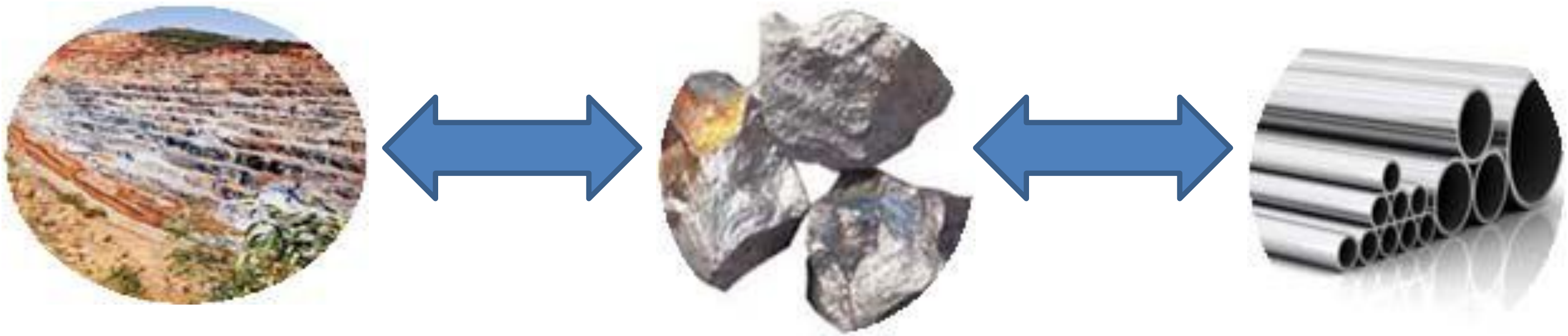
A TENTATIVE MODEL OF TECHNOLOGY IMPROVEMENT IN FERRO-ALLOYS MANUFACTURING PROCESS & THE BUSINESS WAY FORWARD

Presented by ....
Dr. A. K. MAHAPATRA
Director (Technical & Administration)
B C MOHANTY & SON Pvt. Ltd., CUTTACK, ODISHA
Chromite Mines at Kamarda (Jajpur) & Ferro Alloys Plant at Baliapal(Jajpur)
Mobile No - 7008081968, 9437296032
E Mail ID - akmahapatra16@gmail.com

