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Theme: Eletric Steelworks

DEDUSTING SYSTEM: A HOLISTC VIEW*

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Abstract

Technological developments, associated with the constant worry about the environmental impacts arising from industrial activity, it has driven the development of technologies and practices for efficient fumes and particulates capture arising from the manufacturing processes of steel in steel plants in general. Currently, the electric steelshops in operation with Electric Arc Furnaces (EAF), seek parameterize/design dedusting systems able to retain most of the particulates generated during melting and refining of steel in FEA through configurations of equipment, technologies and parameters operation in order to equalize the antagonistic relationship between effective fumes capture and energy balance of the EAF.

The present work gets as a fundamental premise to evaluate critically the possible different settings of the usual dust removal systems, as well as their respective classical parameterizations. The work main purpose is to establish a general rule evaluation technique for dedusting system considering the different modes of operation of an Electric Arc Furnace.

Keyword: Dedusting system; EAF; Adjustiment; Techology.

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1 INTRODUCTION

Steelmaking is an energy intensive process. As a consequence, energy optimization and efficiency increase are important research topics in steel industry. As an example for a steelmaking process the energy balance of an electric arc furnace is discussed in this section. The thermal emissions of the electric arc furnace depend on the input energy mix. The Sankey diagram gives an overview of the in- and output energy flows, as shown in Figure 1.

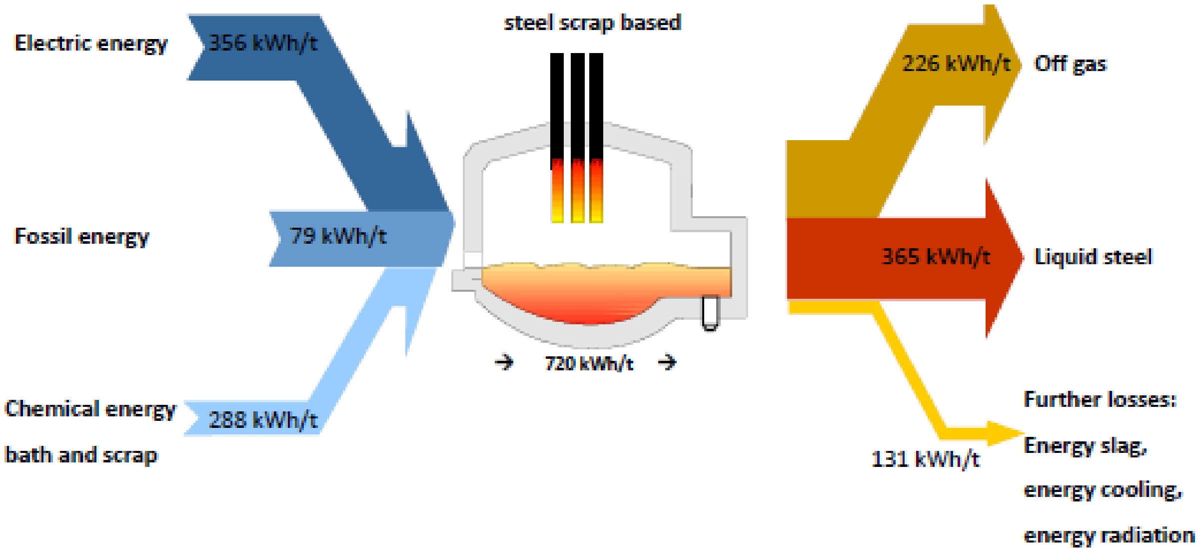

Figure 1. Typical Sankey diagram of an Electric Arc Furnace [1].

1.1 Inlet Energy

According Kirschen [2], the Sankey diagram shows that about 50% of the necessary smelting energy in an EAF is provided by electric energy. The major part of the residual energy input is related to the exothermic chemical reactions in the steel bath. These result from the oxidation of combustible materials in the charged scrap, iron and alloying elements. The remaining energy supply results from the natural gas burners in the furnace and the combustion of charged coal.

