A STUDY OF OPERATIONAL FACTORS IN IMPROVING PRODUCTIVITY OF STEEL MELTING UNITS OF CHITTAGONG STEEL MILLS LIMITED

A Project Thesis

by

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DEPARTMENT OF INDUSTRIAL AND PRODUCTION ENGINEERING

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CERTIFICATE

This is to certify that this work has been done by me and it has not been submitted elsewhere for the award of any degree or diploma or for publication.

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September, 1985

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ABSTRACT

Chittagong Steel Mills Ltd. is the only steel mill in Bangladesh supplying about 40 per cent of the total demand for intermediate and finished steel products in the country. The rated steel making capacity of the mill was 250,000 tons per year, but because of many operational problems, this has never been achieved. In the present work, operational problems of melting units have been studied. It has been found that the main problems come from charge preparation, charge handling, charging procedures, longer melting time and fettling time. Methods for improving the existing situation have been suggested. With the implementation of the proposed measures, steel making capacity can be increased to 188,000 tons per year from the presently attained maximum of 135,000 tons and the average tap-to-tap cycle time of 7.25 hours can be achieved, though these figures fall short of designed capacity of 6 hours. Any further improvement in productivity can be effected only by reduction of melting time which is at the moment 90 minutes longer than the designed value. The thermal efficiency of the furnaces must be radically improved which, at present, is only 8.95 per cent, far below than that of industrial average.

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CHAPTER – I

INTRODUCTION

1.1 Importance of Steel Industry in the Development Activity

In the industrialized countries of the world the development of iron and steel industry took place many decades ago. This industry is both part of, and a necessary condition for general industrial development. The products of the steel industry are almost all intermediate products providing the purchased materials for other industries which in turn convert them into particular forms required by the end-users. A primary role of a national indigenous steel industry is therefore to provide a backward national vertical integration of the industries it serves or in otherwards it is regarded as part of the national industrial base.

The principal advantages of a national steel industry are seen to be:

a) Security of supply: In times when world steel demand is high in relation to steel working capacity it is easier and cheaper to purchase raw materials than to purchase end products. Thus a buffer is provided to insulate the steel consuming industries from extreme fluctuations in the international market.

b) Reduced stock values: If the steel consuming industries were to rely upon imports, the varieties of product type, quality are such that to meet immediate demand the value of national stocks would need to be higher than if production were local.

c) Easier technical access: For some steel products it is advantageous for the steel consumer to have direct communication with the supplier to arrive at acceptable steel specifications.

d) Encouragement of down stream industries: The easy local availability of steel industry products tends to encourage the development of industries which use them.

1.2 The Steel Industry in Bangladesh

Bangladesh started with a poor base of manufacturing activities in primary iron and steel products. Indeed, she made her first entry into this field as late as 1955-56 when the first re-rolling mill was set up in the country. In 1972-73, the number of re-rolling mills stood at 29.

During Pakistan's Second Five Year Plan (1960-65) Chittagong Steel Mills (CSM) was set up with a steel ingot making capacity of 150,000 tons which was raised to 250,000 tons in 1969-70. Its rated capacity alongwith planned product-mix is shown in Table 1.1

Besides CSM, there is a small electric furnace at Mohammadi Iron & Steel Works (MISW) which produces pencil ingots and has little impact on the total requirement of steel products of the country.

Table 1.1 : Capacity and Product of CSM

	Name of Units	Products	Rated Capacity
1.	Melting shop	Steel ingots	250,000 M.T.
2.	Blooming Mill	Billets, sheet bar, slabs and shapes	180,000 "
3.	Bar Mill	Small billets, M.S. Bars	60,000 "
4.	Sheet & Thin plate mill	B.P. sheets & Thin plates	60,000 "
5.	Galvanizing shop	G.P. sheets/C.G.I. sheets	60,000 "
6.	Heavy Plate Mill	Heavy plates	57,000 "

1.3 Brief Introduction of the Problem

The steel melting shop of CSM is running below the rated capacity level, lower than world average, resulting in high production cost. This has primarily been caused by the facilities not being sufficiently maintained in the course of 18 years of somewhat inadequate operation, loss in operating time, reduced productivity, decreased yield, variation in product quality, reduction in thermal efficiency and increased maintenance expenses. Table 1.2 shows a typical steel melting shop performances after its expansion. The highest output as of today was in 1980-81 when 135734 tons of steel ingots were produced, though it constituted only 55% of the rated capacity.

Table 1.2 : Performance of steel melting units

Year	Ingot Prodn. (M.T)	Total Heats (No.)	Yield %			Av. steel making time, Hrs			
			Tap	Good	Pouring	Charge	Melt	Refining	Tap-to-Tap
1971-72	41233	712	92.3	87.5	94.8	1.44	2.61	1.20	NA
1972-73	67966	1165	91.6	86.2	94.1	1.46	3.02	1.31	NA
1973-74	73659	1262	92.4	86.6	93.7	1.25	3.71	1.65	NA
1974-75	76412	1263	91.8	86.1	93.8	1.76	3.39	1.42	NA
1975-76	90400	1529	91.4	85.4	93.4	1.53	3.07	1.40	NA
1976-77	102158	1774	90.4	85.2	94.2	1.96	2.86	1.37	NA
1977-78	111000	1969	91.0	85.4	93.8	2.04	3.12	1.40	NA
1978-79	121464	2203	89.0	83.5	93.8	2.19	2.96	1.18	7.99
1979-80	133315	2418	86.0	81.1	94.3	2.49	3.33	1.33	9.25
1980-81	135734	2498	86.9	81.5	93.8	3.03	2.61	1.17	9.20
1981-82	107525	2002	85.9	80.5	93.7	2.90	2.90	1.20	9.86
1982-83	47401	865	87.8	81.7	93.0	NA	NA	NA	9.05
1983-84	78387	1481	86.8	79.1	91.1	2.95	3.53	1.65	10.02

The present CSM capacity is clearly determined by the steel melting shop productivity. Therefore, the key problem of CSM is how to maximise liquid steel production with the best use of the existing facilities at an acceptable production cost.

1.4 Objective of the Study

The productivity of the steel melting units at CSM is dependent upon a number of operational factors; namely composition of furnace input materials, transportation system for loading and unloading of these materials, time required in performing various operations like melting, refining, tapping, fettling, etc. Melting and refinement time, on the other hand, depends on the thermal efficiency of the furnace. So, the objective of this project was to study the following operational factors in order to determine their effect on the production cycle time and suggest some measures to improve the existing situation:

1. Existing material handling and transportation system to furnace input
2. Constraints affecting the furnace cycle time and their influence on output
3. Factors affecting the thermal efficiency of the furnaces.

CHAPTER - II

PROCESS DESCRIPTION AND ANALYSIS

2.1 Description of Existing Furnaces and Facilities

The melt shop[1] contains four 60 tons capacity basic Open Hearth Furnaces (OHF). Each furnace is of fixed type, 18.6 m long, 6.8 m wide and covers a hearth area of 39 m^2 with three individually operated water cooled doors at the front. The hearth and back walls are magnesia backed by burned magnesia bricks. But the front wall, upper back wall and suspended roof are built in by steel clad chrome magnesia bricks. The furnaces are oil fired through water cooled burners in the port ends and compressed air is used for atomisation. Oxygen is also used for lancing the bath through the charging door and for flame combustion purposes.

Each furnace has two regenerator chambers. The hot flue gas alternately preheats the combustion air, passes through a waste heat boiler for steam production and a conditioning tower followed by a electro-static precipitator which cools and cleans the exhaust gas prior to discharge to atmosphere through a 40 m high chimney.

Loaded bogies of raw materials i.e. pig iron and scrap are brought up to the charging platform from the materials stockyard by the wagon hoist. These are then distributed to the furnaces by diesel locomotive. Each bogie carries four 0.9 m^3 charging boxes and these are charged to the furnaces by one of the two ground chargers. There are two 10 tons over-head service cranes in the charging bay used for handling refractories and additions onto the platform from ground level via an access hatch, and other general works and maintenance duties.

Steel is taken out from the furnaces into a 60 ton capacity casting ladle and then transferred across the pitside bay through 100 ton overhead cranes, to one of the six teeming stands where steel is up-hill teemed into either square ingot or slab ingot moulds.

Ingots are stripped using a multi-hook beam carried by an overhead crane, and the hot moulds are transferred to a 60 m^2 area cooling grid alongside the furnaces. The hot ingots are lifted by tongs carried by overhead crane and deposited on bogies for stacking in yard.

For supplying oxygen to furnaces for flame combustion and refining purposes, there are two oxygen generating units of 550 m^3/hr. capacity each.

2.2 Capacity of Furnaces

The plant supplier, Kobe Steel Ltd., Japan, originally supplied 3 open hearth furnaces of 60 ton charging capacity operating with average tap-to-tap time (discharging cycle of molten steel) of 6 hours to produce 150,000 tons of steel per year. They specified a charge of 60 tons containing 36 tons of scrap (60%) and 24 tons of pig iron (40%). The steel output was calculated as 52 tons giving an ingot production of about 50 tons per heat.

Later, with the addition of one more furnace, Kobe calculated production increase to 250,000 tons per year by altering the charge composition specifically by increasing pig iron content from 40 per cent to 60 per cent; by overcharging the furnaces and by increasing oxygen consumption. With more pig iron in the charge there will be an increase of heat generated in the bath, due to exothermic reactions occuring from the greater carbon and silicon elimination, and for which increased oxygen is required. This increase in heat within the bath is necessary to melt the additional charge within proposed melting time, thereby enabling the 6 hours tap-to-tap cycle. By overcharging Kobe meant that charge weight would be increased to 68 tons for steel output of 58.5 tons. Hence, on the basis of the above assumptions and also continuous operation of 3 furnaces throughout the year, the capacity of furnaces was determined as follows:

a)	Main raw material charge	:	68.0 tons
b)	Liquid steel discharge	:	62 "
c)	Ingot output	:	58.5 "
d)	Average life of each OHF for each relining	:	428 charges
e)	No. of charge per year (250,000/58.5)	:	4280 charges
f)	Furnace working days (428/4 charge per day)	:	107
g)	Minor repair days	:	3
h)	Rate of operation	:	0.73 $(\frac{3}{4} \times \frac{107}{107+3})$

Hence, capacity = 58.5 x 4 charge x 365 x 0.73 x 4 furnace

= 250,000 tons/year.

In the design of the capacity, there is a number of operating parameters to be considered. Although each of these can be further sub-divided into a number of components, there always remains some significant parameters which cannot be calculated. These are matters of judgement and must be based upon norms for steel industry practice.

The principal operating parameters determining steel making capacity are:

i) Furnace availability
ii) Furnace cycle time (average tap to tap time)
iii) Refractory performance
iv) Product yield

2.2.1 Furnace Availability

Furnace availability is calculated from the possible operating time. During operation there are many factors which can cause delays and some of these are beyond the control of the operator. These are called non-operational delays and include

- mechanical breakdowns of machineries
- electrical breakdowns of machineries
- crane breakdowns
- ground charger breakdowns
- refractory patching to furnaces
- power failures

These delays reduce the possible operation hours. The furnace availability can therefore, be expressed as:

$$\frac{\text{Operating time} - \text{non-operating delays}}{\text{Operating time}} \times 100$$

For designing capacity, the availability factor must be taken into account and for optimising production, high availability must be ensured.

In table 2.1 a comparison of main operational factors between designed and actually attained (year of maximum production) figures have been made.

In table 2.2 six month's performance of OHF has been shown.

From these tables, it is calculated that non-operational loss is approximately 6% and this is due to low utilization of the furnace and equipments. As production is increased and greater demands are placed on both furnaces and equipments, the non-operational delays may also increase upto 10 per cent.