Ore Producers

Ferro Alloy Producers

Steel Producers

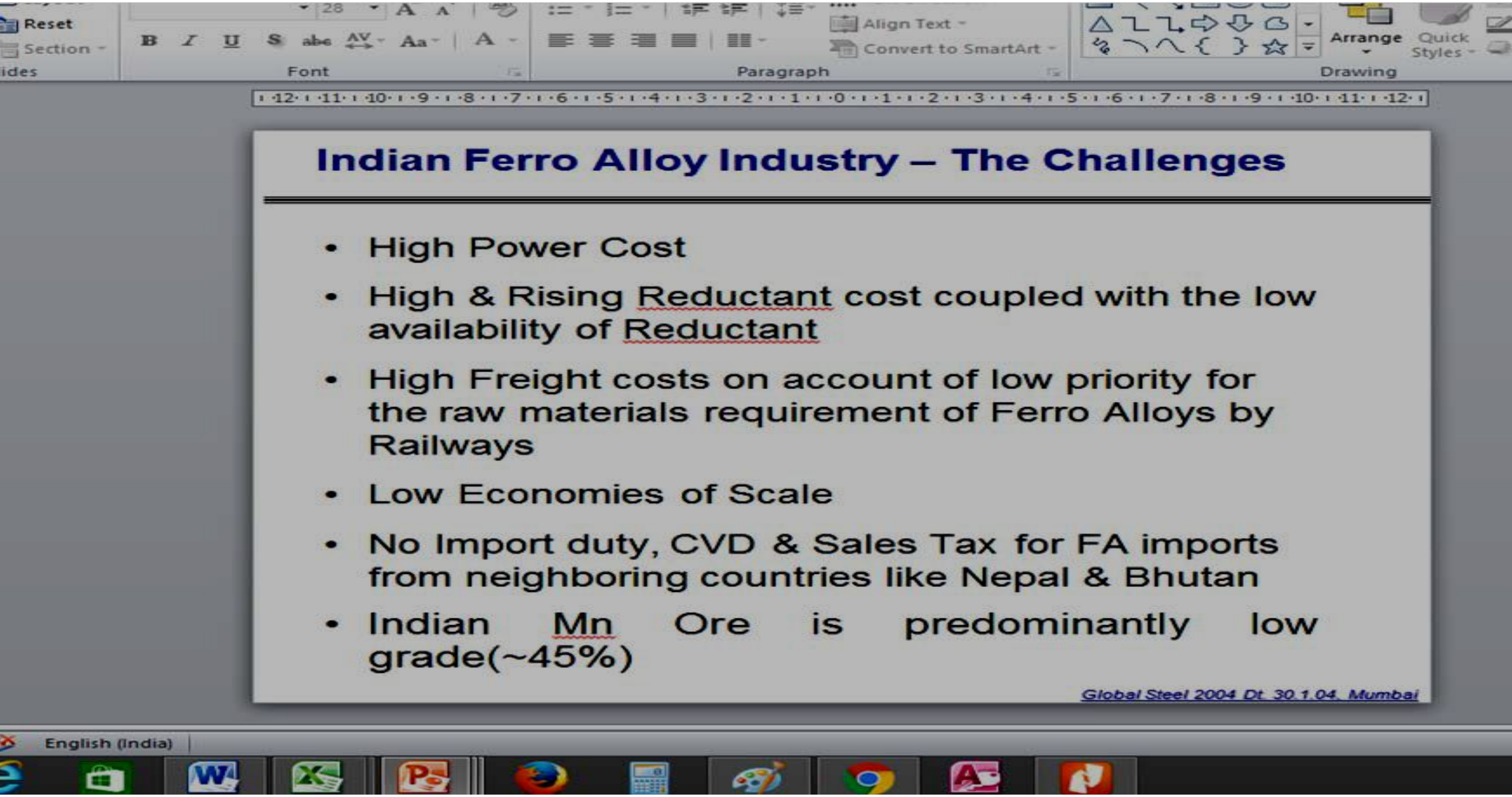


Chrome/ Manganese/Iron/Quartz

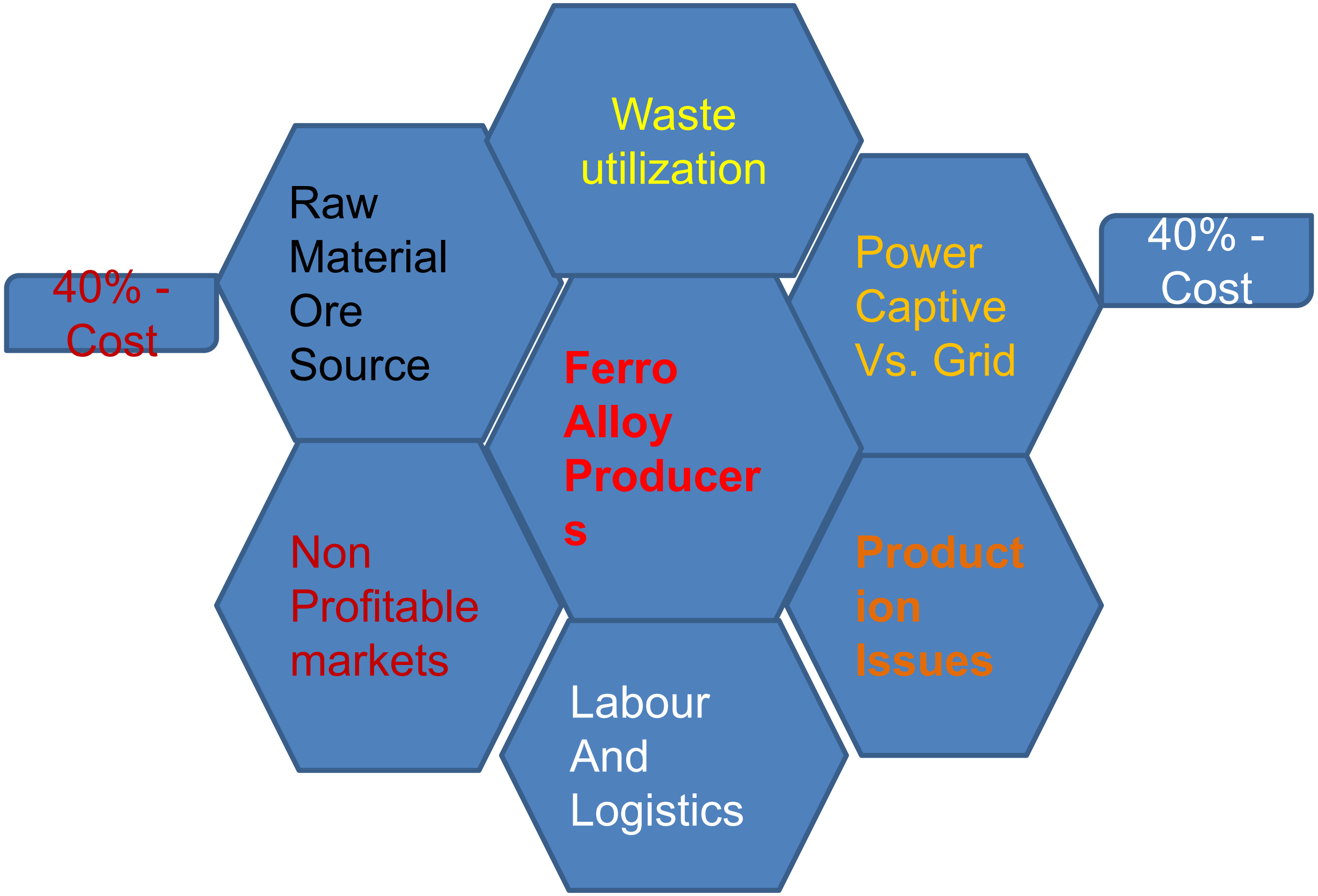
Fe Cr Fe Mn Si Mn/FeSi/FeSiCr

Stainless/Carbon Steel

Issues with Indian Ferro-alloys Industry



VARIOUS CHALLENGES FACED BY THE INDIAN FERRO ALLOY INDUSTRY



MASTER PLAN FOR SURVIVAL

DEPLETION OF HIGH-GRADE ORE

- Low grade beneficiation
- Agglomeration
- Sintering

Key Success Factors For Indian Ferro Alloy Industry

Key Issues	Description	Action Required / Changes Taking Place
Availability of High Grade Mn Ore	• India has limited availability of Medium to Low Grade Mn Ores • Indigenous Manganese Ore grade & quantity better than with China	• Continue to allow free import of HG Manganese Ore • Indian Ore, sweetened with HG Mn Ore suitable for SiMn production.
Coking Coal & LAM Coke availability & cost	• Indian coal has high ash • Exposure to availability & price of LAM coke from China	• Import of low ash coking coal for Ferro Alloy & BF Coke making in India • Blending indigenous cokes with imported LAM coke for economic considerations
Power Availability & Power Cost	• Indian average power tariff at similar level to China. • Power shortages in summer in Eastern India (hub of Ferro Alloy production)	• Power Sector reforms in place - allowing for Captive Power Plants & Power Wheeling. • Increase grid power generation.

Agglomeration & Productivity Improvement for Manganese alloy

Investment in beneficiation & use of agglomerated feed

- Agglomerates offers better reducibility
- Lowers the specific power consumption
- Helps to attain smooth furnace operation

Productivity improvement by having large size of Furnaces

- Smaller furnaces have low per capita output
- Single furnace having high transformer capacity desirable than operating several small furnaces
- Raw materials preparation and handling systems must also be modernized

