Production of Charge Chrome in a 45 MVA Submerged Electric Arc Furnace at Facor, India, Using a Mix of Briquetted and Lumpy Chrome Ores.

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India has emerged as a stable supplier of Charge Chrome to the World Market.

Run-Of-Mine Ore-Rejects, disseminated ores and old dumped materials are upgraded by beneficiation to produce utilisable concentrates. Briquetting process is addopted to agglomerate these concentrates using molasses and lime as binder.

The paper gives a description of various facilities such as Chrome Ore Beneficiation Plant, Briquetting Plant, Raw Material Handling facilities, Submerged Arc Furnace of semi-closed type, gas cleaning plant and product crushing and sizing equipment.

Finally it deals with operational results with varying proportions of briquettes and use of different types of carbon reductants.

INTRODUCTION

At the last INFACON meeting held at Tokyo in May 1983, FACOR had announced the installing of a 100% export oriented Charge Chrome plant with a capacity of 50,000 tonnes per annum. The Charge Chrome production was started in July 1983. The Beneficiation Plant for treatment of very low grade ores and run-of-mine ore rejects as well as the agglomeration plant for briquetting of chrome concentrate were started in 1984.

The Plant has been in continuous operation and till December 1985, a total quantity of about 84,000 tonnes of Charge Chrome has been produced and about 80,000 tonnes has been exported to Japan and European countries. FACOR has thus established itself during the first two years of production as a new and stable supplier of quality charge chrome and has brought India into the world map of established suppliers of Charge Chrome.

The specification of the Charge Chrome exported by FACOR is:

Chromium	55-60%	
Silicon	4%	Max.
Carbon	8%	Max.
Phosphorus	0.025%	Max.
Sulphur	0.025%	Max.

and the actual average as per destination sample analysis of the 80,000 tons exported Charge Chrome is:

Chromium	58.89%
Silicon	3.082%
Carbon	7.90%
Phosphorus	0.0232%
Sulphur	0.0129%

It would be of interest to note the extremely low sulphur content in FACOR's Charge Chrome which makes it more attactive to any steel producer.

HISTORY

FACOR, the largest producer of manganese, silicon and chromium ferro alloys in India were the first to start Ferro Chrome production in 1968. At the same time it acquired mining leases for chromite at Kathpal and Boula and have recently been granted another mining lease at Gurjang in Orissa State to meet their requirements of chrome ores. It has been established that the lumpy ores available are with 35.0 to 50.0% Cr_2O_3 with Chrome/Iron ratio of 1.6 to 2.8. While producing these ores, large quantities of disseminated ores, ore fines and Run-Of-Mine Ore Rejects having 15 to 30% Cr_2O_3 content are also obtained. FACOR produces concentrates out of these otherwise discarded low grade materials, after beneficiation.

As most of the alloy and stainless steel producers in India are having conventional melting units such as induction furnaces and electric arc furnaces the requirement of ferro chrome alloys is desired to contain chromium content of 60% and above and therefore till a few years back the low Cr/Fe ratio Chrome ores were exported. However, FACOR realised that instead of exporting low grade lumpy chrome ores, it would be advantageous if the same is converted to Charge Chrome and exported as a value added commodity. FACOR, therefore, pursued a strategy to utilise the disseminated ores Run-Of-Mine Ore Rejects and waste dumps containing low Cr_2O_3 content. Their R & D Centre undertook Beneficiation studies at their pilot plant for chrome ore beneficiation with 4 tonnes per hour capacity. The investigations established that Run-Of-Mine Ore-Rejects and disseminated ore fines can be upgraded to yield a concentrate containing about 44% Cr_2O_3, 4 to 6% SiO_2 and Cr/Fe ratio 1.8. Since the Iron content is intimately associated in the spinel strucuture of the mineral, Cr/Fe ratio could not be improved this level without sacrificing the recovery.

In order to utilise the chromium concentrates which are in minus 500 micron size, these are agglomerated into briquettes of pillow shape using molasses and hydrated lime as binders and sufficiently strong briquettes could be produced.

The feasibility of production of Charge Chrome using low grade lumpy chrome ores along with briquettes was establised in April 1979 in a 7500 kVA electric submerged arc furnace at Shreeramnagar Works and 500 tonnes of this product was exported to consumers abroad. Their acceptance of the same and its being as per generally accepted International specifications, enable FACOR to obtain Government permission to install a 100 percent export oriented charge chrome plant which would thus utilise optimally the low grade chrome ores and Run-Of-Mine Ore Rejects and ore fines after their beneficiation and agglomeration into briquettes. Hence charge chrome production complex at Boula Mines and at Randia, Orissa consists of three stage operations viz:

1. Beneficiation of Chrome Ores.
2. Agglomeration of Beneficiated Concentrates.
3. Electric Smelting for production of Charge Chrome.

CHROMITE MINING AND CHROME ORE BENEFICIATION PLANT AT BOULA, ORISSA

After deciding to establish the Charge Chrome Plant, the Boula Mines is currently under extensive development. Both open cast mining and underground mining methods are being followed. In order to meet the requirement of chrome ores for the ferro chrome plants in Shreeramnagar, Andhra Pradesh and Charge Chrome Plant at Randia Mining activities have been increased to raise the total ore output at an annual rate of 2,00,000 tonnes. The different types of chrome ores mined at Boula are as follows:

		Cr/Fe ratio	Proportion
Type-1	Hard lumpy, high grade with over 44% Cr_2O_3	2.6-2.8	20%
Type-2	Hard lumpy, low grade with over 35% Cr_2O_3	1.8-2.0	40%
Type-3	Hard lumpy, low grade with Cr_2O_3 25-35%	0.8-1.6	40%

Besides the above, while Mining and grading the same quantities of desseminated ore and low grade fines and Run-Of-Mine ore Rejects are obtained which contain Cr_2O_3 15 to 20%.

While the hard lumpy ores of high grade Type-1 is used for the production of High Carbon Ferro Chrome at Shreeramnagar Plant, the other ores are used at Charge Chrome Plant.