Table 2.1: Operational Factors (Designed & Attained)

Description	Designed figure	Attained (1980-81)
Ingot production capacity	250,000 T/Y	135,734 Tons
Av. Ingot weight per charge	58.5 T	54.2 T
Tap to Tap time	6 hrs.	9.2 hrs.
Availability (100 - non-operation loss time)	100 %	94.4%
Total furnace days operated	1070 days/Y	1005 days
Furnace Repair Days	390 Days/Y	455 Days
Pig Iron - Scrap ratio	60 : 40	43.2 : 56.8
Charging Hour	2 hours	3.03 hours
No. of charging box	46	60

Table 2.2 : Availability of Furnaces from Nov.'83 - April '84

	Nov'83	Jan'84	Feb'84	Mar'84	April'84	May'84	Average
No. of furnaces operated	2	2	2	2	2	2	2
Available time							
- Scheduled operation hours	1344	1488	1608	1416	1488	1392	1456
- Actual operation hours	1012	1181	1306	1086	1109	1084	1129
- Operation loss hours	216	247	266	194	266	249	240
(%)	16	17	16	14	18	18	16.5
i) Fettling (%)	6.5	6.7	6.5	5.3	5.6	6.4	6.2
ii) Bed repair (%)	4.7	4.6	4.2	2.7	5.0	4.0	4.2
iii) Furnace temp. raising(%)	2.9	3.3	3.9	3.9	5.6	6.1	4.2
iv) Tap hole change (%)	0.6	1.4	1.1	0.8	1.3	0.8	1.0
v) Others (%)	1.3	1.0	0.3	1.3	0.5	0.7	0.9
- Non operation loss hours	116	60	36	136	113	59	87
(%)	8.7	4.1	2.3	9.6	7.6	4.2	6.0
i) Mechanical trouble (%)	1.5	0.69	0.55	1.30	1.97	0.92	0.98
ii) Electrical trouble (%)	0.1	-	0.17	-	0.88	0.33	0.24
iii) Crane trouble (%)	0.6	0.74	0.77	0.89	0.91	0.56	0.74
iv) Refractory (%)	1.9	1.40	-	2.23	3.06	1.04	1.60
v) Pit side trouble (%)	0.5	0.4	0.29	0.45	0.76	0.46	0.47
vi) Others (%)	4.1	0.87	0.52	4.73	0.82	0.89	1.97

Note: In Dec. '83 only one furnace operated. Hence data not taken for calculation

2.2.2 Furnace Cycle Time

The furnace cycle time is the time required to get a furnace output on completion of pre-determined activities. These activities are (a) fettling (b) charging (c) melting and (d) tapping . Some factors affecting the cycle time are:

i) furnace condition
ii) charge composition
iii) use of oxygen
iv) quality of furnace repairing material.

It would be ideal if these factors remained constant throughout the campaign but in practice this is impossible to achieve. However, certain factors can be standardised and need only be altered to suit the condition of the furnace as the campaign progresses. In table 2.3 a comparison of designed cycle time with that of achieved time for the period from July 78 to June 81 is given. The values in the table are simple averages of the respective activity durations over the period mentioned.

Table 2.3: Comparison between Standard cycle time and achieved time

Sequential activities	Achieved Av. time (min)	Designed time (min)	Deviation (min)
Primary charging	104	90	14
Burning	34	30	4
Secondary charging	70	30	40
Melting	180	90	90
Refining	61	90	(29)
Tapping and fettling	76	30	46
Total	8 hrs 45 min.	6 hrs.	2 hrs. 45 min.

The excess time is required mainly for prolonged time in charging, meltdown of the charge material and fettling operation prior to next furnace charge. Refining time indicates a negative deviation. It is observed that meltdown time in most cases was not recorded properly and hence this can be assumed as close to designed time.

The charging time depends on the preparation of charged material at the scrap bay where the box weight should be fairly constant for each grade of scrap. An analysis of charging time indicated that number of boxes charged to furnace increased from designed 48 boxes to more than 60 boxes per charge.

The fettling time varies according to the tap-hole condition and to the wear on the refractory walls and bottom. The fettling time includes all operations which prepare the furnace for the next charge, fettling the bottom and banks, tap-hole maintenance and changing, bottom repairs and bottom drying in case of a dirty bottom.

The melting time depends on the thermal efficiency of the furnace. Generally charging overlaps melting in the pig and scrap process and the two together take up two-thirds to three-quarters of the total time of the melt. This period is of prime importance for productivity. During charging, layers of scrap are alternated with pig iron, each batch being allowed to heat properly which makes the charge denser and increases its thermal conductivity.

Enriching air with oxygen increases the pyrometric effect of combustion. In oil fired furnace the best effect is obtained by introducing oxygen either into the burner system or through roof lancing. In practical situation as in CSM, roof lancing is abandoned rather oxygen is injected manually by pipes through furnace doors not much suppmenting the combustion process.

2.2.3 Refractory Performance

The total operating days of a furnace depends on refractory performance. A furnace campaign starts from relining the interior of the furnace with refractory lining including roof of thickness 500 mm. As the operation continues, an intermediate repair with 300 mm brick is made. Obviously, roof life has great influence on the number of operating hours in a year and it should be as high as possible. CSM procures roof bricks from different sources and the records to date are wide fluctuating among the different origins. Tables 2.4 and 2.5 indicate the performance of furnaces at CSM for different brick manufacturers and two thickness of roof brick. The average standard roof life as specified in the design is 280 and 200 heats for 500 mm and 300 mm bricks respectively.

Table 2.4: 500 mm thickness Roof Refractory life

Origin / Year	JS	JO	Y	CZ	IT	IO	P
	Roof life in heats (No. of repair)						
1971–72	304 (1)						
1972–73	–	–	–	–	–	–	87 (1)
1973–74	315 (1)		665 (2)				408 (4)
1974–75	383 (1)	–	–	–	–	263 (1)	273 (1)
1975–76	138 (1)	–	–	–	–	556 (2)	300 (2)
1976–77	541 (2)	–	–	–	–	174 (1)	854 (3)
1977–78	1062 (4)	–	–	–	–	–	196 (1)
1978–79	306 (1)	411 (2)	–	–	–	312 (2)	–
1979–80	–	1349 (6)	–	–	–	392 (2)	–
1980–81	–	907 (5)	–	–	–	417 (2)	–
1981–82	–	193 (1)	–	325 (2)	–	1089 (6)	–
1982–83	–	–	–	–	–	501 (3)	–
1983–84	–	–	–	–	–	1095 (7)	–
Average	265	204	332	162		185	177

JS : Japan Shinagawa
JO : Japan Osaka
Y : Yugoslovakia
CZ : Czechoslovakia
IO : India Orrissa
P : Poland
IT : India Tata

Table 2.5: 300 mm thickness Roof Refractory life

Origin / Year	JS	JO	IO	P	IT
	Roof life in heats (No. of repair)				
1971-72	347 (2)	-	-	-	-
1972-73	511 (3)	-	-	-	-
1973-74	-	-	-	718 (7)	
1974-75	261 (1)	-	-	-	-
1975-76	470 (2)	-	-	-	-
1976-77	-	367 (2)	-	-	-
1977-78	537 (3)	210 (1)	-	-	-
1978-79	-	631 (4)	100 (1)	-	111 (1)
1979-80	392 (3)	-	-	-	367 (2)
1980-81	-	542 (4)	85 (1)	-	-
1981-82	-	753 (6)	74 (1)	-	-
1982-83	-	-	311 (3)	-	-
1983-84	-	-	90 (1)	-	-
Average	180	147	94	103	159

JS : Japan Shinagawa

JO : Japan Osaka

IO : India Orrissa

P : Poland

IT : India Tata

2.2.4 Tapping Yield

The tapping yield from the metallic charge varies directly with the proportion of pig iron charged. This is because pig iron contains 7 to 8% impurities which are oxidised during steel making. A good steel scrap contains very little impurity. So the higher the scrap in the charge the higher will be the tapping yield. Tap yield varied from 85% to 92% as can be seen from table 1.2 due to the use of low quality scrap.

2.3 Raw Material Transportation to Furnace Input

The principal raw materials for steel making are pig and scrap with subsidiary materials of limestone, dolomite & ferro-alloys. Within the works, the lorries of scrap and pig iron are unloaded into the material stockyards by crawler cranes equipped with magnets. Limestone and dolomite are stored adjacent to calcination shop. A flow sheet showing the existing material handling system is given in figure 2.1.

Scrap and pig iron are loaded into the charging box mounted on rail bogies by crawler cranes. The trains of bogies are then moved by diesel locomotives from the stockyard to a rail weighbridge for weighing. After that they are transferred to furnace deck via a wagon hoist. Raw limestone is loaded into the charging boxes by mobile shovel loader and these boxes are added with trains of scrap and pig iron boxes. Burnt dolomite and lime are transported from the calcination shop by rail in hoppers equipped with lids to protect from rain.

An analysis of furnace cycle time (Table 1.2) reveals that cycle time is greatly influenced by the charging time which covers more than 40% of the tap to tap time instead of 30% maximum. One of the reasons is the poor balancing of the scrap within each furnace charge. It has been noted that scrap density varies between 300 kg per box to 2500 kg per box depending on the quality of scrap and the number of charging box per charge increased from standard 48 boxes to more than 60 boxes, on many occasion upto 68.

The second problem is the delays in berthing charge material bogies at the furnace especially when three furnaces operates simultaneously. The wagon-hoist by which wagons are taken up the charge deck and down to rail section operates on the principle of 2 full bogies up and 2 empty bogies down simultaneously. The stated cycle time for this operation is 7.5 minutes and allows to receive 16 standard charges daily but seldom operates above 10 charges due to failure to synchronize the transportation system.

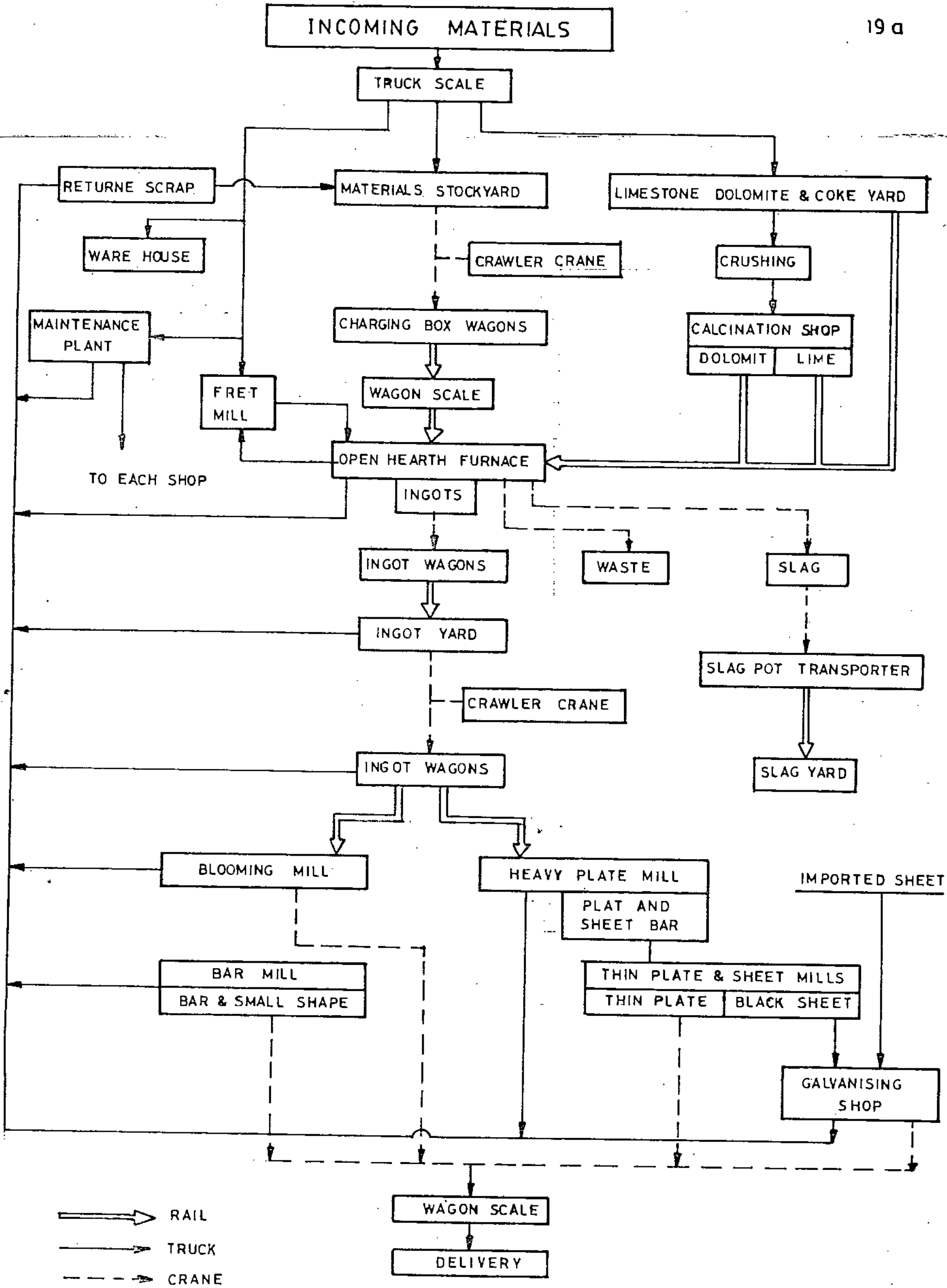


FIG. 2.1. EXISTING MATERIAL HANDLING SYSTEM

CHAPTER - III

PROPOSED DEVELOPMENTS

3.1 Assessment of Optimum Charge Balance

In table 2.3 it has been shown that average tapping cycle length for the existing furnaces is 8 hours 45 minutes. From the table, it can also be observed that the charging time can be minimized by one hour if scrap preparation can be improved and the charge can be loaded into the minimum number of boxes. The worst situation for the supply of raw material occurs when the charge composition consists of 60% scrap and 40% pig iron. At this ratio uncertainty in box density causes acute problem when the scrap is being loaded. A study in this respect was carried out at CSM in co-operation with the concerned personnel to examine the existing charge loading and the result has been tabulated in Table 3.1.