Waste Heat Utilization & Raw material Handling

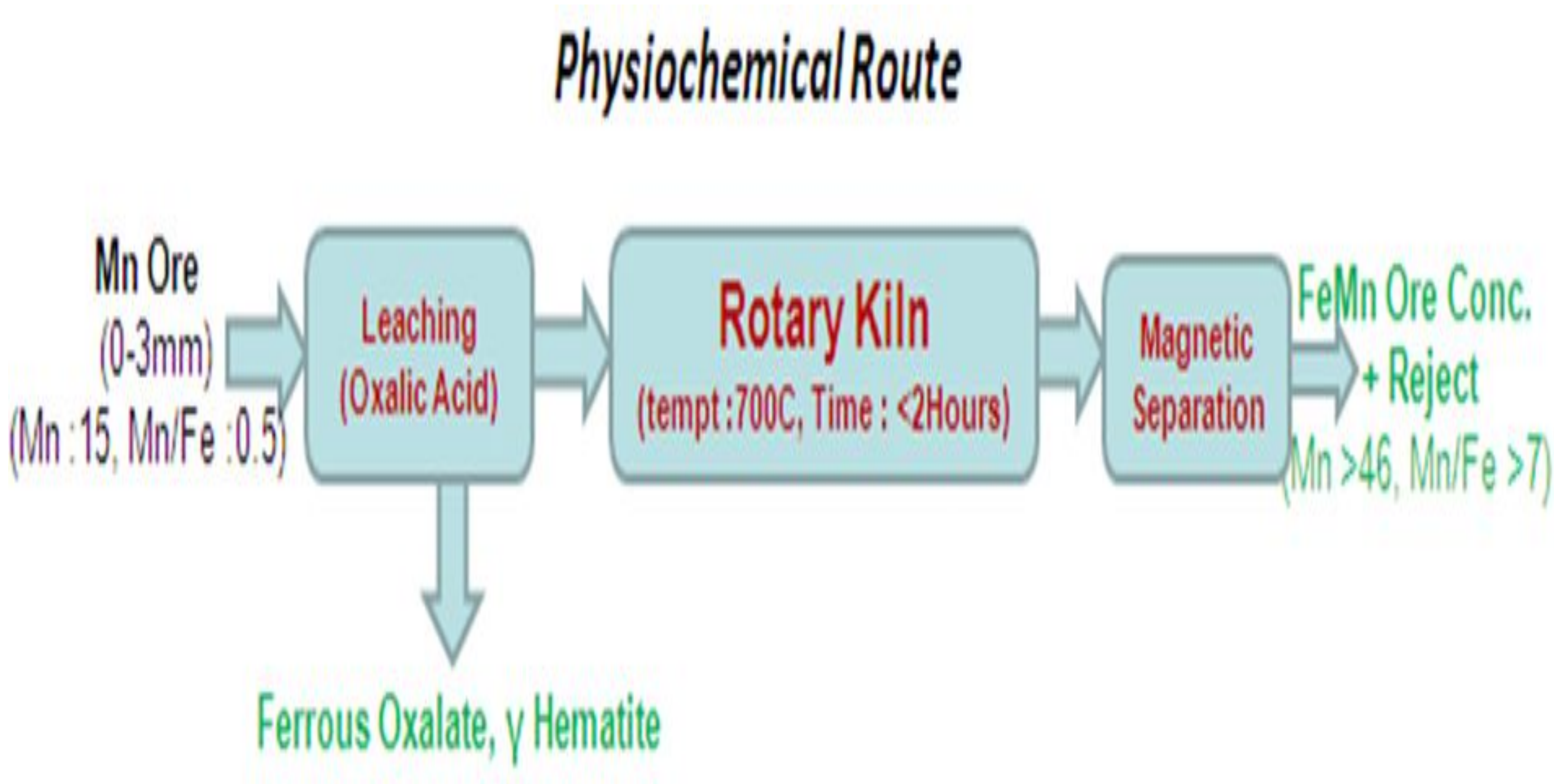
Minimizing heat loss and use waste gases for power generation

- Closed furnace should be adopted than open furnaces
- Will lead to reduce heat loss from the furnace and enable recovery of latent heat in exhaust gases

Proper handling of raw material

- Saving raw materials from adding moisture
- Low moisture level in raw materials reduces specific power consumption and specific consumption of reductants
- Gives steady slag and metal composition

MARCHING FOR CONSERVATION OF MINERAL



MARCHING FOR NEW INNOVATION

- **Waste management of Manganese ore <25% Mn & Innovative commercial technologies for production of products useful for Agriculture**

$MnSO_4$ for agriculture

EXPERIMENT OBSERVATIONS FOR MANGANESE ORE SINTERING

- Low yield with 100% belt spillage material for sintering.
- Good sinter formation with coke fines rather than coal fines.
- High yield is obtained by sintering 100% of high grade manganese ore fines.
- Poor quality of sinter is observed with high siliceous material in the charge blend.
- Environmental aspects are very big challenges in sintering operation

Experiment Conclusion

- **Raw material belt spillages can be sintered in**
- **combination with high grade Mn ore fines only.(Ratio of 20 : 80).**

IMAGES OF SINTERING PROCESS

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Agglomeration of Beneficiated Manganese Ore Fines

SINTERING

Micro-Granulation is a required to sinter the beneficiated Mn Ore fines.

- An acceptable grade sinter (TI : ~70, AI :~10%) can be produced using 10% coke and Mn ore fines.
- Return fines usually generated between 11-13%.
- Feasibility studies has been done for a sinter plant and few sinter plants are also in operation in India and abroad.

BRIQUETING

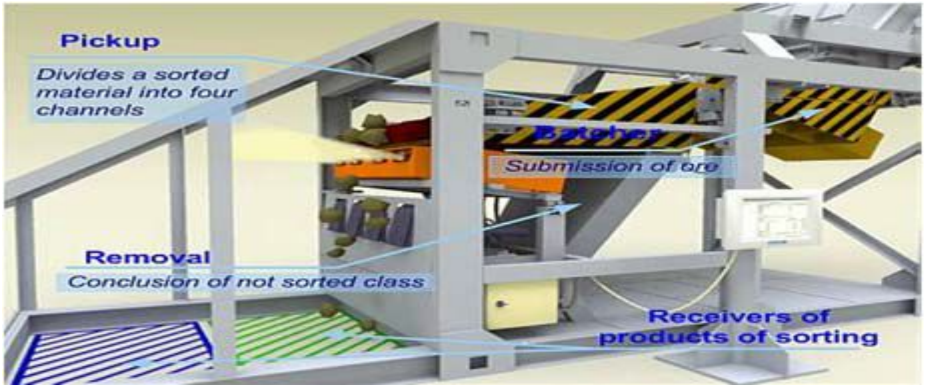
- Mn ore briquettes were produced and trial conducted in different Ferro Alloys Plant.
- 10-15 % briquette usually charged in burden (40 kg out of ore burden of 640 kg).
- No operational problem was faced but increased amount of briquettes can be harmful for closed furnace.
- Many Small scale players are briquetting the fines and using in SiMn product

