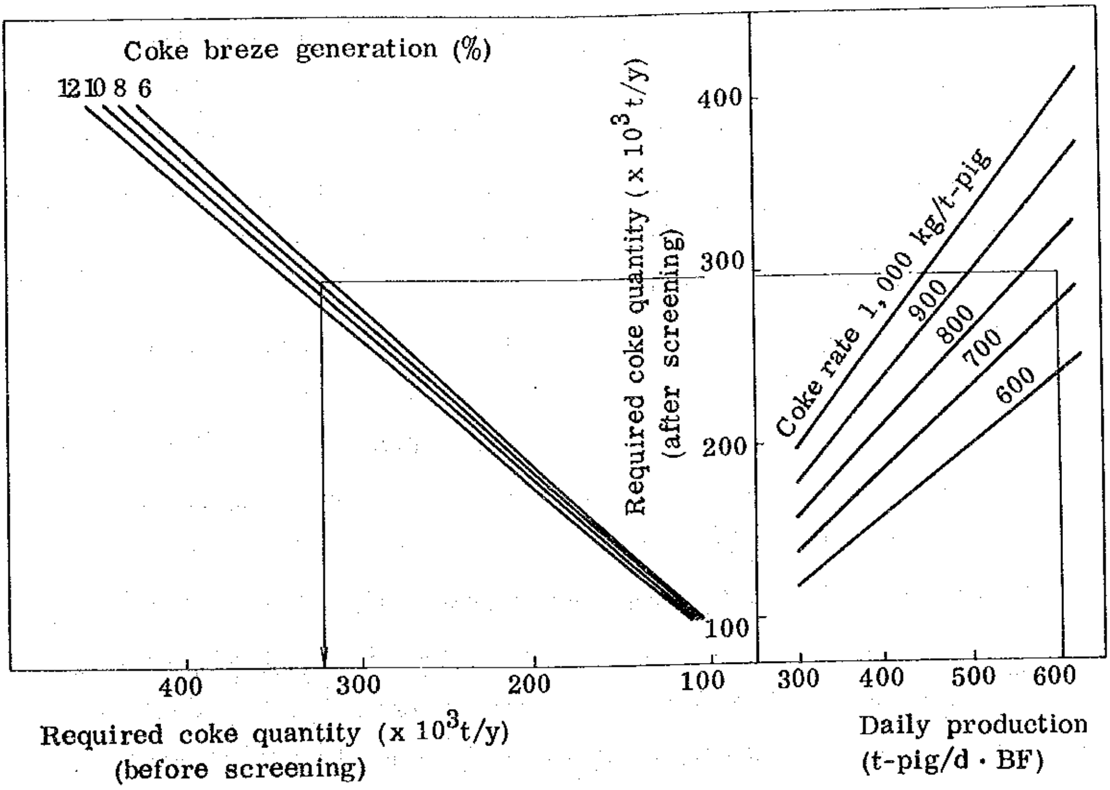


Fig. I.25 Coke balance

For example, the annual requirement of coke for two blast furnaces at P_M of 600 t/d·BF, operation rate of 90% is 295,650 t/y after screening at coke rate of 750 kg/t-pig, and 321,400 t/y (at coke breeze generation of 8%) before screening.

(2) Moisture content in coke

The moisture content in coke purchased by Helwan Works is as high as ave. 7.70%, σ 1.49%. In general, high moisture content in coke is not desirable for blast furnace operation because it causes:

- an increase in adhered fines
- lowered screening efficiency
- increased fluctuation in the moisture content.

Therefore, the moisture content in coke should be controlled to less than 3 - 4%.

(3) Grain size of coke

It is desirable that the minimum grain size of coke be 15 - 30 mm, the maximum grain size 75 - 90 mm, the average grain size 45 - 55 mm and the fines content less than 5% before under-bin screening and less than 2% after under-bin screening. Since control of the fines content is particularly important, screening should be thoroughly performed. In Nos. 1 and 2 blast furnaces having two screens of 2.5 m^2 (1.45 m x 1.75 m), 30 t/hr, there is no problem in screening capacity, but there still is a fear of mesh clogging because of high moisture content. It is advisable, therefore, to check the screens to prevent mesh clogging, and to maintain screening efficiency at a high level.

(4) Mechanical strength of coke

Although there are various methods to indicate the mechanical strength of coke, Nippon Steel mainly employs DI_{15}^{150} (a percentage of +15 mm coke after tumbling sample coke (grain size $\geq$ 50 mm, quantity = 10 kg) 150 times in a drum) of sample coke taken after cutter. The aimed-at minimum D_{15}^{150}, which varies depending on the inner volume of blast furnace, is 79 for a blast furnace of under 1,000 m^3 and is desirable

to be 81 or above to ensure stable operation.

Helwan Works uses MICUM strength and controls the mechanical strength of coke at more than 75% of M_{40} and less than 7.5% of M_{10}. The following ralation holds between D^{150}_{15} and M_{40}.

$$D^{150}_{15} = 33.59\,(M_{40})^{0.39} - 102.4 \text{ .... } \quad (I.4)$$

According to the above equation, D^{150}_{15} of 79 is equivalent to M_{40} of 75.5, and DI^{150}_{15} of 81 to M_{40} of 77.7. In Helwan Works, therefore, it is advisable to slightly raise the control level to M_{40} of 75.5 as the minimum value and preferably to 77.7 or above.

2.3 Intensification of operation control

2.3.1 Availability (Operating time)

In order to maintain high productivity and stable operation of blast furnace, it is essential to reduce the stoppage time and to maintain the availability at a high level (the aimed-at availability >95%).

Availabilities of Nos. 1 and 2 blast furnaces during the period Nov. '75 - Oct. '76 are given in Table I.10. The prime cause for low availability was shortage of coke, so stable supply of coke is an urgent need. Aside from scheduled shutdowns of twice a month, other noteworthy causes were power failure and slag monkey failure. Prevention of power failure requires thorough measures on power facilities while it is necessary for prevention of slag monkey failure to provide additional heat to the hearth by raising the flame temperature in front of tuyere to keep the heart clean, and to intensify the control of tapping and flushing.

Table I.10 Availabilities of Nos. 1 and 2 blast furnaces

Month/Year	No.1 B.F.	No.2 B.F.	Remarks
Nov. '75	87.2%	79.8	
Dec. "	88.5	85.5	
Jan. '76	82.6	89.6	
Feb. "	87.7	91.2	
Mar. "	41.9	95.1	No.1 B.F. stoppage due to coke shortage
Apr. "	0	91.3	"
May "	0	88.7	"
June "	0	92.7	"
July "	28.9	93.1	"
Aug. "	85.2	68.7	No.2 B.F. stoppage due to shortage of coke
Sept. "	97.8	0	"
Oct. "	90.3	7.5	"
Average	57.6	73.6	65.6
Average excluding months when furnaces were stopped due to coke shortage	88.4	89.7	89.1

2.3.2 Tapping and flushing control

The key to imporvment of productivity is how smoothly molten iron and slag are extracted from the inside of blast furnace. Problems to be improved for Nos. 1 and 2 blast furnaces are as follow.

(1) Tapping frequency

Nos. 1 and 2 blast furnaces have recently been operated at the tapping frequency of 8 tappings/d, and this tapping frequency is not necessarily considered few, judging from the inner volume of blast furnaces. It is important, however, not only to tap periodi-

cally, but also to keep the furnace in a dry state by performing tapping and flushing in accordance with the pig iron and slag level in the furnace. That is, adjustment of starting time of tapping and flushing is required. For example, tapping and flushing should be performed earlier than scheduled in the event of insufficient pig iron discharge in the previous tapping or more charging frequency than scheduled.

(2) Flushing ratio

Despite of 700 - 1,000 kg/t-pig of slag volume in Nos. 1 and 2 blast furnaces, flushing ratio (slag volume discharged from the cinder notch/total slag volume) is as low as approximately 30%. In such a state, it is difficult to perform sufficient tapping from a single tap hole. Ideally, flushing ratio should be 60 - 70%. With a single cinder notch now available, flushing could not be performed in the event of monkey failure which is inevitable in blast furnace operation, resulting in a state where slag tends to be left in the furnace. It is necessary to increase the number of cinder notches to two in the next relining so that two cinder notches can be used at any time during flushing and monkey can be replaced as soon as monkey failure occurs to ensure sufficient flushing. Another cause for improper flushing is the phenomenon that the pig iron mingles in the slag discharged from cinder notch. In fear of monkey failure due to this phenomenon, flushing has to be completed a little earlier. In fact, monkey failures have been frequently reported. This is due to the dirty state of the hearth because of insufficient heat. Therefore, it is important to heat the hearth by raising the flame temperature in front of tuyere. (Although the temperature of molten iron has not been measured in Nos. 1 and 2 blast furnaces, the carbon content and the colour of molten iron indicate that the temperature of molten iron is less than 1,400°C, approximately 100°C lower than normal.) Since molten iron temperature is a necessary measure for estimating the state of the

hearth, it is advisable to perform temperature measurement control. (Temperature measurement using optical pyrometer is recommended.) The following measure is recommended for preventing undesirable molten iron mingling in slag discharged from cinder notch and ensuring proper flushing. It is a method to prevent molten iron mingling in slag and to permit slag to smoothly flow to cinder notch by blowing compressed air through cinder notch stopper while cinder notch is closed. The air blown through cinder notch stopper burns coke near cinder notch and raise the temperature to keep the hearth clean. Nippon Steel has gained satisfactory results by introducing this method.

(3) Tapping delay due to transfer lag of ladles

Tapping and flushing delays frequently occur in Nos. 1 and 2 blast furnaces due to transfer lags of molten iron and slag ladles. Causes for ladle transfer lags should be thoroughly investigated, and timely tapping and flushing should be done by purchasing ladles and locomotives, if necessary.

2.3.3 Permeability control

Maintaining good permeability is one of three major factors required for improvement of productivity of blast furnace, together with high operation rate and proper tapping and flushing. Parameters to indicate permeability include followings.

- $\frac{\Delta P}{V} = \frac{\text{Hot blast pressure} - \text{Top pressure}}{\text{Blast volume} + \text{Enriched oxygen volume}} \quad (\text{g/cm}^2/\text{Nm}^3/\text{min})$
- $K = \frac{(\text{Hot blast pressure} + 1{,}033)^2 - (\text{Top pressure} + 1{,}033)^2}{(\text{Bosh gas volume})^{1.7}}$

  $\left((\text{g/cm}^2)^2/(\text{Nm}^3/\text{min})^{1.7} \right)$
- Number of hangings
- Number of slips
- Flue dust generation (kg/t-pig).

The lower the better for all these parameters. In case there is a tendency for these parameters and permeability to deteriorate, it must be due to deterioration of raw materials properties or an increase in pig iron and slag level in the furnace. So, correcting measures should be taken. Above all, the fines contents of sinter and coke immediately before charging have a close relation with these parameters. Therefore, periodical sampling and check should be performed.

Since$\Delta P/V$ and K take different values depending on the inner volume and the hearth diameter, the actual operating results in Japan are shown in Figs. I.26 and I.27 for reference.

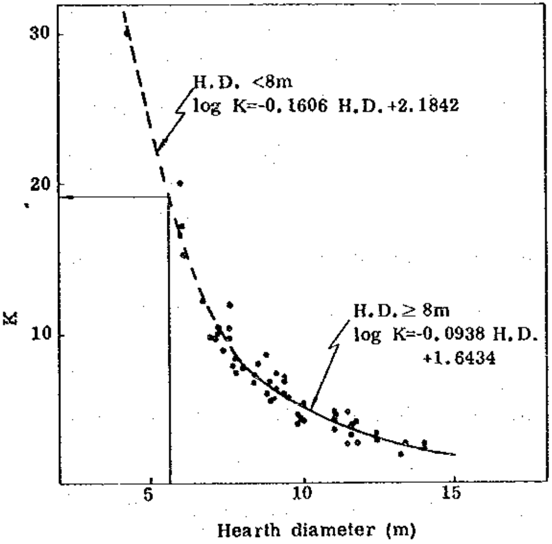


Fig. I.26 Relation between K and hearth diameter

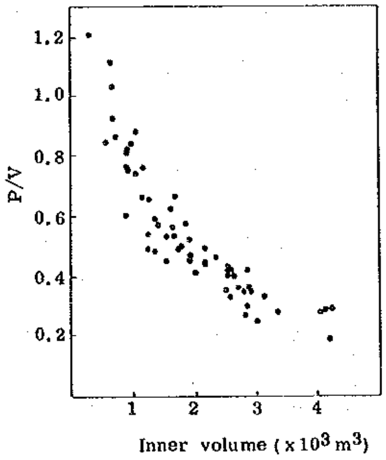


Fig. I.27 Relation between $\Delta P/V$ and inner volume

2.3.4 Control of theoretical flame temperature in front of tuyere

(1) Calculation formula of theoretical flame temperature in front of tuyere

Calculation formula for Helwan Nos. 1 and 2 blast furnaces is approximately expressed by the following equation.

$$T_f = 1,556 + 0.868T_B - 6.428M + 5,314V_{O2} - 5,515Oil - 7,916N.G. \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(I.5)}$$

where T_f : theoretical flame temperature in front of tuyere (°C)

T_B : blast temperature (°C)

M : moisture in blast (g/Nm^3-blast)

V_{O2} : enriched oxygen volume (Nm^3/Nm^3-blast)

Oil : oil (kg/Nm^3-blast)

N.G.: natural gas (Nm^3/Nm^3-blast)

(2) Control of theoretical flame temperature in front of tuyere

As given in Table I.7, the actual results of theoretical flame temperature in Nos. 1 and 2 blast furnaces are mostly less than 2,000°C and particularly in summer when atmospheric moisture rises, theoretical temperature tends to drop remarkably. The cause for low T_f is the fact that blast temperature is only 700°C or so. In order to raise T_f, blast temperature should be raised. In Nippon Steel, Tf is kept at 2,200°C~2,400°C. It is desirable to maintain Tf at 2,100°C minimum and preferably at 2,200°C~2,300°C to stabilize the furnace condition. Along with this, however, measures for improvement of permeability should be taken since rise of Tf often causes permeability troubles.

As T_f varies with moisture in blast, a method to control moisture by adding steam has so far been taken. More recently, however, a method to lower moisture in blast by dehumidifying equipment has been increasingly employed because addition of steam may increase fuel rate (coke rate + injected fuel rate). In Nos. 1 and 2 blast furnaces, it is advisable to control T_f through injected fuel volume or oxygen enrichment in summer when humidity usually rises, in place of addition of steam.

Table I.11 Theoretical flame temperature of Helwan Nos. 1 and 2 blast furnaces

Year	Month	B. F.	Calculated blast volume	Blast temp.	Moisture in blast	Oxygen enrch-ment	Oil rate	Flame temp.
			Nm^3/t-pig	°C	g/Nm^3	%	kg/t-pig	°C
'75	Dec.	No. 1	2,725	690	8.0	0	67	1,968
		No. 2	3,129	660	8.0	0	65	1,963
	Jan.	No. 1	2,789	670	7.0	0	55	1,984
		No. 2	2,823	660	7.0	0	63	1,961
	Feb.	No. 1	2,596	690	6.9	0	61	1,981
		No. 2	2,497	740	6.9	0	45	2,055
	Mar.	No. 1	2,752	670	7.8	0	39	2,009
		No. 2	2,794	710	7.8	0	60	2,004
	Apr	No. 1	-	-	-	-	-	-
		No. 2	3,286	700	8.7	0	78	1,977
	May	No. 1	-	-	-	-	-	-
		No. 2	3,217	670	10.5	0	81	1,931
	June	No. 1	-	-	-	-	-	-
		No. 2	2,891	680	12.5	0	87	1,900
	July	No. 1	3,194	730	15.4	0	29	2,041
		No. 2	2,719	700	15.4	0	70	1,923
	Aug.	No. 1	2,591	670	16.2	0	56	1,914
		No. 2	3,085	640	16.2	0	53	1,913
	Sept.	No. 1	2,617	770	15.4	0	61	1,997
		No. 2	-	-	-	-	-	-

(3) Calculation of T_f in natural gas injection

V_B : blast volume (Nm^3/t-pig)

V_{O_2} : oxygen volume (Nm^3 - O_2/Nm^3-blast)

N.G. : natural gas (Nm^3/Nm^3-blast)

M : moisture in blast (g/Nm^3-blast)

T_B : blast temperature (°C)

T_{NG} : natural gas temperature (°C) = 20°C

C_{air} : average specific heat of air (Kcal/Nm^3·°C) = 0.335

C_{O_2} : average specific heat of O_2 (Kcal/Nm^3·°C) = 0.351

C_{H_2O} : average specific heat of H_2O (Kcal/Nm^3·°C) = 0.389

C_{coke} : average specific heat of coke (Kcal/kg·°C) = 0.375

$C_{B.G.}$: average specific heat of bosh gas (Kcal/Nm^3·°C) =0.360

$C_{N.G.}$: average specific heat of natural gas(Kcal/Nm^3·°C) =0.391

Q_C : $C + 1/2O_2 = CO + Q_C$ (Kcal/kg-C) = 2,450

$Q_{N.G.}$: heat of decomposition of natural gas (Kcal/Nm^3-N.G.) = -1,029

Q_{H_2O} : heat of decomposition of H_2O (Kcal/kg-H_2O) = -3,211

$(C\%)_{coke}$: carbon in coke (kg/100 kg-coke) = 87.92

$(C\%)_{N.G.}$: carbon in natural gas (kg/ 100 kg-N.G) =71.57

$(H\%)_{N.G.}$: H in natural gas (kg/ 100 kg-N.G.) =21.74

$[CH_4]_{N.G.}$: CH_4 in natural gas (Nm^3/100 Nm^3-N.G.) = 84.88

$[C_2H_6]_{N.G.}$: C_2H_6 in natural gas (Nm^3/100 Nm^3-N.G.) = 9.15

$[C_3H_8]_{N.G.}$: C_3H_8 in natural gas (Nm^3/100 Nm^3-N.G.) = 1.88

$[C_4H_{10}]_{N.G.}$: C_4H_{10} in natural gas (Nm^3/100 Nm^3-N.G.) = 0.02

$[NC_4H_{10}]_{N.G.}$: NC_4H_{10} in natural gas (Nm^3/100 Nm^3-N.G.) = 0.05

$[CO_2]_{N.G.}$: CO_2 in natural gas (Nm^3/100 Nm^3-N.G.) = 3.42

$[N_2]_{N.G.}$: N_2 in natural gas (Nm^3/100 Nm^3-N.G.) = 0.60

T_f : theoretical flame temperature in front of tuyere (°C)

T_{coke} : temperature of coke in front of tuyere (°C) = $T_f \times 0.75$

B.G. : bosh gas volume (Nm^3/Nm^3-V_B)

$$T_f : \left\{ \begin{array}{l} \text{Sensible heat of blast} + \text{Sensible heat of natural gas} + \text{Sensible heat of coke} + \\ \text{Heat of decomposition of natural gas} + \text{Heat of decomposition of } H_2O + \text{Heat of combustion of carbon} \end{array} \right\} \div (B.G. \times C_{B.G.})$$

Sensible heat of blast (Kcal/Nm^3-V_B)

$$= \left\{ C_{air} + V_{O_2} \cdot C_{O_2} + M \cdot \frac{1}{1{,}000} \cdot \frac{22.4}{18} \cdot C_{H_2O} \right\} T_B$$

$$= \left\{ 0.335 + 0.351\ V_{O_2} + 0.000484 \cdot M \right\} T_B$$

Sensible heat of natural gas (Kcal/Nm^3-V_B) $= N.G. \cdot T_{N.G.} \cdot C_{N.G.}$

$= 7.82\ N.G.$

Sensible heat of coke (Kcal/Nm^3-V_B)

$$= \left\{ (0.21+V_{O_2}) \cdot \frac{12}{11.2} + M \frac{1}{1{,}000} \cdot \frac{12}{18} + N.G. \cdot [CO_2]_{N.G.} \cdot \frac{1}{100} \cdot \frac{12}{22.4} - N.G. \frac{18.8664}{22.4} \cdot \frac{(C\%)_{N.G.}}{100} \right\} \cdot \frac{100}{(C\%)_{coke}} \cdot 0.75 \cdot C_{coke} \cdot Tf$$

$$= \left\{ 0.07198 + 0.3427 V_{O_2} + 0.0002133M - 0.1870\ N.G. \right\} \cdot T_f$$

Heat of decomposition of natural gas (Kcal/Nm^3-V_B) $= N.G.\ Q_{N.G.}$

$= -1{,}029\ N.G.$

Heat of decomposition of H_2O (Kcal/Nm^3-V_B)

$$= M \cdot \frac{1}{1{,}000} Q_{H_2O} = -3.211M$$

Heat of combustion of carbon (Kcal/Nm^3-V_B)

$$= \left\{ (0.21+V_{O_2}) \frac{12}{11.2} + M \cdot \frac{1}{1{,}000} \cdot \frac{12}{18} + N.G. \cdot [CO_2]_{N.G.} \cdot \frac{1}{100} \cdot \frac{12}{22.4} \right\} Q_c$$

$$= 551.25 + 1.633M + 44.887\ N.G. + 2{,}625\ V_{O_2}$$

Blast furnace gas

$$CO;\quad 2(0.21+V_{O_2}) + M \cdot \frac{1}{1{,}000} \cdot \frac{22.4}{18} + 2N.G. \cdot [CO_2]_{N.G.} \cdot \frac{1}{100} \cdot$$

$$= 0.42 + 2V_{O_2} + 0.001244M + 0.0684\ N.G.$$

$$H_2;\quad M \cdot \frac{1}{1{,}000} \cdot \frac{22.4}{18} + N.G. \frac{18.8664}{22.4} \cdot (H\%)_{N.G.} \cdot \frac{1}{100} \cdot \frac{22.4}{2}$$

$$= 0.001244M + 2.051\ N.G.$$

$$N_2;\quad 0.79 + N.G. \cdot [N_2]_{N.G.} \cdot \frac{1}{100} = 0.79 + 0.006\ N.G.$$

B.G.(Nm^3/Nm^3-V_B) $= 1.21 + 2V_{O_2} + 0.002488M + 2.1254\ N.G.$

$$T_f = [\{0.335+0.351V_{O_2}+0.0004844M\} \cdot T_B - 976.3\ N.G. - 1.578M + 2{,}625V_{O_2} + 551.25] \div (0.3636+0.3773V_{O_2}+0.0006824M + 0.9524\ N.G.) \quad \text{..........(I.6)}$$

Approximate transformation of the above equation into a linear equation yields the following equation.

$$T_f = 1,556 + 0.868\, T_B - 6.428M + 5,314\, V_{O2} - 7,916\, N.G. \quad \ldots\ldots \quad (I.7)$$

2.3.5 Control of blast velocity at tuyere

(1) Formula of blast velocity at tuyere

$$V = \frac{V_B + V_{O2}}{60} \cdot \left(1 + \frac{T_B}{273}\right) \cdot \frac{1,033}{P+1,033} \cdot \frac{1}{S} \quad \ldots\ldots\ldots\ldots\ldots \quad (I.8)$$

V ; blast velosity at tuyere (m/sec.)