On the basis of this result and considering the availability and quality of steel scrap, charging capacity of floor charger, an optimum charge balance with the maximum number of boxes is recommended for different pig iron and scrap ratios and tabulated in Table 3.2.

3.2 Estimation of Charge Time

It has already been mentioned that the worst situation occurs when charge is composed of 60 per cent scrap and 40 per cent pig. Based on calculated charge density per box, there will be required 40 boxes of scrap and 8 boxes of pig iron in 10 wagon and 2 wagons respectively. In

Table 3.1 : Recommended wagon wt. of charge input

1 Wagon = 4 boxes Unit : Kg.

Name of Material	Av. weight per wagon		Recommended Av. wt. per wagon
	Without Supervision	With Supervision	
Pig Iron	10,300	15,440	15,300
Heavy Melting Scrap (Foreign)	3,044	4,055	4,000
Heavy Melting Scrap (Local)	-	4,720	4,000
Pressed Bundle (Local)	-	3,120	3,000
Light scrap	1,380	2,092	2,000
Sheet/Plate cutting	3,083	6,010	5,000
Folded sheet	-	4,740	4,000
Billet end cutting	11,870	14,780	14,000
Runner	6,965	-	7,000
Ingot	12,150	-	12,000
Skull	7,595	8,440	7,500

Table 3.2 : Standardization of charging boxes for varying pig-scrap ratio

1 wagon = 4 boxes   1 charge = 65-68 MT

Reqd. wt. of material & wagon number / Material	Ratio of Pig iron and scrap 40:60 Wt.	40:60 No.	45:55 Wt.	45:55 No.	50:50 Wt.	50:50 No.	Recommended av. wt. per wagon
Pig Iron	26-27	2	30.6	2	34	2	15,300
Heavy Melting scrap	11-12	3	10-12	3	10-12	3	4,000
Pressed Bundle/ Light scrap	5-6	3	5-6	3	5-6	3	2,000
Sheet/Plate/ *Folded sheet	4-5	1	4-5	1	4-5	1	5,000 *4,000
Skull/Ingot	7	1	7	1	-	-	7,000
Billet end/ *Runner	12-14	1/2	10-12	1/2	12-14	1/*2	14,000 *7,000
Total weight	65-68	11-12		11-12		10-11	

Note: In case 50:50 pig and scrap ratio, either 3 wagons containing the total amount of pig iron for a charge or 2 wagons with extra pig iron in seperate wagon to be balanced at the charging deck.

addition to this, 1 wagon of lime stone is charged and 1 wagon of dolomite is required for fettling operation after each charge. Hence, total charge = 14 wagons. This charge is split into 3 shunts of 5, 5 and 4 wagons. However, considering 10% allowance for safety margin, calculation has been made for 15 wagons into three shunts of 5 bogies each which can be berthed in front of a furnace.

Number of boxes on 5 wagons	=	20
Time to charge 20 boxes	=	30 min.
Time for loco to shunt	=	10 "
Time for Loco to berth full bogies	=	10 "

The charge sequence is

To charge 5 wagons	=	30 min.
To shunt	=	10 "
To charge 5 wagons	=	30 "
Warming time	=	30 "
To charge 4/5 wagons	=	25 "
	Total time	125 min.
extra time allownace for Locomotive		10 "
	Total	135 min.

3.3 Estimation of Fettling Time

Fettling time is increased primarily due to:

1) Use of incompletely burnt dolomite which is easily eroded.
2) Use of poor quality magnesia.
3) Furnace temperature is not maintained very close to tapping temperature during bed build up and fettling of dolomite.

If the quality fettling material and correct temperature is maintained fettling time will be reduced to 1 hour against present average of 1.25 hours.

3.4 Estimation of Cycle Time

Cycle time, obviously, will depend on the Keeness of the furnace. As the furnace campaign progresses the keeness of the furnace deteriorates and during the last weeks of operations tap to tap time becomes much longer. Taking this into account the furnace campaign is divided into:

1) Keen furnace
2) Normal furnace
3) Lag furnace

and a new time schedule for cycle activities has been drawn as given in Table 3.3.

Table 3.3: Re-scheduling tapping cycle time

Activities	Keen Furnace	Normal Furnace	Lag Furnace
Charging	2 hours 15 min.	2 hrs 15 minutes	2 hrs 15 min.
Melting	2 hours 30 min.	2 hrs. 45 minutes	3 hours
Refining	1 hour	1 hour 15 minutes	1 hr. 30 "
Tap/Fettle	– 45 min	1 hr.	1 hr. 15 "
Cycle Time	6 hours 30 min.	7 hrs. 15 min.	8 hrs.

The furnaces would operate on an average tap-to-tap time of 7.25 hours and if any bunching occurs in tapping, Keen furnace would be given priority. On this basis, charging platform schedule and Ground Charger Operation for both the chargers have been drawn and depicted in figure 3.1.

3.5 Charging Platform Rail System

The layout of the existing charging platform rail system is shown in figure 3.2. Rail section with shunting capacity as well as the position of the furnaces are drawn. Full bogies of charge materials are received at (1) and empty bogies are pushed at (5) through wagon hoist. Full bogies from (1) are distributed at different rail position by locomotive.

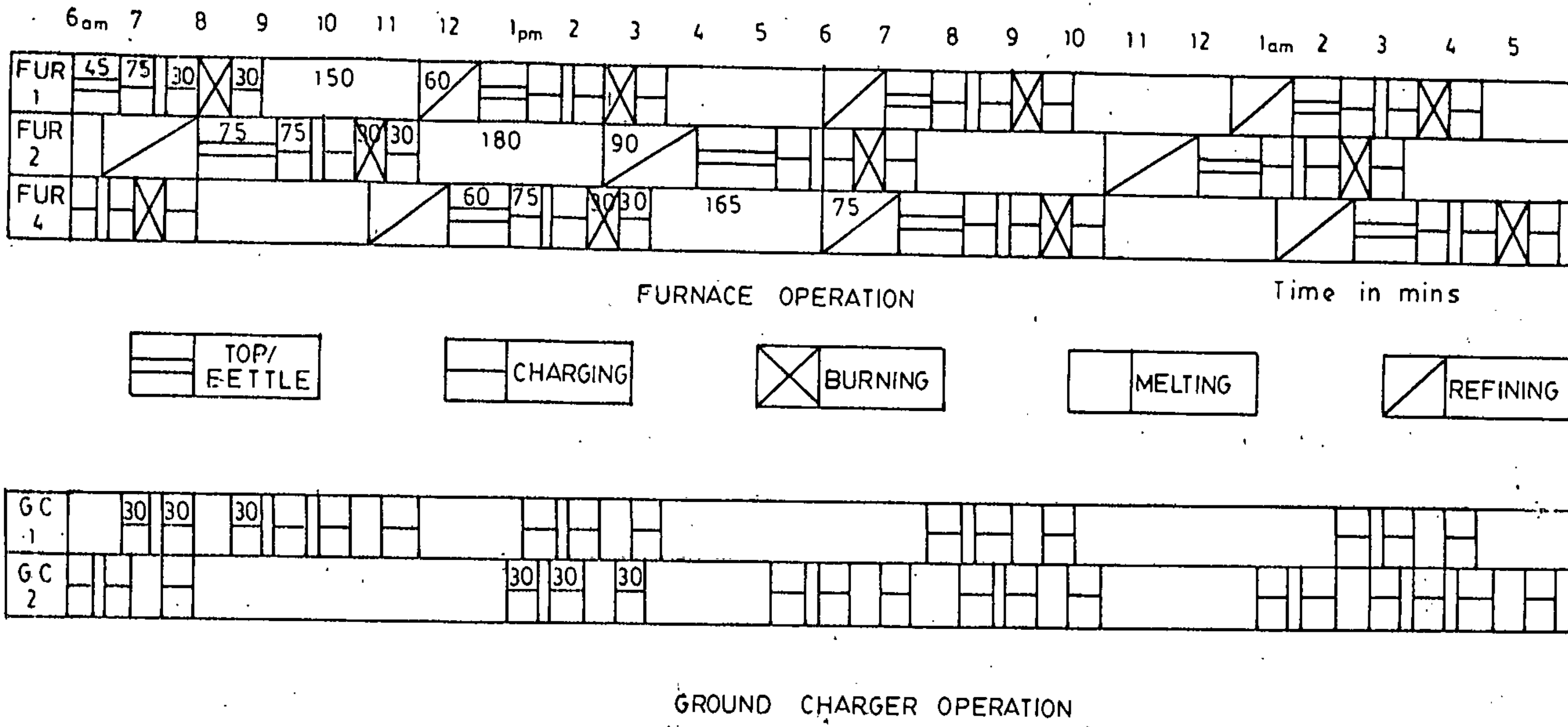
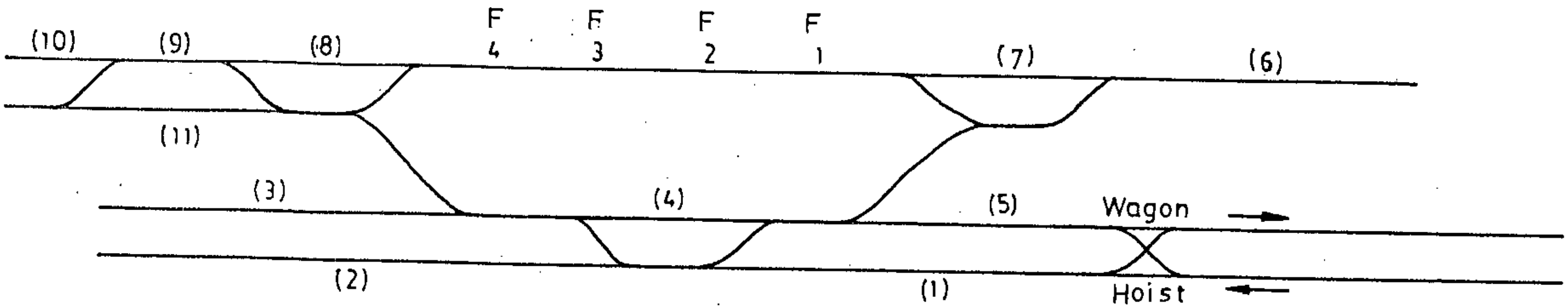


FIG. 3.1. CHARGING PLATFORM SCHEDULE



Bogie capacity on rail section

1)	Bogie recived 80 meters	: 16 bogies
2)	118 meters	: 23 bogies
3)	92.5 meters	: 18 bogies
4)	40 meters	: 8 bogies
5)	55 meters	: 11 bogies
6)	70 meters	: 14 bogies
7)	38 meters	: 7 bogies

Fce No 1	25 meters	: 5 bogies
Fce No 2	25 meters	: 5 bogies
Fce No 3	25 meters	: 5 bogies
Fce No 4	25 meters	: 5 bogies
(8)	39 meters	: 7 bogies
(9)	32 meters	: 6 bogies
(10)	23 meters	: 4 bogies
(11)	64.5 meters	: 12 bogies

FIG.3.2. CHARGING PLATFORM RAIL SYSTEM

In figure 3.3 and 3.4 configuration of charging platform has been drawn according to charging and tapping schedule shown in figure 3.1. This configuration indicates the positions of bogies on a 24 hour basis, so that the tap-to-tap activities for the simultaneous operations of three furnaces are done un-hindered.

