CONTINUOUS IMPROVEMENT FOR FUGITIVE EMISSIONS CONTROL

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ABSTRACT

The ferroalloy industry is well aware of the benefit and need for continually improving the control of emissions generated from operations because of the positive benefits to employees, the community, and the environment. With this in mind, ERAMET Norway Sauda (ENS) recently developed a programme for the continuous improvement of fugitive emissions control in the refining area of their smelter. The first step of this programme was a series of linked studies that provided a holistic view of the generation and mitigation of fugitive emissions. The linked studies included benchmarking existing conditions, attaining an understanding of the interactions between operations and the generation of fugitive emissions, the development of conceptual solutions that work within the constraints of the refining operations, and performing a techno-economic evaluation of the developed solutions so that the priority for implementing solutions could be established.

The successful completion of this work required a diverse set of skills to develop the necessary understanding of all the issues affecting the generation and capture of fugitive emissions, and the experience to know what is necessary for conceptual solutions to work. This paper describes the methodology used in completing the first step of ENS's continuous improvement programme for fugitive emissions control and the outcomes that were achieved. In addition, some examples of work completed to date by ENS to monitor and improve the control of emissions are discussed.

1 INTRODUCTION

Emission control is an ongoing concern throughout the ferroalloy industry. Increasingly stringent regulations on emissions to the environment and contaminant concentrations in the workplace along with the desire to increase production and improve the working environment all require continual improvement to emission control systems. Investments in these systems benefit employees, the surrounding community, and the environment.

Developing cost effective solutions for reducing emissions in an operating plant can be a challenge. Difficulties often arise in understanding the complex interactions between various operations and multiple emission sources, the performance of the overall building ventilation, and changing weather conditions. Not withstanding, the solutions that are developed must work within the constraints of the exiting operations while being cost effective. This is particularly true because, although investment in emissions reductions provide clear benefits to health and safety and community relations, they are not typically perceived as having direct payback, e.g., through increased pay metal production. Given these challenges, the successful completion of these studies requires a holistic view of the issues, diverse skill set and relevant experience in knowing what will work.

This paper discusses a series of linked studies recently undertaken to develop a program for fugitive emissions control in the refining area at ENS to ensure that regulatory standards were met, targets for continuous improvement were being achieved and to prepare for planned expansion projects.

Figure 1 shows the layout of the furnace hall, in which the majority of equipment considered in the present study is located. The smelter at ENS has undergone numerous changes throughout its life, and adapting the layout and building structure for modernized operations always represents a challenge.

The approach taken for achieving fugitive emissions control improvements is as follows:

1. Complete an inventory of the emission sources
2. Benchmark the performance of the existing equipment in use to capture and clean the emissions.
3. Study the interactions between various sources of emissions, the different operations, and overall building ventilation characteristics.
4. Develop concepts for improvements
5. Estimate the costs associated with these improvements and then prioritize them based on technical and economic considerations.