V_B ; blast volume (Nm^3/min.)

V_{O2}; enriched oxygen volume (Nm^3/min.)

T_B ; blast temperature (^oC)

P ; hot blast pressure (g /cm^2)

S ; total area of tuyeres (m^2)

(2) Control of blast velocity at tuyere

The actual values of blast velocity at tuyere in Nos. 1 and 2 blast furnaces are as low as 110 - 180 m/sec, as shown in Table I.12. In order to keep the combustion zone in front of tuyere in a proper state, 200 - 250 m/sec of blast velocity is required and the proper diameter of tuyere should be selected in accordance with operating conditions.

The proper diameter of tuyere with respect to $V_B + V_{O2}$ and T_B is shown in Fig. I.28 under the following conditions:

$$\frac{\text{Hot blast pressure (g/cm}^2\text{) - Top pressure (g/cm}^2\text{)}}{V_B + V_{O2}\ (Nm^3/min)} = 0.9,$$

Top pressure = 50 g/cm^2

Number of tuyeres = 10,

V = 230 m/sec.

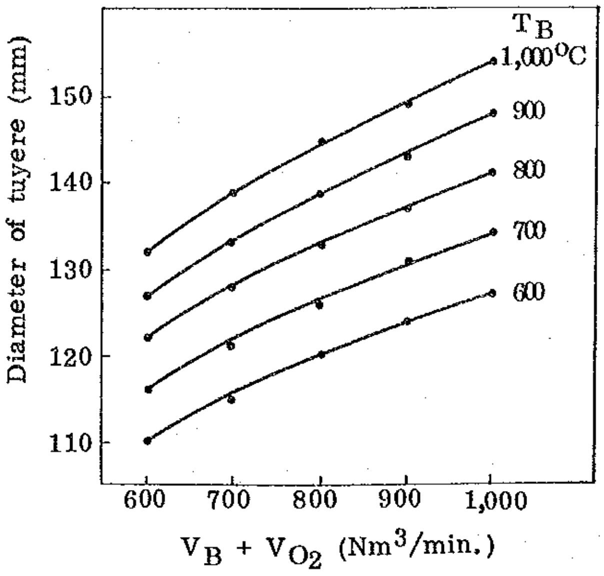


Fig. I.28 Diameter of tuyere under the condition of 230 m/sec. of blast velosity at tuyere

Table I.12 Blast velosities at tuyere of Helwan Nos.1 and 2 blast furnaces

Year	Month	B.F.	Calculated blast volume*	Enriched oxygen volume	Blast temp.	Hot blast pressure**	Total area of tuyeres***	Blast velosity at tuyere
			Nm^3/min	Nm^3/min	^{o}C	g/cm^2	m^2	m/sec.
'75	Dec.	No.1	621	0	690	750	0.165	128.2
		2	671	0	660	750	0.165	134.3
'76	Jan.	1	680	0	670	750	0.165	137.5
		2	641	0	660	750	0.165	128.3
	Feb.	1	690	0	690	750	0.165	142.5
		2	636	0	740	750	0.165	138.2
	Mar.	1	635	0	670	750	0.165	128.4
		2	766	0	710	750	0.165	161.5
	Apr.	1	-	-	-	-	-	-
		2	844	0	700	750	0.165	176.1
	May	1	-	-	-	-	-	-
		2	840	0	670	750	0.165	169.9
	June	1	-	-	-	-	-	-
		2	797	0	680	750	0.165	162.9
	July	1	548	0	730	750	0.165	117.9
		2	735	0	700	750	0.165	153.4
	Aug.	1	658	0	670	750	0.165	133.1
		2	737	0	640	750	0.165	144.3
	Sept.	1	725	0	770	750	0.165	162.2
		2	-	-	-	-	-	-

* Calculated from carbon balance.

** Because of no data available, hot blast pressure was estimated at 750 g/cm^2.

*** Total area of tuyere = $\pi/4\cdot(0.145)^2\cdot 10 = 0.165\ m^2$

2.3.6 Fuel injection

(1) Oil injection

When combustion control is properly performed, oil injection exercises a marked effect on reduction of coke rate and improvement of productivity. With improper combustion control, namely excessive oil injection, oil flame in front of tuyere becomes darker and longer, producing soot floating on gas cleaning water. Parameters for combustion control include theoretical flame temperature in front of tuyere; T_f and the ratio of oxygen volume in blast to oxygen volume required for perfect combustion of oil; μ (excess oxygen ratio).
With the present T_f of less than 2,000 °C, effected oil injection cannot be expected. Fig. I.29 shows the relation between oil rate and T_f at blast temperature 1,000°C, blast humidity 10.9 g/Nm^3 (average atmospheric moisture in a year), fuel rate 850 kg/t-pig and blast consumption (without oxygen enrichment) 2,380 Nm^3/t-pig, T_f of 2,200 - 2,300°C is the desired temperature range.

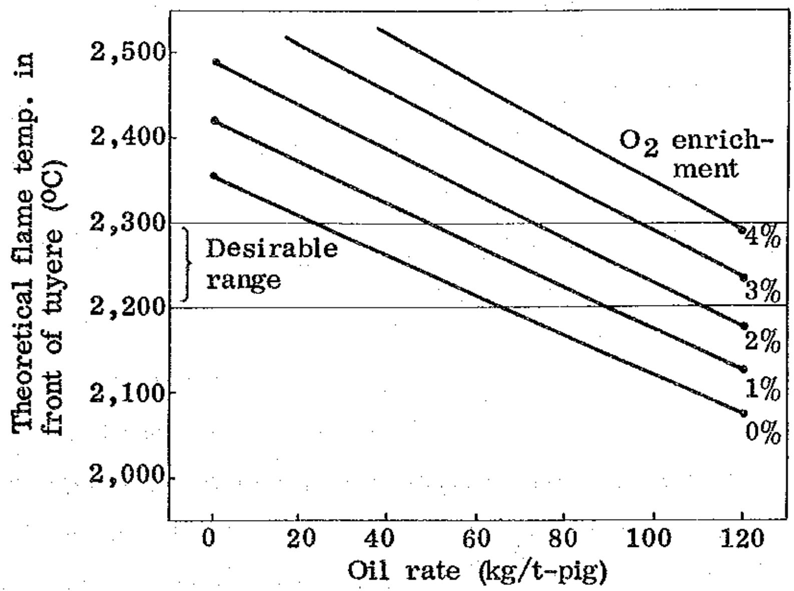


Fig. I.29 Relation between theoretical flame temperature, oil rate and oxygen enrichment level

Oxygen volume required for perfect combustion of 1 kg of oil used in Helwan Works (C% = 83.5, H% = 12.0) is 2.23 Nm^3/kg-oil. Although the higher μ is the more favorable, in practical operation, the lower limit value is 1.2 and the safety zone is 2.0 or above. As shown in Fig. I.30, μ varies with fuel rate level, but 100 kg/t-pig of fuel rate can be regarded as a measure of $\mu \geq 2.0$.

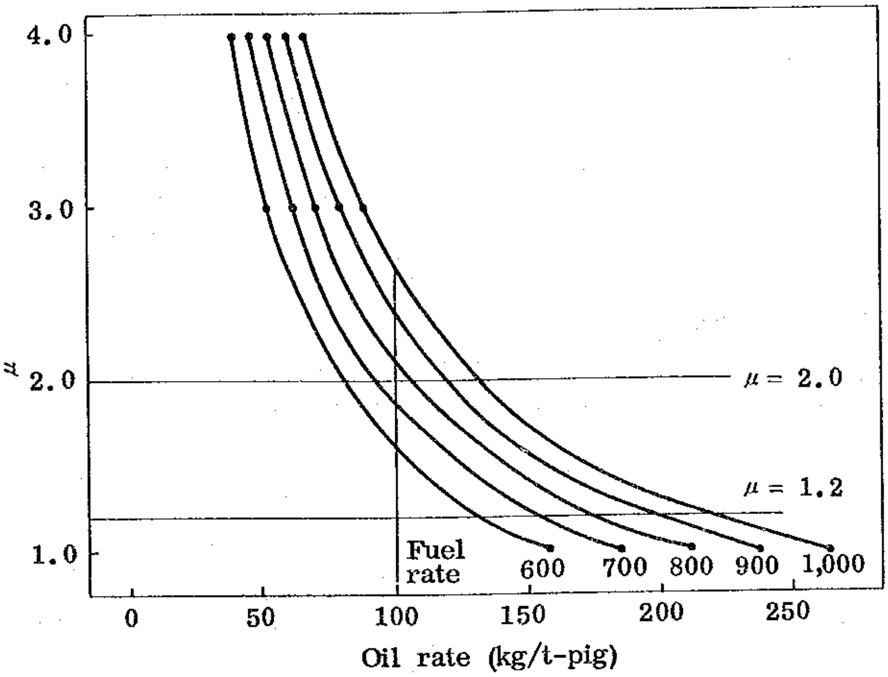


Fig. I.30 Excess oxygen ratio in oil injection

(2) Natural gas injection

It is said that the efficiency of coke rate reduction is poorer in natural gas injection that in oil injection and the coke rate per 1 Nm^3/t-pig is decreased by 0.6 - 0.8 kg/t-pig. As in the case of oil injection, combustion control in natural gas injection usually relies on T_f and μ. Fig. I.31 shows the relation between Tf and natural gas rate under the same condition. As shown in the figure, one of salient characteristics of natural gas injection is the decrease of T_f compared with oil injection.

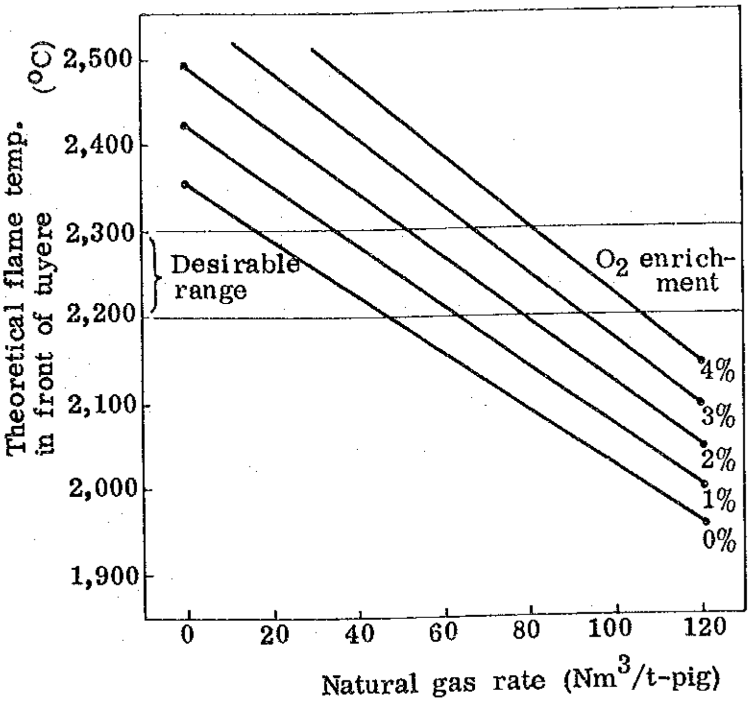


Fig. I.31 Relation between Tf, natural gas rate and oxygen enrichment level

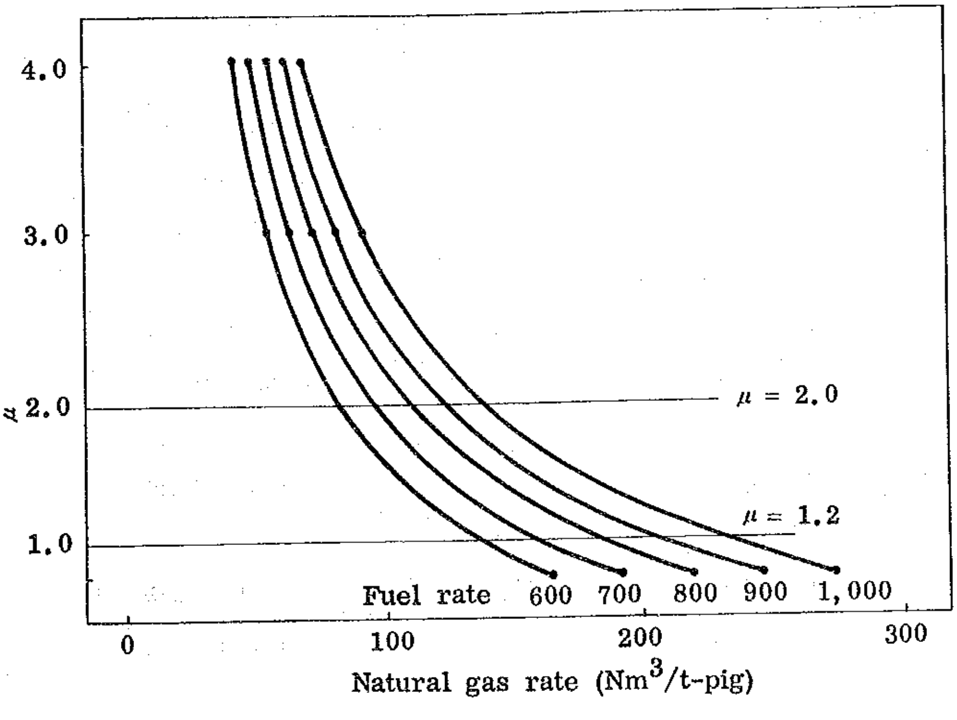


Fig. I.32 Excess oxygen ratio in natural gas injection

Oxygen volume required for perfect combustion of 1 Nm^3 of natural gas (1 Kmol = 18.8664 kg, C% = 71.57, H% = 21.74) is 2.15 Nm^3/Nm^3-N.G. As shown in Fig. I.32, 100 Nm^3/t-pig can be ragarded as a measure of the safety zone.

When applying fuel injection, fuel should be injected through all the tuyeres to ensure even injection in the circumferential direction in the furnace and to maintain μ and T_f in a good condition.

2.4 Improvement of equipment

2.4.1 Blast furnace

(1) Profile of blast furnace

In the current design, the hearth diameter is small while the throat diameter and the total effective height are large, compared with the inner volume. In addition, the bosh angle is small and the shaft angle is large, compared with standard design. In the proposed design (Fig. I.33), special consideration was given to enlargement of the hearth diameter and optimization of the profile on the assumption that the existing foundation, steel structure and top charging equipment are used as they are. Major alterations are as follows.

Inner volume	575 m^3	→	623 m^3
Hearth diameter	5,100 mm	→	5,700 mm
Belly diameter	6,500 mm	→	6,800 mm
Throat diameter	5,200 mm	→	5,100 mm
Belly height	1,500 mm	→	2,200 mm
Shaft height	13,250 mm	→	11,950 mm
Throat height	600 mm	→	1,200 mm
Bosh angle	76°51'58"	→	81°4'10"
Shaft angle	87°11'29"	→	85°55'53"

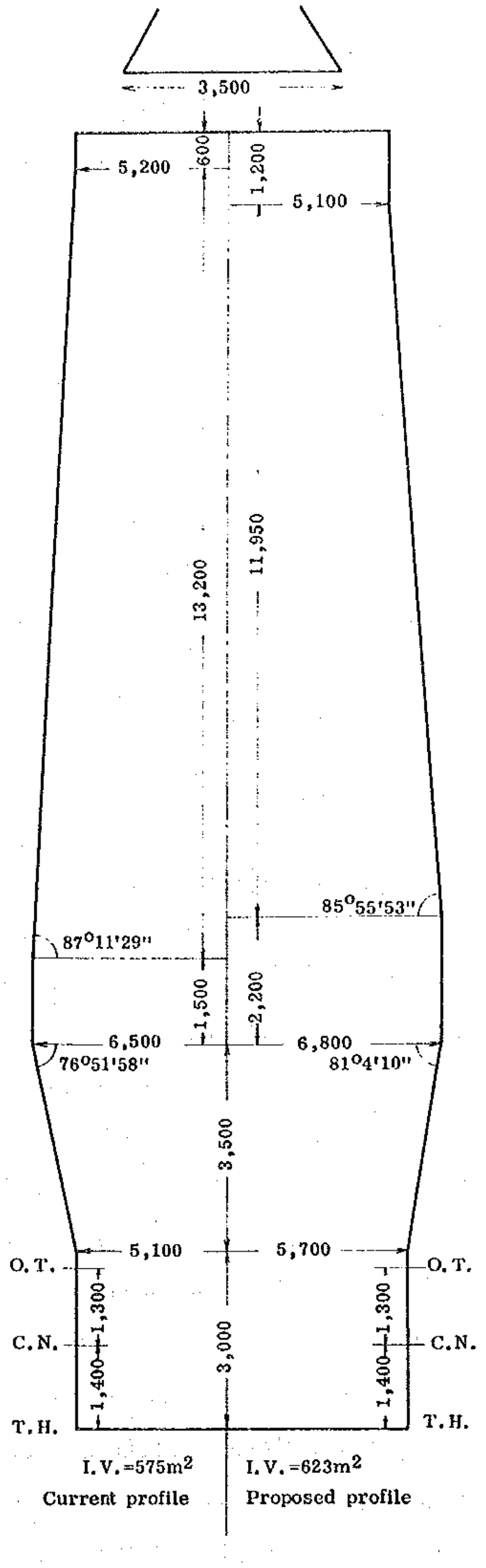


Fig. I.33 Comparison of blast furnace profiles

(2) Cooling system

1) Cooling system

There are two major cooling systems, namely, the cooling plate system and the stave cooling system. The former has a drawback in gas sealing function, and the latter in the supporting function of bricks. In low top pressure blast furnaces, gas sealability is not so critical, so the cooling plate system should be adopted giving priority to supporting function of bricks. The open type cooling plates made of steel plate, which are now used in Nos.1 and 2 blast furnaces have low cooling capability. Therefore, they should be replaced with the closed type cooling plates made of copper. The water spray cooling employed in bosh is not desirable becuase it may cause cracks on the shell in the event of the worn-out of linings. The cooling plate system is better than the spray cooling system.