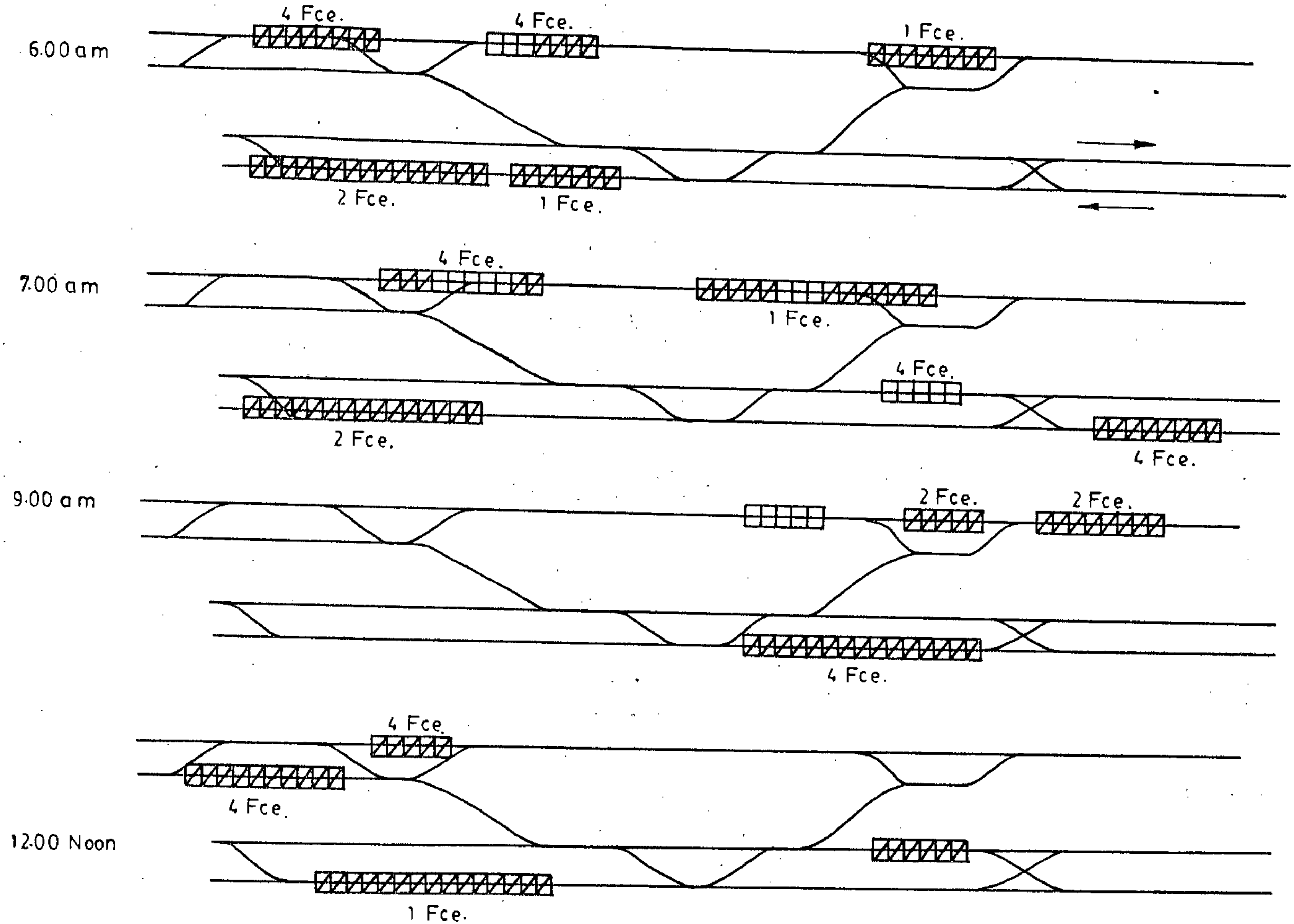


FIG.3.3. CONFIGURATION OF CHARGING PLATFORM

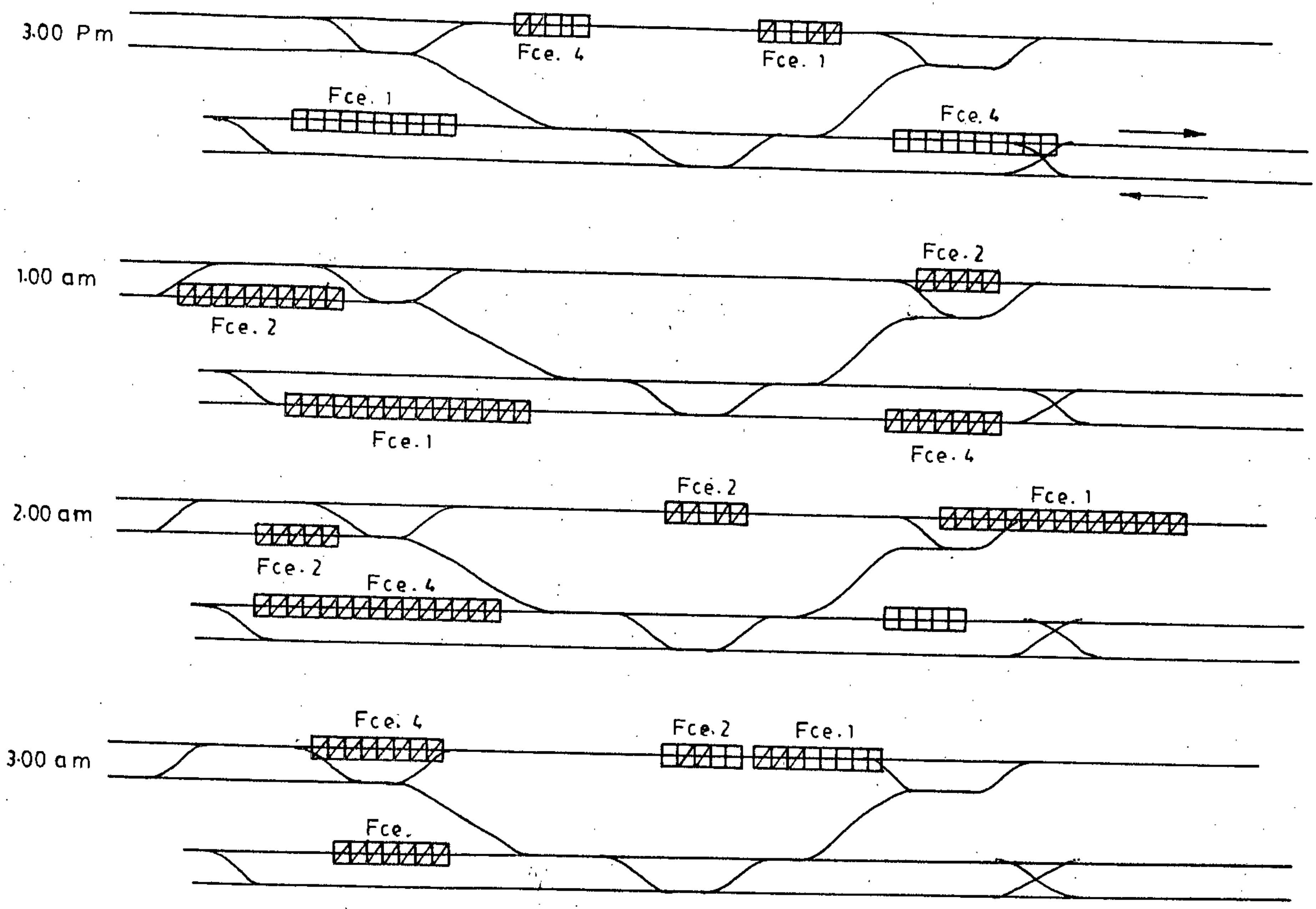


FIG.3.4. CONFIGURATION OF CHARGING PLATFORM

CHAPTER - IV

HEAT BALANCE AND THERMAL EFFICIENCY OF OHF

4.1 Heat Input

One of the main characteristics of an Open Hearth Furnace is its heating capacity i.e. the maximum amount of fuel that can be supplied to, and burnt in the combustion chamber per unit time. Of course, there exists the concept of mean maximum heat input which is the average hourly expenditure of heat in the furnace per heating cycle. The ratio of the maximum heat input to the mean heat input is called the co-efficient of enforcement or boost coefficient, the value of which varies between 1.2 and 1.4 as stated by LYCHAGIN[2] and shown in Table 4.1.

Besides the heat consumed in heating the bath, every furnace loses some heat into the surrounding atmosphere through roof, wall and bottom, cooling system, charging doors, furnace lining and other openings. Some heat is also carried away by flue gases. Therefore, the heat input into the melting chamber should be sufficient to heat the bath and to compensate for all heat losses.

4.2 Thermal Efficiency

The thermal performance of a furnace is characterised by its fuel efficiency and is the ratio of the heat absorbed by the furnace as a result of combustion of a unit of fuel to the heat value of this quantity

Table 4.1 : Specific chemical heat expenditure and heat input of OHF

Furnace capacity Tons	Oil fired furnaces			Heat input boost co-efficient
	Specific heat expenditure 10^6 k.cal/ton q	Heat input 10^6 k.cal/h		
		Average Q av.	Maximum Q max.	
5	2.75	3.25	4.50	1.40
10	2.16	4.50	6.30	1.40
15	1.87	5.60	7.80	1.40
20	1.74	6.80	9.20	1.35
25	1.64	7.40	10.00	1.35
30	1.60	8.40	11.30	1.35
50	1.46	11.00	14.30	1.30
70	1.38	13.10	17.00	1.30
85	1.32	15.00	19.50	1.30
125	1.26	17.80	23.20	1.30
185	1.15	22.50	28.20	1.25

of the fuel. The generalized formula described by Bornatsky[3] is

$$n_f = \frac{(Q_f + Q_s) - (Q_{f.g} + Q_{in.c})}{Q_f} \qquad \ldots \quad \ldots \quad (4.2.1)$$

where, Q_f = heat value of the fuel in K.cal

Q_s = physical heat of the fuel and the air for combustion

Q_{fg} = the amount of physical heat carried away by the flue gas in the burning of a unit fuel

$Q_{in.c}$ = heat losses due to incomplete combustion of fuel.

It is evident from this formula that, if the fuel is burnt completely, the lower the temperature of the flue gases and the higher the temperature of preheating of the air in the regenerators, the higher is the fuel efficiency.

Thermal efficiency differs from that of the fuel efficiency and is defined as the ratio of the heat absorbed by the bath to the heat value of a unit of fuel. Bornatsky indicated that in an OHF only 20 to 30 per cent of the heat input serves any useful purpose and the balance compensating for losses. A small portion of the lost heat can be used to generate steam by waste heat boilers, thus increasing total thermal efficiency to maximum 40 per cent.

4.3 Thermal Efficiency and Heat Balance

Determination of thermal efficiency is based on calculations of all items of heat supplied or available and evaluation of heat used, lost or distributed which may be termed as heat balance. A listing of heat input and heat expenditure for heat balance of OHF has been suggested by LYCHAGIN, shown in Table 4.2. LYCHAGIN also calculated the average values for the items of the heat balance for the melting process (Table 4.3). These values refer only to the melting process and are independent of the design and capacity of the open hearth furnace.

It is evident from this table that when similar steels are melted, the fuel consumption increases as the pig iron content in the charge increases. However, on taking into account the amount of heat generated during the combustion of CO formed in the bath, the heat consumption per kg of charge decreases as the pig iron content in the charge is increased.

4.3.1 Formulation of various components in the heat balance:

a) Chemical heat of fuel

$$q_5 = Q.X \qquad \ldots \qquad (4.3.1.1)$$

where, Q = calorific value of the furnace oil in k.cal/kg

X = fuel consumption kg/kg.