The various ores raised after their sizing and chemical analysis are grades according to Cr_2O_3 content and Cr/Fe ratio, blended, stockpiled and sent to the Charge Chrome Plant.

The desseminated ore fines, Run-Of-Mine Ore Rejects and waste dumps containing chromium values are stockpiled at the Mines site and are sent for processing in the chrome ore beneficiation plant.

Chrome Ore Beneficiation Plant

A Beneficiation plant based on wet gravity separation with 36 tonnes per hour feed capacity has been designed and erected at the Boula Mines. The flow sheet of the plant is indicated in Fig. 1. It consists of ore feed and handling system, crushing and grinding systems with a Rod Mill with 26 tonnes per hour capacity, hydrosizer, hidro-cyclones, spiral concentrator, Triple deck reciprocating tables, concentrate dewatering and collection unit, tailings thickener and disposal system.

The Plant commenced production in March 1984. The actual average chemical analysis of the feed, concentrates and tailings is given in Table I. It can be seen from Table I that while the Cr_2O_3 content is upgraded from 16-20% to 40 to 44%, and silica is brought down from 27-30% to less than 7.0%, the Cr/Fe ratio is improved to 1.8. In order to further recover Cr_2O_3 values lost to tailings, further middling grinding equipments and fine separation technique are proposed to be incorporated. Investigations are also under way to improve the Cr/Fe ratio economically by other methods such as magnetic separation. The concentrate produced is transported by trucks to agglomeration plant at Randia which is about 38km away.

TABLE :: I.

CHROME ORE BENEFICIATION PLANT.

(ANALYSIS OF FEED, CONCENTRATES & TAILINGS)

MATERIAL	FEED - %				CONCENTRATES - %				TAILINGS-%	RECOVERY - %	
	Cr_2O_3	FeO	SiO_2	Cr/Fe ratio	Cr_2O_3	FeO	SiO_2	Cr/Fe ratio	Cr_2O_3	Weight	Cr_2O_3
Blend No. 1	16.00	15.67	35.00	0.90	43.76	28.61	6.78	1.34	7.57	23.29	63.70
Blend No. 2	17.31	15.86	36.00	0.96	43.50	25.34	7.25	1.51	6.96	28.32	71.17
Blend No. 3	20.47	14.87	32.00	1.21	45.09	24.26	5.84	1.63	7.87	33.85	74.56

AGGLOMERATION PLANT

In order to utilise the chrome concentrates produced in the chrome ore beneficiation plant, in the submerged arc furnace, it is necessary to agglomerate the same into a lumpy form. It was decided to adopt the briquetting process for agglomeration since the concentrates obtained are of coarse particle size and for briquetting process neither further grinding nor any elaborate heat hardening is necessary as in the case of pelletising.

Briquettes Production

The flow sheet of the briquetting plant is given in Fig. 2. The plant consists of chrome ore concentrates receiving ground hopper, conveyor system and covered stockpiles shed. Reclaiming is done by a payloader and material is fed to a bin of 200 tons capacity from where it is taken by skip hoist to Silos of the briquetting plant. This consists of automatic weighing and proportioning system, lime and molasses dosing system, Twin multi-muller Mixer, feeding system to the Double Roll Press having 20 tonnes per hour capacity, vibrating screen to remove under-size briquettes and recyle through bucket elevator to the briquetting press, briquettes conveying and stockpilling system. The briquetting press is of Dry and high pressure roller type with recessed pockets to form pillow shaped briquettes. The unique feature of this press is automatically adjustable driving system to obtain quality briquettes even under varying conditions. The roll pressure is imparted by a hydraulic device by means of which pressure can be varied from 60 to 140 kg/cm^2 to obtain the necessary mechanical strength.

Molasses and hydrated lime are used as binders. The specifications of binders are given to Table II and III respectively. Molasses and lime are used to an extent of 2.0 to 4.0% each.

TABLE II

MOLASSES SPECIFICATIONS

Total reducing sugar	50%	Min.
Brix value	80%	Min.
Polarisation	52%	Min.
Specific gravity	1.35	Min.

TABLE III

SPECIFICATIONS OF HYDRATED LIME

Constituents	Percent
CaO	65 - 70
$Ca(OH)_2$	85 - 93
SiO_2	4.0 Max.
P	0.020 Max.
L.O.I.	22 - 30

Size: 100% below 400 microns.
70% below 75 microns.
Bulk density 800 kg/m^3

TABLE : IV

PHYSICAL PROPERTIES OF CHROME ORE BRIQUETTES.

Particulars.	Unit	Pocket size-I	Pocket size - II.
Size.	mm	80x62x30	58x47x23
Shape		Pillow	Pillow
Average weight per briquette	gms	230	98
Apparent density.	gm/cc	3.4 to 3.6	3.4 to 3.6
Bulk density.	kg/m^3	1700-1750	1700-1750
Angle of repose.		$33^{\circ}45'$	$33^{\circ}50'$
a) Green strength per briquette.	kg	35-50	35-50
b) Strength of cured briquette after 4 hours.	kg	150	150
Drop strength of cured briquettes. (Dropped 10 kgs of briquettes from a height of 3 meters on a steel plate)	%		
	+40mm	81.2	82.8
	-40 +25mm	14.0	12.0
	-25+10mm	2.4	3.9
After five drops.	-10+6mm	0.6	0.4
	- 6mm	1.8	0.9
		100.0	100.0

Briquettes of pillow shape with requisite strength and smelting properties are produced. The physical properties of the briquettes produced is given in Table IV. The properties of the briquettes after storage over several months clearly indicate that the briquettes retain their strength even after long storage under varying weather conditions.

Alternate binder systems have also been tried with Magnesium lignosulphonate and lime or starch in case there is difficulty in procuring molasses.

ELECTRIC SUBMERGED ARC FURNACE

The smelting plant inclusing the chrome ore briquetting plant has been set up at Randia in Balassore District of Orissa State. It is adjacent to Baudpur Railway Station and close to the National High Way No. 5 connecting Madras and Calcutta. Paradeep Port which is used for export of charge chrome is about 140 km away from the plant. Thus all the infrastructural facilities for receipt of various raw materials and for export of the charge chrome are readily available. A location map is shown in Fig. 3.