As for the cooling of the hearthwall, the present water spray system is acceptable.

2) Cooling area

In the current design, cooling plates are provided up to the upper end of the shaft, but the cooling of the upper shaft may cause scaffolding. Standard cooling area is approximately 2/3 of the effective height of blast furnace. The cooling area in the proposed design is up to the level 12,300 mm above the tuyere level.

The current cooling plate insertion density in Nos. 1 and 2 blast furnaces is as coarse as minimum 600mm, maximum 1,000mm in intervals. When raw materials of high alkali content are charged, the reinforcement of the cooling system is the most effective method to protect bricks from alkali attack. In view of this, it is necessary to increase the cooling plate insertion density. In the proposed design, 540 pieces of cooling plates (20 pieces/step x 27 steps) are inserted in a staggered fashion. The vertical interval is 400mm from the first step in bosh to the 18th step in the lower shaft, 500mm up to the 23rd step in the middle shaft, and 600mm up to the 27th step.

A total of 6 stages of pipe connections of cooling plates will be used, namely, 3 stages of 4-piece connection for the part from the upper bosh to the lower shaft which is subject to high thermal load, and 3 stages of 5-piece connection for the lower shaft and the middle shaft.

3) Water balance

Assuming that the required water amount per stage of pipe connection is 60 l/min, the total required water amount for the cooling plate system is 430 m^3/hr. (i.e. 60 l/min x 20 x 6 = 7.2 m^3/min)

As for the required water amount for tuyere and tuyere cooler, assuming that 250 l/min of water is fed to each of them, the total water requirement, including two sets of cinder notches, is 360 m^3/min. (250 l/min x 2 x 12 = 6 m^3/min)

The water requirement for water spray of the hearth can be met by 790 m^3/hr of effluent water from the cooling plate system and the tuyere cooling system.

Although the total cooling water requirement for the blast furnace proper is 790 m^3/hr, aside from this, 150 m^3/hr or water is required for cooling the hot blast valves and 60 m^3/hr for miscellaneous uses, thus bringing the total water requirement for a unit of blast furnace to 1,000 m^3/hr. However, the current water balance of 750 m^3/hr per unit of blast furnace will leave a deficiency of 250 m^3/hr per unit of blast furnace, or a total of 500 m^3/hr. (Although exhaust water of 800 m^3/hr from gas cleaning equipment of Nos.1 and 2 blast furnaces is used for general services after two stages of cleaning, an increase in Cl concentration in the water by the use of Baharia ore of high Cl concentration could cause troubles in equipment in plants using this service water. Therefore, it is advisable to construct an independent recirculating system of gas cleaning water by installing a treatment equipment near the blast furnaces to prevent the adverse effect on other facilities. In such a case, the existing gas cleaning water supply system (750 m^3/hr) can be used to meet the deficiency of 500 m^3/hr in Nos.1 and 2 blast furnaces.)

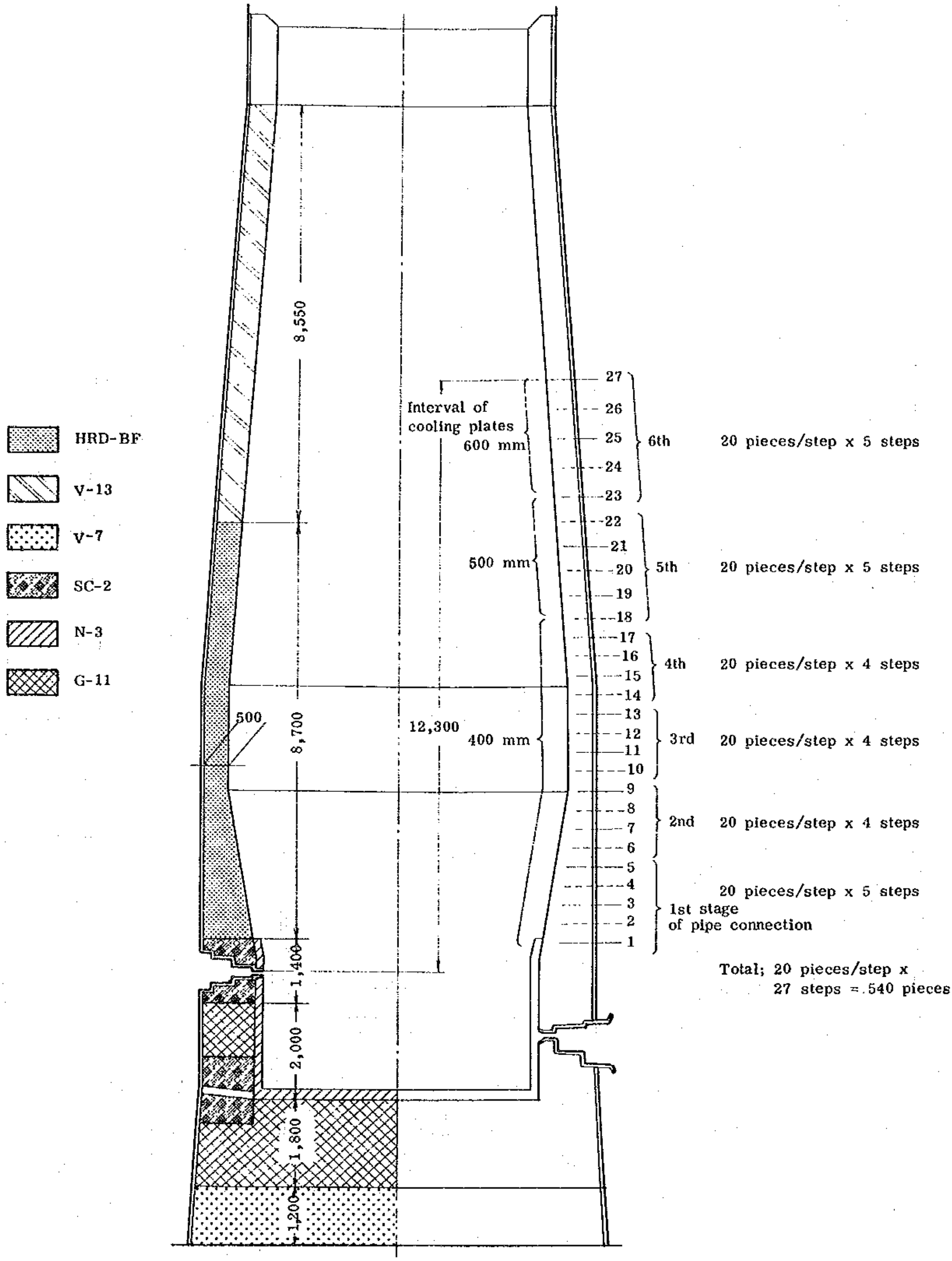


Fig. I.35 Brickwork

Fig. I.34 Cooling plate systems

(3) Brickwork

Fig. I.35 shows refractories to be used in brickwork which was designed giving importance to alkali resistance. Specifications for each refractory are as follows.

Table I.13 Refractory specifications

Symbol Item		G11 (Carbon brick)	HRD-BF	SC-2	V-7	V-13	N-3
Refractoriness (SK)				≥ 36	≥ 34	≥ 33	≥ 31
Apparent porosity (%)			≤ 17	≤ 17	≤ 16	≤ 16	≤ 26
Bulk density(kg/m^3)		≥ 1.50	≥ 3.10	≥ 2.45	≥ 2.30	≥ 2.25	≥ 1.90
Crushing strength (kg/cm^2)		≥ 350	≥ 1,000	≥ 550	≥ 400	≥ 400	≥ 200
Refractoriness under load*T_2(°C)			≥ 1,700	≥ 1,550	≥1,500	≥ 1,500	≥ 1,350
Chemical component (%)	Al_2O_3		≥ 92	≥ 50	≥ 40	≥ 38	
	Fe_2O_3		≤ 0.3	≤ 2.0	≤ 2.0	≤ 2.0	
True specific gravity (kg/m^3)		≥ 1.90					
Total porosity (%)		≤ 2.0					
Bending strength (kg/cm^2)		≥ 80					
Thermal expansion 0 - 1,500°C		dy/dx = 0					
Applications		Hearth & bottom	Bosh, belly, and lower shaft	Tuyere, tap hole, and cinder notch	Bottom	Middle & upper shafts	

*Under a load of 2 kg/cm^2 in the testing method of DIN 51053 Bl 1

The total weight of blast furnace refractories is 1,200 t/BF including unshaped refractories

(4) Instrumentation of blast furnace

The present instrumentation of Nos.1 and 2 blast furnaces consists of the following instruments.

- Blast volume gauge
- Hot blast pressure gauge
- Hot blast temperature gauge
- Top gas pressure gauge
- Top gas temperature gauge
- Top gas analyzer

The abovementioned instruments are the minimum requirements for blast furnace operation. Although they could permit operation fare farely, the present instrumentation rather insufficient. Those instruments which are recommended to add include brick thermometers, shaft pressure gauges, internal gas distribution measuring device, optical pyrometers for measuring molten iron temperature, etc.

Above all, measurement of brick temperature is essential to maintenance of the furnace.

As shown in Fig. I.36 the recommended measuring points of brick temperature totals 21 points, namely, a point at the center of the lowermost hearth, 4 points around the hearth and 16 points (4 step x 4 points/ step).

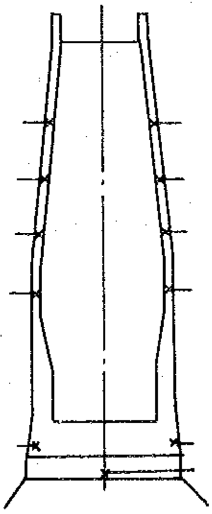


Fig. I.36 Temperature measuring points

2.4.2 Hot blast stove

(1) Capacity

1) Specification

Hot blast stoves for Nos. 1 and 2 blast furnaces at Helwan use brickwork different in type from one stove to another as shown below. This not only makes it difficult to perform operation control of the overall hot blast stoves but also makes it inevitable that the blast temperature is determined by the lowest-capacity stove. Unification of brickwork designs is therefore desired. Further, the operation with 2 units of hot blast stove cannot justify raising the blast temperature. For a higher blast-temperature operation, it is necessary to operate with 3 units of hot blast stove.

No.11 hot blast stove	Old German type	Planned to be relined into a French type during 1978 (either No. 11 or No. 12)
No.12 hot blast stove	Old German type	
No.13 hot blast stove	Egyptian type	
No.21 hot blast stove	Egyptian type (Under construction; to be put into service during 1977)	
No.22 hot blast stove	Old German type	Planned to be relined into a new German type (either No. 22 or No. 23)
No.23 hot blast stove	Old German type	

The study on the hot blast stove capacity is made with respect to the French type brickwork, which is seemingly close to the employed in Nippon Steel.

The main specifications of it are shown below.

Type: cowper (with French type brickwork)

Diameter of shell : 6 m

Height of shell : 29.795 m

Max. dome temp. : 1,250°C

Sectional area of checker room : ca. 15.96 m^2

Total height of checkerwork : 23.6 m

Total heating surface : 15,445 m^2/stove

Total weight of checker bricks : 465 t

Sectional area of combustion chamber : 2.70 m^2

Hole diameter of checker brick : av. 0.0411 m

Hole ratio : av. 42.6%

Specific heat of checker brick : av. 0.29 Kcal/kg°C

Specific gravity : av. 2.15

2) Presumptions for capacity calculation

Combustion gas calorie : 900 Kcal/Nm^3

Dome temperature : 1,250°C

Excess air ratio : 1.17

Combustion air volume/combustion gas volume : 0.838

Exhaust gas volume : 1.748 Nm^3/Nm^3-combustion gas

Specific heat of exhaust gas : 0.392 Kcal/Nm^3.°C

Combustion air temperature : 20°C

Cold blast temperature : 90°C

Max. exhaust gas temperature : 350°C

On blast -changeover- on gas : 40 min. - 10 min. - 70 min.

Dirty coefficient of checker brick surface : 0.70 to 0.80

3) Calculation results

The calculation results are shown in Fig. I.37. Under the conditions that the daily production is 600 t/d, coke rate 743 kg/t-pig, oil rate 80 kg/t-pig, air leak ratio 10% and the oxygen enrichment 2%, 950 Nm^3/min of blast plus 25 Nm^3/min of oxygen pass through the hot blast stove. The heating surface required to obtain a given blast temperature varies with the value of the dirty coefficient. Here, 0.7 is used with conservatism as the dirty coefficient. As obvious from Fig. I.37, heating surfaces of 10,600 m^2/stove and 15,200 m^2/stove are required, respectively, to obtain the blast temperature of 1,000°C and 1,050°C. As the French type design has a heating surface of 15,445 m^3/stove, it is sufficient to obtain the higher blast temperature. When the French

type brickwork is employed, therefore, the heating surface permits the blasting at a maximum blast temperature of 1,050°C and at 1,000°C on a consistent basis.

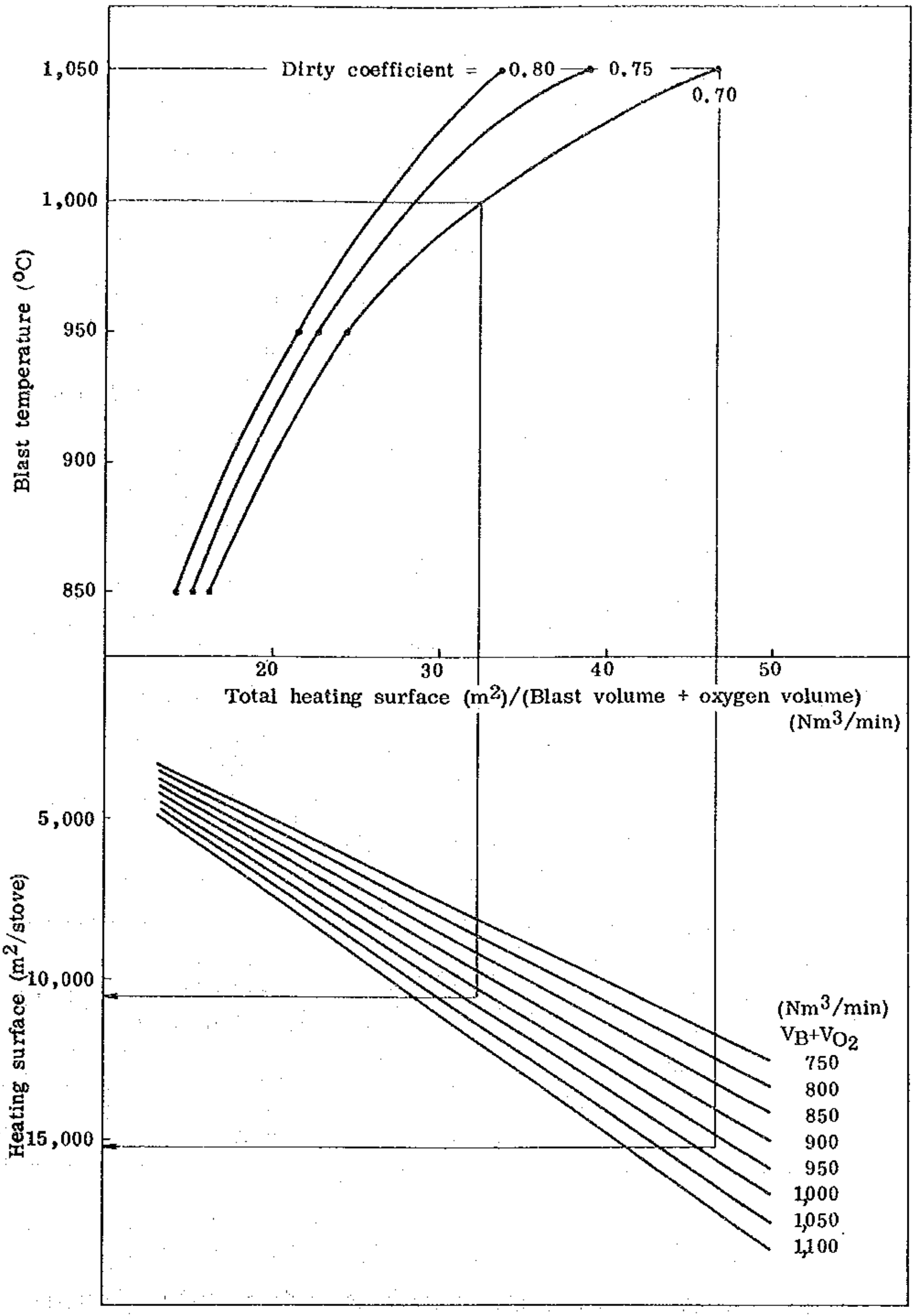


Fig. I.37 Blast temperature attainable in case of the French type hot blast stove (1,250°C dome temperature)

4) Burner capacity

$$\eta = \frac{(T_B - T_C) \cdot C\ \text{blast}\ (V_B + V_{O2}) \cdot t_B}{Q_G \cdot V_G \cdot t_G} \quad \cdots\cdots\cdots\cdot \quad (\text{I}.9)$$

T_B ; hot blast temperature (°C)
T_C ; cold blast temperature (°C) (=90°C)
C blast; average specific heat of blast between T_C & T_B (Kcal/Nm^3)
$V_B + V_O$; blast volume + oxygen volume (Nm^3/min.)
V_G ; combustion gas volume (Nm^3/min.)
QG ; combustion gas calorie (Kcal/Nm^3)
t_G ; on-gas time (min.) (= 70 min.)

From the formula (I.9), the thermal efficiency η of the hot blast stoves for Nos. 1 and 2 blast furnaces can be calculated to be nearly 70%. To obtain the blast temperature (T_B) of 1,050°C when V_B plus V_{O2} is 975 Nm^3/min., t_B 40 minutes and t_G 70 minutes, the gas

volume (V_G) of $\dfrac{(V_B + V_{O2}) \cdot (T_B - T_C) \cdot C\ \text{blast} \times t_B}{\eta \cdot Q_G \cdot t_G}$

is required. If the combustion air volume is to be determined from Figs. I.38 and I.39, the combustion gas volume and air volume are, as evident in Table I.14, well within the capacity of the burner and burner fan with more than 10% of allowance.

Table 2.10 Combustion gas volume and air volume

Q (Kcal/Nm^3)	Theoretical combustion air (Nm^3/Nm^3-gas)	Excess air ratio	Combustion gas volume (Nm3/hr)	Combustion air volume (Nm^3/hr)
900	0.72	1.17	17,400	14,700
1,000	0.80	1.35	15,700	17,000

As parameters for consistent combustion in the hot blast stove, a thermal load on the combustion chamber of 300,000 Kcal/m^3 or less and an exhaust gas speed of 5.0 Nm/sec or less are applied.

At the operating conditions as shown in Table I.14, both the thermal load on the combustion chamber and the exhaust gas speed are, as given in Table I.15, within the safety ranges.

Table I.15 Thermal load on combustion chamber and exhaust gas speed

Q ($Kcal/Nm^3$)	Total combustion heat (Kcal/hr)	Exhaust gas volume (Nm^3/hr)	Thermal load ($Kcal/\text{-}m^3$)	Exhaust gas speed (Nm/sec.)
900	1.57×10^7	30,500	245,400	3.2
1,000	1.57×10^7	31,000	245,400	3.2

In the above table, volume of combustion chamber = 64 m^3

sectional area of combustion chamber = 2.7 m^2

From the above considerations, it can be said that the hot blast stoves for Nos. 1 and 2 blast furnaces at Helwan, if a French type or equivalent brickwork design is adopted, will have the capacity which enables the blasting at a maximum blast temperature of 1,050°C and at 1,000°C on a consistent basis.