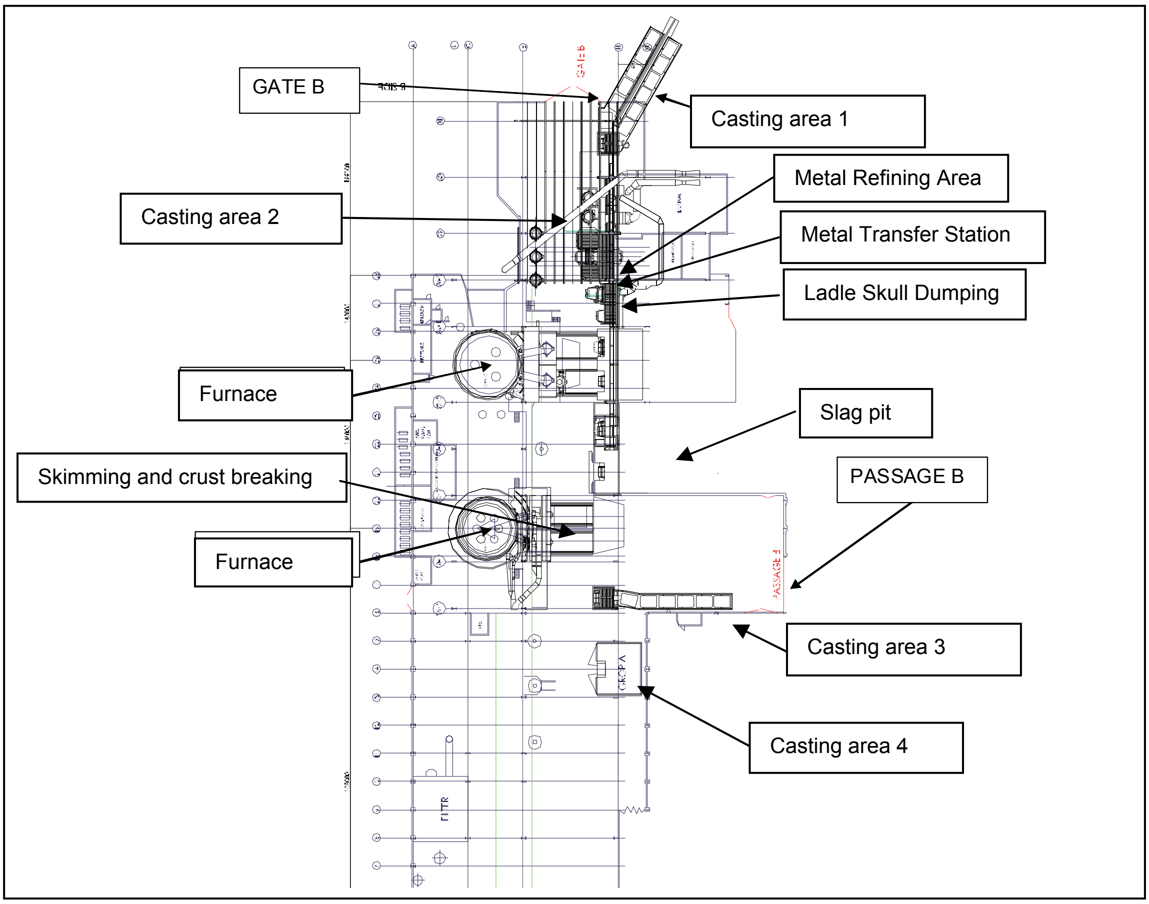

Figure 1: Layout of the furnace hall.

2 EMISSIONS INVENTORY

The first step in the analysis of the plant fume and dust emissions is to perform a detailed inventory of all emission sources. The objective of the analysis is to clearly understand what emissions are being generated, the release rate at each point, and the plant processes and practices that result in their production. For a comprehensive evaluation, the list of emission sources should be combined with the plant layout and location of the stations at which detected emissions are being generated.

In developing a quantitative understanding of the characteristics and behaviour of fugitive emissions, the following steps are followed:

1. Complete a fume and dust emissions inventory for the smelter. This requires identifying all emission sources for both normal operations and upset conditions.
2. Use quantitative methods to measure the rate and composition of the emissions generated. This includes opacity measurement techniques, direct sampling techniques such as cartridge filters, and numerical modeling tools such as computational fluid dynamics (CFD). Sampling information is logged and trended to develop clear understanding of fugitive emission behaviour and the operations responsible for the diffuse emissions.
3. Use atmospheric dispersion modelling software, such as Calpuff, to help characterize the dispersion of the fugitive emissions for different environmental conditions.

The data generated from this work is used as inputs to the engineering solution development work. In addition, the modeling tools can be used to provide a predictive understanding of the impact of proposed changes to equipment or operations.

The diffuse emission sources that have been identified at ENS in the refining area of the smelter are listed in Table 1. Most of the listed processes occur inside the smelter; therefore fumes that are not being captured through the fume control system are introduced to the outside environment through roof openings. Two exceptions are the slag pit and west sand bed, both of which are located outside the building.