Table 4.2: Heat balance of Open Hearth Furnace

Heat input	Heat expenditure
q_1 by the liquid pig iron	q_8 on heating the metal
q_2 heat from exothermic reactions	q_9 on heating the slag
q_3 heat of slag formation	q_{10} on dissociation of the ore
q_4 heat of combustion of CO from the bath to CO_2	q_{11} on decomposing limestone
q_5 chemical heat of fuel	q_{12} on heating CO_2 from decomposed limestone
q_6 sensible heat of the fuel	q_{13} on heating CO_2 formed by decombustion of CO from the bath
q_7 sensible heat of air.	q_{14} on losses with escaping gases
	q_{15} dissociation and incomplete combustion of fuel
	q_{16} heat losses with combustion products
	q_{17} losses through brickwork of furnace chamber, with the cooling water and from radiation through opening charging doors.

Table 4.3 : Heat balance for melting 1 kg of charge in an OHF

Process	Steel grade	Quantity of pig iron in charge (%)	Heat input ($q_1 + q_2 + q_3$) k.cal/kg.	Heat expenditure ($q_8 + q_9 + q_{10} + q_{11} + q_{12} + q_{13}$) k.cal/kg	Heat deficiency on the process (q_o) k.cal/kg	Heat of combustion of CO from the charge to CO_2 (q_4) k.cal/kg
Scrap process on solid pig iron	Low carbon	40	87	363	276	70
		50	105	418	313	87
		60	123	473	350	104
	Medium carbon	40	84	354	270	63
		50	102	411	309	88
		60	119	467	384	97
	High carbon	40	80	338	258	55
		50	98	410	312	77
		60	115	454	339	87

Table 4.4 : Heat losses through brickwork of furnaces (50-70 ton)

Roof of furnace	Front wall	Back wall	Hearth	Radiation loss through doors
14000 k.cal/m^2/hr	6500 k.cal/m^2/hr	3100 k.cal/m^2/hr	2050 k.cal/m^2/hr	550,000 k.cal/m^2/hr.

b) Sensible heat of fuel:

$$q_6 = T \cdot C \qquad \ldots \quad (4.3.1.2)$$

T = Temperature of oil at its pre-heated temperature

C = Specific heat of oil at that temperature

c) Sensible heat of air:

$$q_7 = T.a.C_1 \qquad \ldots \quad (4.3.1.3)$$

T = Temperature of air at its preheated temperature

a = Air consumption for burning 1 kg fuel oil, nm^3/kg.

C_1 = Specific heat of air at the preheated temperature

d) Heat losses due to gases escaping from charging doors:

The losses are generally assumed to be 6 percent of the chemical heat of the fuel i.e.

$$q_{14} = 0.06\ q_5 \ \text{k.cal/kg} \qquad \ldots \quad (4.3.1.4)$$

e) Heat lossess from the dissociation and incomplete combustion of of fuel:

This loss can also be assumed to be 6 percent of the chemical heat of the fuel i.e.

$$q_{15} = 0.06\ q_5 \ \text{k.cal/kg} \qquad \ldots \quad (4.3.1.5)$$

f) Heat carried off with combustion products from furnace chamber:

$$q_{16} = T'.b.C_2 \ \text{k.cal/kg} \qquad \ldots \quad (4.3.1.6)$$

where T' = Temperature ^oC of combustion products leaving the furnace chamber

b = the quantity of combustion products per kg of fuel oil nm^3/kg

C_2 = Specific heat of the combustion products at T' ^oC

g) Heat losses through brickwork of furnace chambers, with cooling water and from radiation through charging doors:

This is based on thickness & type of brick used

Table 4.4 gives values of heat losses through different sections of furnace, as quoted by LYCHAGIN.

$$q_{17} = (A_1 + A_2 + A_3) \text{ k.cal/kg of charge} \quad \ldots \quad (4.3.1.7)$$

where,

A_1 = heat loss through the brickwork of furnace chamber

A_2 = heat loss with the cooling water

A_3 = heat loss by radiation through the charging doors.

Now using table 4.3 and comparing the input and expenditure sides of the heat balance, the equation becomes:

$$q_4 + q_5 + q_6 + q_7 = q_o + q_{14} + q_{15} + q_{16} + q_{17} \quad \ldots \quad (4.3.1.8)$$

From this equation, the value of x, where x is the consumption of oil in kg/kg charge, may be determined.

Then the heat consumption per kg charge can be determined as

$$q' = X.Q \text{ k.cal/kg of charge} \quad \ldots \quad (4.3.1.9)$$

In terms of ingot output, the heat consumption is given by,

$$q = q'/n \text{ k.cal/kg of ingots} \quad \ldots \quad (4.3.1.10)$$

where, n is the output of good quality ingots from 1 kg of charge.

The heat consumption can also be determined with the aid of the utilization co-efficient of the heats of combustion of the fuel n_1 which is the ratio of the heat left in the furnace chamber to the heating power of the fuel i.e.

$$\eta_1 = \frac{q_5 + q_6 + q_7 - q_{14} - q_{15} - q_{16}}{q_5} \quad \ldots \quad (4.3.1.11)$$

From equation (4.3.1.11) the total heat expenditure in OHF per ton of ingots is determined from the expression:

$$q = \left(\frac{q_o - q_4\eta_2}{h\eta_1} + \frac{q_{17}}{p\eta_1}\right) x\ 10^6 \text{ k.cal} \quad \ldots \quad (4.3.1.12)$$

where,

q_o = heat expenditure, 10^6 k.cal/ton of charge

q_4 = heat due to combustion of carbon monoxide from the charge, 10^6 k.cal/ton of charge

q_{17} = total heat loss from the furnace chamber 10^6 k.cal/hour

h = output of good quality ingots per/hour

η_1 = utilization co-efficient of fuel oil

η_2 = utilization co-efficient of the heat from the combustion of CO from the charge

p = output of the furnace in ton per hour.

4.4 Calculation of Thermal Efficiency

The calculation of thermal efficiency is based on available data for the production year 1980-81, since, in this year ingot production of CSM was highest. The following summarises the data:

i) average charge 66.5 tons

ii) good ingot output 54.2 tons

iii) Tap to tap time 9.2 hrs

iv) Pig-scrap ratio 43:57

v) Quantity of charge melted per sec. $\frac{66500}{3600 \times 9.2} = 2.00$ kg

vi) Furnace output per hour (av.) = $\frac{54.2}{9.2}$ = 5.9 tons ingot (p)

vii) Output of good quality ingot per ton charge = 0.815 ton (h)

ix) Surface area of roof = 85 m^2

x) Surface area of frontwall = 14.5 m^2

xi) Surface area of back wall = 22.2 m^2

xii) Surface area of Hearth = 70 m^2

xiii) Cross-sectional area of furnace door, 1.550 x 1.620 = 2.511 m^2

xiv) Average pre-heated air temperature = 1100°C

xv) Average rise in cooling water temperature = 30°C

xvi) Average cooling water flow through furnace structure = 205 m^3/hr.

xvii) Average temperature of the combustion temperature = 1700°C (assumed)

xviii) Average calorific value of furnace oil used = 9470 k.cal/kg

xix) Average steel quality produced = Low carbon

xx) Furnace roof brick : chrome magnesite.

A. Heat input in the furnace

i) Heat from the combustion of fuel oil = 9470 k.cal/kg

ii) Sensible heat of air, preheated at an average temperature of $1100^{\circ}C$, calculated from graph 4.1 and with excess air of 20% 3900 x 1.2 = 4680 k.cal/kg.

iii) Sensible heat of fuel oil, negligible and neglected

Hence, total heat input = 9470 + 4680 = 14150 k.cal/kg

B. Heat expenditure

i) From graph 4.1, the combustion products (at $1700^{\circ}C$) carry off heats, q_{16} ... ... 8950 k.cal/kg

ii) Heat loss due to dissociation and incomplete combustion assumed as 6 percent of the heating power of fuel, q_{15} ... ... 570 k.cal/kg

iii) Heat loss with gases escaping through the charging doors, assumed as 6 percent of the heating power of fuel, q_{14} ... 570 k.cal/kg

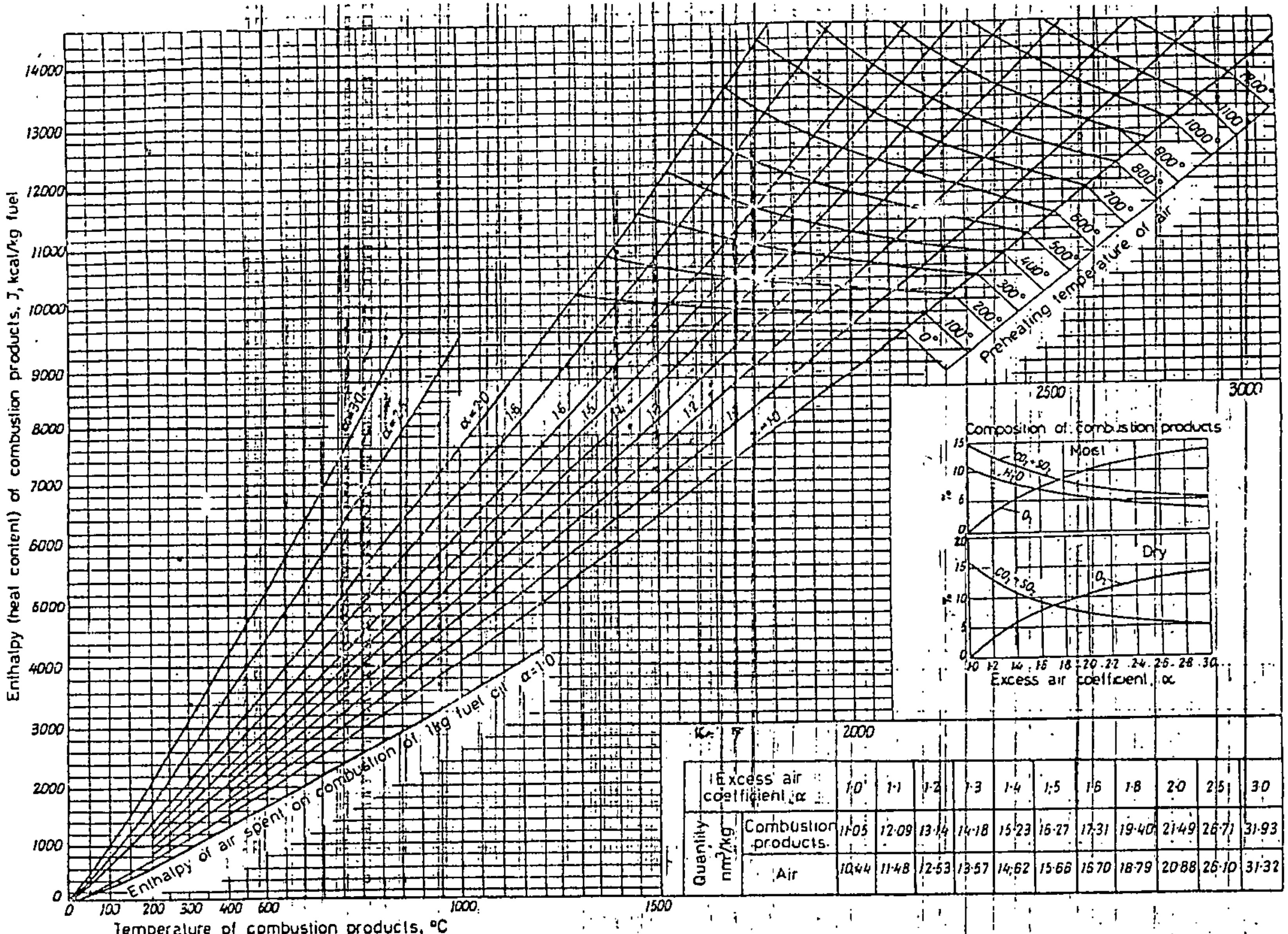
Total heat expenditure = 10090 k.cal/kg

$$\eta_1 = \frac{14150 - 10090}{9470} = 0.428$$

C. Heat losses

i) Total heat losses through brickwork of furnace calculated as per table 4.5 ... 1.495×10^6 k.cal/hr

ii) Heat losses through opening of the charging door having cross-sectional area of 2.511 m^2, assuming door opening 30% of tap to tap time and radiation loss as per table 4.4, 2.511 x .55 x 2.76/9.2 = 0.414×10^6 k.cal/hr



		Excess air coefficient, α	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·8	2·0	2·5	3·0
Quantity	nm^3/kg	Combustion products	11·05	12·09	13·14	14·18	15·23	16·27	17·31	19·40	21·49	26·71	31·93
		Air	10·44	11·48	12·53	13·57	14·62	15·66	16·70	18·79	20·88	26·10	31·32

Graph 4.1 : Calculation for the combustion of fuel oil in air (atomization with air)

Ref. A.S. LYCHAGIN, "Open Hearth Furnace Design", London Butter Worths, 1962, pp 205

Table 4.5 : Total heat losses through brick work of furnace

Section of the furnace	Surface area m^2	Heat loss $k.cal/m^2/hr$	Total loss $10^6 k.cal/hr.$
Roof of furnace	85	14000	1.19
Front wall	14.5	6500	0.094
Back wall	22.2	3100	0.068
Hearth	70	2050	0.143
			1.495

iii) Heat losses with cooling water

Water flow per hour x rise in temp. 205 x 30 = 6.15×10^6 k.cal/hr.