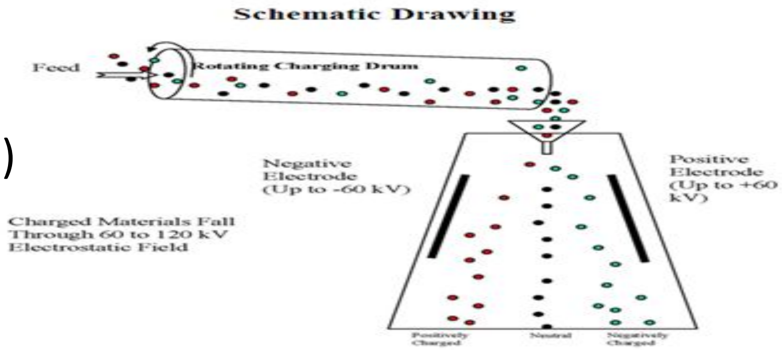
Mn-ORE BENEFICIATION- NEW TECHNOLOGIES

Physical Beneficiation

- **a) Automatic Ore Sorter**
- **b) Electrostatic Separation**
- **c) Magnetic Flocculation**

(a)





(b)

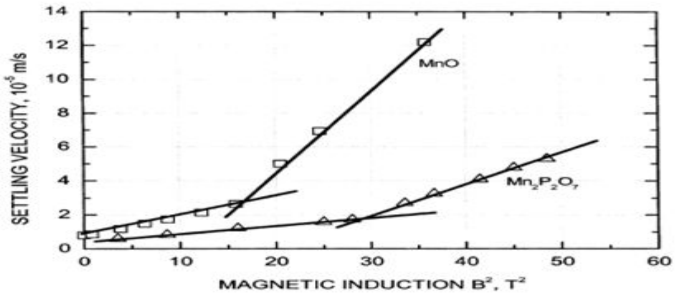


Figure 6. Effect of magnetic induction on the magnetic flocculation of MnO and $Mn_2P_2O_7$ fines (van Kleef et al., 1983).

(c)

Mn-ORE BENEFICIATION- NEW TECHNOLOGIES

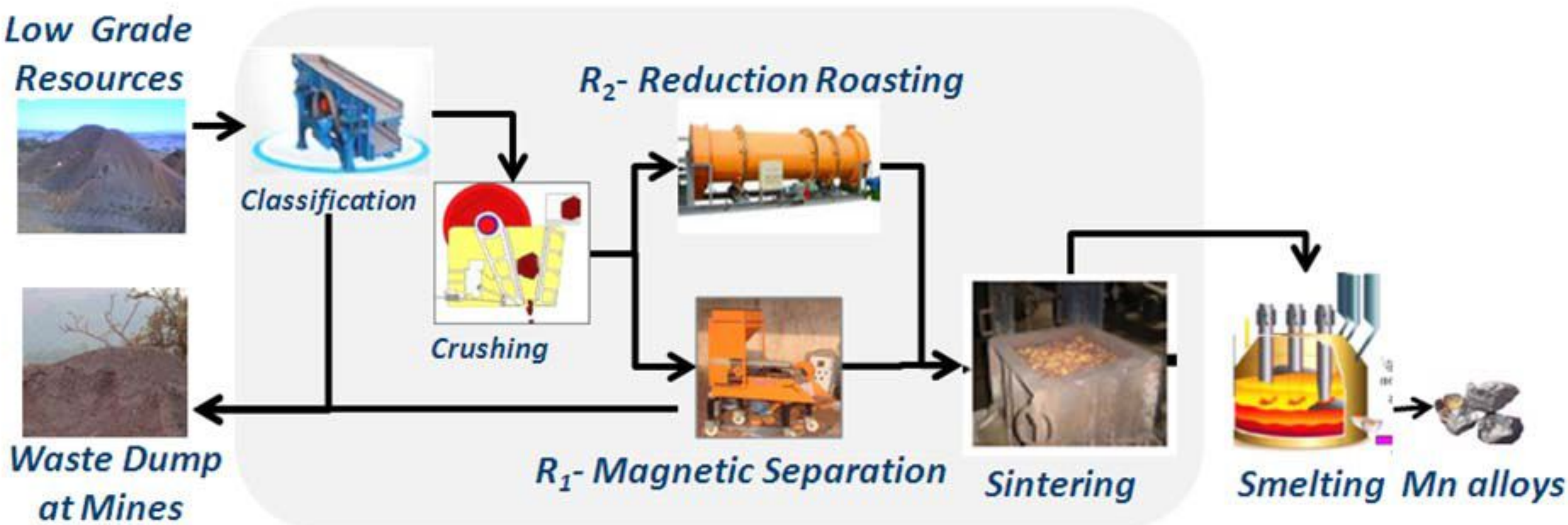
Pyrometallurgical Route
- **Magnetic Separation**
- **Reduction Roasting**

$$2FeO(OH) \longrightarrow Fe_2O_3 + H_2O \quad [1]$$

$$3Fe_2O_3 + CO \longrightarrow 2Fe_3O_4 + CO_2 \quad [2]$$

$$Fe_3O_4 + CO \longrightarrow 3FeO + CO_2 \quad [3]$$

$$FeO + CO \longrightarrow Fe + CO_2 \quad [4]$$



Mn-ORE BENEFICIATION- NEW TECHNOLOGIES

Hydrometallurgical Methods

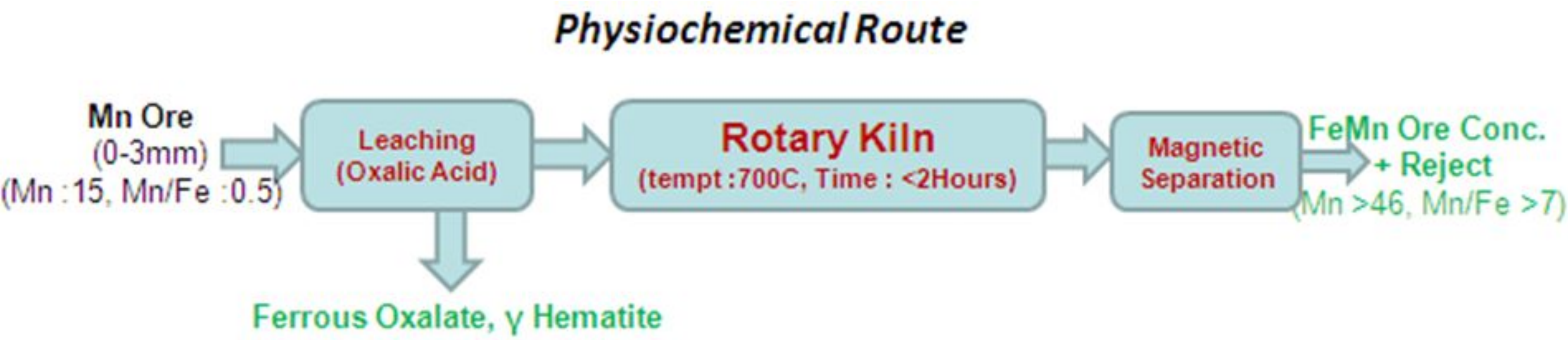
- **Leaching :**

  Reducing agents natural gases, oxalic acid, methanol, carbohydrate, coal, graphite, sulphur dioxide, hydrogen, cornstalk, etc., and then the product was leached with sulfuric acid, HNO3, HCl etc.