(2) Combustion control

At the hot blast stoves for Nos. 1 and 2 blast furnaces, the blast furnace gas with calorific value as high as 1,000 $Kcal/Nm^3$ diluted with excess air is burnt. This practice, it is thought, may cause variation in flame temperature wider than ordinary practice and provide the brick temperature beyond the permissible level. Precise combustion control will therefore be needed. To this end, it is necessary to have a clear view of the relation between the dome temperature and the calorific value of blast furnace gas used and the excess air ratio.

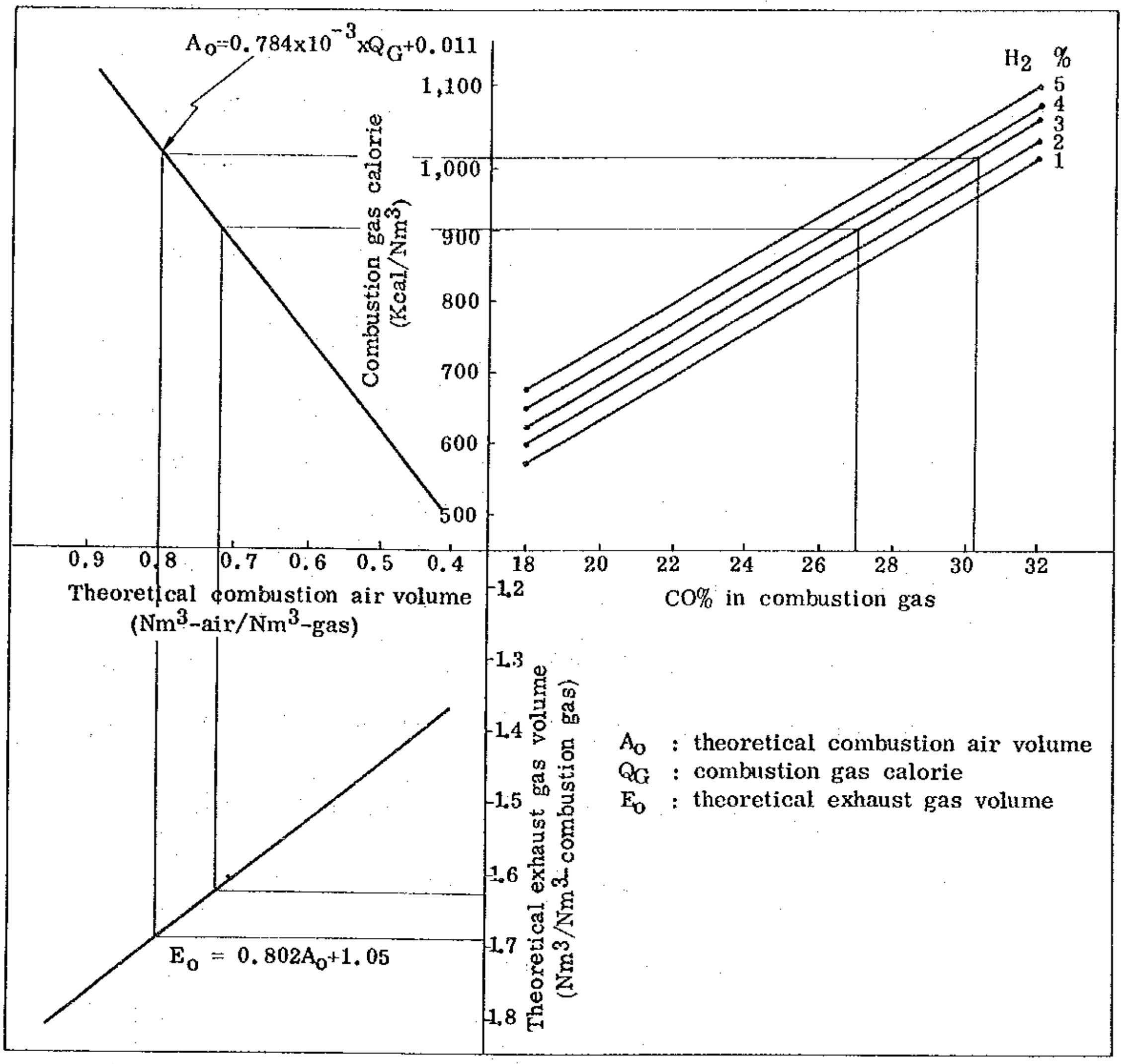


Fig. I.38 Theoretical combustion air and exhaust gas volumes

Though it varies to some extent with the percentage of hydrogen content of blast furnace gas, the theoretical combustion air volume required to attain complete combustion of blast furnace gas can approximately be expressed by the formula (I.10), a linear function of gas calorie.

$$A_o = 0.784 \times 10^{-3} \times Q_G + 0.011 \quad \text{.....................} \quad (I.10)$$

where A_o represents the theoretical combustion air (Nm^3/Nm^3-gas) and Q_G the gas calorie ($Kcal/Nm^3$).

The exhaust gas volume produced in this case can be expressed by the formula (I.11)

$$E_0 = 0.79A_0 + 1 + 0.001244\,(M_1 + A_0M_2) \quad \text{.......................} \quad (I.11)$$

where E_0 represents the theoretical exhaust gas (Nm^3/Nm^3-gas), M_1 the moisture content of blast furnace gas (g/Nm^3) and M_2 the moisture in air (g/Nm^3).

If M_1 is 40 g/Nm^3 (in the combustion gas saturated moisture and mist are contained) and M_2 is 10 g/Nm^3,

$$E_0 = 0.802A_0 + 1.05 \quad \text{.......................................} \quad (I.12)$$

The results of calculations made using the formulas (I.10) and (I.12) are shown in Fig. I.38.

When the excess air ratio is given α , the actual combustion air volume A (Nm^3/Nm^3-gas) can be expressed by the expression:

$$A = \alpha A_0 \quad \text{..} \quad (I.13)$$

$$E = E_0 + 1.0124\,(\alpha - 1)A_0 = (1.0124\,\alpha - 0.2104)A_0 + 1.05. \quad \text{......} \quad (I.14)$$

The theoretical flame temperature at the excess air ratio of α is:

$$T_F = \frac{T_G \cdot C_G + A \cdot Tair \cdot Cair + Q_G - Q_w}{E \cdot C_E}$$

$$= \frac{3.46 + 6.2\,\alpha(0.784 \times 10^{-3} \times Q_G + 0.011) + Q_G}{\{(1.0124\,\alpha - 0.2104)(0.784 \times 10^{-3} \times Q_G + 0.011) + 1.05\}\ C_E} \quad \text{...} \quad (I.15)$$

Nomenclature:

T_F (°C) : theoretical flame temperature

T_G (°C) : blast furnace gas temperature (= 30°C)

Tair (°C) : combustion air temperature (= 20°C)

C_E(Kcal/Nm^3·°C): specific heat of exhaust gas

C_G(Kcal/Nm^3·°C): specific heat of blast furnace gas (= 0.322 at 30°C)

Cair(Kcal/Nm^3·°C):specific heat of combustion air (= 0.310 at 20°C)

Qw (Kcal/Nm^3) : heat of vaporization of mist in blast furnace gas (= 6.2 Kcal/Nm^3 at 10 g-H_2O (l)/Nm^3)

It is empirically known that the dome temperature to be measured by a thermocouple equals to 95% of T_F. Hence, the dome temperature; T_D, be obtained from the equation:

$$T_D = \frac{3.46 + 6.2\,\alpha\,(0.784 \times 10^{-3} \times Q_G + 0.011) + Q_G}{\{(1.0124\,\alpha - 0.2104)(0.784 \times 10^{-3} \times Q_G + 0.011) + 1.05\}\ C_E} \times 0.95 \quad \text{..} \quad (I.16)$$

The results of calculation are shown in Fig. I.39.

Since Q_G of Nos. 1 and 2 blast furnaces is about 1,000 Kcal/Nm^3, the excess air ratio should be maintained at about 1.35 to maintain the dome temperature at 1,250^{o}C.

At Helwan, sheathed thermocouples are used to measure the dome temperature. It is made clear that such errors as follows are associated with these thermocouples:

- * measuring error due to the use of sheath : 30^{o}C
- * measurement variation with location (the temperature of the top of the dome does not always represent the maximum temperature.) : 20^{o}C

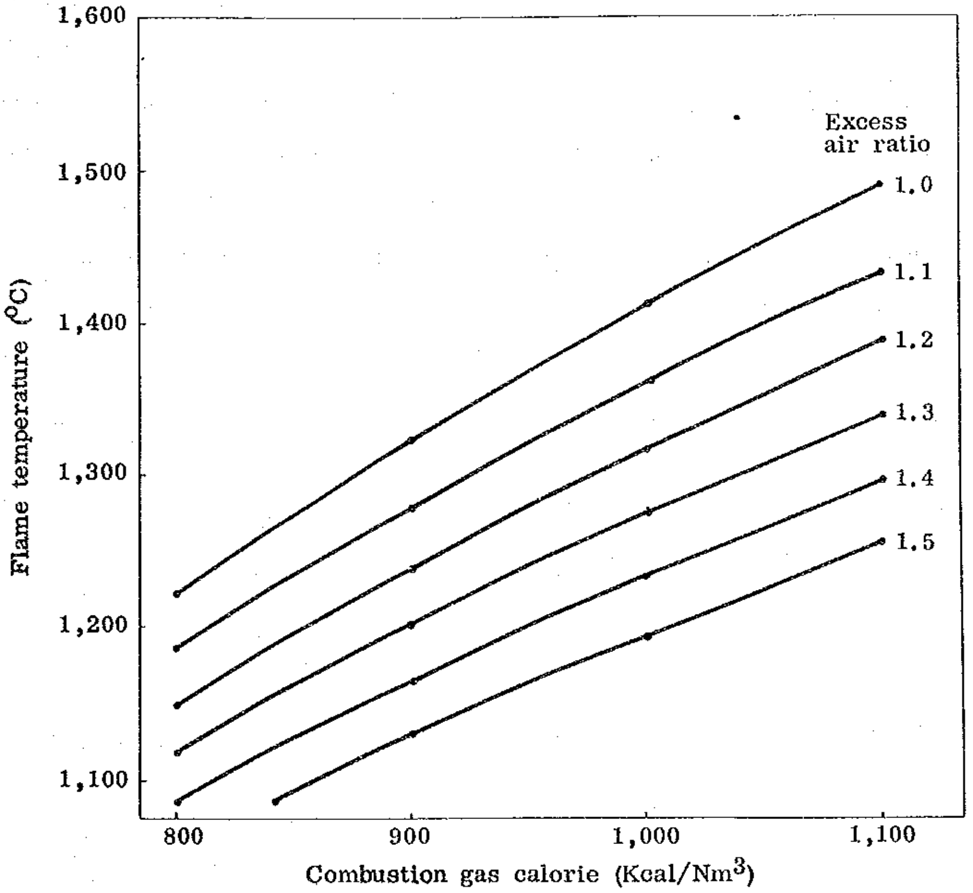


Fig. I.39. Relation between gas calorie and flame temperature at different excess air ratios

The actual dome temperature, therefore, is 50°C above the level actually measured. This means that the dome temperature controlled to the level 50°C below the maximum permissible brick temperature. As a checker support, cast iron with Cr additives which can serve in the temperature range up to 400°C is used both for Nos.1 and 2 blast furnaces. As the result of actual measurement of the checker support temperature at Nippon Steel, it has been found that it is 100°C at the maximum higher than the exhaust gas temperature. For safety therefore, the exhaust gas temperature should be controlled under 300°C, or 350°C at the highest.

(3) Brickwork of hot blast stove

In Fig. I.40, the materials of each brick suitable for use at the maximum dome temperature of 1,250°C are indicated. In this selection, particular importance is attached to the creep characteristic at elevated temperatures and 1,300°C (maximum dome temperature plus 50°C) is taken as the maximum permissible brick temperature. The specifications of each refractory material is indicated in Table I.16.

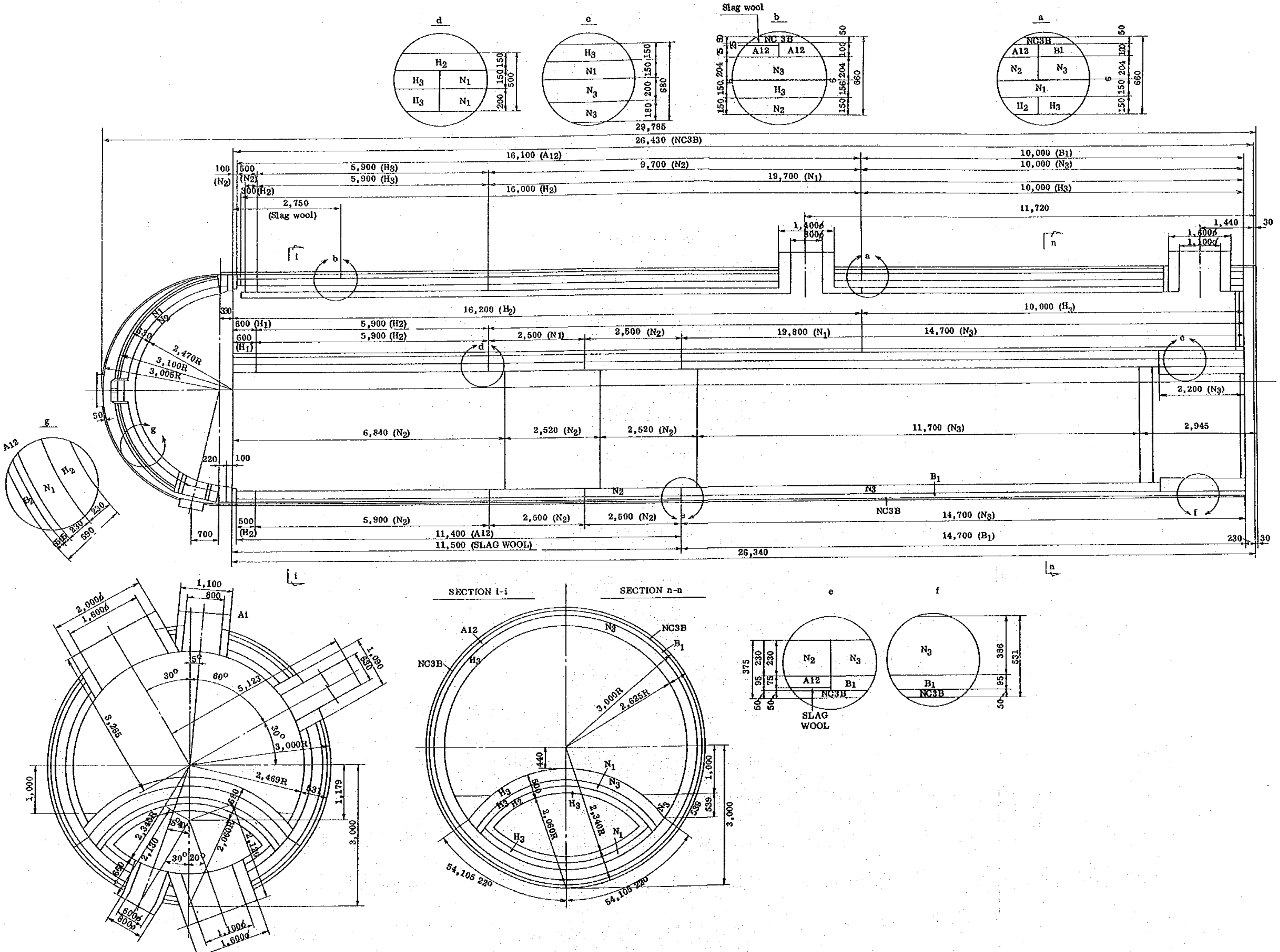


Fig. I.40 Brickwork of hot blast stove

Table I.14 Specifications of bricks for hot blast stove

Item / Code		H-2	H-3	N-1	N-2	N-3	A-12	B-1	NC-3B
Refractoriness (SK)		≥ 37	≥ 35	≥ 34	≥ 33	≥ 31			≥ 20
Apparent porosity (%)		≤ 27	≤ 27	≤ 24	≤ 24	≤ 26			
Bulk density (kg/m^3)		≥ 2.20	≥ 2.10	≥ 2.00	≥ 1.95	≥ 1.90	≤ 0.55	≤ 0.70	After firing
Compression strength (kg/cm^2)		≥ 300	≥ 250	≥ 200	≥ 200	≥ 200	≥ 8	≥ 25	
Bending strength (kg/cm^2)									≥ 3.0 at 1,300°C
Permanent linear change (%)		1,500°C +0.2 ~ -0.6	1,500°C +0.2 ~ -0.6	1,400°C 0 ~ -0.5	1,400°C 0 ~ -0.6	1,350°C +0.5 ~ -0.5			1,300°C +1.0 ~ -1.0
Chemical component	Al_2O_3(%)	≥ 60	≥ 50						≥ 35
	Fe_2O_3(%)						≤ 1.0		
Temperature to give rate of shrinkage after reheat less than 2% (°C)							1,300 °C ≤ 0.5	900°C	
Softening temperature under load (°C)*				≥ 1,350	≥ 1,350	≥ 1,350			≥ 1,120
Creep ** (%)		1,300°C ≤ 1.0	1,250°C ≤ 1.0	1,200°C ≤ 1.0	1,150°C ≤ 1.0	1,150°C ≤ 1.0			
Thermal conductivity (Kcal/m·hr·°C)							≤ 0.16	≤ 0.17	

* The temperature reached when the material swells to the maximum, in accordance with DIN 51053 B1 1.

** Deformation caused by applying 2 kg/cm^2 load for 50 hrs., in accordance with the creep testing method DIN 51053 B1 2.

(4) Hot blast pipe line

1) Prevention of air leak

As indicated in Table I.17, Helwan Nos. 1 and 2 blast furnaces produce air leak to a noticeable degree. Such a large air leak has led not only to a substantial energy loss but to decline in the blast temperature and productivity. Leaks are concentrated around flanges of hot blast valves and flanges and spherical sliding parts of the bustle branch pipe. It can be thought that these are attributable to improper accuracy of finish and defects on the sliding surface and low precision of installation.

To prevent these leaks, therefore, those improperly finished sliding parts should be replaced. Also, packings should be replaced when any of hot blast valves are replaced.

Table I.17 Air leak at hot blast pipe lines for Nos. 1 and 2 blast furnaces

Year	Month	B. F.	volume (Nm^3/min)	Calculated blast volume (Nm^3/min)	Air leak ratio (%)
'75	Dec.	No. 1	1,019	621	39.1
		2	1,120	671	40.0
'76	Jan.	1	867	680	21.6
		2	1,034	641	38.0
	Feb.	1	864	690	20.1
		2	853	636	25.4
	Mar.	1	743	635	14.6
		2	1,015	766	24.5
	Apr.	1	-	-	-
		2	1,069	844	21.0
	May	1	-	-	-
		2	1,030	840	18.5
	June	1	-	-	-
		2	1,016	797	21.6
	July	1	862	548	36.4
		2	1,125	735	34.7
	Aug.	1	1,135	658	42.0
		2	1,103	737	33.2
	Sept.	1	1,146	725	36.7
		2	-	-	-
Average			1,000	714	28.6

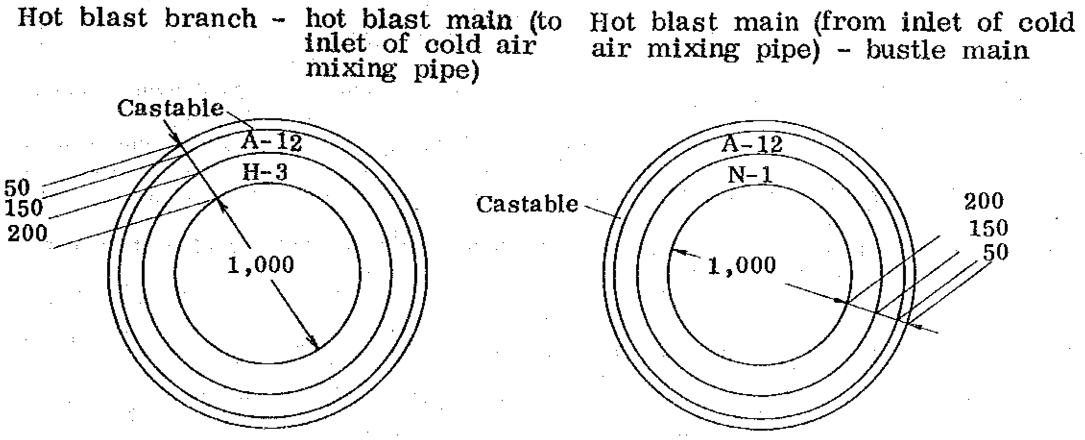
Leaks from the bustle branch pipe may be prevented effectively by inserting packing into the spherical sliding part. It seems that the area of the sliding part is too small.