Total loss $q_{17} = 8.059 \times 10^6$ k.cal/hr.

D. Total Heat expenditure in OHF

Substituting values in equation 4.3.1.12, the total heat consumption,

$$q = \left(\frac{0.276 - 0.070 \times 0.8}{0.815 \times 0.428} + \frac{8.059}{5.9 \times .428}\right) 10^6 \text{ k.cal/ton}$$

$$\simeq 3.82 \times 10^6 \text{ k.cal/ton ingot.}$$

E. Rate of heat input

The mean heat input during the melt is

$$Q \text{ mean} = 3.82 \times 10^6 \times 5.9 = 22.538 \times 10^6 \text{ k.cal/hr.}$$

i.e. fuel consumption per sec. $= \dfrac{22.538 \times 10^6}{9470 \times 60 \times 60} = 0.661$ kg/sec.

F. Heat balance of furnace chamber

Heat input:

i) chemical heat of fuel

0.661 x 9470 = 6260 k.cal/sec. ... 66.1 per cent

ii) Sensible heat of air at 1100°C

0.661 x 4680 = 3093 k.cal/sec. ... 32.7 per cent

iii) Heat due to the combustion of carbon monoxide from the charge

2.00 x 0.8 x 70 = 112 k.cal/sec. / Total heat input = 9465 k.cal/sec.	...	1.1 percent / 100

Heat expenditure:

i) On the process (excluding heat of exothermic reaction)

2.00 x 280 = 560 k.cal/sec. ... 5.9 per cent

ii) Losses with the cooling water

6150000/3600 = 1708 k.cal/sec. ... 18.0 percent

iii) Through brickwork of furnace chamber

1495000/3600 = 415 k.cal/sec. ... 4.4 percent

iv) Through opening of doors

414000/3600 = 115 k.cal/sec. ... 1.2 percent

v) With escaping gases

0.661 x 0.06 x 9470 = 376 k.cal/sec. ... 4.0 percent

vi) Losses due to dissociation and incomplete combustion

0.661 x 0.06 x 9470 = 376 k.cal/sec. ... 4.0 percent

vii) Carried off from the furnace chamber with the combustion products at 1700°C

.661 x 8950 = 5915 K.cal/sec. ... 62.5 percent

Total heat expenditure = 9465 K.cal/sec 100.0 percent

G. Thermal efficiency of the furnace

Using data from the heat balance, the thermal efficiency

$$\eta_{th} = \frac{560}{6260} \times 100 = 8.95\%$$

CHAPTER - V

RESULTS AND DISCUSSIONS

Major aspects for determining the capacity utilization of the plant have been considered and the calculations have been made on the basis of available data. As discussed in this research work, there has always been a large discrepancy between production achievement and plant supplier's rated capacity. During investigation of the plant facilities and operations at the works, the main purpose was to answer the following questions:

1) Is the plant supplier's increased capacity of 100,000 ton per year ingot production realistically judged by adding one furnace and changing pig ratio 40 percent to 60 percent as designed originally ?

2) What will be the maximum attainable capacity ?

Proper explanations of the quoted point one had not been found except the record of the "Performance and Guarantee Tests" for the furnaces nos. 1, 2 and for the furnace no. 3 for itself and furnace no. 4 that have been incorporated in Appendix - A.

Guarantee tests for furnace nos. 1 and 2 were conducted on the basis of pig ratio of 40 percent whilst identically designed furnace no. 3 with 60% pig and over charging. The most important point to note here that these test[illegible] ere conducted on individual furnaces whereas capacity calculation was based on simultaneous operation of three furnaces throughout the year. Had the plant supplier's test been based on simultaneous operations of the furnaces, there would be different results on the tap-to-tap time vis-a-vis capacity of the melting units.

5.1 Attainable Capacity

On the basis of operating parameters as mentioned earlier, an operating schedule (Fig. 5.1) has been drawn up with the following data.

i)	Days available for operation in a year	= 365
ii)	Number of operating furnaces	= 3
iii)	Tap-to tap time (average) hours	= 7.25
iv)	Furnace availability	= 90%
v)	Downtime for major repair	= 30 days
vi)	Downtime for minor repair	= 15 days
vii)	500 mm roof life (maximum)	= 265 heats
viii)	300 mm roof life (maximum)	= 145 heats

The operating schedule shown in Fig. 5.1 is obviously based on best judgement of the results achieved in some cases or to be achieved by careful planning. The information from Fig. 5.1 is set out in tabular form in Table 5.1 and the total operating days have been used in calculation of steel making capacity.

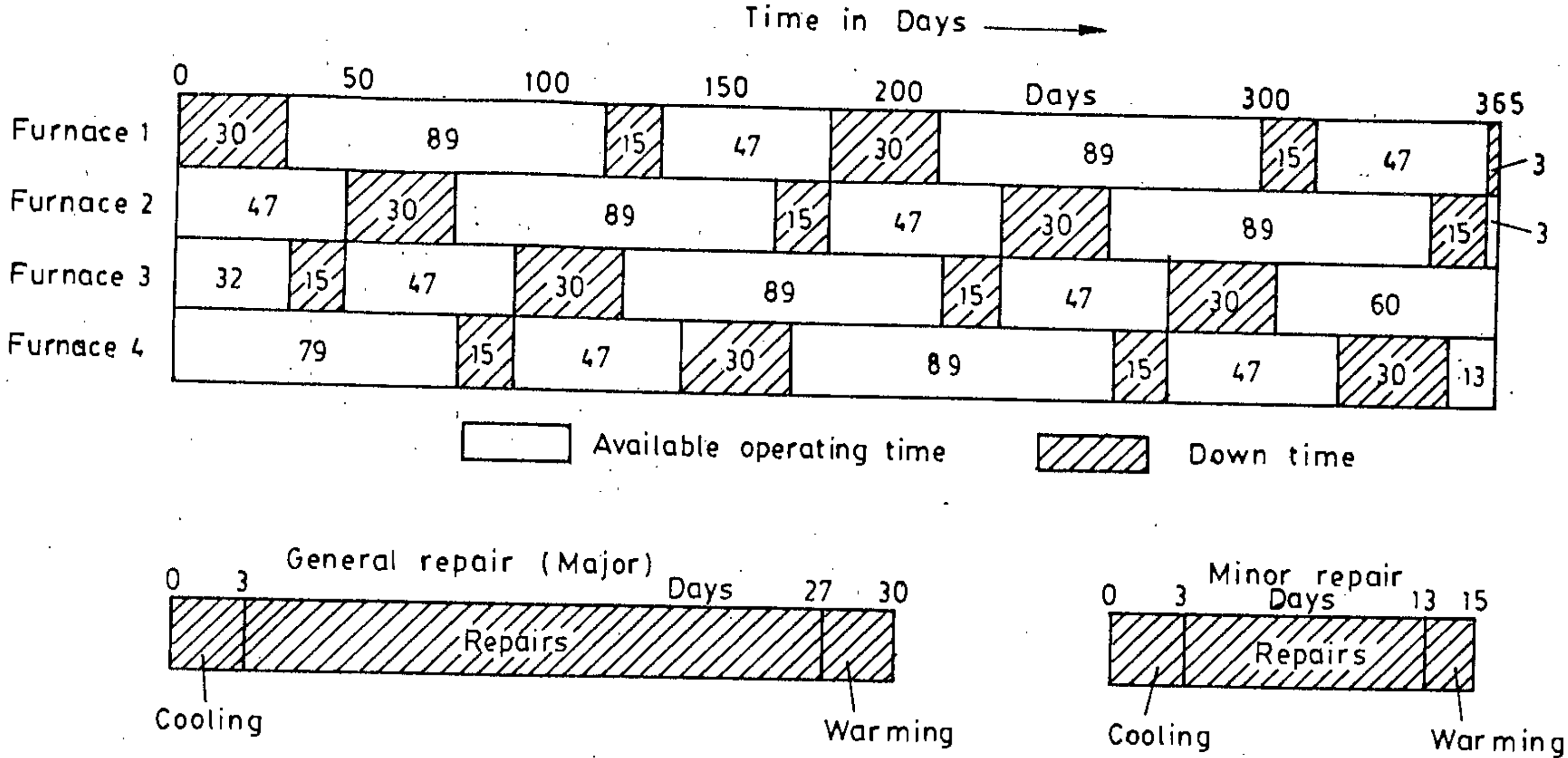


FIG. 5.1. THREE FURNACE OPERATION SCHEDULE

Table 5.1 : Availability of Furnaces on improvements

Furnace	Available operating time Days/year	Downtime Days/year
No. 1	272	93
No. 2	272	93
No. 3	272	93
No. 4	272	93
Total	1088	372

Available operating days = 1088

Hence, actual operation days with 90% availability = 979

Number of heats per annum = 3241

∴ Ingot making capacity = 58 x 3241 = 188,000 Tons.

5.2 Management

In order to produce the increased capacity with three furnaces it will become necessary to co-ordinate the activities of melt shop, casting bay, materials stock yard and transportation networks. It is suggested to form a shift management team to co-ordinate all these activities round the clock and to make necessary communication with the day management of the melting shop. The structure of the Melting shop management is shown in figure 5.2.

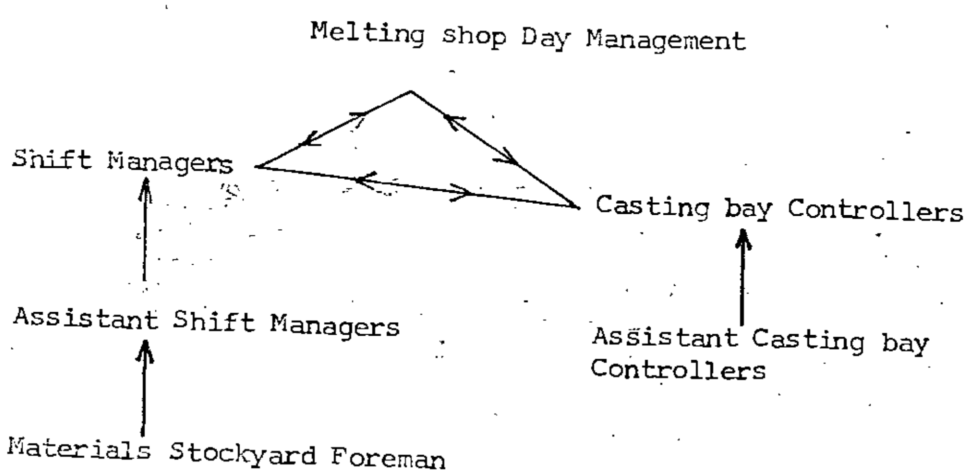


Fig. 5.2 : Structure of Melting shop Management

Responsibilities of the management team will be:

i) The shift manager of the melting shop will have overall responsibility for the melt shop, casting bay, materials stockyard and steel making materials. His main duties would be directed to the tapping, fettling and operation of OHF and the organization of the casting bay to match furnace operations.

ii) The assistant shift manager of the melting shop will report directly to shift manager and will be responsible for all the activities of furnace operation. He will make furnace program, ensure that correct materials reach the furnace, proper use of oxygen is made and other utilities available.

iii) The casting bay controller would have overall responsibility for the casting bay under the direction of the melting shop shift manager. He would ensure that teeming ladles, upteem sets and slag pots are available for the furnace due to tap during his shift.

iv) The assistant casting bay controllers would be responsible for all activities relating to casting bay including general housekeeping.

v) The materials stockyard foreman would be fully responsible for materials receivals and storage, weighing and transportation of these materials as per furnace schedule. He would ensure that charging errors are minimised and proper box weight with standard charge materials are despatched.