- **Floatation :**

  The chemicals of pertrolium, sodium sulphonate and oxidized paraffin soap are used to catch rhodochrosite in floatation dressing.

- **New Methods : Physicochemical Beneficiation**



Mn Alloys Production Process

Input

HG Mn ore

MG Mn ore

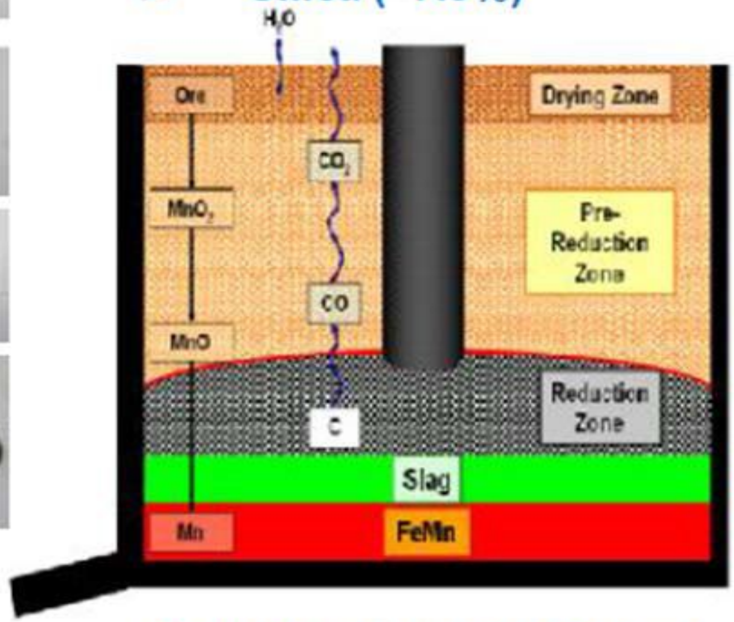
Flux

Coke

Process

Process

- Temp (1350-1380°C)
- Basicity (0.58-0.62)
- Silica (~7.5%)



Reduction stages of Mn ore

$$MnO_2 \rightarrow Mn_2O_3 \rightarrow Mn_3O_4 \rightarrow MnO \rightarrow Mn$$

Slag (180Kgs/T)

Output

Products

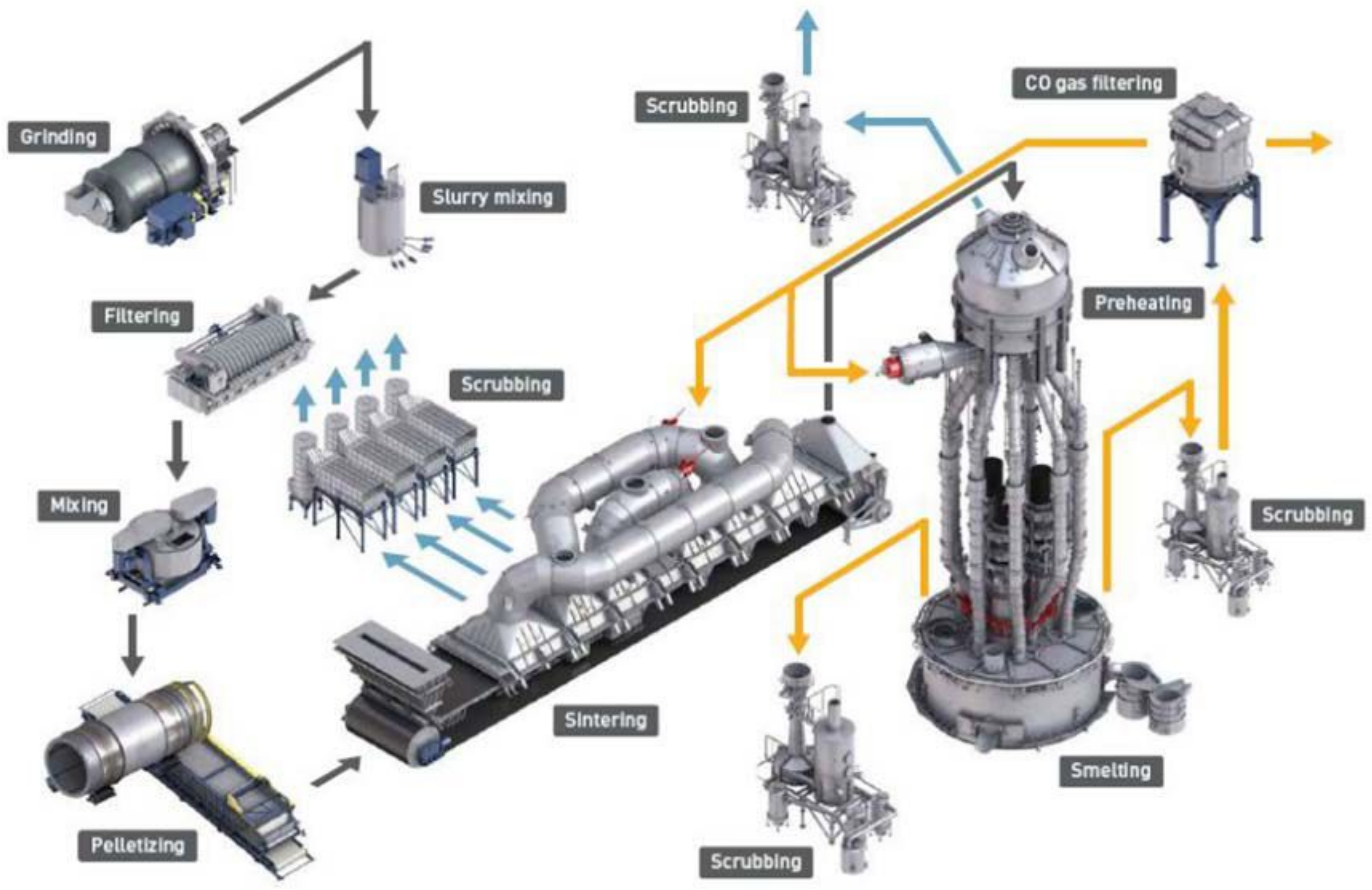
- High Carbon FeMn (Mn=70%)