In attempting higher blast temperatures and oxygen enrichment, more positive measure should be taken to prevent such air leaks since erosion of any portion of the stove piping may lead to significant accidents.

2) Replacement of hot blast pipe line

Blast normally flows through the hot blast pipe at 60 m/sec. To achieve a blast rate of 1,100 Nm^3/min at 1,050^{o}C, it is therefore necessary to increase the inner diameter of the hot blast pipe from current 0.9 m to 1 m. At the same time, the increased blast temperature should be accompanied with increase in the thickness of lining from 250 mm to 400 mm. This automatically necessitates replacement of the existing pipe shell with an inner diameter of 1.40 m with the new one with an inner diameter of 1.80 m.

Fig. I.41 shows the recommended lining construction of the new pipe line.


Hot blast branch - hot blast main (to inlet of cold air mixing pipe)

Hot blast main (from inlet of cold air mixing pipe) - bustle main

Fig. I.41 Lining construction of hot blast pipe line

(For lining materials, refer to Table I.16.)

II STEEL MAKING

Investigation of the layout, deterioration of the major facilities and levels of working technique has been made with emphasis on possibilities of remodelling the steelmaking process and equipment, which would accompany alteration of the iron ore brand (from the Aswan ore to the Baharia ore).

1. Problems of the Existing Thomas Plant

As a result of investigating the Thomas Plant, the following points can be cited as major problems.

a) Deterioration of the principal equipment and facilities has reached such a stage that their replacement is warranted. For example, this is particularly true of the DEMAG 50t and 25t cranes and casting car, although the building itself is in good condition despite its age.

b) As far as the plant layout as a whole is concerned, it is narrow. Especially, the layout of the ingot-making bay is not properly arranged so that the material flow is crisscrossing, thereby causing interruptions.

c) Many parts of the equipment require maintenance, while the conditions are such as to make it impossible to provide proper maintenance. For example, the hot metal weigher is, at present, in no serviceable condition, and the hot metal weighing itself is not performed.

d) Instrumentation in terms of operation control is virtually nil. What is considered essential in operation is missing, e.g., flux weighing, measuring the volume of air blast to the Thomas converter, amount of power in the electric furnace and even temperature of the hot metal and molten steel.

e) Yields are very low. Yield of steel produced at the Thomas converters is as low as 73%.

f) Performance of refractories is exceedingly bad. For example, the ladle lining life is only 5 to 8 heats.

g) Ingot control after teeming is inadequate. For instance, the track time, which depends greatly upon the capacity of the soaking pit, or the ingot transfer lot is not proper.

2. Rehabilitation Plan

Roughly speaking, the following 3 conceptions are available in regard to the rehabilitation plan as a result of the steelmaking process change.

The first is to reinforce the existing 80t top-blown converter plant and to consolidate steelmaking production except electric furnaces.

The second is to convert the existing Thomas converters to those capable of a new process. The third is to establish a new steelmaking plant near the existing Thomas Plant.

The top-blown converter method and bottom-blown oxygen converter method are considered for the new process. As a preliminary proposal for the master plan to convert to the new process, the following five alternatives are presented.

Each alternative assumes that the electric furnaces will be in operation as they are now.

Alternative 1	The existing Thomas Plant will be closed, while the 80t LD Plant will be reinforced.
Alternative 2 (A)(B)	The Thomas Plant will be remodelled into the OBM plant.
Alternative 3	The existing Thomas Plant will be remodelled into the LD plant.
Alternative 4	A new LD plant will be added near the existing Thomas Plant.
Alternative 5	A new OBM plant will be added near the existing Thomas Plant.

3. Conceptions of the Equipment Reinforcement, Remodelling and Addition in Each Alternative

The basis for suggesting the reinforcement, remodelling or addition of the principal equipment in each alternative can be outlined below.

Alternative 1

a) To cope with the expanded converter capacity, one unit of bloom continuous casting machine will be added to the existing emergency teeming bay. The cast bloom shall measure 300 mm x 400 mm square so that rail steel cab be rolled from it.

b) The tundish bay, bloom yard, ladle bay, emergency teeming bay, which are necessary for a), will be added.

c) Since the tonnage of hot metal handling will increase, a 1200t hot metal mixer will be added. Accordingly, a hot metal receiving crane will be added.

Alternative 2 (A)

a) The furnace capacity (t/heat) shall remain unchanged, 17 t/heat. Though is seems possible to increase the capacity (t/heat) of the existing vessel through the expected imrprovement in yield, reduction in (oxygen) blow rate and decrease slag volume due to reduced consumption of burnt lime, it is planned here that the furnace capacity will remain unchanged because nodata is available on the tolerable limit of the tilting device.

If the capacity of the tilting device permits, therefore, the furnace capacity increase will become realistic.

b) The existing flue ducts will be completely removed, and a new emission type waste gas cleaning apparatus will be added to each furnace.

c) In order that temperature control of the molten steel can be accomplished by iron ore during blowing, a new bunker above the furnace and a chute will be added to each furnace.

Transport of iron ore to the bunker above the furnace will be done by the belt conveyor.

d) The powder injection method will be adopted to blow burnt lime with oxygen from the furnace bottom. Hence, the equipment required for this method such as burnt lime crusher and transport equipment and holding hopper will be added.

e) A building between coulmns 3 - 9 in the existing converter bay B - D will be remodelled. (See DWG. 3)

f) A service crane for maintenance will be added between columns B - D in the existing converter bay.

g) A teeming platform will be added to the existing bay to create the second ingot-making yard.

h) Accepting molten steel from the converter to the ladle and carrying it to the second ingot-making yard will be done by the ladle car.

i) All cranes in the second ingto yard will be newly installed.

Alternative 2 (B)

a) The furnace capacity (t/heat) shall remain unchanged, 17 t/heat. Though it seems possible to increase the capacity (t/heat) of the existing vessel through the expected improvement in yield, reduction in (oxygen) blow rate and decrease slag volume due to reduced consumption of burnt lime, it is planned here that the furnace capacity will remain unchanged because nodata is available on the tolerable limit of the tilting device.

If the capacity of the tilting device permits, therefore, the furnace capacity increase will become realistic.

b) The existing flue ducts will be used as it is as the waste gas cleaning apparatus.

c) The existing hopper above the furnace will be replaced with the one having a weigher and electromagnetic feeder. For transport of iron ore, the telpher currently in use will be diverted for use.

d) The powder injection system will be used to blow burnt lime with oxygen from the furnace bottom. Consequently, the equipment required for this operation such as burnt lime crusher and transport equipment and holding hopper will be newly installed.

e) A teeming platform will be added to the current bay to creat the second ingot-making yard.

f) Accepting molten steel from the converter to the ladle and carrying it to the second ingot-making yard will be done by the ladle car.

g) Cranes in the second ingot-making yard will all be newly installed.

Alternative 3

a) The furnace capacity (t/heat) shall remain unchanged, 17 t/heat. Though it seems possible to increase the capacity (t/heat) of the existing vessel through the expected improvement in yield, reduction in (oxygen) blow rate and decrease slag volume due to reduced consumption of burnt lime, it is planned here that the furnace capacity will remain unchanged because nodata is available on the tolerable limit of the tilting device.

   If the capacity of the tilting device permits, therefore, the furnace capacity increase will become realistic.

b) The existing flue ducts will be completely removed, and a new emission type waste gas cleaning apparatus will be added to each furnace.

c) A flux bunker (burnt lime, iron ore, fluorspar etc.) and a chute will be added to each furnace. Belt conveyor will be used for flux transport to the bunker above the furnace.

d) The lance-related equipment will be added inside the converter bay.

e) A building between columns 3 - 9 in B - D of the existing converter bay will be remodelled. (See DWG. 7)

f) A service crane for maintenance will be added between columns B and D in the existing converter bay.

g) A tap hole will be added to the converter for improving yields.

h) A teeming platform will be added to the existing bay to create the second ingot-making yard.

i) Accepting molten steel from the converter to the ladle and carrying it to the second ingot-making yard will be done by the ladle car.

j) Cranes in the second ingot-making yard will all be newly installed.

Alternative 4

a) Hausing facilities will be newly furnished.

b) A new LD converter plant, 36t/heat x 2 units, will be added.

c) A waste gas cleaning apparatus of the waste gas emission type will be added to each furnace.

d) A flux bunker (burnt lime iron ore, fluorspar, etc.) and a chute will be added. Transport of flux to the bunker above the furnace will be by means of belt conveyor.

e) Lance-related equipment will be added to the converter bay.

f) A service crane for maintenance will be added to the converter bay.

g) For hot metal storage, a 600t hot metal mixer will be added.

h) For scrap handling a storage pit will be set up in the plant, where scrap is weighed and made available for release.

i) For ingot-making, the teeming platform, mould cooling floor, ladle repair area, etc. will be added.

j) Accepting molten steel from the converter to the ladle and carrying it to the ingot-making yard will be done by the ladle car.

k) All cranes will be newly installed.

Alternative 5

a) Hausing facilities will be newly furnished.

b) The OBM plant, 36 t/heat x 2 units, will be built.

c) A waste gas cleaning apparatus of the waste gas emission type will be added to each furnace.

d) So that molten steel temperature control during blowing can be performed by iron ore, a bunker above the furnace and a chute will be added to each furnace. Transport of iron ore to the bunker above the furnace will be by means of the telpher.

e) The powder injection system will be used to blow burnt lime with oxygen from the furnace bottom. Consequently, the equipment required for this operation such as burnt lime crusher and transport equipment and holding hopper will be newly installed.

f) A 600t hot metal mixer will be added for hot metal storage.

g) For scrap handling, a storage pit will be set up inside the plant, where scrap is weighed and made available for release.

h) For ingot-making, the teeming platrorm, mould cooling floor, ladle repair area, etc. will be added.

i) Accepting molten steel from the converter to the ladle and carrying it to the ingot-making yard will be done by the ladle car.

j) All cranes will be newly installed.

4. Conceptions Underlying the Layout of Each Alternative.

Plane, cross-sectional and front views for each of the 5 alternatives are shown in DWG 1 - 15, and they can be outlined as follows for each alternative.

Alternative 1

a) DWG 1 As shown in the plane view, one unit of the vertical with bending-type bloom continuous casting machine will be newly installed between columns E_1 - P.

b) An emergency molten steel teeming bay will be set up on the opposite side of the bloom continuous casting machine.

c) A building will be added between columns E - E_1 as a place for tundish repair. Transporting the tundish will be done by a car.

d) A building will be added between columns B and D, where a 1200t hot metal mixer is to be installed. At the same time, a hot metal receiving crane will be added.

e) For the ladle repair area, a building between columns D - E will be added.

f) For the bloom yard, a building will be added between columns 129 - 138 from I - M.

Alternative 2 (A)

a) DWG 3 As the cross-sectional view indicates, the flue ducts in between columns C and D in the existing converter bay will be completely removed, and the waste gas cleaning apparatus and iron ore continuous feeding device-related equipment will be newly

installed here.

b) As for scrap handling, loading into the scrap chute is performed at the current scrap yard for electric furnaces, and the scrap is transferred by a car. For changing the car direction, the turn table is utilized.

c) As for the ladle repair area, the existing teeming pit for the Thomas converters will be discontinued, and it will be used as the ladle repair area.

d) DWG 2 Arrangement of the burnt lime crushing, sizing, transport and storage facilities, and oxygen, LPG, N_2 gas holders are shown in a plane drawing.

e) For ingot-making, a building will be built in parallel with the existing building E column. The teeming platform and mould cooling floor will be set up in two places so that no disorder may be caused in sequential operations of each element of ingot-making.

Alternative 2 (B)

a) DWG 5 As shown in the cross-sectional view, remodelling of the building between columns B and D in the existing converter bay and removal of flue ducts will not be performed.

b) The existing hopper above each furnace will be replaced in such a way that continuous feeding of iron ore can be done.

c) Scrap handling and the ladle repair area will be the same as Alternative 2 (A).

d) Ingot-making will be the same as Alternative 2 (A).

Alternative 3

a) DWG 7 As shown in the cross-sectional view, the flue ducts in between columns B and D of the building in the existing converter bay will be completely removed and remodelled.

b) Scrap handling and the ladle repair area will be the same as Alternative 2 (A).

c) Ingot-making will be the same as Alternative 2 (A).

Alternative 4

a) The LD converter plant, 36 t/heat x 2 units, will be added on the south side of the existing Thomas Plant.

b) The shape of the vessel will be concentric. It will be designed in such a way that the charging and tapping operations can be done at mutually opposite positions.

c) For the flux bunker above the furnace, a bunker jointly for 2 furnaces will be installed in the center of No. 1 and No. 2 converters. Consequently, each flux will be released from the bunker above the furnace. After weighing, it is brought by the shuttle conveyor to the relay hopper of each furnace for storage there, and whenever necessary, it is chuted into the furnace.

d) The cooler, gas ducts, induced draft fan, etc. of the waste gas cleaning apparatus will be installed indoors, and the emission tower will be set up on the converter bay. Also, the cooling tower, water softening device, water supply pump, etc. for the water treatment system will be installed on ground level outdoors.
The thickner and hydroextractor, etc. for the water treatment system will be placed on ground level outdoors.

e) The lifting and lowering of the lance along the lance guide will be performed by a winch.

f) Diverting the existing hot metal mixer for use as the hot metal mixer have been studied. Since there are many layout difficulties, it is decided to install a new 600t hot metal mixer instead.

g) Scrap stored in the storage pit in the plant will be loaded to the scrap chute by the magnet crane. After weighing, it is charged into the converter by the crane. Scrap will be one-chute charging, and scrap transport to the plant will be by freight cars.

h) For ingot-making, the teeming platform and mould cooling floor will be separately set up in 2 places so that no disorder may be caused in sequential operations of each element such as teeming, drawing, ingot handling, and mould setting.

i) The ladle repair area will be in 2 places -- the ingot-making bay and by the mould cooling floor. Setting the stopper will be done in the center of the area.

j) Plane, cross-sectional and front views are shown in DWG 8 - 11.

Alternative 5

a) An OBM converter plant, 36 t/heat x 2 units, will be added on the south side of the existing Thomas Plant.

b) The shape of the vessel will be concentric, and it is designed in such a way that the charging and tapping operations can be performed at mutually opposite positions.

c) A weigher and an iron ore bunker with an electromagnetic feeder will be installed above each furnace. Transport to the bunker above the furnace will be done by telpher.

d) The cooler, gas ducts, induced draft fan etc. of the waste gas cleaning apparatus will be installed outdoors. The emission tower will be installed over the converter bay. Also, the cooling tower, water softening device, water supply pump, etc. for the water treatment system will be installed on ground level outdoors. The thickner and hydroextractor, etc. for the dust collecting water treatment equipment will be placed on ground level outdoors.

e) The powder injection system will be used for blowing burnt lime with oxygen from the furnace bottom. Consequently, the equipment necessary for this operation such as the burnt lime crusher and transport equipment and holding hopper will be installed on ground level outdoors. As for the valve stand, its outdoor location will be about 7m above floor level outside the instrumentation room.

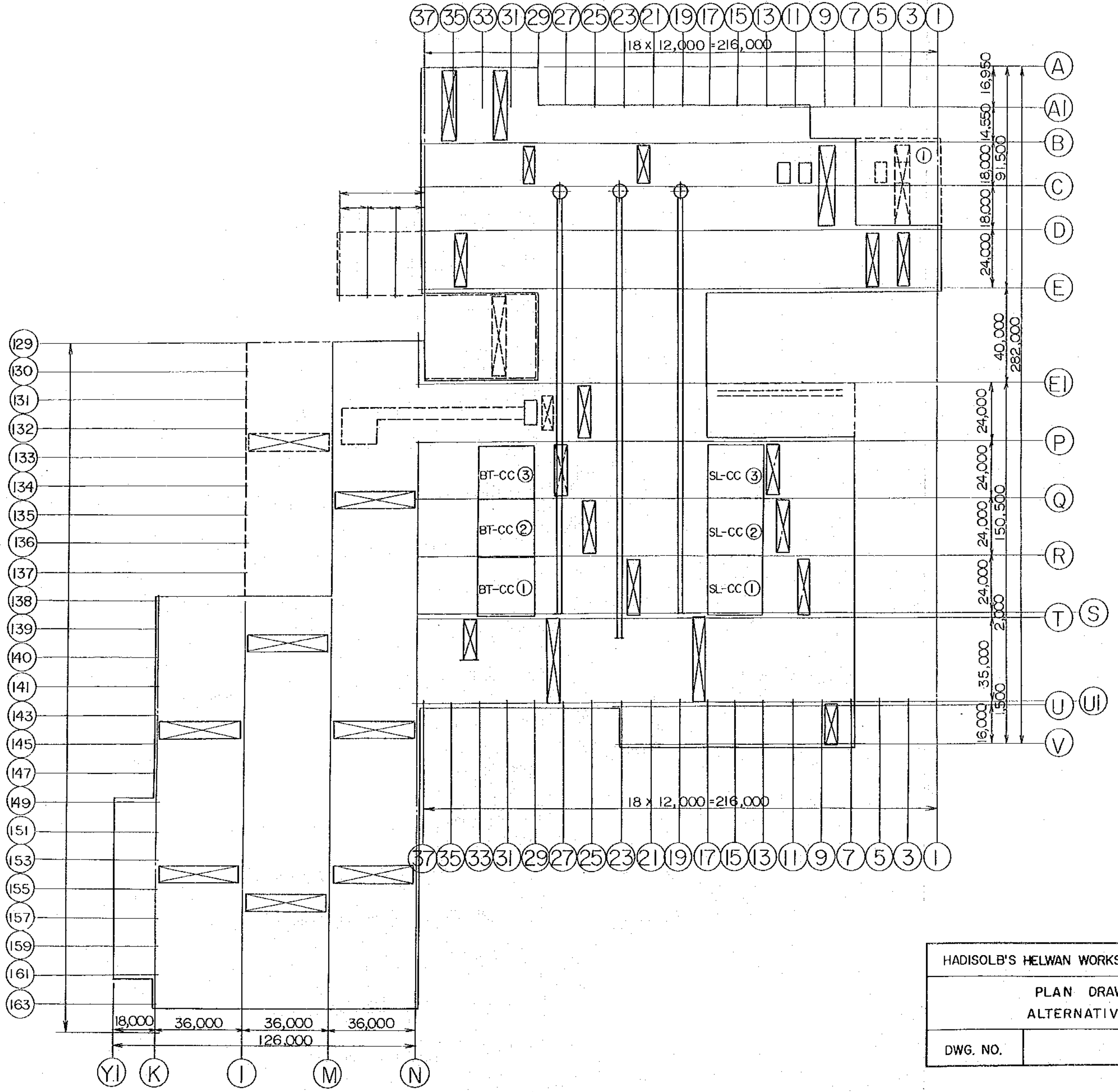
f) It is conceived to set up the furnace bottom repair area in the ingot-making yard. It will be between rails of the side track for the ladle car for No. 1 and No. 2 furnaces.

g) The rail gauge of the ladle car and furnace bottom exchange car will be of the same dimensions. As a result, the furnace bottom exchange car will stand ready on the rails of the ladle car of the furnace standing-by.