1.2 Outlet Energy

Regarding the outlet energy flows the major part of the energy leaves the system with the discharged liquid steel and slag. The further energy amount is the heat transferred to the cooling system and the sensible heat of the off-gas, which is about 20-30% of the input energy. These two energy flows are in the focus for heat recovery. Further losses are caused by radiation during furnace charging, by leakage air and by the water cooled panels of the furnace shell. Some of the largest fluctuations in temperature and mass flow in steelmaking processes occur in the off-gas of electric arc furnaces. A characteristic temperature and mass flow profile based on measurements of an electric arc furnace is given in Figure 2.

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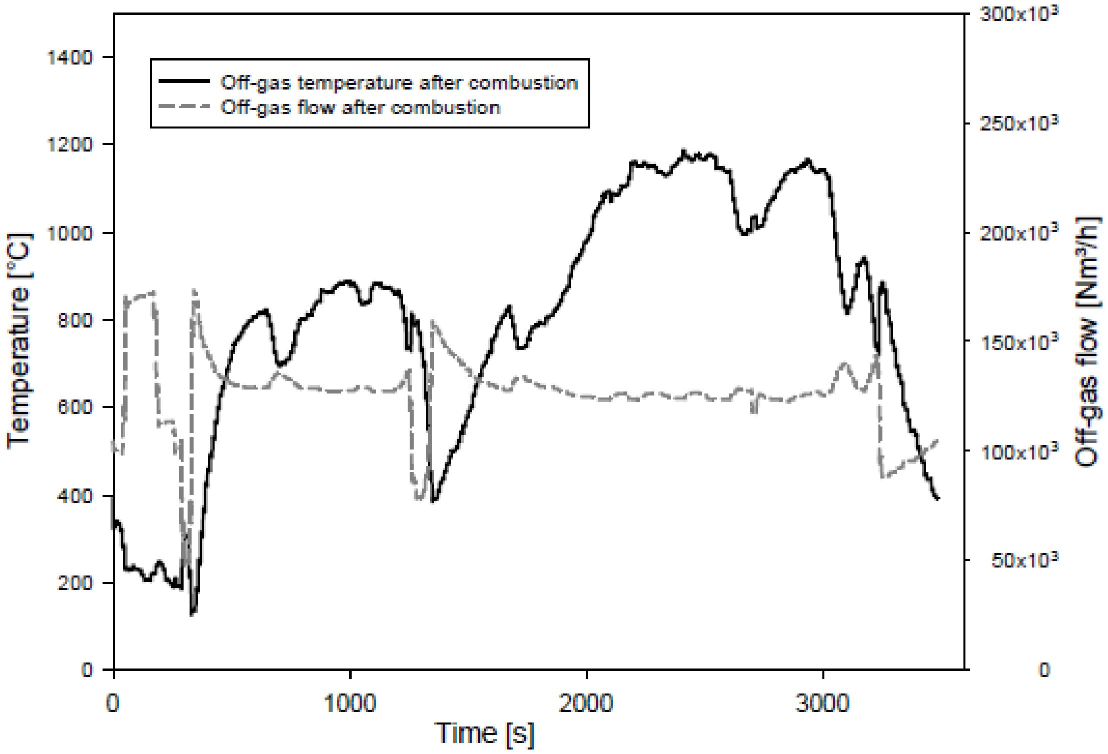

Figure 2. Off-gas profile of an 120to electric arc furnace based on measurements.

Based on these facts, the study of dedusting system extraction profile got an expressive place in the steelmaking processes, because through of it it’s possible to improve the energy consumption of EAF’s.
The dusting system can be divide into two parts:

- the primary extraction system, The defined as the system that controls the emissions directly from the furnace during melting. and
- the secondary extraction system, defined as the system that controls the emissions out of the furnace hole and roof, each one with your own particularities [3].

1.3 Primary Fume Control System

The primary fume control system is defined as the system that controls the emissions directly from the furnace during melting. The design of primary fume control system is based on providing sufficient system capacity to accommodate the heat and volume of the off-gas evolved from the furnace. The important factors that affect the design are as follows:

- Melting practice
- Furnace geometry (openings)
- Fume evacuation method and, in this case, the “dog house” enclosure evacuation

1.4 Secondary Fume Control System

The secondary fume control system is defined as the equipment required for control of charging and tapping emissions in case the ‘doghouse’ enclosure is not utilized. A canopy hood is part of the secondary fume control system and its main purpose is to

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control emissions generated during the charging and tapping operations. It could also be used to collect intermittent fugitive emissions from melting operations when, for any reason, the 'doghouse' enclosure is not fully closed and utilized [4].