Slag

- FeMn slag (MnO : 30%-36%)

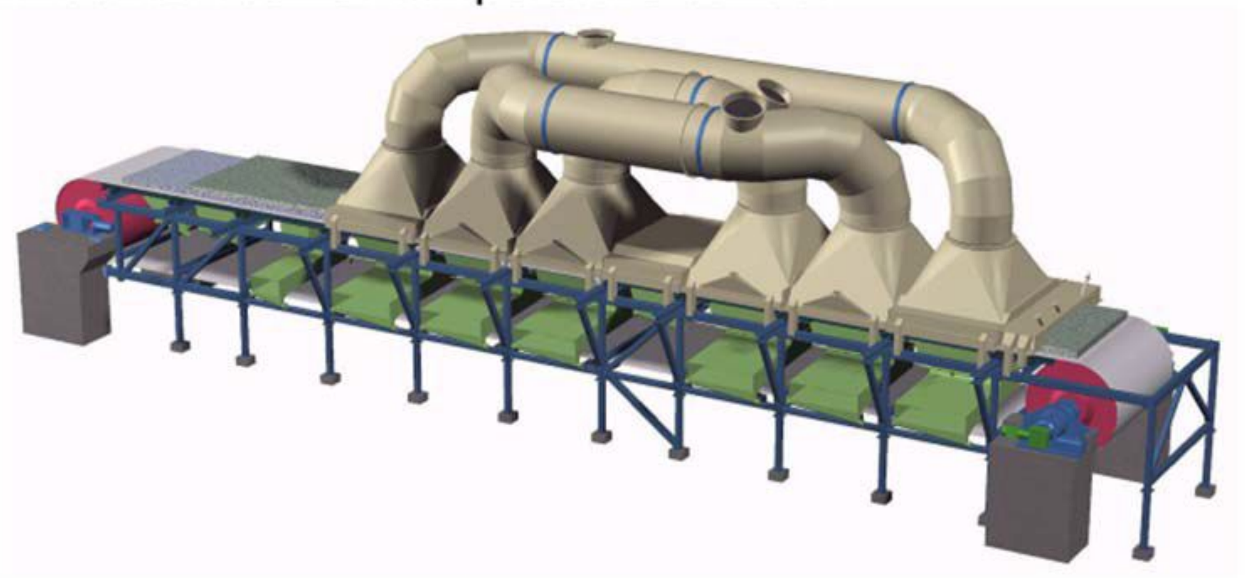
PROCEDURES AT FERRO MANGANESE PLANT

OUTOTEC PROCESS



ENERGY EFFICIENT PROCESS FOR PALLETISING AND SINTERING

- 63% from recycling gases
- 20% from coke
- 10% from concentrate itself
- 7% from burner fuel for temperature control

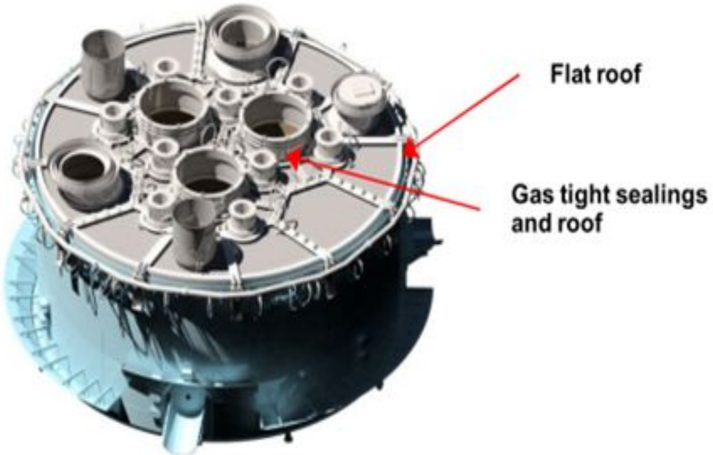


PREHEATING OF THE CHARGE

- Every 100 °C saves up to 70 kWh/t metal in furnace
  - Increased capacity of smelting furnace up to 15%
- Stable smelting furnace operation
- Uses CO-gas which is collected from furnace as fuel