Table 1: Diffuse Emission Sources in the Smelter

Diffuse Emission Source	Hooding
Casting area 4	Yes
Ladle skull dumps for recycle	Yes
Casting pit area 3	Yes – only at pour point
Furnace 11 & 12 pouring into slag pit - inside	Yes
Slag skimming station	Yes
Metal transfer station	Yes
Metal refining area	Yes
Casting area 2	Yes
Casting area 1	Yes – only at pour point
Furnace 11 & 12 taphole and launder	Yes
Furnace 11 & 12 tapping ladle station	Yes - Furnace 12, No - Furnace 11
Crust breaking	No
Slag skimming	No
Slag pouring into slag pit and dig out – outside	No
Refining ladle moves, full & empty	No
Metal ladle and slag pot movements	No

The quantification of the fume sources that contribute to the overall fugitive emissions within the plant and the surrounding area is a significant challenge. Operations within the smelter are varied and highly integrated, and climatic variations do impact the performance of the control equipment and dispersion characteristics of the emissions.

3 EVALUATION OF EXISTING EMISSION CONTROL EQUIPMENT

The second step in the study is to evaluate the performance of the existing equipment, including exhaust hoods, environmental filters, fans, ducting, and the control system. This step is critical to identifying opportunities for improvement.

The fume control system at ENS is comprised of two filter systems providing exhaust at the various stations or at the furnaces, the environmental filter and the metal refining filter. A schematic of the system is shown in Figure 2. Table 2 summarizes the exhaust flow rates at each of the stations serviced by the environmental filter system. The system connected to the environmental filter is controlled by a series of manual dampers that allow the exhaust flow to be directed to a particular station. The measured total flow rate to the filter ranged from 200,000 Nm^3/h, with only Fans 2 and 3 operating, to 373,000 Nm^3/h with all three fans operating.

The maximum capacity of the environmental filter was assessed to be 361,000 Nm^3/h. This value is based on the known gross filter area, a net filter area calculated as 95% of gross, an estimated filter velocity of 0.9 m/min, and an estimated gas temperature of 60°C. An operating filter velocity of 0.6 to 0.75 m/min is recommended based on best practice, which would reduce the capacity to 300,000 Nm^3/h. This analysis suggests that the filter is operating at maximum capacity and any additional flow through the system would compromise its performance.

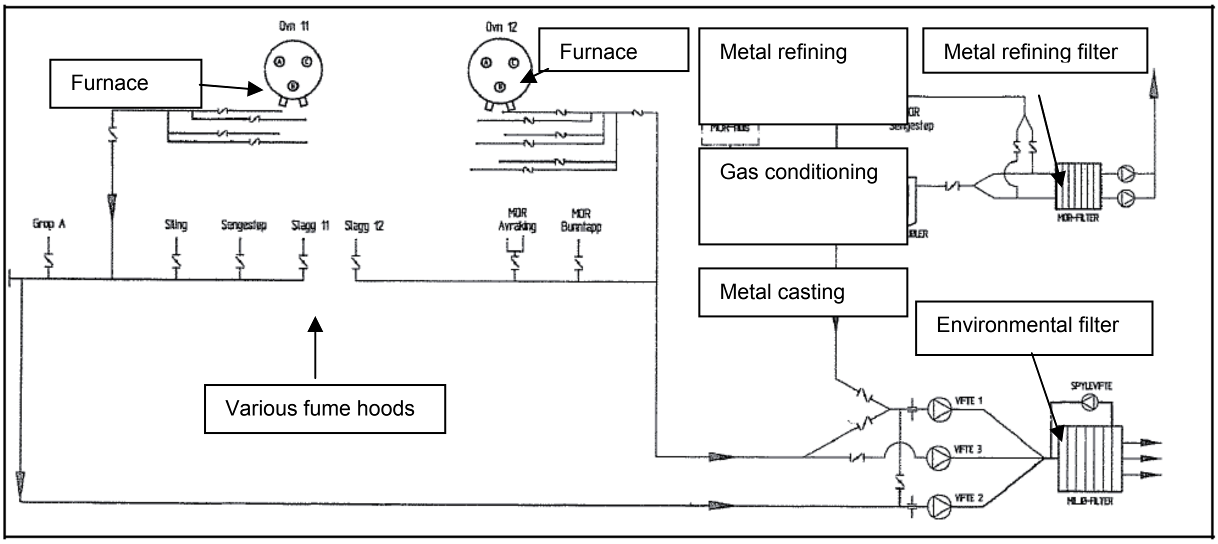

Figure 2: Schematic of the ENS fume emissions control system.