Furnace charging plumes consist of three phases. The first phase occurs when the roof is open. At this point the plume is the result of the airflow induced by the molten steel in the furnace (open furnace flow). The second phase occurs as the scrap bucket opens and charges the furnace. The airflow is a result of the air displaced by the scrap that causes the combustibles in the charge to ignite. This results in fireball characteristics of the EAF charging plume. The final phase (post surge) occurs as the bucket clears the furnace. At this point the emissions are caused by the buoyancy induced by the hot furnace and the burning combustibles in the scrap [5].

To control charging emissions, off-takes must (at minimum) have sufficient exhaust to accommodate the continuous portion of the plume (open furnace and post surge flow). It is not practical to supply sufficient exhaust to match the scrap charging plume peak flow rates because of the excessively high exhaust volumes required. The short duration peaks (scrap charge fireballs) may be stored in the hood storage space where the fume system can gradually exhaust them. Charging emissions are usually quantified using field observations and video recording measurements [6].

In addition to the required exhaust capacity, the secondary system design basis includes the physical dimensions required for the canopy hood to function properly for the capture of charging fumes. The canopy hood should:

- Physically cover the largest plumes generated during charging.
- Have sufficient storage volume to contain the charging plume until the exhaust system can evacuate the fumes from the hood.
- Have a face velocity of at least 0.5 m/s to contain emission within the hood and tiered roof to ensure appropriate fume storage re-circulation flow pattern.
- Have vertical sidewalls deep enough to ensure the rising plume fully enters the hood without a change in the momentum in relation to the meltshop building depending on the charging crane geometry and meltshop height.
- Have hood exhaust rate to match the continuous plume source (i.e. the higher of open furnace / post surge flow).

Tapping emissions are caused by the motion of air resulting from the molten steel flowing into the ladle. Unlike scrap charging, the plumes are produced at a constant flow rate with duration of approximately 1 to 1.5 minutes. Exhaust rates, sufficient to match the tapping plume flow rate, must be provided to control tapping emissions [7].

2 METODOLOGY

For this work, the main propose was evaluate the capacity of extraction by each system and, of course the emission control. By this, the dedusting system was divide into three parts:

- 4th hole,
- dog house and
- secondary, and different heat sources were simulate in order to evaluate simultaneously the capacity of the dedusting system not only to control the fume emission, but also, to optimizing the energy losses.

For this, it has been defined three scenarios:

- protected the equipment;
- improving the furnace energy;
- optimizing both of then.

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The Figure 3 shows the different scenarios describe bellow.