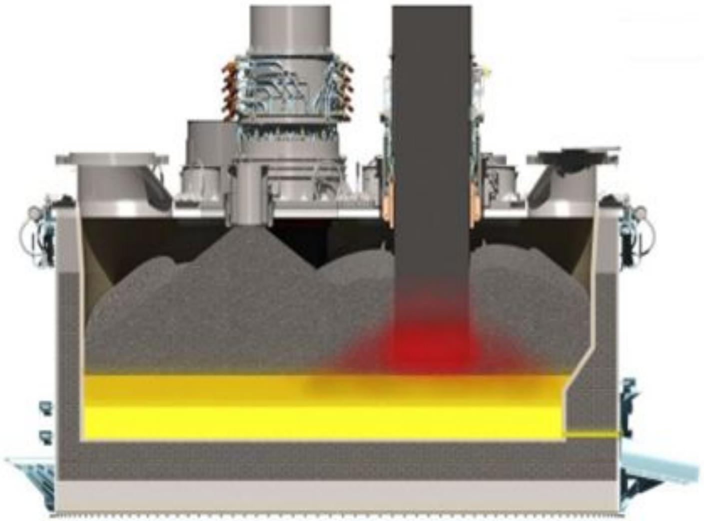
SEALED SUBMERGED-ARC FURNACE

- Gas tight design
- Produces CO-gas for sintering a pre-heating

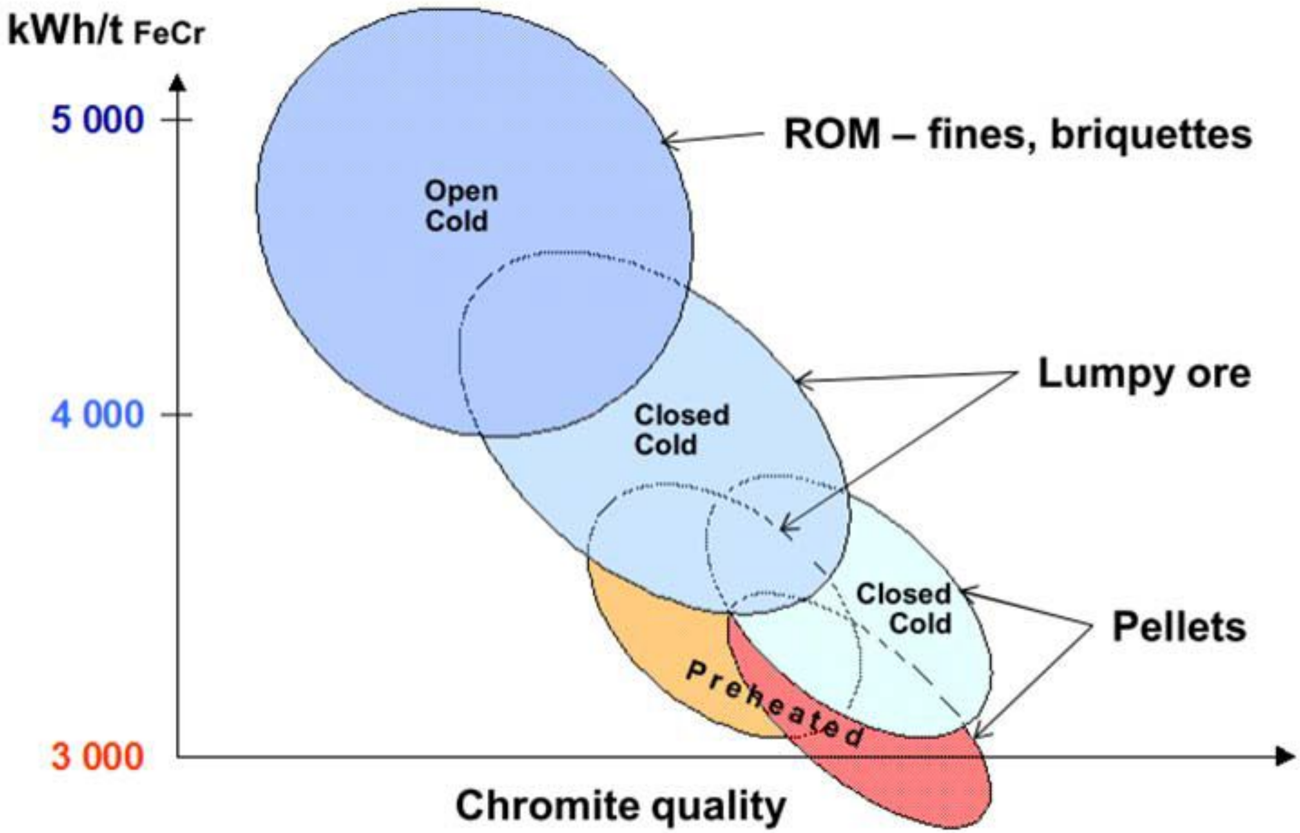


Benefits

- Lower heat losses
  - ➢lower energy consumption
- Lower reductant consumption
- Lower el. paste consumption
- Higher recovery
- Lower emission – minimize Cr6+
  - open 1000-7000 ppm
  - **closed 5-100 ppm**



POWER CONSUMPTION IN SMELTING



PROCESS IMPROVEMENTS TOWARDS MINERAL CONSERVATION

- **Wide variation in the low grade Chrome Ore Quality**

- Buffer Management & Proper Blending

- Good Process Control to Minimise Losses

- Data Bank Generation on Process – Generation of Circuit data
- Distributed Control System (DCS),
- Floatex Density Separator
- TQM Approach – Shift wise Plant performance Monitoring (Daily management)
- Optimization of Process Parameters – such as mill speed, ball size, ball load & pulp density of ball mill

- **Recovery of Ultra Fine Chromite Particles**

- Wash water Spirals, and Vacuum belt filter

- **Tailings Disposal**

-We adopted tailings de-watering technology using Press Filters

- **Reprocessing / Reuse of Stockpiled Tailings**

- - We have developed Tailings Beneficiation process.

IMPROVEMENT JOURNEY IN BENEFICIATION OF CHROME ORE FOR BETTER MINERAL CONSERVATION

OBJECTIVES

- *Economic Use of Mineral*
- *Conservation of Resources for Next Generation*
- *Enviro-Friendly Process Technologies to utilise the resources.*
- *Generate revenues for the stake holders*
- *Statutory Guidelines – IBM, / State Govt*
- *For sustainability of high grade chromite resources and to satisfy the continuous demand in the future needs, beneficiation of lean/sub-grade ores is imperative.*
- *From the mineral conservation point of view, it is necessary to maximize the utilization of lean grade ore and minimize high grade ore consumption*.

BRIQUETTING OF CHROMITES ORE

- ***In developing a technology for briquetting of chrome ores, it is important not only to study the mineralogical and grain-size characteristics of the chrome ore fines but also to make an informed choice of the type and quantity of the binder and the conditions for producing a physically and chemically competent green and cured briquette.***

- ***The molasses-lime combination binding mechanism involves the adhesion of molasses due to stronger intermolecular forces in the sucrose structure that confers the initial green strength. The second stage which occurs during curing involves the dissolution of CaO and is characterized by chemical and polymeric metal complexation to form the calcium saccharate bond between lime and molasses (hot briquetting - with the "gluing" action caused by the binder).***

LAYOUT MODIFICATION OF BRIQUETTE PLANT

- **Briquette plant should be set of at back site of furnace building, adjacent to pollution plant.**
- **Briquette plant should be adjacent to chrome ore stock shed.**
- **Briquette plant should be surrounded with thick green plantation as per the forest and environment department concern.**
- **Briquette stacking length should be more (approx to sixty meters) with as possible as low drop height (approx- 1.5 mtrs)**

- Briquette stacking design should be taken in such a concrete platform that each lot having conical base with pneumatic opening mechanism to down load upon conveyor which will to be installed in under ground ways.
- Briquette feeding to day stock bin from briquette stacking yard should be through conveyor only keeping close watch that briquette bin level should be 60-70% always.

CHUTE TUBE FILLING PATTERN

- Alternate chute tube should be filled with charge always which will give initiation for pre-heating
- Centre chute should be kept full with charge material always.
- Chute discharging point at furnace hearth should be minimum level of height from rim only

DESIGN OF POLLUTION PLANT

- Furnace generated flue gas through chimney ducting to pollution plant-bag filters-pollution stack should be connected to chrome ore shed with special design of ID-fan.
- Temperature of filtered flue gas is around 100-120 degree centigrade which will help for pre heating of ores at initial stage- minimising FO consumption in dryer.