The smelting plant and the residential colony for employees is set up in an area of 250 acres. The plant consists of raw materials receiving and stockpiling yards, covered storage sheds, conveying equipments and utility services, smelting furnace, product sizing & handling and storage system, pollution control system and the agglomeration plant. Raw Materials consisting of different chrome ores, carbonaceous reducing agents and fluxes are taken from storage yards by front-end loaders and conveyor belt system for filling into the day-bins. The Day-bin house consists of 14 concrete bins arranged in a circular module being fed by a revolving conveyor. Batching of raw materials is computerised. The same computer has also provision for furnace data logging.

TABLE : V.

ELECTRIC SUB MERGED ARC FURNACE : DESIGN DATA.

Furnace.	Semi covered and stationary.
Transformer rating.	45000 KVA. three single phase transformers each of 15000 KVA.
Primary voltage	33 KV ± 12%, 50 Hz ± 3%
Secondary voltage.	171V - 230V (R)-350 V(in 35 taps
Tap changing system.	On load.
Secondary current.	112.96 K Amps.
Shell diameter.	12400 mm
Shell height.	6010 mm
Hearth diameter.	9880 mm
Hearth depth.	4400 mm
Tap hole level above hearth.	400 mm
No. of tap holes.	3
Electrode diameter.	1550 mm
Electrode centre to centre distance.	3875 mm ± 5%
Electrode operation stroke	1000 mm
Maintainance stroke.	1600 mm
Slipping stroke.	Max 50 mm, Normal : 15 mm.

Moisture correction, error compensation and automatic slipping of electrodes are some of the special features of the computerised control. Seven sets of weigh hoppers placed beneath the day-bins weigh automatically with help of load cells raw material as per mix order and feed to a conveyor belt through a common collection hopper. The charge components are thus mixed and transported by an inclined belt conveyor to a revolving conveyor system at the top of the furnace for distributing into 14 overhead charging hoppers. The submerged arc furnace is of Tanabe Kakoki, Japan make with 45 MVA transformer. Some design parameters of the furnace are indicated in Table V.

The metal and slag are tapped together at regular intervals six to nine times a day. Tapping operation utilises a drilling machine for taphole opening and a swivel type mud-gun for closing. Molten metal and slag are colletec in ladles arranged in cascade. Slag is decanted and the clean metal is teemed into a continous single strand casting machine with chill moulds mounted on it. The casting machine contains 130 chill moulds to produce caste of 400 x 1400 x 120 mm. Each cast weighs about 280kg. After cooling the metal casts fall into trays placed on trolleys which are pulled in with the help of an electric winch under an E O T Crane, by which they are lifted and unloaded into a grizzly with 125 mm square openings.

A mobile hydraulic breaker is provided along with the hopper with grizzly to break the larger pieces of metal and push it through 125 x 125 mm openings. The material falls into a hopper provided with an apron feeder to feed at a regulated rate into a jaw crusher where it can be crushed to a size below 80 mm if required. The crushed material is conveyed to a vibrating screen to separate minus 10 mm fraction and the plus 10 mm fraction is discharged into another conveyor provided with a tripper moving all along the conveyor to stockpille upto 10,000 tonnes of charge chrome in the yard.

Pollution Control & Dust Collection

A dry bag house fumes filteration and dust collection system has been incorporated to prevent any environment air pollution. The system consists of a filter bag house collecting unit with auxiliary equipments to extract, cool and collect the particulate matter from the fumes of smelting furnace.

Two separate lines are provided each with individual main fan and filter bag dust collectors. The bag house is of bottom inlet pressure type and comprises of six compartments in each line. Each compartment of bag-house has a total of 128 filter bags arranged in rows of 8 x 16. There are therefore a total of 1,536 filter bags in the entire bag-house. The filter bags are of fibre glass with .0.292 m dia x 10.3 m height. The cleaning and collection is achieved by reverse air flow principle. On full load operation, the gas volume amounts to about 300,000 Nm^3/hr. The dust load is 0.5 gm/Nm^3. The dust content in the cleaned gas is brought down to less than 20 mg/Nm^3. The gases completely free of any abnoxious matter are discharged to atmosphere.

The dust is of micron size range with 75% below 150 microns and 50% below 75 microns. The typical chemical analysis of the dust collected is indicated in Table VI.

The dust collected is pelletised in disc pelletiser and disposed off or diverted to the Agglomeration Plant where it is re-cycled along with chrome ore fines for briquetting.

Production of Charge Chrome

FACOR obtains their major ore requirements from their captive mines at Boula which is 38 km away from the Plant. It also makes use of some chrome ores from other nearby mines. The lumpy chrome ores which are of low grade are further graded and blended into stockpiles according to Cr_2O_3 and FeO contents in order to attain feed with a uniform physical and chemical composition.

TABLE : VI.

CHEMICAL ANALYSIS OF DUST COLLECTED IN GAS CLEANING PLANT.

Constituent	Composition in percent.	
	From cyclone	From bag house hopper.
Cr_2O_3	19.75	18.14
FeO	21.32	20.62
SiO_2	18.92	17.24
MgO	12.40	13.51
Al_2O_3	10.91	9.48
CaO	1.26	0.56
L.O.I.	15.44	18.30
n.d	-	2.15
	100.00	100.00

The various chrome ores along with chrome ore briquettes produced at the Agglomeration Plant are used in different proportions to arrive at an average blend analysis to conform to the predetermined material balance not only with reference to Cr_2O_3 and Cr/Fe ratio but also MgO/Al_2O_3 ratio which plays a vital role in the smelting operation. The Chemical composition of several chrome ores used are indicated in Table VII. The screen analysis of these ores is given in Table VIII.

Imported low phosphorus low Ash coke is used as the main reducer. Non-coking coal with Phosphorus 0.02% Max. which is available from nearby Talcher coal fields is used as a reducer to an extent of about 30% of the total fixed carbon requirement. The chemical analysis of coke and coal used in smelting operations is given in Table IX.