Table 2: Recorded exhaust flow rates for individual stations.

Station		Exhaust Flow Rate [Nm^3/h]
Fan 1	Casting area 2	114,000
	Casting area 1	105,000
Fan 2	Casting area 4	145,000
	Ladle skull dumps for recycle	104,000
	Casting area 3	120,000
	Furnace 11 slag pouring into slag pit – inside	113,000
	Furnace 11 tapping – right side	115,000
	Furnace 11 tapping – left side	125,000
Fan 3	Slag skimming station	100,000
	Metal transfer station	112,000
	Furnace 12 slag pouring into slag pit – inside	96,000
	Furnace 12 tapping – right side	114,000
	Furnace 12 tapping – left side	113,000

Two programs were undertaken to help understand the operation of the fume control system. Firstly, a numerical model of the fume control system was constructed using a commercial, one-dimensional duct-network modeling package. This model also provides a tool for optimizing the fume control system performance.

Secondly, to fully understand current system performance and effectively and efficiently engineer improvements to the system, a measurement campaign was undertaken to benchmark existing performance. This is done through carefully planned and controlled measurements. Such a measurement campaign includes the following:

1. Ambient temperature and pressure readings throughout the duration of the campaign.

2. For each station and furnace:
    a. Total flow, temperature, and static pressure
    b. Face velocity and temperature at the hood or pick-up points with the station damper in the open position. This would be performed either before or after the operation.
    c. The damper position
3. For each fan:
    a. Total flow, temperature, and static pressure at the fan inlet
    b. Pressure rise across the fan
    c. Static pressure at the inlet of the filter compartments
    d. Pressure drop across the filter compartments
    e. Fan amps and speed or damper positions

Best practices should be followed for measurement procedures to ensure the efficacy and therefore the usefulness of the data [1].

4 SYSTEM ANALYSIS

Performance of the emission control system is impacted by factors such as interactions between various operations, overall building ventilation characteristics, and weather patterns. The third step in the study is a system analysis to improve understanding of these interactions and identify any issues or opportunities for improvement.

A ventilation survey is performed including velocity, temperature, and pressure measurements at building inflows and outflows, and flow visualization using fumes or smoke bombs. Environmental dispersion and/or CFD modeling are also useful tools for understanding these interactions. Modeling is particularly beneficial because, once developed, models can be further utilized to evaluate the performance of conceptual designs.

A ventilation survey was completed by ENS. Figure 3 summarizes the measured flows into and out of the building. The furnace hall at ENS was designed to operate under natural ventilation, with fresh outdoor air entering at low elevations into the work zone and hot air exhausted through the roof. The measurements show that while 80% of air enters at the eastern side of the building, most of the outflow occurs at the western side. Over the years, operations have changed such that all of the process heat is generated in the eastern part the building; yet, the roof ventilators have not been modified. Fumes that are not captured by hoods have a long residence time in the building prior to exiting the roof ventilators on the west side. A long residence time allows the fumes to disperse, making them more difficult to evacuate and ultimately adversely affecting indoor air quality. The survey also showed down-drafting through some of the roof ventilators, creating undesirable flow patterns for ventilation and fume control.

During the ventilation survey, smoke bombs were used to evaluate hood performance. An example of this method and the type of information it can provide is shown in Figure 4. All smoke is captured when it is released within the 2 m of the hood face. However, when the smoke is release lower, closer to the source, a cross-draft blows much of the smoke past the hood without capture.

5 CONCEPTUAL DESIGN

Conceptual solutions for improving fume and dust capture are evaluated in this phase of the analysis. These concepts are generated based on industry best practice and empirical analysis and may then be refined using CFD modeling analysis.