FURNACE OPERATIONAL POINT OF VIEW

- Required charge level in furnace hearth.
- Required electrode length as per the furnace design.
- Good agglomeration of chrome fines to have sufficient strength in furnace charge burden. This minimises fines generation(taking 72 hrs cured briquette as a feed) Fines generated reverts to slag phase thereby reducing chromium recovery.
- Proper stoichiometry calculation as well as choice of reductants to reduce Cr_2O_3 in ore, which prevents Cr_2O_3 losses in slag.
- Proper selection of reductants having good reactivity(CRI & CSR> 50) and strength. This ensures proper reduction of Cr_2O_3 in ore

- Increased heat efficiency by suitable selection of current and voltage ranges with proper electrode tip positioning(0.7-0.75 x electrode diameter). This improves thermodynamics and kinetics of reduction.

- Proper selection of slag composition. This reduces Cr_2O_3 losses to slag and entrapment of Ferrochrome alloy droplets in slag.

- Proper mineralogy ,size and reducibility of chrome ore also affects for Cr_2O_3 losses into slag.

- Since reduction of chrome ore in solid state is significant, fine ores(chipps) could be used in the furnace. The fine chrome ore is very readily reduced in solid state before it is melted, resulting in a low Cr_2O_3 content of the slag.

- Proper permeability of charge material should be there to effectively utilize CO gas for reduction. For this size range should be as close as possible because wide size range blocks void space in charge materials.

- Too high silicon content in the alloy can reduce Cr_2O_3 dissolved in slag by silico-thermic reaction and in turn the Si content of metal decreases, but this reaction is only significant at high Si contents.

- **If the Cr_2O_3 content in the ore is too high , some of the chromium oxide will not be totally reduced and could be observed in the tapped slag.**
- **There is an optimum range for the reducibility of ore. The MgO/Al_2O_3 ratio is directly proportionate to the Cr_2O_3 in the slag. The optimum ore is with MgO/Al_2O_3 between 2.2 to 2.5(chrome ore from Iran). In this range Cr recovery is above 90% and the energy consumption is the lowest.**
- **Suitable furnace hearth design parameters like KVA/square mtrs of hearth area(350-450), KVA/cubic mtrs ofhearth volume(100-250), KVA/ square mtrs of electrode pitch circle area(1500-2500) determines optimum smelting conditions thereby effecting chromium recovery .**

- Feed consists of temporarily bound fines with higher specific surface are which in turn leads to improved reaction kinetics and thermodynamics leading to the improved energy utilisation efficiency and smelt ability.
- Slag chemistry should be maintained in such pattern that always melting point of slag(1650-1750 degree centigrade) is > melting point of metal by minimum 150 degree centigrade
- Metallurgical calculation should be based keeping metal volume more then the volume of slag

- **Basicity of the slag should be maintained within the range 1.1-1.2 to have the easy separation as well as easy flow of alloy and slag.**
- **Silica in the slag should be maintained within the range 28-30(basic slag) to obtain the slag temperature above than metal, that is why when alloy become low-silicon due to certain reason, silica increased in slag(above 30) which lower the slag temperature and initiates for poor separation of metal and slag, as a result alloy become porous with slag contamination.**

- **Hot alloy tapping should be taken with short runner with 2-nos CI- circular pan placing in series upon a well design track-trolley in different level and slag to be taken in slag pot connecting a adjustable runner.**
- **Tapping planning should be done in such pattern that all total of alloy of a tapping should be accumulated in 1st pan.**
- **Hot alloy carrying pan should not taken for realeasing before 5-hrs of tapping in order to avoid leakage.**

METAL HANDLING POINT OF VIEW

- At metal handling yard (adjacent to tapping bay),slag layer above the metal face on pan should removed effectively, prevailing to contamination.
- During sizing (10-40 mm) care should be taken upon repeated hammering. Taking lumps size (40-150 mm) order is better.
- Slag contaminated metal should be processed again and again (screening as well as picking) as maximum as in the metal handling yard before sending to jigging plant.

- Double jigging should be taken in same series after getting the tailings from two floating baths(one for size rang of feed 8-20 mm and other 0-8 mm placed parallely. The double jigging machine placed on series should take the material(tailings) from previous two jig's output get mixed (via one intermediate crusher to have -6 mm size) in one feed conveyor, which may give you 2-3 % of metal output of total tailings get fed.

REDUCTION REACTION INSIDE FURNACE HEARTH

. *SiO2 + C = SiO + CO*

2. SiO + 2C = SiC + CO

3. 2SiO2 + SiC = 3SiO + CO

4. SiO + SiC = 2Si + CO

5. SiO2 + 2 C = Si + 2 CO

6. Fe2O3 + 3 C = 2 Fe + 3 CO

7. A1203 + 3 C = 2 Al + 3 CO

8. CaO + C = Ca + CO

MnO2 → **Mn2O3** → **MnO (Low oxidation statae)**

Mno + C = Mn + CO

Cr_2O_3	+	3C	=	2Cr	+	3CO
Fe_2O_3	+	3C	=	2Fe	+	3CO
SiO_2	+	2C	=	Si	+	2CO
P_2O_5	+	5C	=	2P	+	5CO

RATE OF SMELTING REACTION

Solid- Gas reaction at (750-1000)degree centigrade

- Stability of material at hot bath
- Having more porosity
- Having more surface area
- Reductant & Flux should be in close proximity(Composite Briquette- Flux + Reductant grounded to 175 micron size then taken with as usual 6-mm ore to make composite briquette in press with the application of binder)) – drop of specific power by 200-250 Kwh
- Preheated as well as in same vicinity (palletising- all three components, ie- ore, flux & reductant are grounded to 175 micron then sintered palletising at steel belt) – drop of specific power by 450-500 Kwh.

CONCLUSION

Maximum portion of the income of Ferro-alloy manufacturers is taken away by electricity. Hence the aim of any metallurgist is to innovate and try to adopt processes which will help bring down the power consumption as power is precious (40% cost) in smelting reaction process or to use cheapest source of energy in pursuit of this –

1)SHOWA DENKO, 2) OUTOKUMPU which was later modified by X-strata processes were developed. Now one has to try for solid state reduction using natural gas along with Nitrogen & Hydrogen. This should be the latest innovation. As charge pre-heating origin from Japan , Outokumpu procedure origin from Finland and later on X-strata (complete premus process)origin from South-Africa keeping an unique ambition of Sp.power reduction/cost


thank you!
Happy to answer any additional queries