CHAPTER - VI

CONCLUSION AND RECOMMENDATION FOR FURTHER STUDY

6.1 Conclusion

In the present work, operational problems of steel melting units of Chittagong Steel Mills Ltd. have been studied and measures have been suggested for improving the productivity. From the analysis, the following points have become apparent.

i) The charge composition of 60% pig and 40% scrap as suggested by the plant manufacturer KOBE Steel Ltd., Japan, has never been achieved due to various reasons. Instead, pig iron - scrap ratio of 43.2 : 56.8 has been attained (Table 2.1). As a result, the required number of charging boxes has increased from 46 to 60 and the charging time has also increased by about an hour.

In tables 3.1 and 3.2, methods have been suggested for improving charge preparation. This will reduce the number of charge boxes to 48 for scrap and pig iron. It has been found that the charging time will be reduced to 2 hours 15 minutes - a reduction by about 45 minutes.

ii) In table 3.3, tap-to-tap cycle times for keen furnace, normal furnace and lag furnace have been recalculated. The average cycle time has been found to be 7.25 hours, which is a substantial improvement over the presently attained average time of 8.75 hours. But it is apparent that the designed cycle time of 6 hours is not achievable, unless melting time can be drastically reduced. The existing melting time is 90 minutes longer than the designed value.

iii) The thermal efficiency of OHF has been calculated and found to be only 8.95% which is much below the industrial average.

iv) Charge handling system has been studied and it has been found that the present system is quite adequate for handling chargesfor a cycle time of 7.25 hours. In figures 3.1 and 3.3, charging platform schedule and charging platform configuration have been suggested on 24 hourly basis.

v) Figure 5.1 gives three furnace operation schedule for a year as the fourth furnace will always be under maintenance. In table 5.1, furnace availability on improvement has been given. On the basis of 90% availability of furnaces, it has been calculated that the ingot making capacity can at best be increased to 188,000 MT. This shows an improvement of 39% over the maximum ingot production of 135,000 MT obtained in 1980-81. But this figure falls much below the manufacturer's rated capacity of 250,000 MT.

vi) For implementing the suggested measures and for proper synchronization of all related activities, an improved management system has also been suggested outlining the functions and responsibilities of various management personnel.

6.2 Recommendations for Further Study

In the present study, attention was given mainly to steel making capacity. But improvement in this sector is not the end in itself since the problem is related to other downstream activities as well. Molten metal has to be casted into ingots for further processing into finished products. The casting operations include teeming into moulds, stripping, set preparation, mould cleaning, mounting of moulds on the sets, laddle preparation and repairs, slag pot changing, removal of stickers from the ingot moulds and other general housekeeping activities.

In CSM, there are four cooling grids each of which can hold three sets of square moulds (180 nos.). Since one grid needs to be reserved for slab moulds, three grids are left for square moulds. For the designed 6 hours tap-to-tap time from three furnaces and nine sets of moulds in circulation, cooling grid occupancy time for the moulds is only 14 hours. For at least first 8 hours of this fourteen hours, the moulds are too hot for any preparation work to be carried out. In the remaining six hours, men cannot work whilst further hot moulds are placed in the grid.

Secondly, in the casting process, leakages occur due to the breakage of refractory bricks and liquid steel spreads over the casting area and forms into solid steel mass which can only be removed by gas cutting. Further, leakage reduces yield and affects quality.

In view of the above problems, it is recommended to carryout investigations on the following areas:

i) To investigate the present ingot making facilities and to synchronize casting process with that of increased production.

ii) To conduct a techno-economic study on the introduction of Continuous Casting Process (CCP) for the improvement of better yield and quality.

REFERENCES

1 Kobe Steel Limited (1970); Expansion for Chittagong Steel Mills, Annex 1, Specifications.

2 Lychagin, A.S.(1962); Open Hearth Furnace Design, London Butter Worths, pp 18-22.

3 Bornatsky, I; Open Hearth Hand Book, A Handbook, Foreign Languages Publishing House, Moscow, pp 206-208.

APPENDIX - A

APPENDIX - A

KOBE STEEL, LTD.
CHITTAGONG, EAST PAKISTAN.

Date: April 3, 1967.

TEST RECORD

This is the record of the PERFORMANCE AND GUARANTEE TESTS of the following Unit and Section :

Date of Test : March 26,27,28 & 29, 1967.

Unit : A/1 —— Melting Shop.

Section : No. 4 Furnace and their accessories including waste Heat Boilers and Smoke Arrestor.

a) O. H. Furnace. No.1

KOBE STEEL LTD.,

Approved by :

FRIED KRUPP INDUSTRIEBAU

Approved by :

EAST PAKISTAN INDUSTRIAL DEVELOPMENT CORPORATION.

OBE STEEL, LTD.
CHITTAGONG, EAST PAKISTAN.

TEST RECORDS OF GUARANTEE TEST RUN OF NO. 1-O.H.F.

Date - April 3rd. 1967.

Guarantee Figures	Results of twelve heats
1) Steel quality :	
C 0.15	C Max. 0.084
Mn 0.6	Mn Max. 0.420
Si 0.3	Si Max. 0.040
P 0.06	P Max. 0.020
S 0.06	S Max. 0.042
2) Minimum Out-put :	
530 ton of cast ingot including rest block, excluding runners and funnels/72 hours continuous test period	652.6 ton of good ingots and 3.1 ton of rest blocks were produced per continuous 72 hours and 7 minutes, that is 651.5 tons of out put per 72 hours.
3) Yield during test period:	
87% Cast ingot and so forth based on metallic change	89.6 %
4) Refining period :	
Max. 70 min / charge	Average of twelve heats : 45.7 min. Max. of twelve heats : 60 min.
5) Maximum heat consumption :	
1.2×10^6 Kcal/ton of cast ingot and so forth.	0.996×10^6 Kcal/ton.

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KOBE STEEL, LTD.
CHITTAGONG, EAST PAKISTAN.

Guarantee Figures			Results of twelve heats	
6) Consumption of material to be charged such as :				
Scrap	690	kg/ton of cast ingot and so forth	Scrap	676.0 kg/ton.
Pig	460	- do -	Pig	441.8 kg/ton.
Lime	50-75	- do -	Lime	47.4 kg/ton.
Lime Stone	6-10	- do -	Lime Stone	0 kg/ton.
Ferro Mn	12-15	- do -	Ferro Mn	12.4 kg/ton.
Ferro Si	3	- do -	Ferro Si	2.7 kg/ton.
Al	0.6	- do -	Al	0.18 kg/ton.
Flourspar	1	- do -	Flourspar	0 kg/ton.
				(Pig ratio 39.7 %)

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KOBE STEEL, LTD.
CHITTAGONG, EAST PAKISTAN.

Remarks on guarantee test :

1. The test was carried out continuously from 7:35 P.M. on 26th March to 7:42 P.M. on 29th March resulting twelve charges.

2. The minimum out put will be calculated and converted as follows :

Test hours : 72 hours 7 minutes

Amount of total output : 652.6 tons

Accordingly :

Tons per 72 hours : 651.5 tons

3. Although lower calorific value of fuel oil shall be required as regards heat consumption, we have to calculate the consumption in accordance with gross calorific value, because M/S. Burmah Eastern Ltd., supplier of fuel have failed to equip with facilities enabling to analise such elements as hydrogen and Oxygen in steel.

Our calculation bases on a disadvantage, since lower calorific value is generally that of about 95% against gross calorific value. However, our figures show very satisfactory results in spite of such a disadvantage.

Heat consumption will be calculated as under :

Total oil consumption	: 71,705 litres
Total production amount	: 668 tons
Specific gravity of fuel oil	: 0.9027
Gross calorific Value	: 10,278 Kcal / kg
Heat consumption	: 0.996×10^6 Kcal / ton.

Details of each heat

Name		(1) A102	(2) A103	(3) A104	(4) A105	(5) A106	(6) A107	(7) A108	(8) A109	(9) A110	(10) A111	(11) A112	(12) A113	Total	Remarks
1. Steel quality (analysis)	C	0.05	0.065	0.66	0.07	0.08	0.065	0.68	0.07	0.07	0.084	0.055	0.08		
	Mn	0.32	0.35	0.25	0.34	0.34	0.37	0.28	0.39	0.36	0.42	0.35	0.35		
	Si	—	—	0.008	0.009	—	—	—	0.04	0.004	—	—	0.02		
	P	0.007	0.011	0.013	0.018	0.020	0.020	0.015	0.013	0.013	0.020	0.010	0.010		
	S	0.040	0.041	0.040	0.045	0.043	0.033	0.024	0.046	0.039	0.034	0.030	0.034		
2. Out put	Good ingot	54,000	54.280	53.000	54.000	55.000	55.000	54.000	55.300	54.000	54.000	52.920	54.000	649.500	652.45 T per
	Rest blocks	200	0	700	700	300	300	0	100	200	300	0	300	3.100	72 hou. 57 min i.e.
	Total	54.200	54.280	53.700	54.700	55.300	55.300	54.000	55.400	54.200	54.300	52.920	54.300	652.600	65.15 T per [illegible] hours
3. Yield	Metalic charge	62.010	62.120	62.330	62.650	62.310	62.800	62.140	62.220	61.850	61.630	62.230	61.970	746.340	
	Cast ingot & so forth	55.450	55.530	54.950	55.950	56.650	56.550	55.250	56.850	55.550	55.550	54.170	55.550	668.000	
	Yield	89.2	89.3	88.2	89.3	90.7	90.3	89.0	91.3	90.0	90.5	87.1	89.6	89.5	
4. Refining period		37	58	52	47	30	55	47	60	32	30	43	60	548	45.7 min/ch
5. Heat consumption (heavy oil)	l/charge	5.920	6180	6.370	5.640	6.070	5920	5980	5950	5.540	5.755	6.160	6140	71.165	0.96×10^{6}
	l/ton	106	111	116	101	107	105	108	105	100	103	114	111	107.3	kcal/ton
6. Materials	Scrap kg/ch	37.190	38.010	37.380	38.090	37.570	38.360	37.320	37.570	37.680	37.250	37.860	37.150	451.430	676.0 kg/t
	Pig kg/ch	24.820	24.170	24.950	24.560	24.740	24.440	24.820	24.650	24.170	24.380	24.370	24.840	295.110	441.8 kg/t
	Lime kg/ch	2.500	3.000	2.500	2.540	2500	3,000	2.500	2.520	3.000	2.500	2500	2540	31.600	47.4 kg/t
	Lime stone kg/ch	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ferro Mn kg/ch	300	750	650	630	250	700	700	740	500	550	790	500	6.950	12.4 kg/t
	Ferro Si kg/ch	150	150	150	150	150	150	150	150	150	150	150	150	1.800	2.7 kg/t
	Al kg/ch	10	10	10	10	10	10	10	10	10	10	10	10	125	0.15 kg/t
	Flourspar kg/ch	0	0	0	0	0	0	0	0	0	0	0	0		0

Date : May 30, 1967.

TEST RECORDS.

This is the record of the PERFORMANCE AND GUARANTEE TESTS of the following unit and/or Section.

Date of the Tests	:	May 17,18,19,20, 1967.
Unit	:	No. A/1 - Melting Shop
Section	:	No. 4 - Furnaces and their accessories including Waste Heat Boiler and Smoke Arrester.

a) OH-Furnace No.2.

KOBE STEEL, LTD.

Approved by :

FRIED. KRUPP INDUSTRIEBAU.

Approved by :

EAST PAKISTAN INDUSTRIAL DEVELOPMENT CORPORATION.

TEST RECORDS OF GUARANTEE TEST RUN OF No.2. O.H.F.