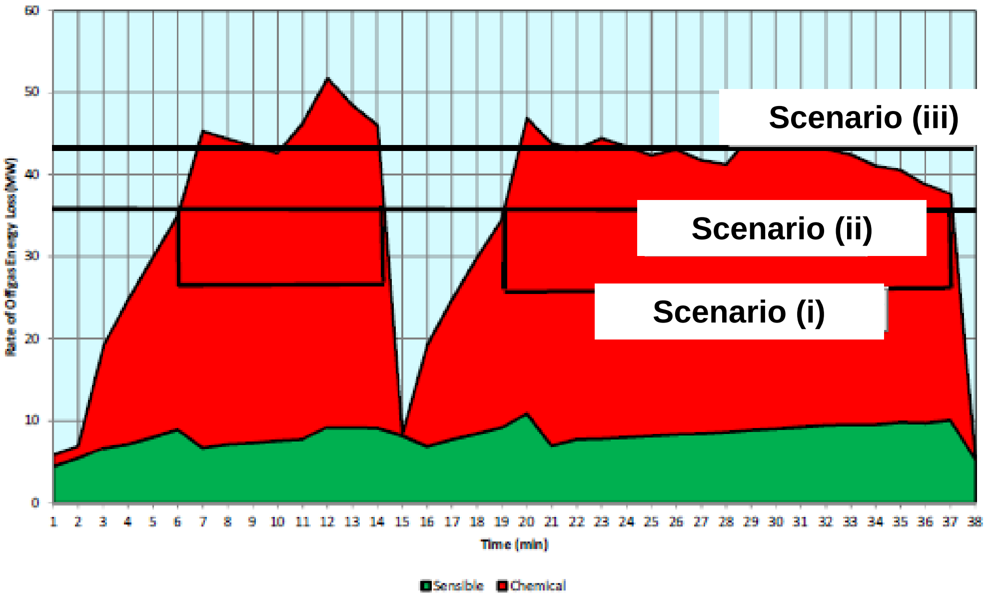

Figure 3. Three different scenarios evaluated by the work.

2.1 Furnace Parameters

For the scenarios simulations, the follow parameters has been used, according Table 1.

Table 1. Furnace Parameters.

Parameter	Units	Future
Furnace Diameter	m	5.0
Power on time	Min.	38
Number of charges	#	2
Metal tapped per heat Max / Avg	tonnes	55 / 52
Carbon content of steel after ref. (min.)	%	0.03-0.12
Oil in scrap	%	2
Total Heel	tonnes	10
Maximum active power	MVA	45
Average power input	MW	30.8
Total energy consumption per heat	kWh	19,500
Total energy consumption per heat	kWh/t	375
Oxygen Lances	#/type	1/Manipul
O2 lances Maximum injection rate	Nm^3/h	~2,300
Total lances O2 input per heat	Nm^3	1533
Total O2 usage per heat	Nm^3	2,014
Total O2 usage per heat per tap tonne	Nm^3/t	38.7
Max. C (graphite) injection rate	kg/min	80
Total C (graphite) injection per heat	kg	400
Burners	#/type	3
Capacity per burner	MW	3.5
Burner total gas input per heat	Nm^3	433
Burner gas usage per heat per tap ton	Nm^3	8.3

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This information was used as input for the furnace model. It should be noted that not very aggressive furnace practice was chosen for model simulation.

Several different scenarios variations were investigated and modeled to achieve the worst possible operating conditions for the fume control system design. Most of the modeled scenarios achieved, or were close to, the required tap temperature and carbon content in the specified time range.

The furnace model output data, showing several possible scenarios with example heat load profiles, are shown below. The worst-case off-gas energy profile peaks for the fume control system requirements ranged between 45MW and 55MW. These peaks were typically short in duration. The resulting heat load profiles and off-gas chemistry prediction were used to establish the design basis for the emission control system. The primary fume control system would be unnecessarily oversized for most of the heat if designed to evacuate all fumes during the peak heat loads. Therefore, throughout typical operation it can be expected that a portion of emissions generated during the peak heat loads (only intermittent and not continuous fugitives) should be evacuated with the furnace enclosure (dog house) and/or modified canopy hood system. All modeled cases were analyzed and the summaries of results were used to estimate 4th hole requirements. The possible primary fume control system design bases were determined based on the resulting off-gas energy profile peaks and our experience.

2.2 CFD Modeling

CFD modeling is a numerical technique of solving the basic fluid flow equations, which arise from an analysis of the physics of fluid dynamics. A flow regime is divided into a large number of smaller volumes called cells. This collection of cells is usually referred to as the solution grid.

In a basic CFD analysis, the partial differential equations representing the conservation of mass, momentum and energy are applied to each cell. Due to the relationship between each cell and its neighbors, the set of equations representing all the conservation equations for all the cells in the flow domain results in a higher number of non-linear, coupled partial differential equations. A CFD solver is used to iteratively solve the set of equations. The computational domain consists of the equipment internal dimensions. Flow is permitted to pass into and out of the simulation region as required to balance mass momentum and energy.

In addition to the basic flow equations, those representing turbulence, density, and fume-air mixing were included in the CSN new equipment models.

There are many advantages of using CFD modeling techniques. Foremost among them are that they enable one to investigate flows where it is not possible to make direct observations (e.g. inside the canopy hood during charging surge) and to investigate the resulting flow that would arise from changes to the input conditions before actually implementing the change.

Note that in situations where flow field observations and measurement are not available it is not wise to draw direct quantitative conclusions from the models without proper validation. It is, however, appropriate to use the models to draw qualitative conclusions from the simulation results.