Based on the composition of the available chrome ores, FACOR has standardised the production of Charge Chrome with Cr 57-59%. Thus the material balance is made with an optimum blend of chrome ores. A typical material balance is indicated in Table X. It can be observed from Table X that the ore blend is of self-fluxing composition, but

TABLE : VII.

CHEMICAL ANALYSIS OF CHROME ORES IN PERCENT.

	Cr_2O_3	FeO	SiO_2	MgO	Al_2O_3	CaO	P	Cr/Fe
Boula grade-A	44.0-46.0	16.0-18.0	9.5-11.0	15.0-17.0	9.0-11.0	0.5-0.7	0.007	2.1 - 2.5
Boula grade-B	39.0-41.0	16.5-18.5	12.0-14.0	15.0-17.0	9.0-11.0	0.5-0.7	0.007	1.85- 2.2
Boula grade-C	36.0-39.0	18.0-20.0	15.0-17.0	16.0-18.0	9.0-11.0	0.6-0.8	0.007	1.6 - 1.9
Grade - D	42.0-44.0	14.0-16.0	12.0-15.0	14.0-16.0	12.0-14.0	0.7-0.9	0.007	2.3 - 2.8
Grade - E	38.0-40.0	19.0-21.0	10.0-12.0	10.0-12.0	12.0-14.0	0.7-0.9	0.007	1.6 -1.85
Grade - F	38.0-42.0	21.0-25.0	6.0 - 8.0	15.0-17.0	12.0-14.0	0.8-1.0	0.007	1.35-1.75
Boula briquettes	36.0-40.0	19.0-21.0	6.0 - 9.0	14.0-16.0	9.0-11.0	3.0-5.0	0.007	1.5 -1.85

TABLE : VIII.

SCREEN ANALYSIS OF CHROME ORES IN PERCENT.

Chrome ores.	-90+75mm	-75+40mm	-40+25mm	-25+10mm	-10mm	Bulk density kg/m^3
Boula grade-A	15.6	64.1	14.1	6.2	-	1.966
Boula grade-B	6.5	60.4	16.5	12.2	4.4	2.135
Boula grade-C	-	81.8	12.1	4.5	1.6	2.027
Grade - D	20.3	46.3	16.3	7.3	9.8	1.889
Grade - E	14.0	52.4	12.6	8.5	12.5	1.921
Grade - F	47.1	31.1	8.4	5.0	8.4	1.828
Boula briquettes.	-	71.1	12.6	7.2	9.0	1.705

TABLE : IX

CARBONACEOUS REDUCTANTS.

	CHEMICAL COMPOSITION IN PERCENT.										
	F.C.	V.M.	Ash	P	S	FeO	SiO2	Al2O3	MgO	CaO	TiO2
Imported coke.	87	1.0	12.0	0.02	0.8	0.84	6.52	3.21	0.24	0.34	0.11
Talcher non coking coal.	45	35.0	20.0	0.02	0.6	1.40	11.20	4.80	0.60	0.40	0.20

SCREEN ANALYSIS IN PERCENT.

	+40mm	-40+25mm	-25+10mm	-10+6 mm	-6+3 mm	-3mm	Bulk density kg/m3
Imported coke.	1.15	47.05	45.29	2.17	4.34	-	0.706
Talcher non coking coal.	1.50	28.51	42.65	17.82	4.95	4.57	0.522

TABLE X

MATERIAL BALANCE

(a) Raw material analysis (weights are in kgs)

Material	Qnty	Cr_2O_3	FeO	SiO_2	Al_2O_3	MgO	CaO	Cr	Fe	Cr/Fe ratio	F. C.
Boula - B	100	39.86	15.16	13.17	9.00	15.00	0.50	27.27	12.33	2.31	-
Boula - C	100	37.50	18.17	15.73	10.94	18.10	0.50	28.66	14.67	2.06	-
Grade - D	100	43.83	13.30	11.73	13.00	15.12	0.50	29.99	10.34	2.90	-
Grade - F	100	39.36	24.58	7.12	12.40	15.50	0.84	26.93	19.12	1.41	-
Briquettes	100	36.20	18.78	6.74	10.02	16.90	4.58	-	14.61	1.70	-
Imported coke	100	-	0.84	6.52	3.21	0.24	0.34	-	-	-	87.35
Talcher coal	100	-	1.40	11.20	4.80	0.60	0.40	-	-	-	43.30
Bauxite	100	-	4.15	3.35	61.10	-	2.92	-	3.23	-	-
Quartzite	100	-	0.30	98.00	0.50	0.20	0.30	-	-	-	-
Boula - B	750	298.95	113.70	98.77	67.50	112.50	3.75	-	-	-	-
Boula - C	750	281.25	136.27	117.97	82.00	137.75	3.75	-	-	-	-
Grade - D	100	43.83	13.30	11.73	13.00	15.12	0.50	-	-	-	-
Grade - F	200	78.72	49.16	14.24	24.80	31.00	1.68	-	-	-	-
Briquettes	600	217.20	112.68	40.44	60.12	101.40	27.48	-	-	-	-
Total chrome ore	2400	919.95	425.11	283.15	247.42	397.77	37.16	629.44	330.64	1.90	-
Imported coke	400	-	3.36	26.08	12.84	0.96	1.36	-	-	-	349.40
Talcher coal	175	-	2.45	19.60	8.40	1.05	0.70	-	-	-	75.77
Bauxite	120	-	4.98	4.02	73.32	-	3.50	-	-	-	-
Quartzite	120	-	0.36	117.60	0.60	0.24	0.36	-	-	-	-
Total		919.95	436.26	450.45	342.58	400.02	43.08	629.44	339.31	1.86	425.17

Slag Formation	kg	Slag analysis	kg	%
MgO	400.02	Cr_2O_3	64.40	5.0
Al_2O_3	342.58	FeO	25.76	2.0
CaO	43.08	SiO_2	412.16	32.0
Cr_2O_3	64.40	MgO	400.02	31.1
(Cr 44.06)		Al_2O_3	342.58	26.6
FeO	25.76	CaO	43.08	3.3
(Fe 20.04)				
Slag vol. except SiO_2	875.84		1.288.00	100.0

Total Slag volume at 32% SiO_2: 1288 kg.