Hatch's best practice is to design systems that achieve 95% capture efficiency (see Equation 1) when the criteria for plume opacity from the building is 10% [2]. A higher or lower capture efficiency is used if a different criteria is applied.

$$capture\ efficiency = \frac{total\ mass\ of\ \ fume\ captured}{total\ mass\ of\ fume\ emitted} \times 100\% \qquad (1)$$

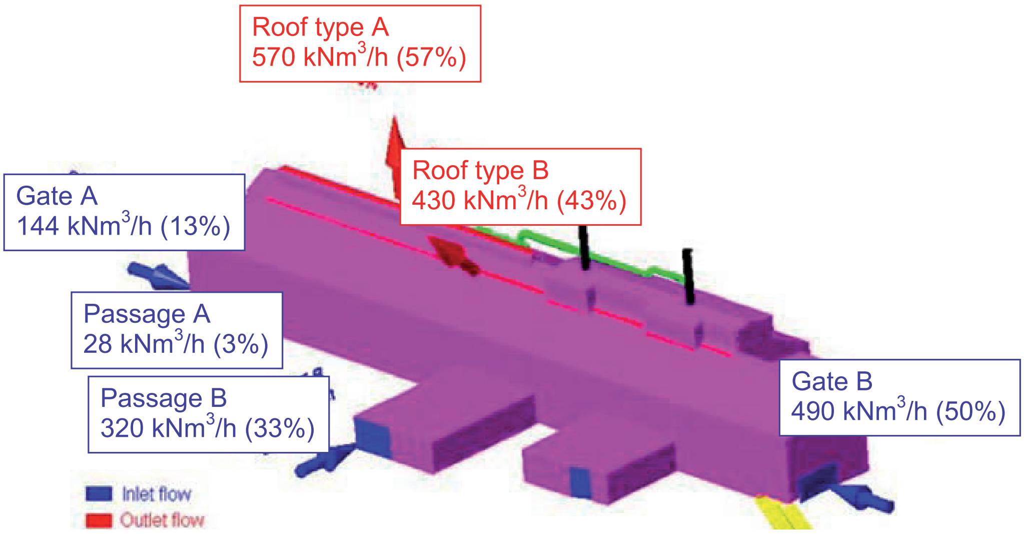

Figure 3: Schematic showing measured flows into and out of the building.

Figure 4: Smoke tracer analysis of casting area 1 canopy hood.

In all cases, the preferred solution approach to controlling fume and dust is prioritized as follows [3]:

1. First, try to reduce or eliminate fumes at the source. One example is to change the technology used for stirring in the converter from gas blowing to an alternative method, because gas blowing is known to generate fumes.
2. Second, use local hoods. Placing hoods close to the emission source ensures that fumes are captured before they are diluted, which decreases the exhaust flow requirements to achieve a given capture efficiency.
3. Third, use pull or push-pull hoods. These hoods have higher exhaust flow requirements and greater pressure drops than local hoods, but still limit dilution somewhat.
4. Forth, use remote receiving hoods. Canopy hoods located high above the source and similar remote hoods have high exhaust flow requirements to achieve a given capture efficiency because of plume growth and dilution. These hoods are also highly susceptible to cross-drafts and interference by other equipment such as overhead cranes.
5. Finally, as a last resort, full building evacuation may be considered. This approach is the least efficient. Furthermore, exhaust flow rates must be high enough to both cope with dilution of the fume and to prevent fallout of solids and overheating of the building.

A hood-enclosure concept was already in use at ENS at the time of this study, and is considered to be very capable of efficient fume capture. Enclosures are generally a preferred method for fume capture because fugitive emission escape is limited to gaps and openings in the enclosure, which can be controlled. Specifically, enclosures offer four main advantages: (1) the enclosure offers containment of the fume and is generally unaffected by drafts; (2) the enclosure has great potential for noise control; (3) the bulk of the heat, fume, and dust are contained within the enclosure, which improves working conditions nearby; (4) the enclosure may be used for both primary and secondary control of fumes reducing the need for two separate evacuation systems. The main disadvantage of enclosures is the potential for interference with normal operation and maintenance, such as interference with cranes or furnace movements. In many cases this disadvantage is not considered acceptable in existing plants. In this case, ENS is very dedicated to fume control as indicated by the hood enclosure design implemented already.

Figure 5 shows the style of hood-enclosure adopted at ENS. The exhaust requirement at the pouring hood face is based on the plume rise velocity, which may be measured with video analysis or estimated empirically. Based on Hatch experience, the system should be designed for a velocity of 0.5 m/s at the enclosure openings. Therefore, openings and gaps in the enclosure should be minimized to reduce overall exhaust rate requirements.