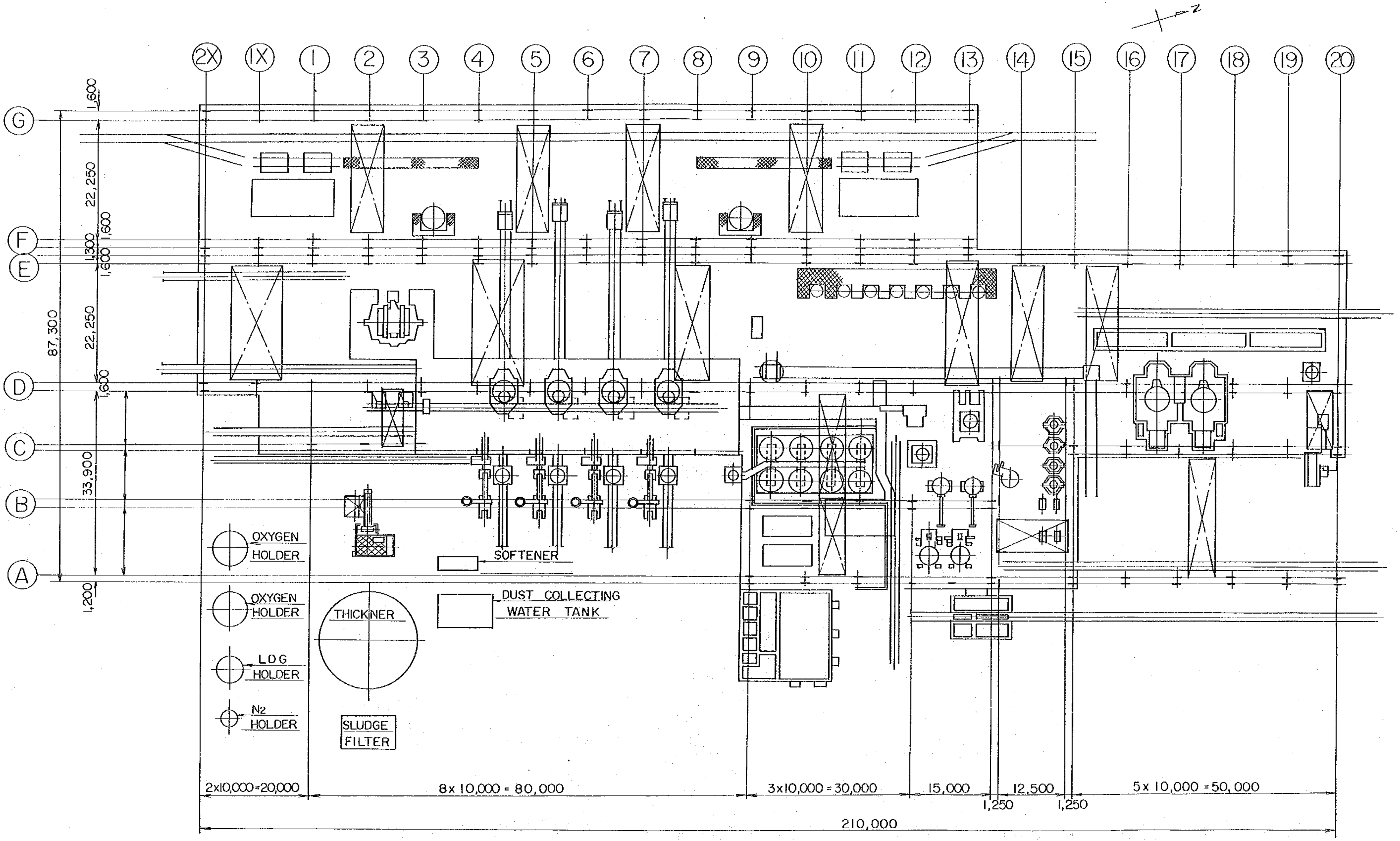
h) Therefore, if the furnace bottom exchange car is needed, the teeming crane will be utilized for transferring the car.

i) The hot metal mixer, scrap handling, ingot-making equipment, etc. will be the same as Alternative 4. See f) through i) in Alternative 4.

j) The plane, cross-sectional and front views are shown in DWG 12 ~ 15.



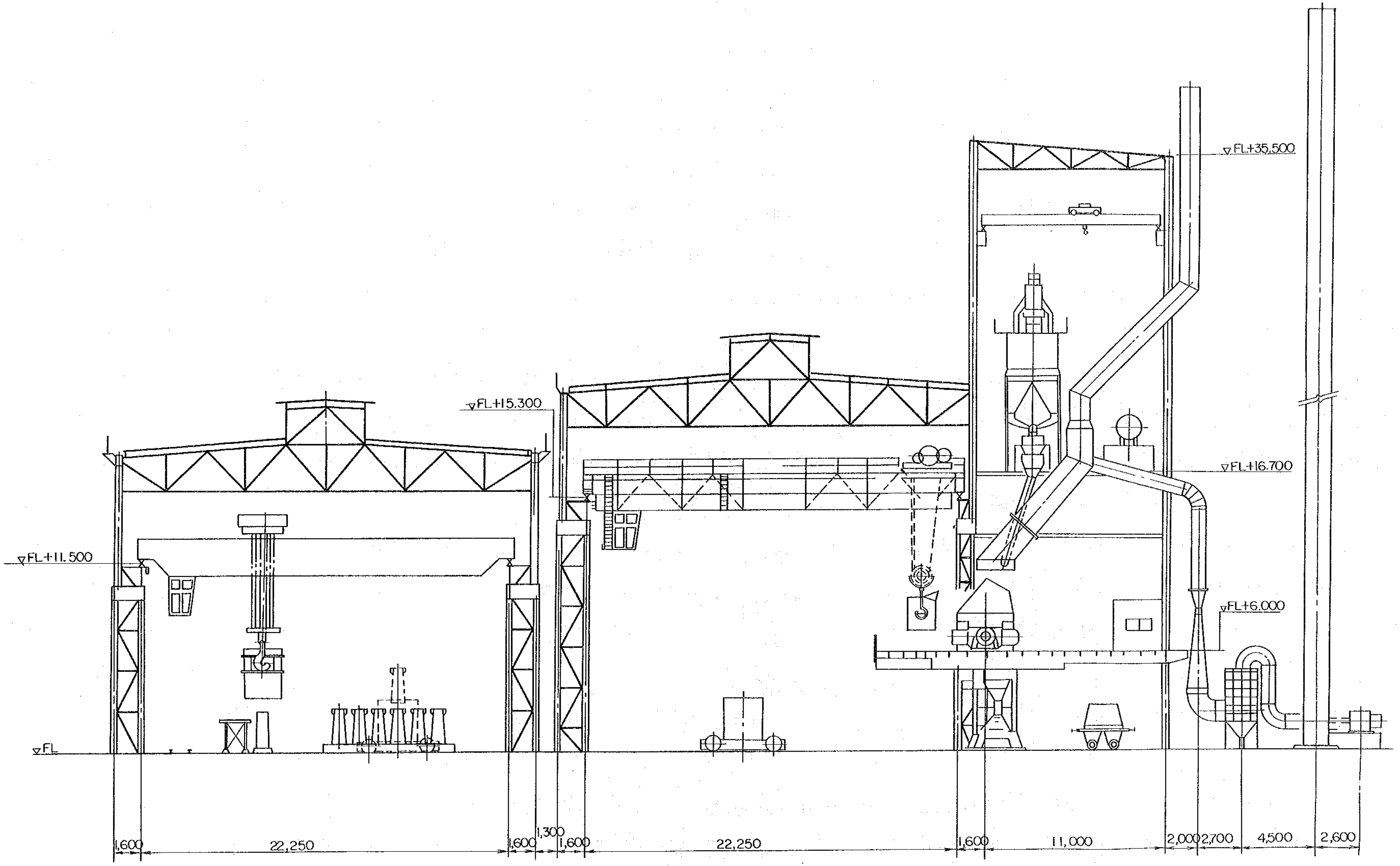
HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)	
PLAN DRAWING ALTERNATIVE I	
DWG. NO.	1



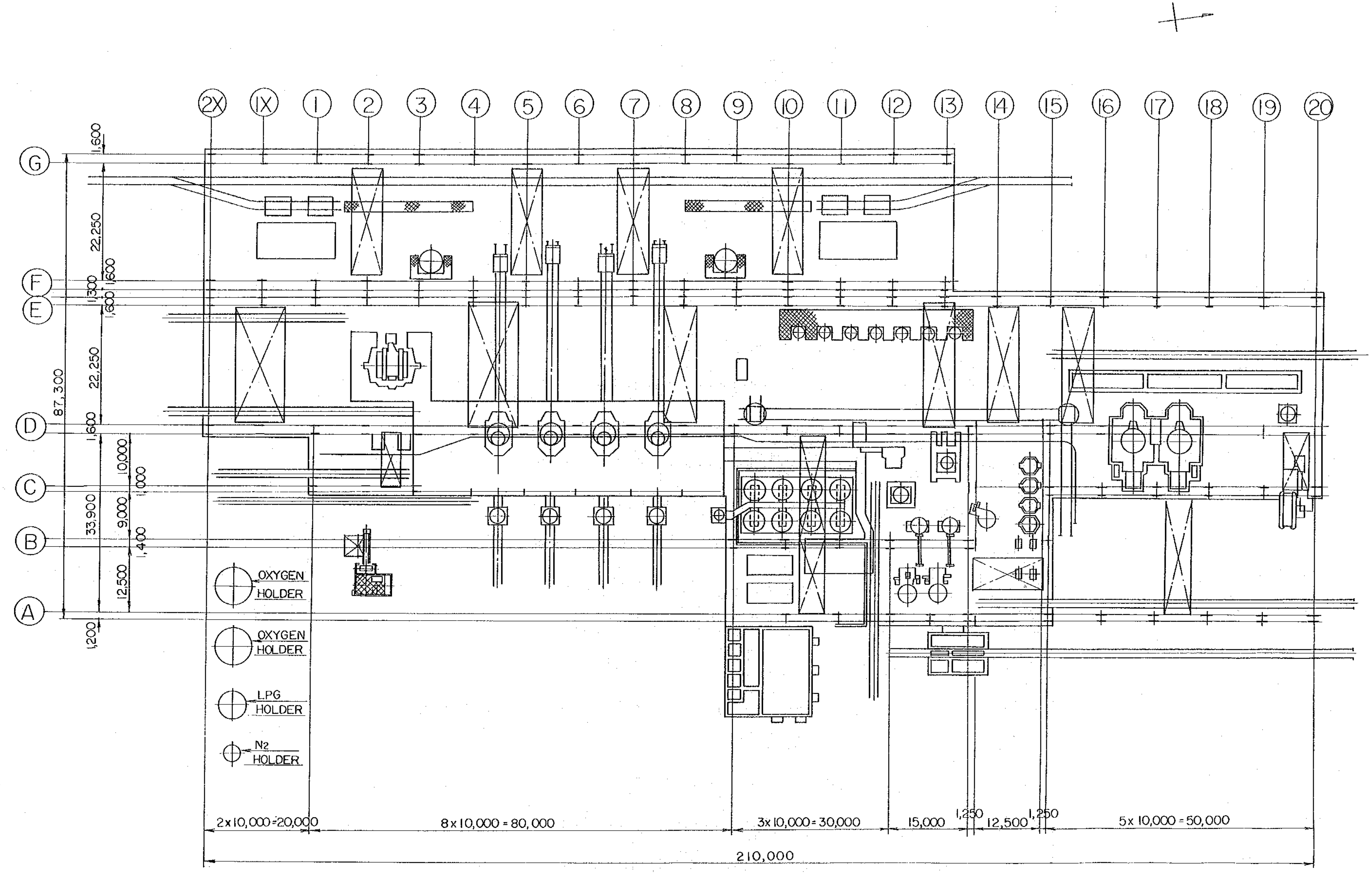
HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

PLAN DRAWING
ALTERNATIVE 2 (A)

DWG. NO.	2



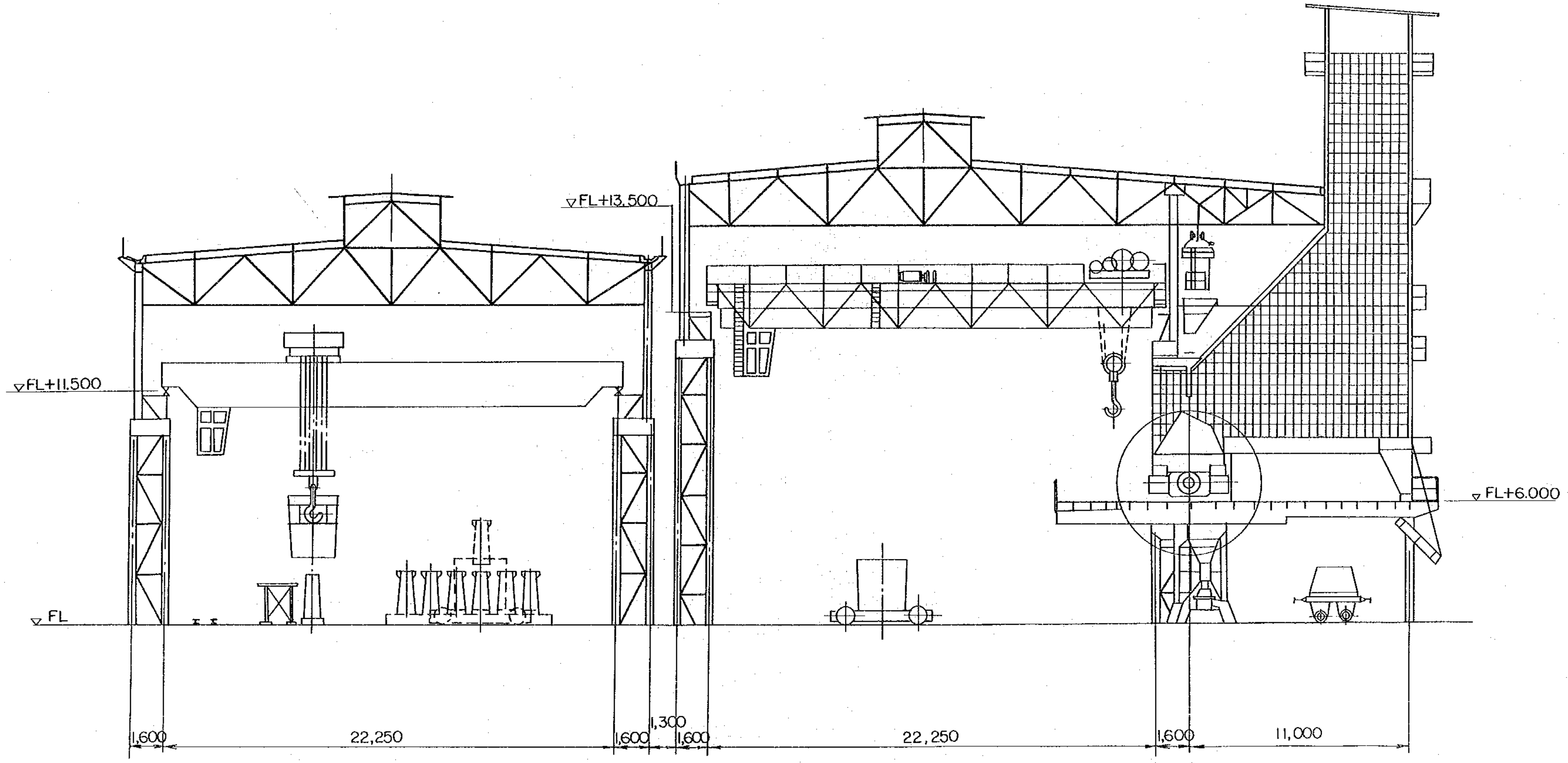
HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)	
SECTION OF TOP BLOWING PLANT ALTERNATIVE 2 (A)	
DWG. NO.	3



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

PLAN DRAWING
ALTERNATIVE 2 (B)

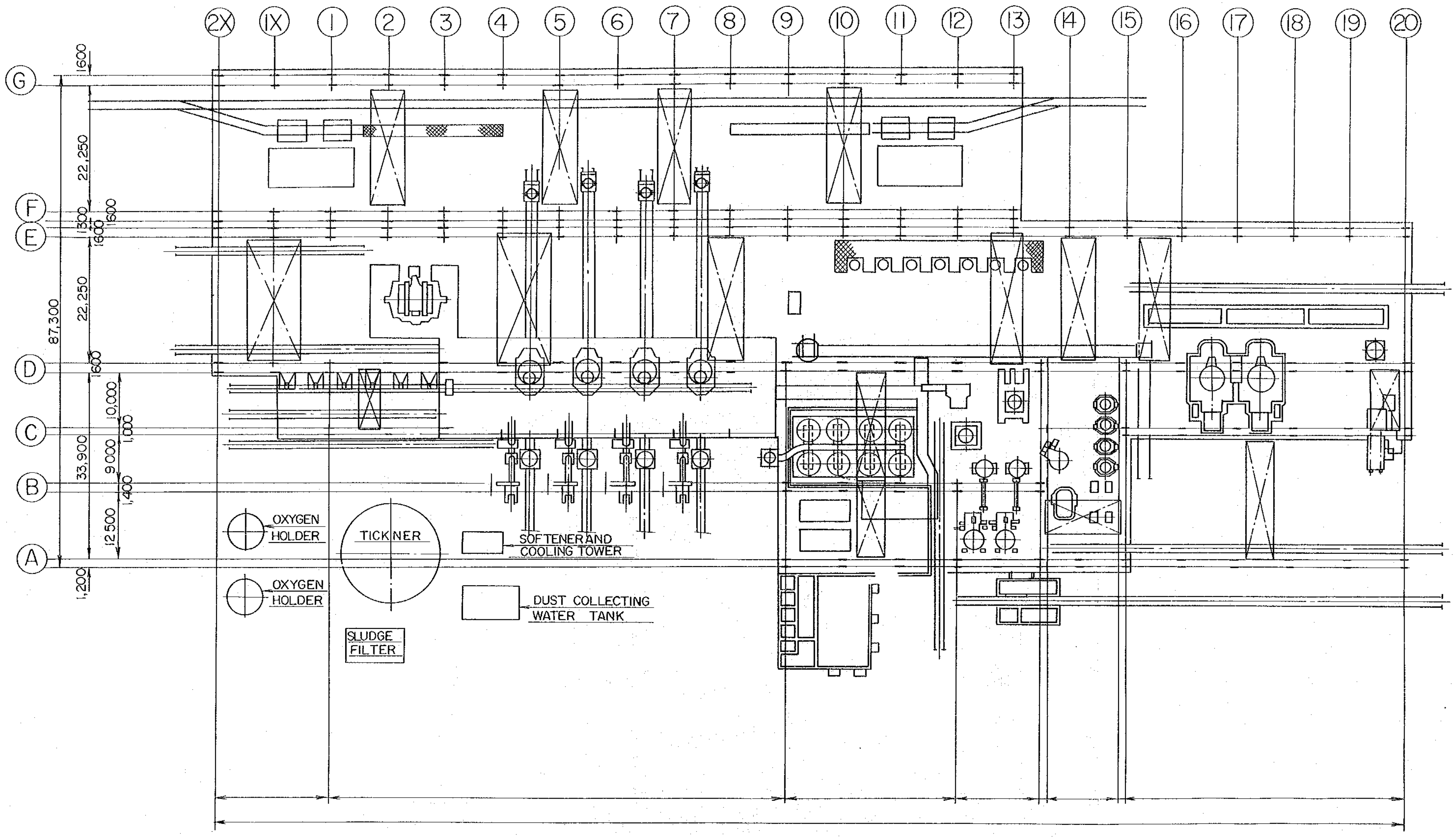
DWG. NO. 4



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

SECTION OF BOTTOM BLOWING PLANT
ALTERNATIVE 2(B)