Metal.

Cr:(629.44 - 44.06) x 0.97 = 567.82

Fe:(399.31 - 20.04) x 0.98 = 312.88

TOTAL 880.70

Metal volume : $\frac{880.70}{0.90}$ = 978.56 kg

% Cr in metal: $\frac{567.82 \times 100}{978.56}$ = 58.03%

SiO_2 required for metal. $978.56 \times \frac{2.5}{100} \times \frac{60}{28}$ = 52.42 kg

Flux requirement

SiO_2 for Slag. 412.16

SiO_2 for Metal. 52.42

Total SiO_2 464.58

Fixed carb.

For chromium:
$(919.95 - 64.40) \times \frac{36}{152}$ = 202.63

For iron:
$(436.26 - 25.76) \times \frac{12}{72}$ = 68.42

For Silicon:
$52.42 \times \frac{24}{60}$ = 20.97

For carburisation:
$978.56 \times \frac{7.5}{100}$ = 73.39

365.41

TABLE : XI.

OPERATION DATA.

P E R I O D	I	II	III	IV
Production - MT	21,122	6,992	12,347	3,633
Lumpy chrome : Briquettes.	100:0	86:14	76:24	89:11
Coke : Coal.	87:13	100:0	86:14	86:14
Average furnace load MW	30	28	28	28
Input chromium %	27.53	27.88	26.97	27.03
Input Iron %	13.26	13.62	14.19	14.18
Cr/Fe ratio.	2.08	2.05	1.90	1.91
MATERIAL CONSUMPTION PER TONNE OF CHARGE CHROME.				
Lumpy chrome Ore : Tonne	2.594	2.223	1.961	2.279
Briquettes : Tonne	-	0.348	0.626	0.274
Total : Tonne	2.594	2.571	2.587	2.553
Coke : Tonne	0.531	0.557	0.523	0.475
Coal : Tonne	0.155	-	0.167	0.163
Fixed carbon : Tonne	0.481	0.448	0.465	0.434
Quartz : Kg	28.4	49.2	58.9	35.7
Bauxite : Kg	25.4	115.6	148.6	122.7
Electrode carbon paste-kg	28.7	24.5	17.3	14.0
Power for smelting - KwH	4310	3982	3911	3793
Slag volume. : Tonne	1.30	1.20	1.25	1.25
CHARGECHROME ANALYSIS.				
Cr .. %	59.33	59.93	57.79	58.24
Si .. %	3.24	2.94	2.95	2.90
C .. %	7.78	7.96	7.78	7.83
S .. %	0.0125	0.0155	0.0174	0.0207
P .. %	0.0246	0.0217	0.0226	0.0228
SLAG ANALYSIS.				
Cr_2O_3 .. %	3.87	4.48	4.98	5.01
FeO .. %	1.21	1.80	1.62	1.70
SiO_2 .. %	34.39	33.13	33.09	33.08
MgO .. %	37.40	37.10	33.21	33.40
Al_2O_3 .. %	22.70	22.50	22.42	21.82
CaO .. %	0.52	0.84	4.20	4.17

sometimes a small quantity of Bauxite is found necessary and is incorporated to maintain MgO/Al_2O_3 ratio in the ore blend.

Smelting operation has been carried out initially with the use of 100% lumpy chrome ores and thereafter the lumpy ore was replaced with briquettes in different proportions. The proportion of coke and coal have also been varied. The typical mix proportions of ore and briquettes and its impact on operation data for specific periods are indicated in Table XI.

Some Comments on the Smelting Operation

The furnace after its start up and attainment of full load of 30 MW has performed well by the constant vigil exercised by technical personnel who are closely monitoring the performance. All the difficulties have been tackled appropriately and the furnace is operated continously.

The average specific power consumption per tonne of saleable 10- 50 mm sized Charge Chrome with 57 to 60% content is 3900 kWh/ton which we consider quite normal for cold Charge and having a salg volume of 1200 kg/ton of Charge Chrome. The particular feature of the ore mix is their self fluxing nature with very little requirement of external flux additions.

The lumpy Boula ores are easily reducible but are having slightly high MgO/Al_2O_3 ratio which is adjusted briquettes and other ores of bauxite as flux. These ores do not decrepitate on heating and the permeability of the charge mix is maintained during smelting operation in the furnace. The use of these uniformally blended ores and briquettes promotes uniform smelting rate with good distribution of reaction gases in a wide zone evident from flames on the surface of the charge and regular descent of the charge. The adoption of a semi-covered furnace with stocking facilities enables to easily monitor the smelting rate and attain uniform distribution of the charge mix around the electrodes.

The use of some quantity of non-coking coal with low sulphur and low phosphorus content is practiced to enable lowering the input cost. The semi-covered furnace is found helpful in this regard since the high volatile matter of the coal is burnt at the charge surface pre-heating the upper layers of the charge and the char thus formed is found to have better reactivity and resistivity. No adverse effect is noticed on the furnace operation or in the smelting process while using coal with coke. The proportion of cola used is presently about 30% but it can be increased to higher level.

Electrode penetration is maintained at 2.5 to 3 metres below the charage level. For controlling and ascertaining the electrode position, electrode lengths are measures periodically. The electrode carbon paste consumption amounts to 3.5 to 4.0 kg/MWh.

Presently the chromium recovery in the saleable product is about 88% while the loss into slag amounts to about 6%. In the ladle skulls and during the slag decantation from the ladle after tapping, some metallics get entrapped in the slag. To enable recovery of such metallics, a plant is being set up comprising facilities for crushing, sizing, magnetic separation and jigging. It is expected to be ready before end of 1986. With this, the overall recovery of chromium in the metal is expected to improve further by an extend of 3 to 5%.

ENERGY CONSERVATION MEASURES

In the smelting process for charge chrome materials the two items contributing to thermal energy input are: 1) The carbonaceous Reducing Agents such as coke and coal and 2) Electrical Power. The cost of both these items is increasing year by year and efforts are always directed to minimise their usage.