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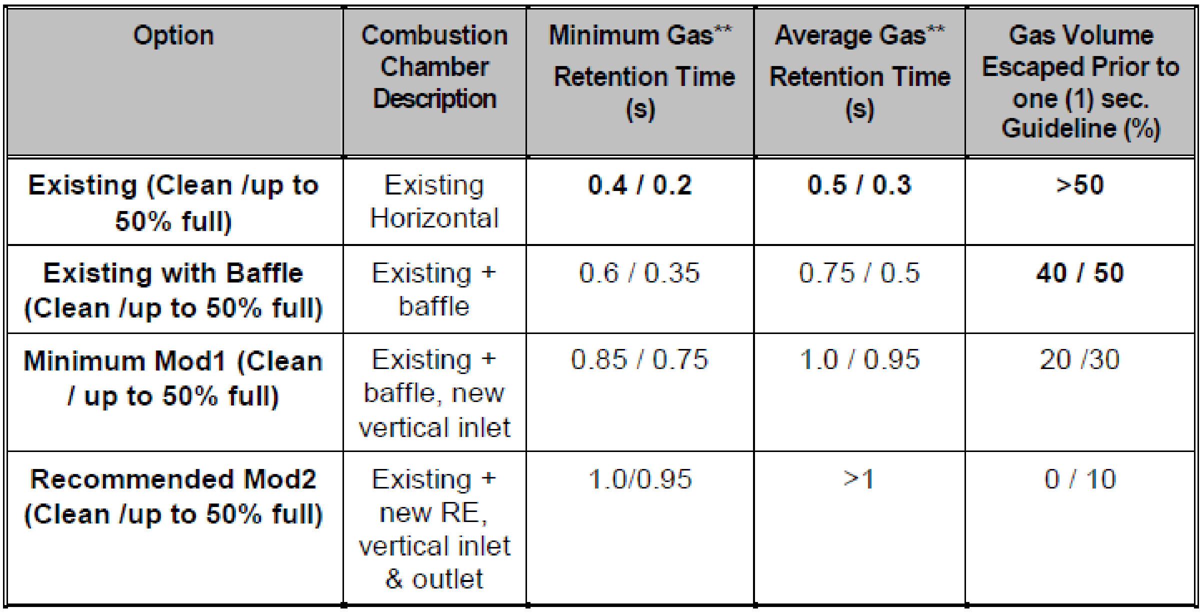
3 RESULTS AND DISCUSSION

3.1 Combustion Chamber

The combustion chamber performance conclusions were result of the modeling and related calculations. A summary of the modeled options and related results are presented below in Table 2.

Table 2. Summary of CFD Modeled Results (during peak heat load)



Option	Combustion Chamber Description	Minimum Gas** Retention Time (s)	Average Gas** Retention Time (s)	Gas Volume Escaped Prior to one (1) sec. Guideline (%)
Existing (Clean /up to 50% full)	Existing Horizontal	**0.4 / 0.2**	**0.5 / 0.3**	**>50**
Existing with Baffle (Clean /up to 50% full)	Existing + baffle	0.6 / 0.35	0.75 / 0.5	**40 / 50**
Minimum Mod1 (Clean / up to 50% full)	Existing + baffle, new vertical inlet	0.85 / 0.75	1.0 / 0.95	20 /30
Recommended Mod2 (Clean /up to 50% full)	Existing + new RE, vertical inlet & outlet	1.0/0.95	>1	0 / 10

3.2 Canopy Hood

Selected canopy hood geometry designs were tested for charging plume capture & evacuation efficiency to show the difference in performance. Canopy hood exhaust flow rates ranging from 400,000 to 1,000,000m3/h were used to determine the efficiency curves. Charging scenario with timeframe for the fully open furnace roof of 10:10:10 (10 seconds open furnace flow, 10 seconds charging bucket surge, 10 seconds post surge flow) was used to create and compare performance curves. Figure 4 shows modeled results and visual comparison of the canopy hood charging performance results.