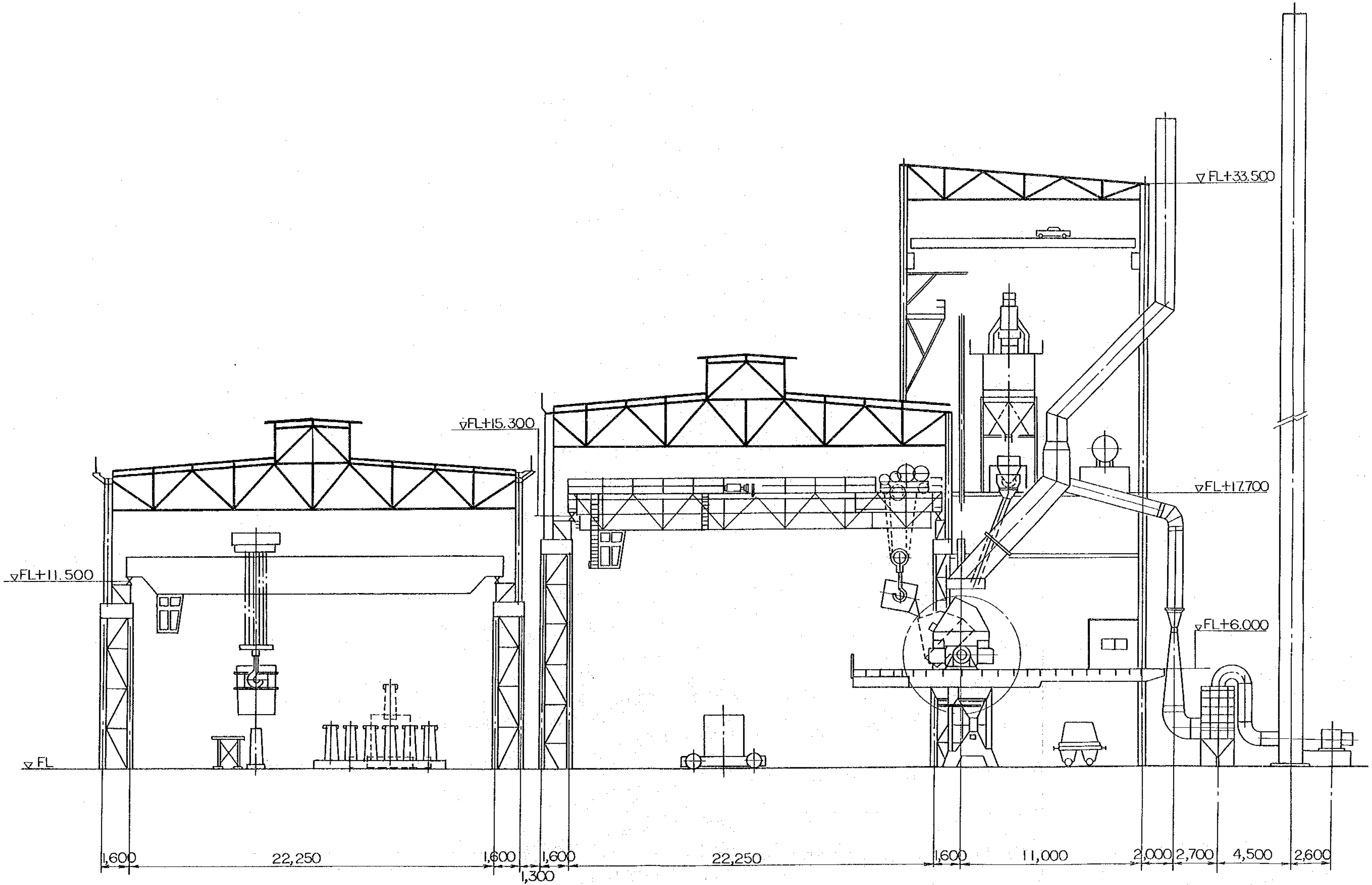
DWG. NO. 5



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

PLAN DRAWING
ALTERNATIVE 3

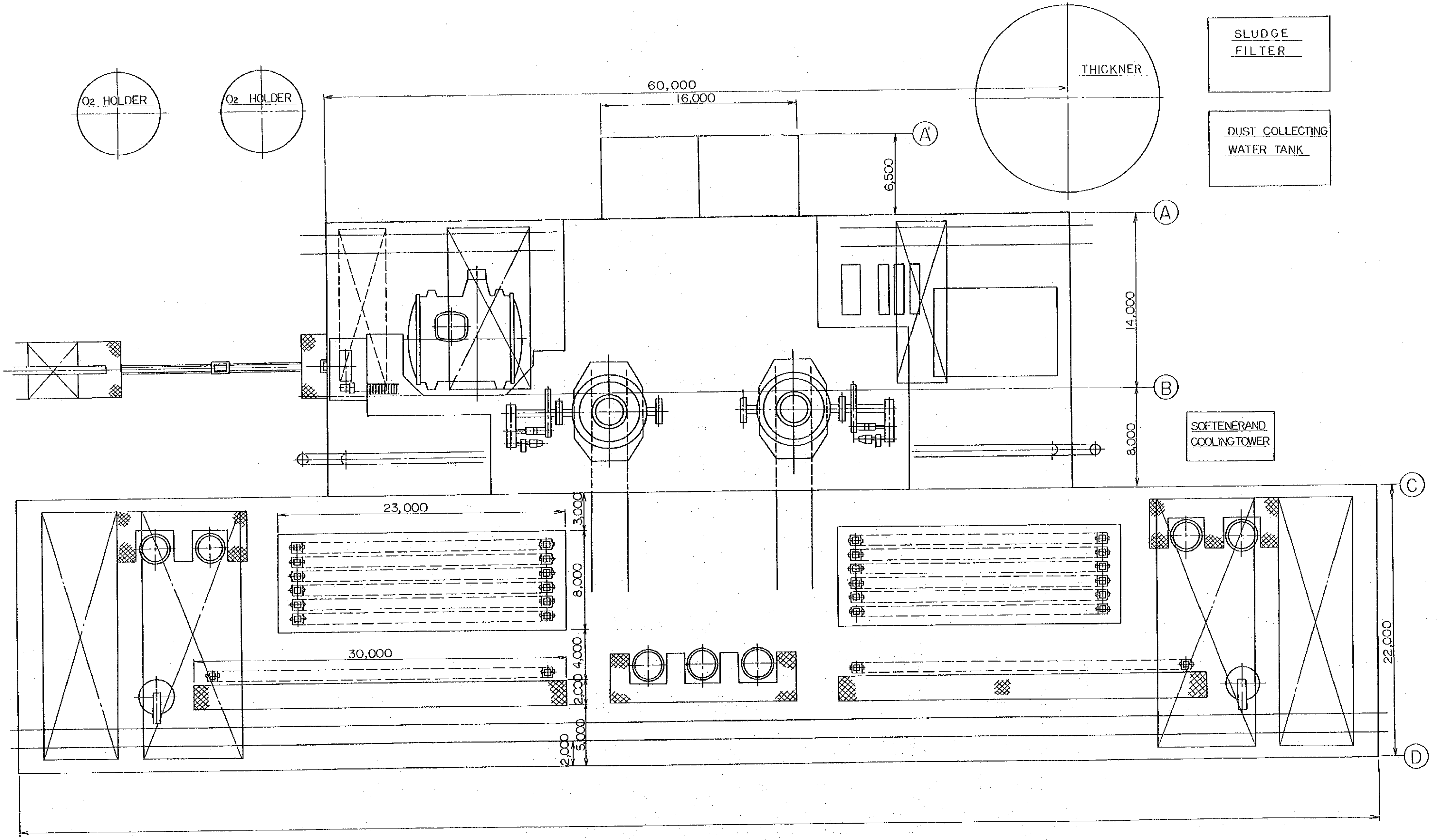
DWG. NO. 6



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

SECTION OF TOP BLOWING PLANT
ALTERNATIVE 3

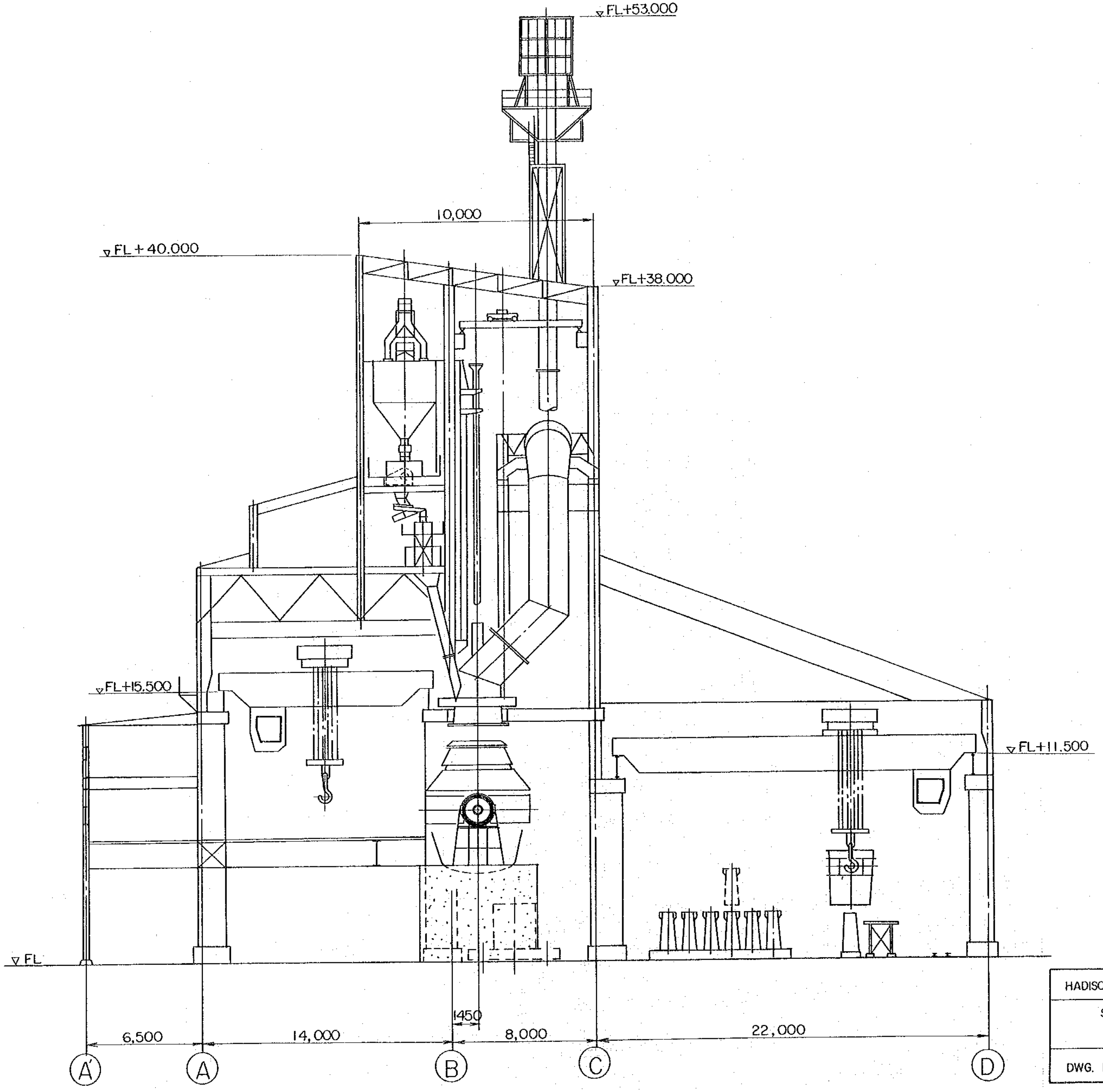
DWG. NO.	7



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

PLAN DRAWING
ALTERNATIVE 4

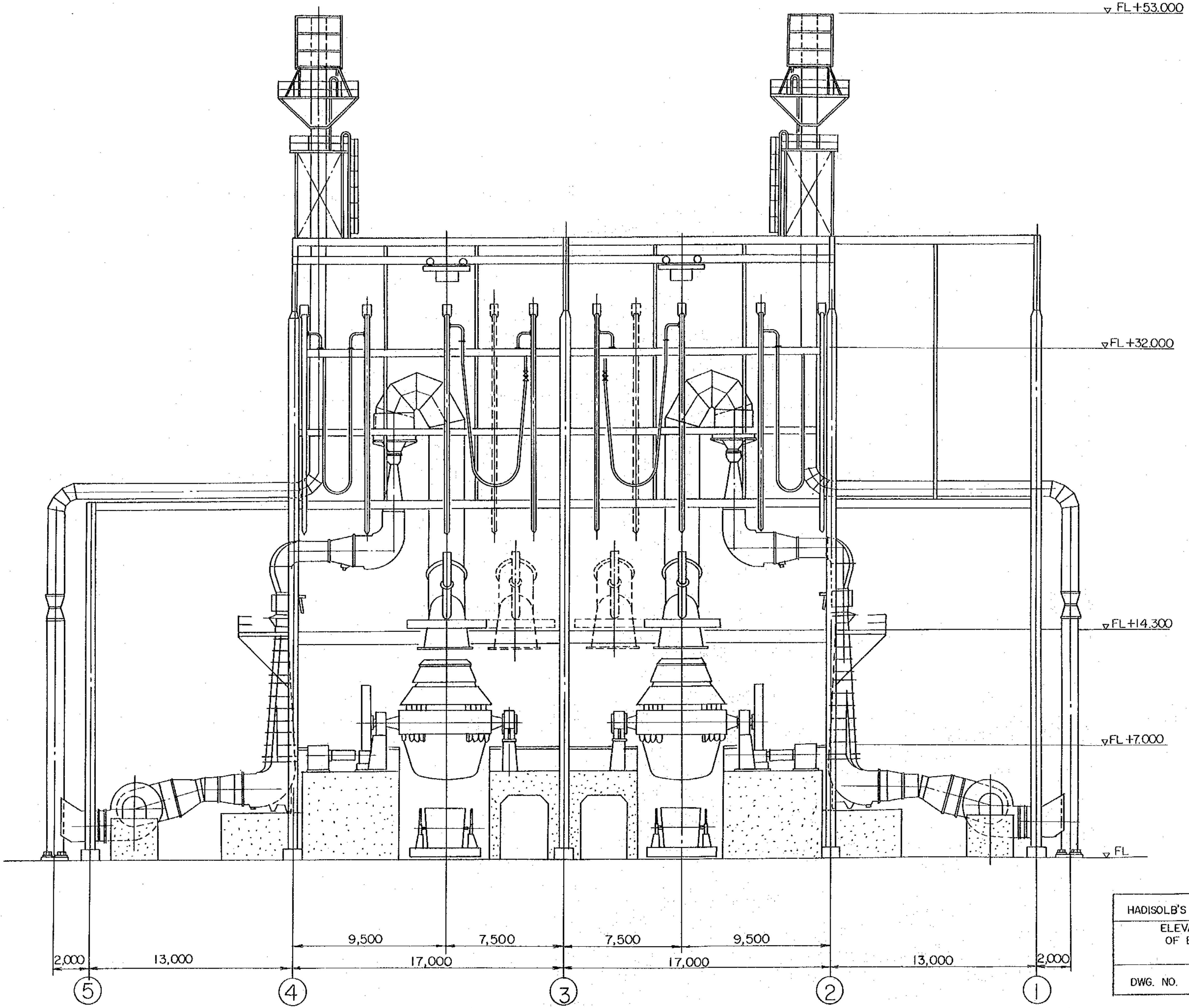
DWG. NO. 8



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

SECTION OF TOP BLOWING PLANT
ALTERNATIVE 4

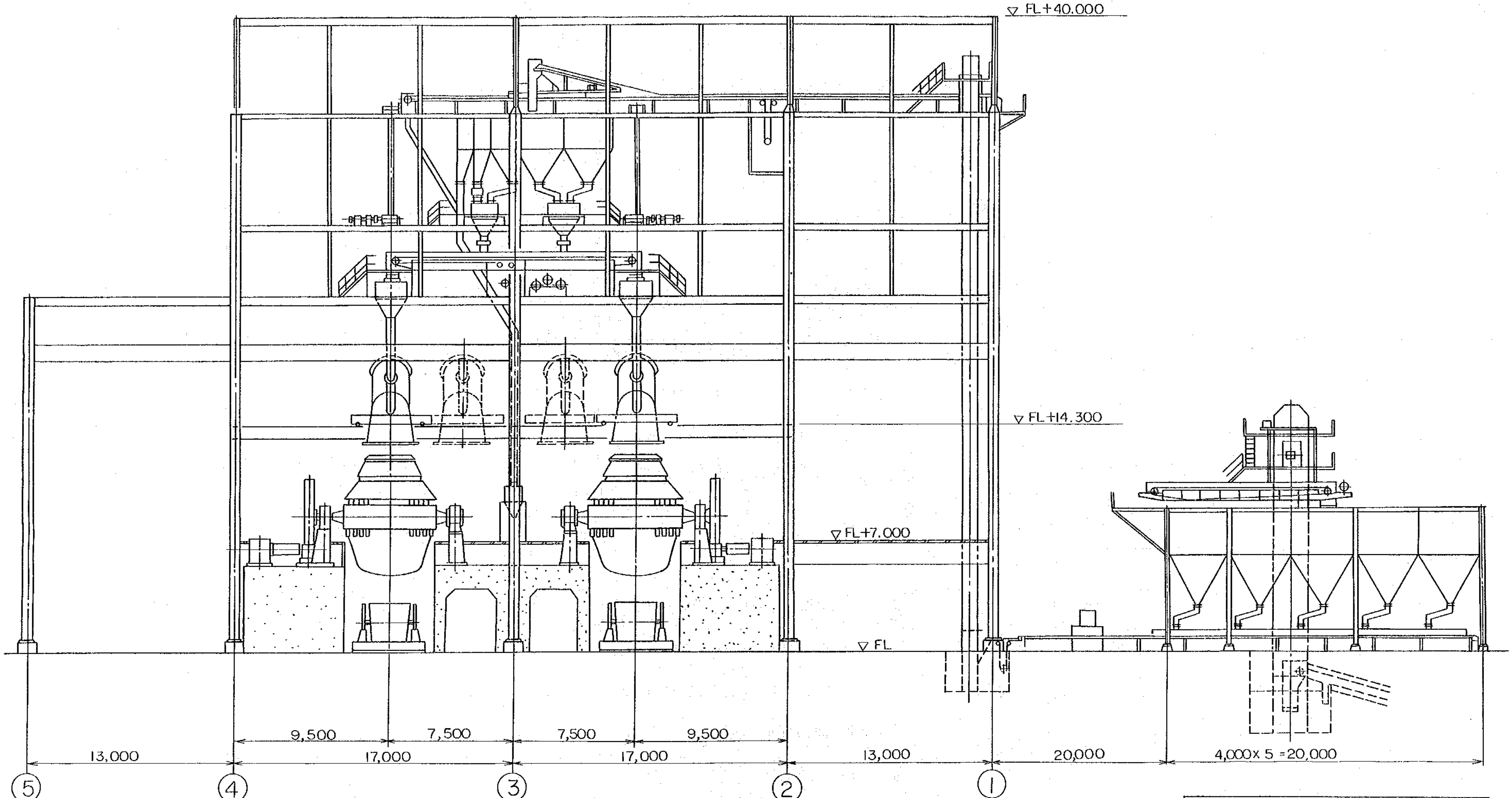
DWG. NO. 9



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

ELEVATION (GAS TREATING SIDE)
OF BOTTOM BLOWING PLANT
ALTERNATIVE 4

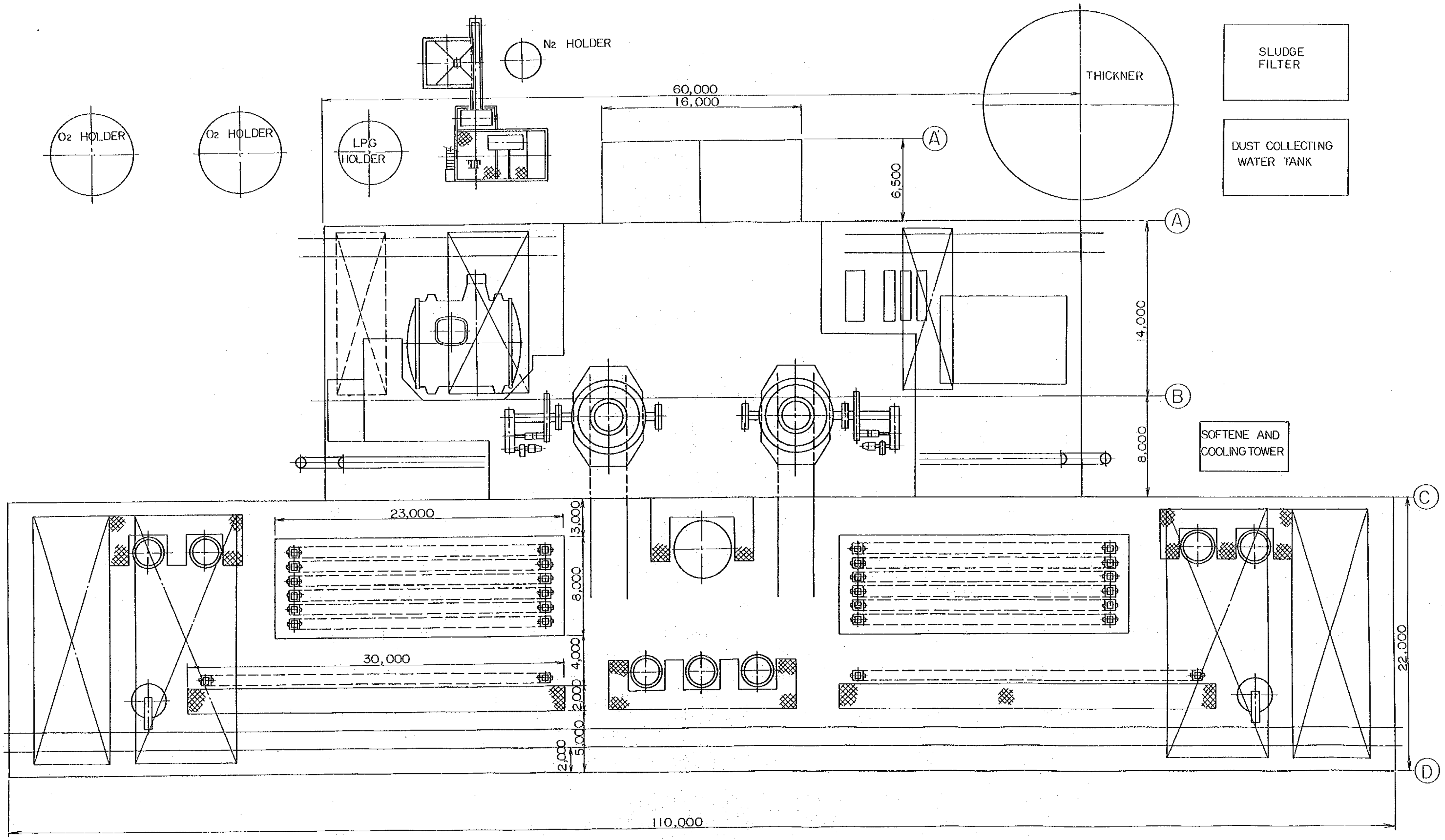
DWG. NO.	10



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

ELEVATION (FLUX SIDE)
OF BOTTOM BLOWING PLANT
ALTERNATIVE 4

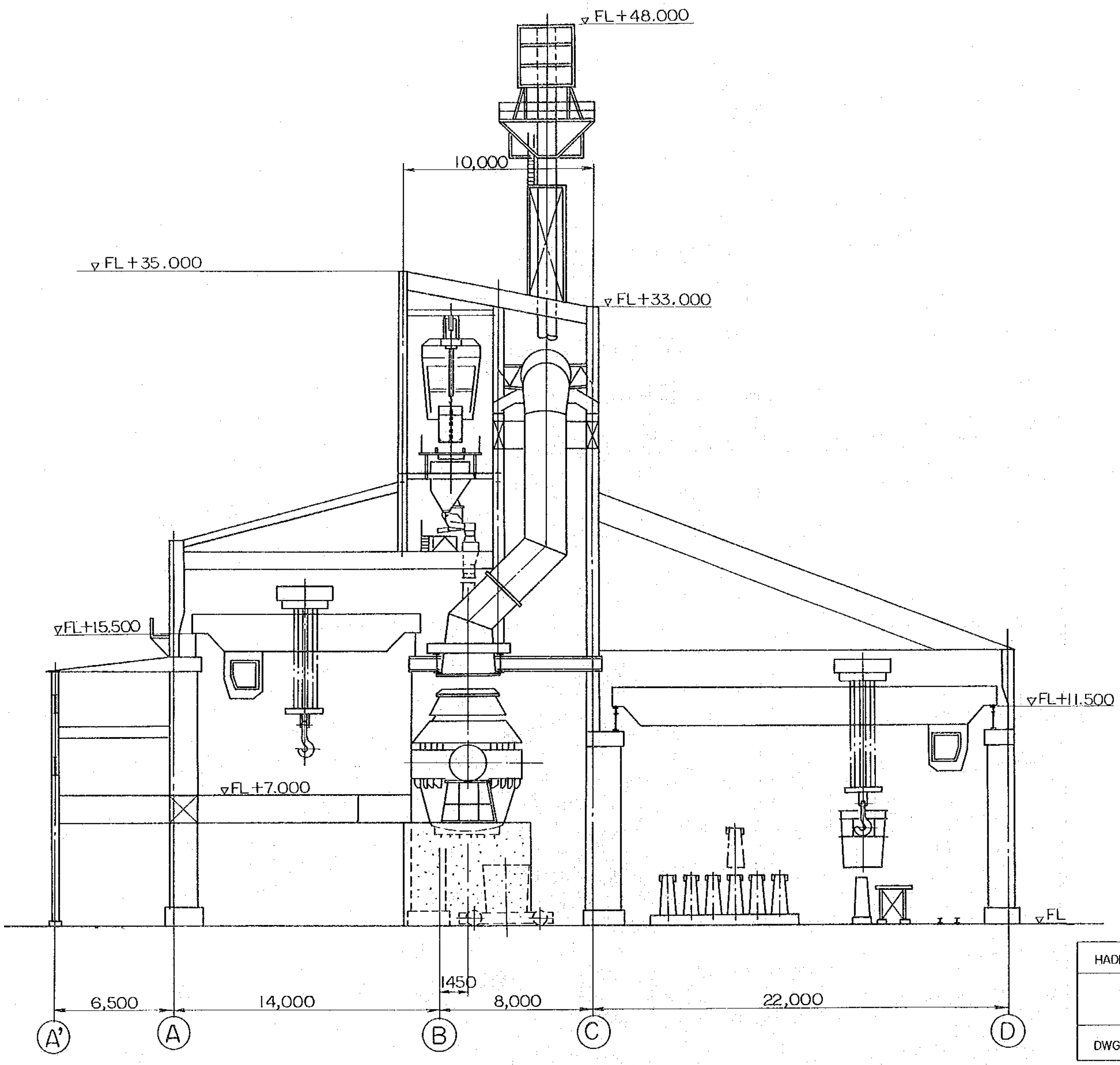
DWG. NO.	11



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

PLAN DRAWING
ALTERNATIVE 5

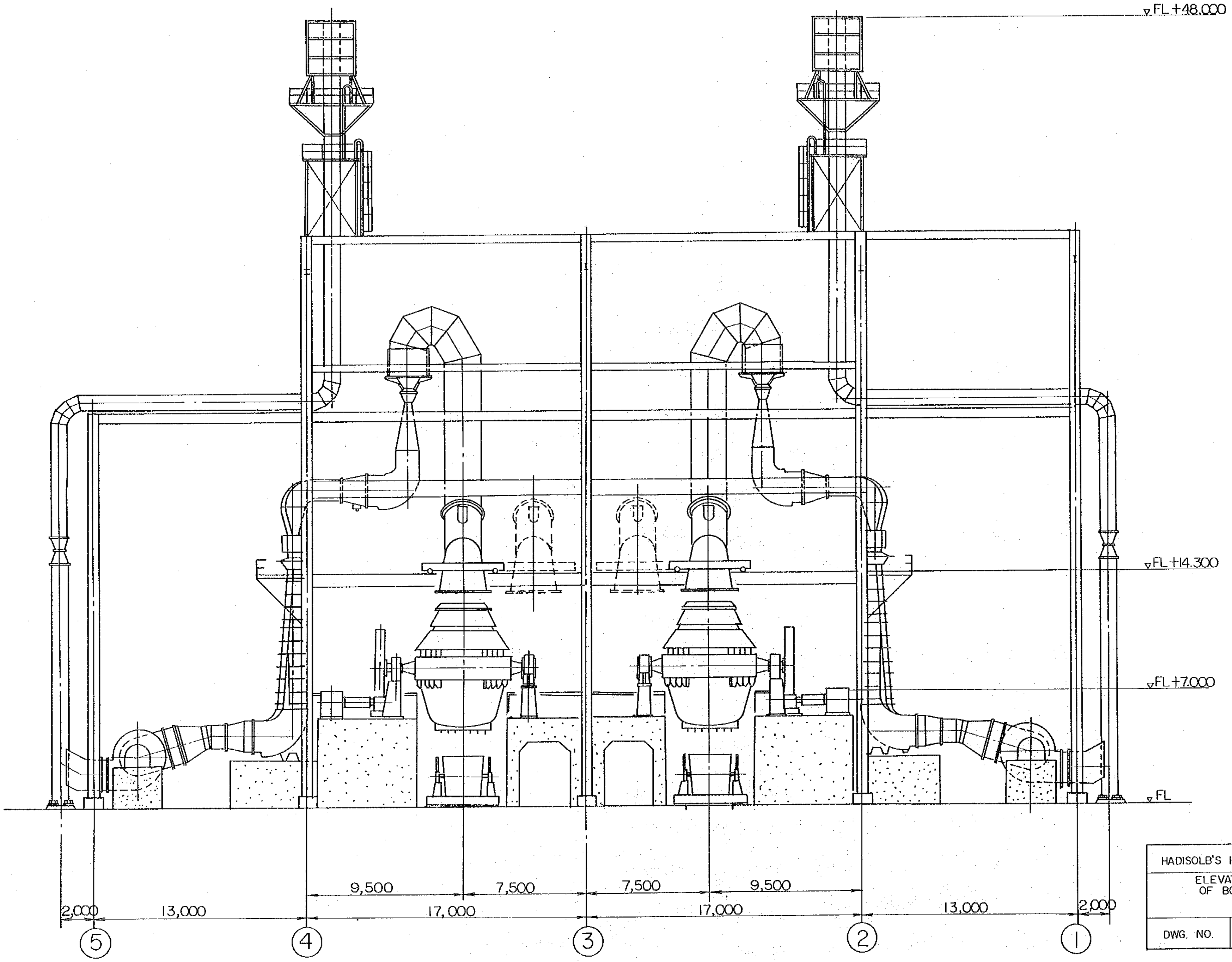
DWG. NO.	12



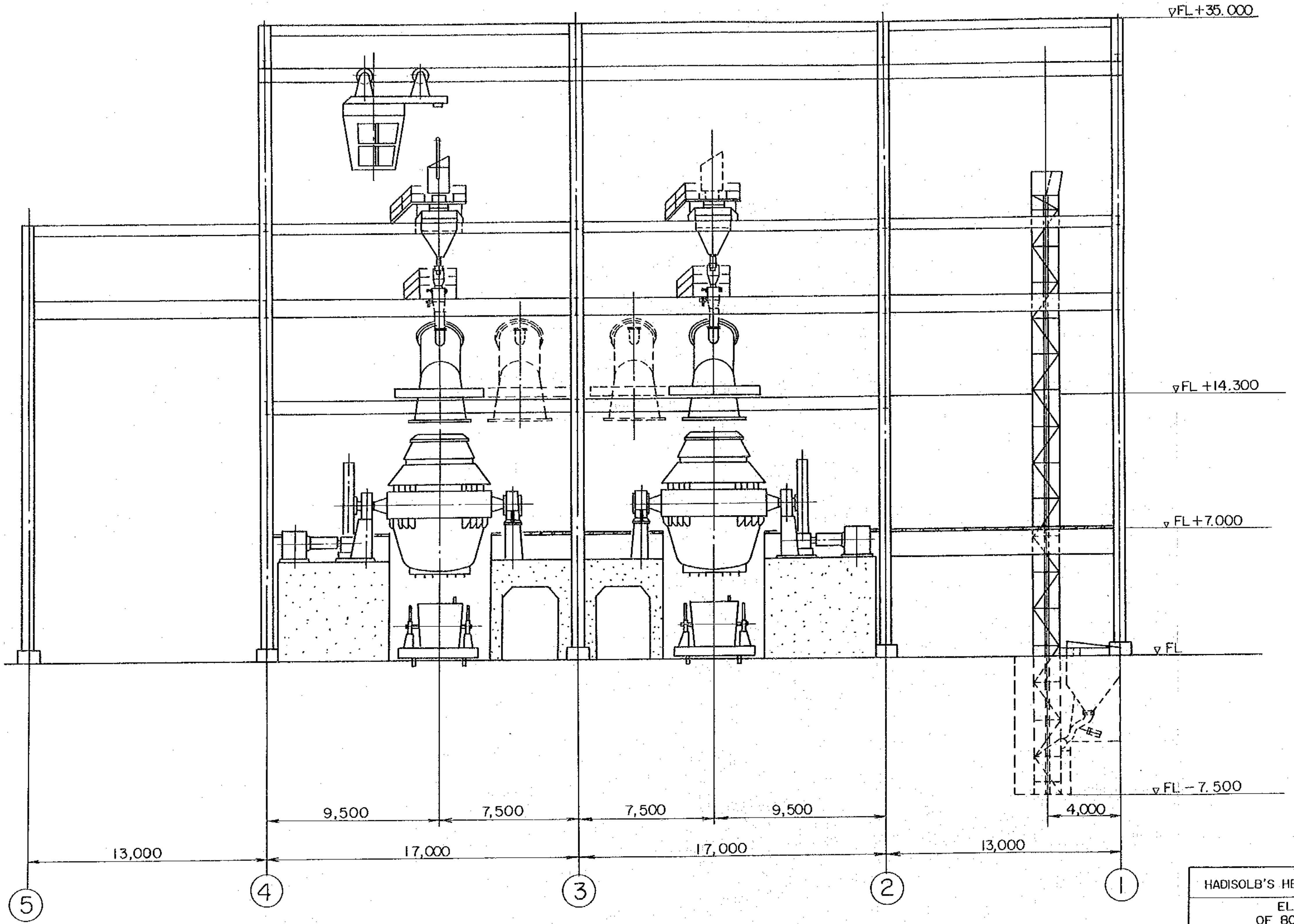
HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

SECTION OF TOP BLOWING PLANT
ALTERNATIVE 5

DWG. NO. 13



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)	
ELEVATION (GAS TREATING SIDE) OF BOTTOM BLOWING PLANT ALTERNATIVE 5	
DWG. NO.	14



HADISOLB'S HELWAN WORKS (STEEL MAKING PLANT)

ELEVATION (FLUX SIDE)
OF BOTTOM BLOWING PLANT
ALTERNATIVE 5

DWG. NO. 15

5. Overall Time Scheduling of Each Alternative

Results of examining general engineerign and construction methods for each of the 5 alternatives are outlined in the following. A period of time necessary for determining suppliers of each equipment is omitted from the overall schedule as attached.

Alternative 1

a) Factors determining the engineering and construction schedule basically despend upon the continuous casting machine proper.

b) Hence, as the attached engineering and construction schedule shows, engineering and construction on the sections to be added to each building will most probably be completed before completion of the installation of the continuous casting machine proper.

c) What needs to be careful about during the engineering and construction period is the hot metal transport inside the plant at the time of building the hot metal mixer bay and at the time of bringing in the hot metal mixer proper. It is considered that there will be no production decrease due to construction work.