The selection and use of carbon reductants is very much dependent on the Phosphorus, Sulphur and Ash content. A certain size specification is also desired to control the porosity and resistivity of the charge depending upon type and physycal properties of chrome ores used which may be lumpy, pellets, briquettes, friable fines or a combination.

If coke breeze with the same specifications as coke is available at a lower price of large quantity of fines is generated while screening prior to feeding into the furnace which would otherwise be rejected, such coke fines can be advantageously incorporated to produce composite ore and coke briquettes.

There is no scope for minimising the total consumption of fixed carbon required in the process except by marginal quantities by controlling the surface burn off losses, since necessary amount of carbon is essentially required for reduction of the oxides and carburization of metal.

A simple thermal balance for charge chrome production using cold charge is indicated in Fig. 4.

It can be noted that the total mount of energy equivalent to 8300 kWh is required to produce one tonne of charge chrome containing about 58-60% chromium, 2-4% Silicon using a mix of 80% lumpy chrome ores and 20% briquettes. Out of this the electric power contributes 3900 kWh. According to thermodynamics, only one third of the heating value of the carbon is utilised for reduction purposes while two thirds of it is left in the gas. The major scope of energy saving is therefore directed towards utilisation of the furnace gas having the energy equivalent of 2640 kWh.

Some of the well established processes make use of the calorific value of gas for pre-heating the charge materials and thus save specific electric power required per tonne of charge chrome by 800-1100 kWh. If preheating of the raw materials is practiced, it is seen that a saving of about 80 kWh can be achieved for every 100°C preheating of the charge as depicted in Fig. 5

We have considered a proposal to make use of this potential energy by converting the semi-closed furnace, cleaning the furnace gas and using the same for preheating the charge including the briquettes and feeding hot charge into the furnace. However, an evaluation of the cost/benefit analysis indicates a negative aspect because the total available energy in gases is not utilisable for preheating alone. Unless all the energy can be made useful the economic viâbility is not established. Heavy capital investiment is required for the modifications and new equipments to be installed. In addition there is recurring operating and maintanence cost and power requirement for additional equipments. These costs versus savings in preheating alone do not make the investment economically viable despite additional production with the same power input. Hence it does not appear conducive to pursue energy saving measures with the large additional investment required at the present stage. At the moment we are concentrating all our efforts to maintain the operation of the furnace at the most optimum and stable conditions with higher proportion of briquettes so that the slag volume can be minimised with marginal saving in power consumption. The semi-covered furnace further provides flexibility in the use of different types of chrome ores, various proportions of lumpy and briquetted chrome ores, friable chrome ores and use of coal. However, when the situation justifies the additional investment, energy conservation measures as envisaged will be implemented.