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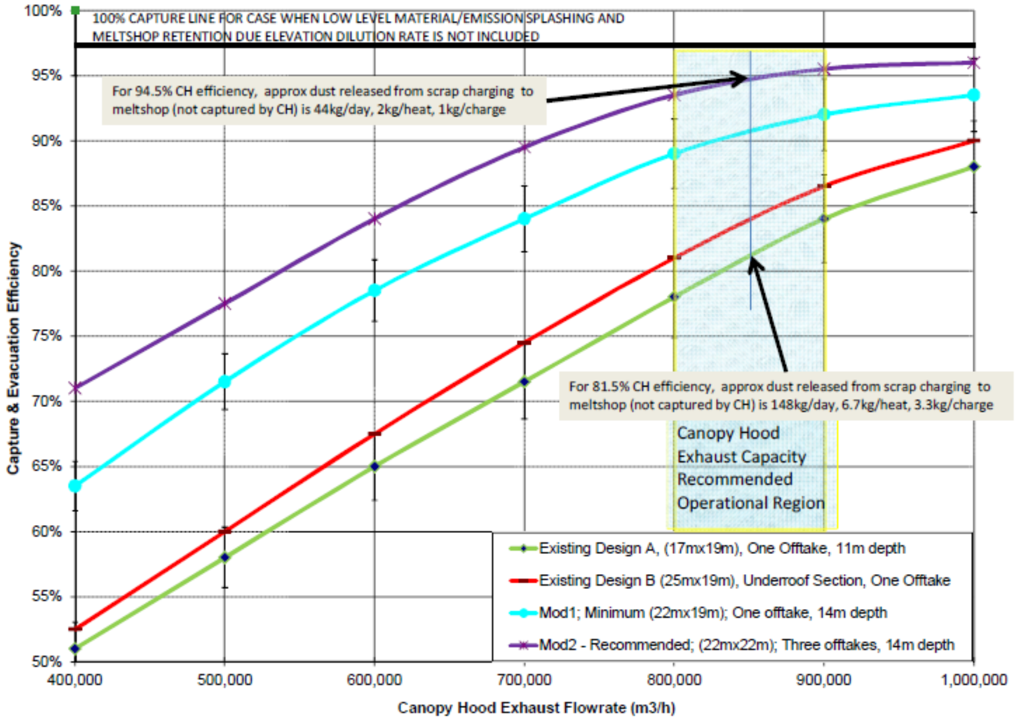

Figure 4. Canopy Hood Charging Performance Curve (30sec Charging Fully Open Furnace Roof Operation, 1m/s Indoor Air Draft).