d) As shown in the attached schedule, the engineering and construction work will take about 29 months.

Alternative 2 (A)

a) As a method of remodelling, it was considered to close 2 of the existing Thomas converters in order to minimize production decreases due to construction.

Accordingly, production will be less than a half during the construction period.

b) In order to newly install the waste gas cleaning apparatus and iron ore bunker above the furnace, for the first remodelling, it will be necessary to remodel the two Thomas converters closer to the hot metal mixer.

c) Consequently, to put the remaining Thomas converters in operation, the burnt lime receiving hopper will have to be moved to the electric furnace side so that burnt lime receiving can be done to operate the Thomas converters.

d) Note that the distance between the existing Thomas converters is a narrow 10 m, thus making the working environments extremely poor for building work on the top and installation of the equipment.

e) Therefore, depending on the construction stiuation, there is a possibility that the Thomas converters need to be fully closed.

f) As shown in the attached schedule, the engineering and construction work will take about 39 months.

Alternative 2 (B)

a) This is exactly the same as a), b) and c) of Alternative 2 (A)

b) As shown in the attached schedule, the engineering and construction work will take about 30 months.

Alternative 3

a) This is the same as a), b), c), d) and e) of Alternative 2 (A).

b) As shown in the attached schedule, the engineering and construction work will take about 39 months.

Alternative 4

a) Since the LD converter plant is to be newly built on the south side of the existing Thomas Plant, there are no restrictions on engineering and construction whatsoever.

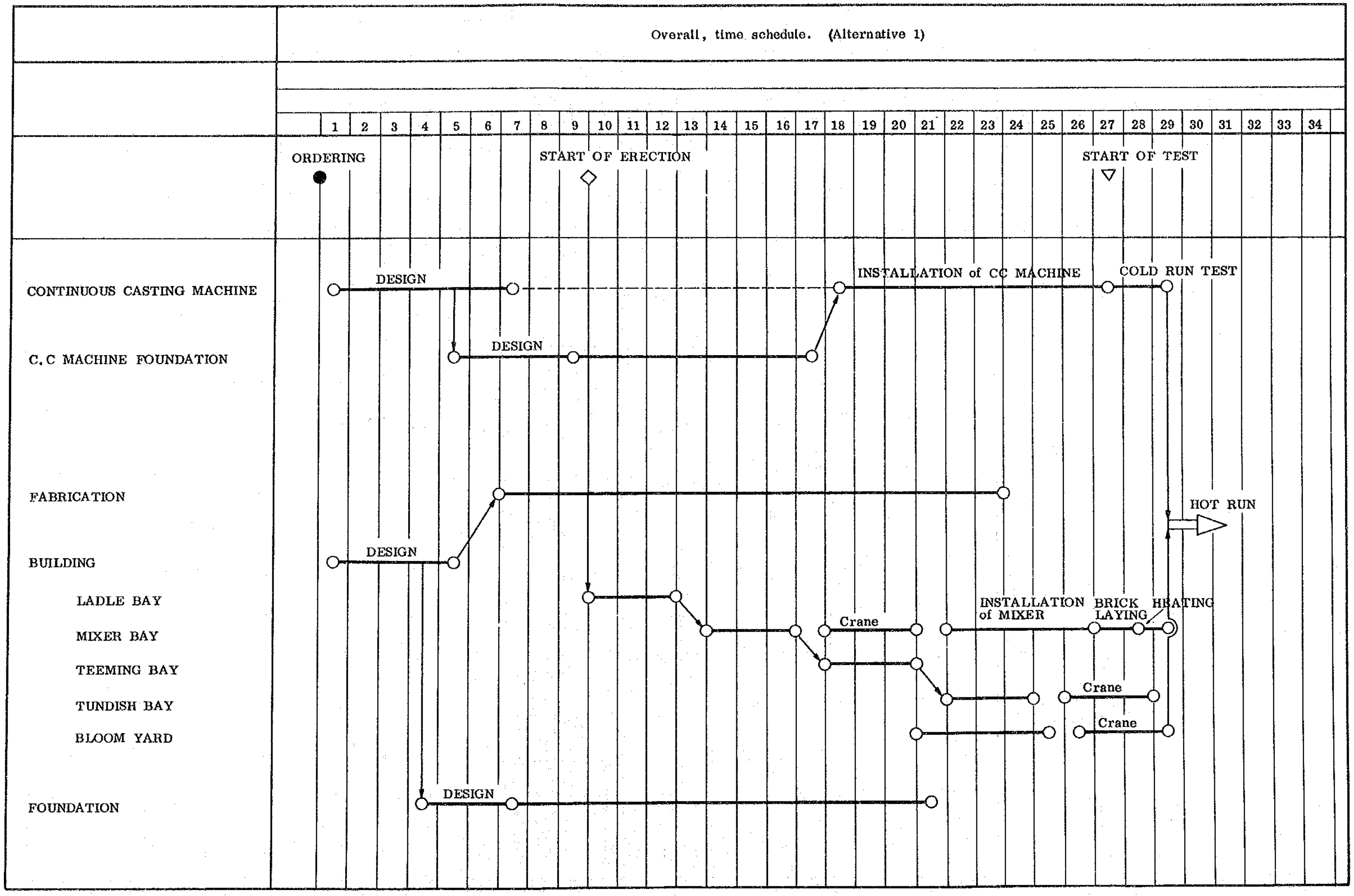
b) When the new steelmaking plant is finished, changes of the hot metal, slag disposal and ingot transport lines will be necessary. However, this can be done in a short time if shut-down maintenance days are utilized.

c) As shown in the attached schedule, about 34 months will be needed for completion of the engineering and construction work.

Alternative 5

a) This is the same as a) and b) of Alternative 4.

b) As shown in the attached schedule, about 34 months will be needed to complete the engineering and construction work.



Overall, time schedule. (Alternative 1)