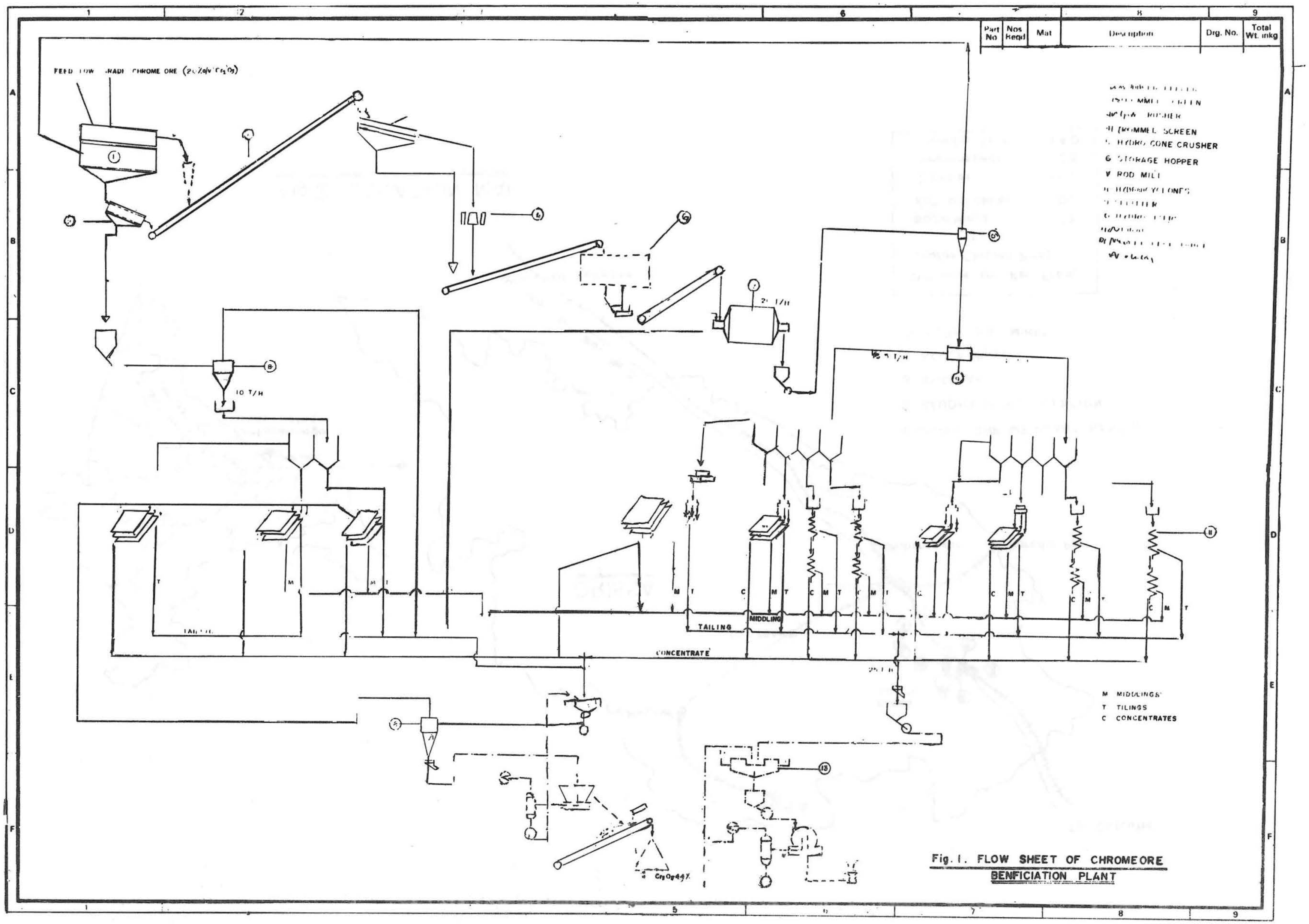
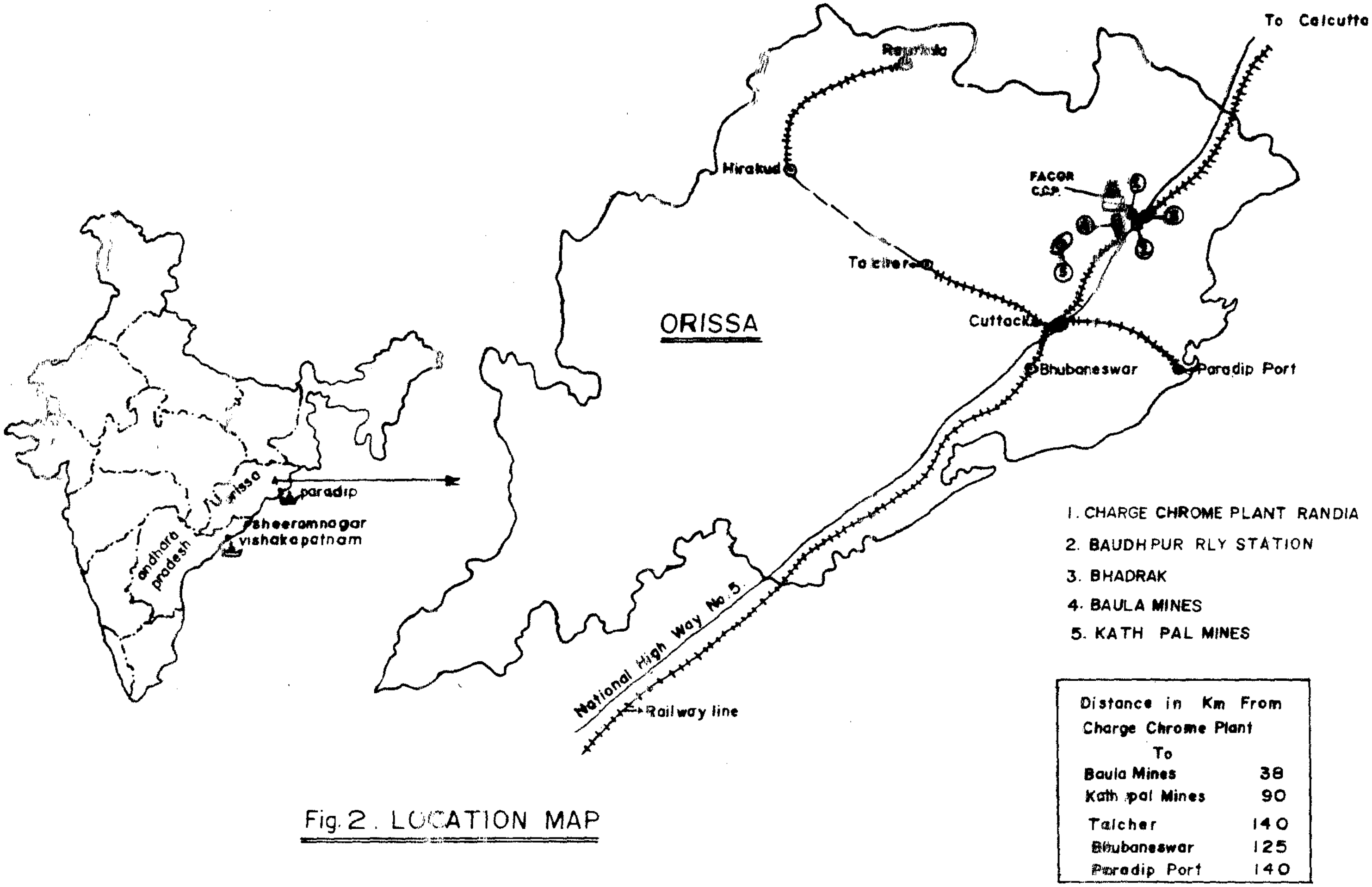


Fig. 1. FLOW SHEET OF CHROMEORE BENFICIATION PLANT



Distance in Km From Charge Chrome Plant To	
Baula Mines	38
Kath pal Mines	90
Talcher	140
Bhubaneswar	125
Paradip Port	140