Guarantee figures	Results of twelve heats
1) Steel quality :	
C ∠ 0.15	C Max. 0.13
Mn ∠ 0.6	Mn Max. 0.46
Si ∠ 0.3	Si Max. 0.24
P ∠ 0.06	P Max. 0.010
S ∠ 0.06	S Max. 0.040
2) Minimum output : 530 ton of Cast ingot including rest block, excluding runners and funnels/ 72 hours continuous test period.	668.6 ton of good ingots and 3.1 ton of rest blocks were produced per continuous 72 hours that is 671.7 tons of out put per 72 hours.
3) Yield during test period : 87% Cast ingot and so forth based on metallic charge	92.1%
4) Refining period : Max. 70 min/charge	Avarage of twelve heats : 28.8 min. Max. of twelve heats : 44 min

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Gurantee figures	Results of twelve theats
5) Maximum heat consumption : 1.2×10^6 Kcal/ton of cast ingot and so forth	0.966×10^6 Kcal/ton
6) Consumption of material to be charged	
Scrap 690 kg/ton of cast ingot and so forth	Scrap 655.4 kg/ton
Pig 460 - do -	Pig 430.0 kg/ton
Lime 50-75 - do -	Lime 47.4 kg/ton
Lime Stone 6-10 - do -	Lime Stone 0 kg/ton
Ferro Mn 12-15 - do -	Ferro Mn 3.2 kg/ton
Ferro Si 3 - do -	Ferro Si 0.88 kg/ton
Al 0.6 - do -	Al 0.35 kg/ton
Flourspar 1 - do -	Flourspar 0 kg/ton
	(Pig ration 39.6%)
7) Oxygen Consumption.	(15.0 Nm^3/ton)

KOBE—STEEL, LTD.
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Remarks on guarantee test

1. The test was carried out continuously from 7:20 p.m. on 17th May to 7:20 p.m. on 20th May, resulting twelve charges.

2. The minimum output will be calculated as follows.

Test hours	:	72 hours
Amount of good ingot	:	668.5 tons
Amount of [illegible]	:	[illegible]
Accordingly total output	:	67[illegible].7 tons

3. Although lower calorific value of fuel oil shall be required as regards heat consumption, we have to calculate the consumption in accordance with gross calorific value, because [illegible] fuel, have failed to equip with [illegible] as hydrogen and oxygen in steel.

Our calculation bases on a disadvantage, since lower calorific value is generally that of about 95% against [illegible] value. [illegible] our figures show very satisfactory results in spite of such a disadvantage.

Heat consumption will be calculated as under.

Total oil consumption	:	[illegible]
Total Production amount	:	680 tons
Specific gravity of fuel oil	:	0.[illegible]
Gross calorific Value	:	10,[illegible] Kcal/kg.
Heat consumption	:	0.936×10^6 Kcal/ton.

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CHITTAGONG, EAST PAKISTAN.

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Name			(1) B204	(2) B205	(3) B206	(4) B207	(5) B208	(6) B209	(7) B210	(8) B211	(9) B212	(10) B213	(11) B214	(12) B215	Total	Remarks
1. Steel quality (analysis)	C	(%)	0.08	0.08	0.08	0.09	0.13	0.10	0.12	0.08	0.07	0.07	0.07	0.08		
	Mn	(″)	0.28	0.35	0.35	0.35	0.39	0.36	0.39	0.46	0.35	0.33	0.40	0.35		
	Si	(″)	0.01	0.12	—	0.035	0.16	0.038	0.037	0.14	—	—	0.34	0.007		
	P	(″)	0.01	0.008	0.008	0.01	0.01	0.005	0.01	0.012	0.01	0.01	0.008	0.01		
	S	(″)	0.032	0.037	0.035	0.035	0.033	0.033	0.033	0.043	0.040	0.034	0.035	0.034		
2. Output	Good ingot	(ton)	58,700	54,120	57,820	55,000	54,180	54,940	56,900	55,020	56,940	55,880	53,100	56,000	668,600	
	Rest blocks	(″)	750	0	0	500	50	800	0	0	100	560	0	300	3,060	
	Total	(″)	59,450	54,120	57,820	55,500	54,230	55,740	56,900	55,020	57,040	56,440	53,100	56,300	671,660	
3. Yield	Metalic charge	(ton)	61,090	62,150	62,690	61,660	62,[illegible]40	62,250	61,740	62,220	62,650	62,900	62,240	62,160	746,820	
	Cast ingot & so forth	(″)	60,700	55,720	59,070	56,750	55,[illegible]30	56,990	59,150	56,620	58,290	57,690	54,700	57,550	688,060	
	Yield	(%)	97.5	89.3	94.2	[illegible]	[illegible]	91.5	[illegible]	[illegible]	93.4	91.7	87.8	92.2	92.1	
4. Rifining Period		(min)	40	44	35	[illegible]	[illegible]	25	[illegible]	[illegible]	28	30	15	20	347	28.8 min/ch
5. Heat consumption (heavy oil)	ℓ/charge		6050	5,740	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5,710	6,200	71,595	0.966 x 10[illegible]
	ℓ/ton		100	103	106	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	107	103	105	107	104.1	kcal/[illegible]
6. Materials	Scrap	kg/ch	37,350	37,610	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37,920	[illegible]	36,090	37,650	450,940	655.4 [illegible]
	Pig	kg/ch	24,740	24,540	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24,730	[illegible]	24,160	24,510	295,850	430.0 [illegible]
	Lime	kg/ch	3,000	3,000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2,500	2,500	2,500	32,630	47.4 [illegible]
	Limestone	kg/ch	0	0	0	[illegible]	[illegible]	0	0	[illegible]	0	0	0	0	0	0
	Ferro Mn	kg/ch	160	150	100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	250	200	170	200	2,200	[illegible]
	Ferro Si	kg/ch	0	150	0	[illegible]	[illegible]	0	[illegible]	150	0	0	150	0	600	[illegible]
	Al	kg/ch	11	40	10	[illegible]	[illegible]	10	[illegible]	[illegible]	10	[illegible]	40	10	241	
	Flourspar	kg/ch		10	0	[illegible]	[illegible]	0	0	10	0	0	0	0		
(7) Oxygen Consumption	O_2	Nm³/ch	620	1047	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	826	1166	862	809	10,3[illegible]	
	N[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

KOBE STEEL, LTD.
CHITTAGONG, EAST PAKISTAN.

EGT-79/70 28th November, 1970.

Result of Guarantee Test
O.H.F. No. 3 for Itself and O.H.F. No. 4

This is to report the results of guarantee test performed as acceptance test for both O.H.F. No. 3 and O.H.F. No. 4 by operating the former to attain guarantee values specified for the latter, in accordance with KSL proposal made by their letter Ref. No. EGT-63/70 dated 14th November as duly approved by CSM on 17th November, 1970 and Memorandum of Agreement agreed between the parties in this regards in the following way with the following results.

1. Guarantee Test Period :

10.00 A.M., 19th November —— 5.00 A.M., 22nd November, 1970 for a period of 67 hours net.

2. Guarantee Test Results :

Results attained were as given below in comparison with figures specified for O.H.F. No. 4.

1) Steel quality

	C	Mn	Si	P	S
Guarantee figure,	<0.15	<0.60	<0.30	<0.06	<0.06
Result	0.06-0.12	0.24-0.43	0.01	0.03	—

	Guarantee figure	Result
2) Minimum output	650 tons of cast ingot including rest block, excluding runners and funnels per 72 hours continuous test run period.	716.2 tons per 72 hours (as specified in the left)

—— to be continued ——

KOBE STEEL, LTD.
CHITTAGONG, EAST PAKISTAN.

3) Yield

85.5% cast ingot and so forth based on metallic charge	91.3% (as specified in the left)

4) Refining period

Max. 70 min/charge	Average 63.6 min/charge

5) Maximum heat consumption

Max. 1.3 x 10^6 Kcal/ton of cast ingot and so forth	Average 113.3 1/ton showing below the left.

6) Consumption of [illegible] to be charged

Scrap	470 kg/tons of cast ingot etc.	433.4 kg/ton	- ditto -
Pig	<705 kg/ton "	662.2 kg/ton	- ditto -
Lime	<75 kg/ton "	32.7 kg/ton	- ditto -
Lime stone	<10 kg/ton "	Nil	- ditto -
Ferro Mn	<15 kg/ton "	3.5 kg/ton	- ditto -
Ferro Si	<3 kg/ton "	Nil	- ditto -
Al	<0.6 kg/ton "	Negligible	- ditto -
Fluospar	<1 kg/ton "	Nil	- ditto -
Scrap content	1.4 ton/box	0.91 ton/box	

3. Formula for data :

The results above are shown on the following bases in accordance with the specifications.

1) Minimum output

Good ingot	...	655,870 kg
Rest block	...	10,630 kg
Total obtained	:	666,500 kg

$$\frac{666,500}{67} \times 72 = 716,234 \text{ kg}$$

to be continued

2) Yield

$$\frac{\text{Total output}}{\text{Total metallic charge}} \times 100 = \frac{683,400}{748,710} \times 100 = 91.3\%$$

3) Maximum heat consumption

$$\text{Unit consumption} = \frac{\text{oil consumed}}{\text{total output}} = \frac{77,410 \text{ l}}{68,340 \text{ kg}} = 113.3 \text{ l/t}$$

Fuel oil used is not known for its specific gravity and lower calorific value; however, heavy oil for O.H.F. is to be specified as given below making the result passed whatever value is taken up.

Value to be specified for O.H.F. oil

Specific gravity : 0.89 – 0.95 at 80 – 90 °C
Lower calorific value : 9,500 – 10,000 Kcal/kg

Consumption at the worst condition above .

$$\frac{113.3 \text{ l}}{0.95} \times 10,000 = 1.19 \times 10^6 \text{ Kcal/t.}$$

Thus, the guarantee figure of 1.3×10^6 Kcal/t can be well satisfied.

4) Material consumption

	Consumption / total output		Kg/t
Scrap	296,170	683.4	433.4
Pig	452,540	"	662.2
Lime	22,380	"	32.7
Lime stone	Nil	"	Nil
Ferro Mn	2,400	"	3.5
Ferro Si	Nil	"	Nil
Al	5	"	Negligible
Fluospar	Nil	"	Nil

Consumption / box

Scrap content	748,710	823	0.910 t/box

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— to be continued —

KOBE STEEL, LTD.
CHITTAGONG, EAST PAKISTAN.

The both parties hereby confirmed and certified that the guarantee test by O.H.F. No. 3 for both O.H.F. No. 3 and O.H.F. No. 4 had passed successfully and satisfactorily.

M. S. Hydor,	H. Nuhbegovic,	M. Tanaka,
Production Manager	Technical Adviser	General Manager,
Chittagong Steel Mill	Chittagong Steel Mill	K. S. L.

Encl. : List of Data obtained by Guarantee Test.

MT/SH/Rakshit

22-11-1970

LIST OF DATA obtained by GUARANTEE TEST (OH.F No. 3 for OH.F. No. 4)

		C4134	C4135	C4136	C4137	C4138	C4139	C4140	C4141	C4142	C4143	C4144	Total	Average
Steel Quality		PR-15	PR-15	PR-10	PR-10	PR-10	PR-10	PR-15	PR-10	PR-10	PR-10	PR-10	—	—
Chemical Composition (%)	C	.12	.11	.10	.10	.08	.09	.12	.06	.09	.09	.08	—	—
	Mn	.36	.39	.35	.37	.30	.32	.35	.24	.30	.43	.35		
	Si	—	—	—	—	—	—	—	—	<.10	<.10	<.10		—
	P	—		—	—	—	—			.030	.025	.027		—
Charging Qty (kg)		65.780	65.280	68.020	68.020	68.240	68.060	68.100	67.730	67.960	68.120	67.400	748.710	68.065
Total Output (kg)		59.890	61.940	63.180	64.860	63.880	61.230	62.780	60.680	62.740	60.940	61.340	683.400	62.127
Good Ingot (kg)		58.140	60.260	61.180	63.460	62.520	48.780	61.430	59.280	61.240	59.640	59.940	655.870	59.625
Rest Block (kg)		400	430	750	100	—	8.350	100	100	200	—	200	10.630	966
Yield (%)		87.1	90.7	92.9	95.4	93.5	90.0	92.2	89.6	92.3	89.5	91.0	—	91.3
Refining Period (min)		45	60	55	95	70	75	35	70	85	40	70	700	63.6
Heat Consumption (l)		5910	6970	7300	8280	6530	6850	8410	7100	6800	6580	6680	77410	7037
Scrap (kg)		27.920	27.300	23.240	27.220	25.600	27.240	29.860	26.930	27.020	27.300	26.540	296.170	26.925
Pig Iron (kg)		40.860	40.950	44.780	40.800	42.640	40.820	38.240	40.800	40.940	40.820	40.860	452.540	41.140
Lime (kg)		2.100	2.000	2.000	2.000	2.000	2.000	2100	2.080	2.000	2.000	2.100	22.380	2.035
FeMn (kg)		230	220	180	220	220	200	100	230	150	450	200	2.400	218.2
Al (kg)			-						5	—	5		10	
No. of Boxes		72	76	72	80	80	56	80	87	68	72	80	823	74.8

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