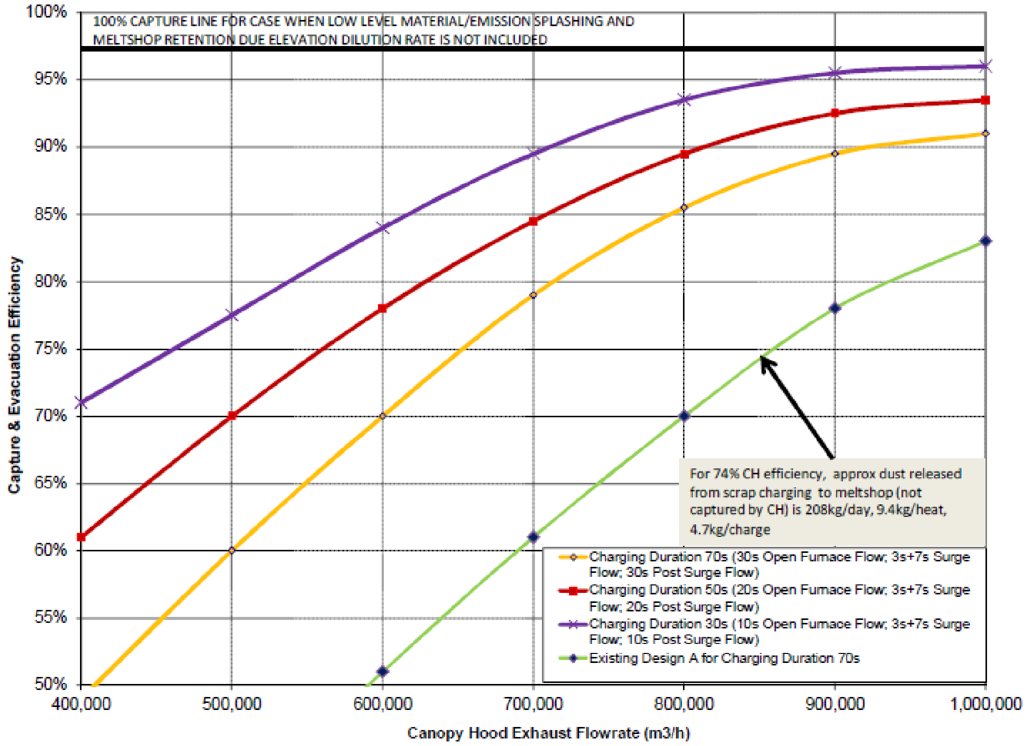

Figure 5. Canopy Hood Charging Performance Curve - Charging Fully Open Furnace Roof Operations Duration.

The longer open furnace duration leads to decreased canopy hood exhaust efficiency.

The canopy hood recommended geometry design Option Mod2 was also tested for various indoor air cross drafts to show the changes in charging fumes

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capture/evacuation efficiency under different operational conditions. Estimated air cross drafts varied between 0.5 and 1.5 m/s. Therefore, three different conditions (0.5, 1.0 and 1.5m/s) were modeled. The results are summarized visually in Figure 6.

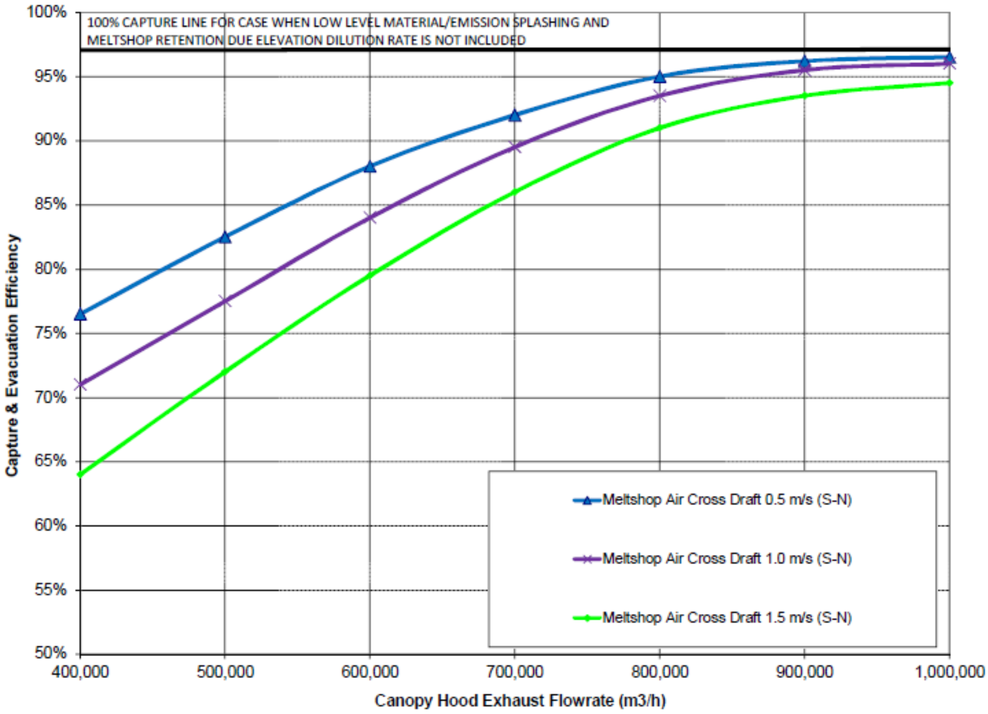

Figure 6. Canopy hood charging performance curve - meltshop air cross drafts comparison.

4 CONCLUSIONS

Based on the results showed in this paper, it's clear to see that it's pretty possible to operate either protecting the dedusting system or improving the EAF energy losses. On the other hand, it necessary to evaluated some specific design parameters in order to check if the design allow or not to work optimizing the furnace without damage the dedusting system.

The CFD results show that it's possible to balance the heat source by EAF into the primary and secondary extraction holes in order to avoid either problems in the bag house or in the energy capture from the EAF.

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