Fig. 2. LOCATION MAP

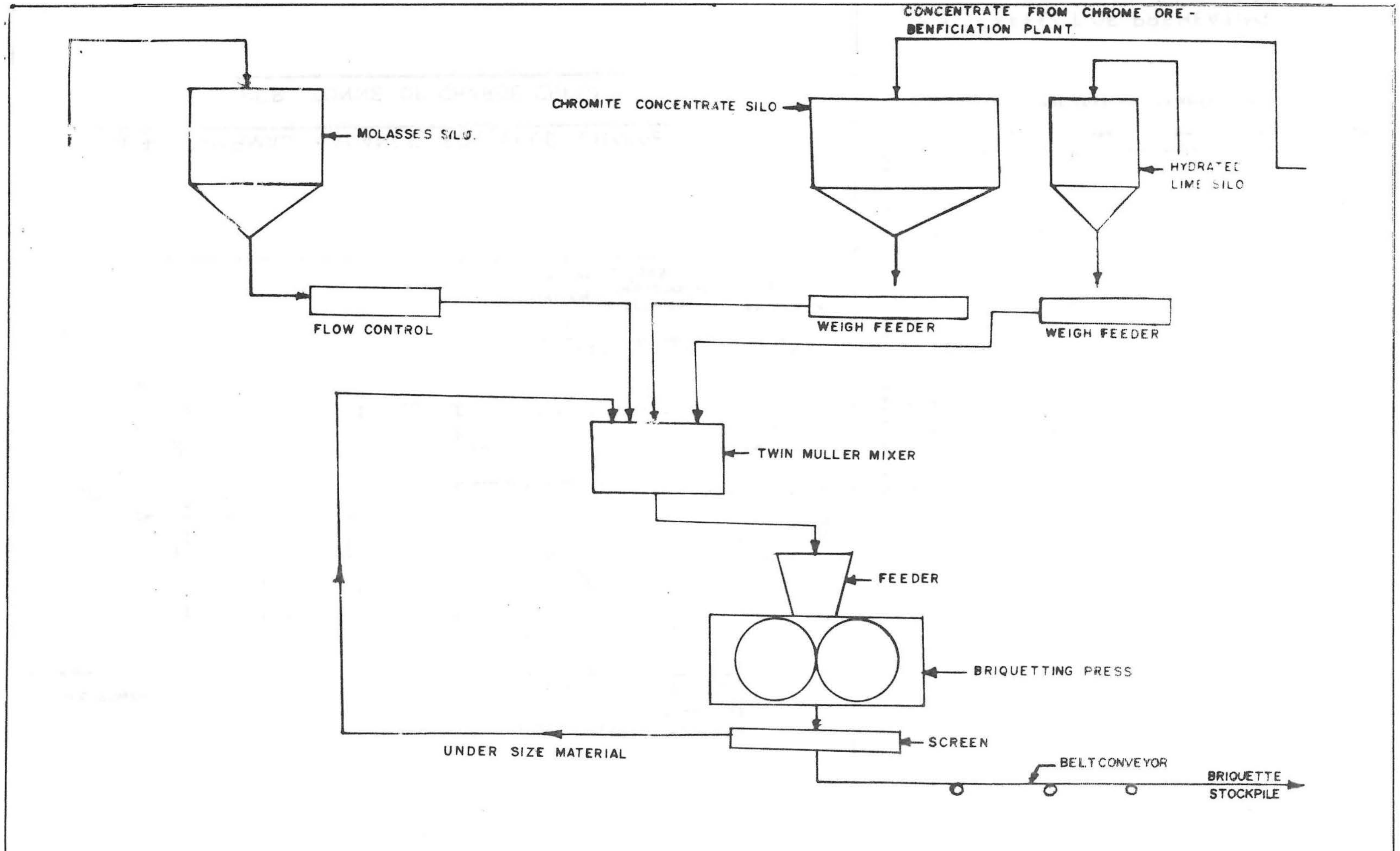


Fig. 3. FLOW SHEET FOR BRIQUETTING PLANT

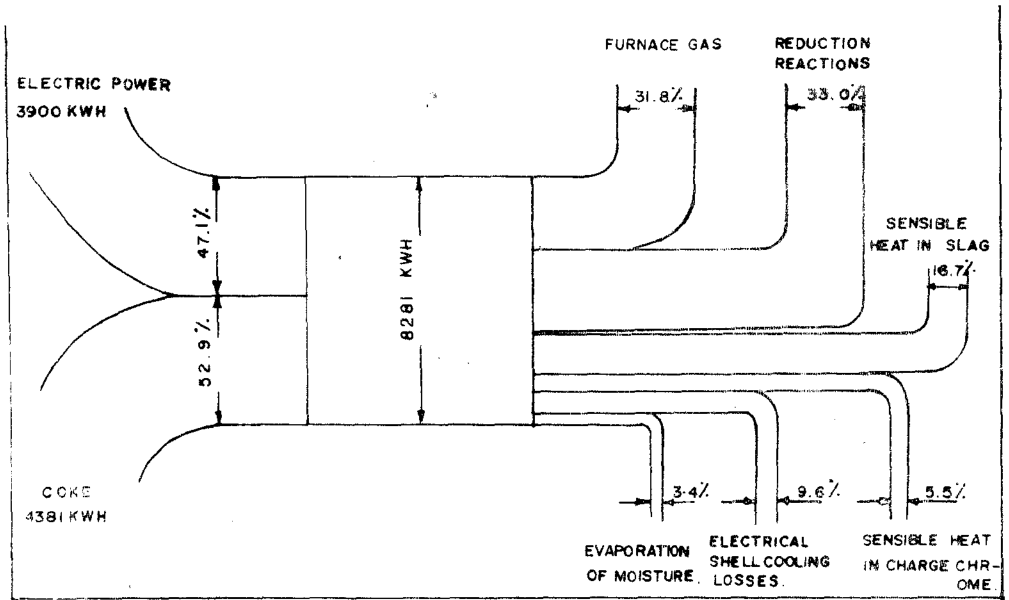


Fig. 4 · THERMAL BALANCE FOR COLD CHARGE PER TONNE OF CHARGE CHROME.

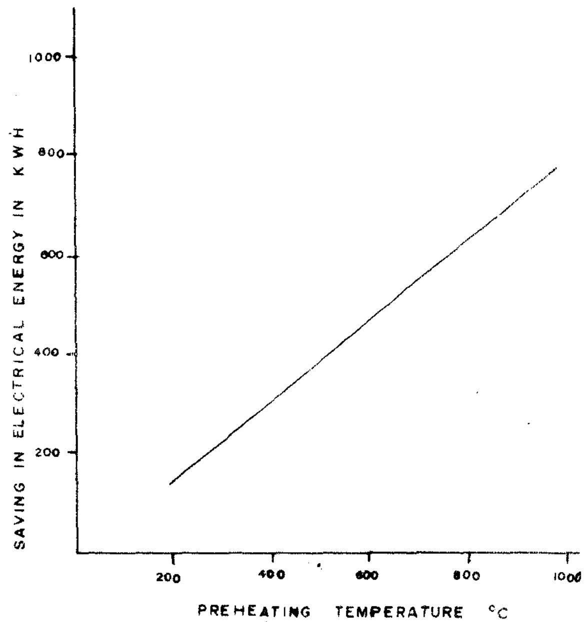


Fig.5 · EFFECT OF PREHEATING IN ENERGY SAVING