Based on site observations, several measures were identified to improve capture efficiency at ENS. The enclosures can be improved as follows:

- For some operations such as slag pouring fume capture would be improved by extending the hood face of the enclosure over the stream of molten metal. The hood shape can be estimated based on observations and refined using CFD modeling techniques. Extending the hood face will require an increase in exhaust flow rate.
- Currently cranes are used for pouring. Cranes are generally not precise and the ladle placement during pouring is not always optimal for fume capture. One option is to switch to mechanical tilters for pouring operations. Tilters allow for more precise ladle placement and reduce the interference due to overhead crane access.
- To reduce the risk of fume dispersion before entering the pouring hood, the sidewalls of the enclosure, as shown in Figure 5, should be extended to the front edge of the hood. This modification will reduce the impact of cross-drafts.
- Changing pouring practices such that the metal is poured from the ladle at the lowest possible height would reduce the amount of fume generated. Pouring from a great height increases reactions with the air thus lowering capture efficiency. Fume emissions are increased and pay metal is lost.

Uncontrolled emissions occur when metal ladles and slagpots are handled post tapping. Exposed liquid metal surfaces will always produce some fume and the practice of rough skimming produces much more. The total amount of fume produced from these operations and its relative contribution to total plant emissions must be assessed to determine if control of these emissions is required. Much of these emissions could be reduced by eliminating rough skimming and upgrading the slag skimming machine to take this job. The new slag skimming machine should operate within a well-designed enclosure. Crane scheduling can also be improved to minimize the time that open ladles are handled. If additional measures are required, then installation of remote capture hoods can be considered.

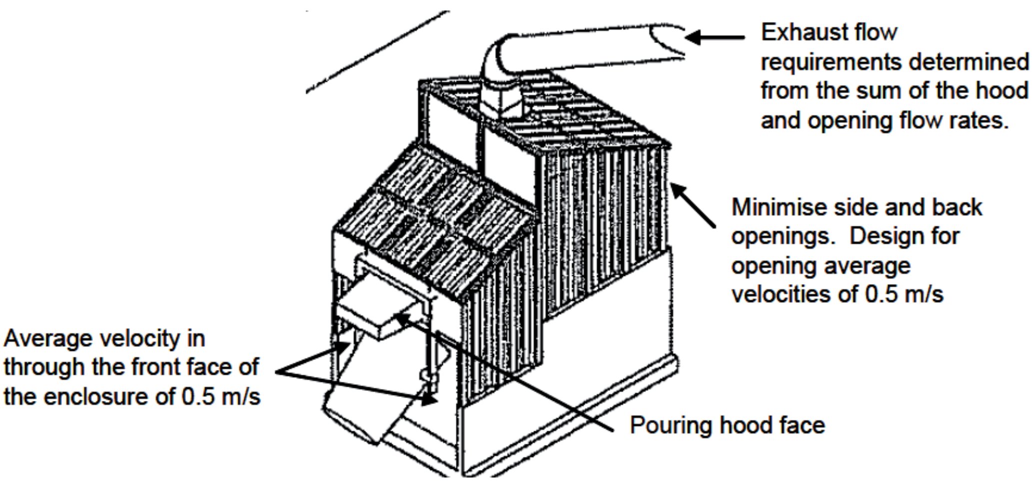

Figure 5: Fume hood enclosure concept used at ENS.

Several conceptual design improvements were identified from the ventilation survey presented in Section 4. To minimize the observed strong cross draft, Gate B must be closed. A man door is planned to allow access while minimizing the amount of time that this gate is open. To promote a more vertical flow pattern for any fugitive emissions, the roof ventilators in the western portion of the building should be closed. The remainder of the roof ventilators in the eastern part should be left open. This change will allow contaminants to move more quickly out of the working zone. It is still to be determined if the fugitive emissions are at a low enough concentration to be released directly through the roof monitors. It is expected that both the existing curtain wall and a new scavenging hood will be required in the roof above the MOR converter, as shown in Figure 6.

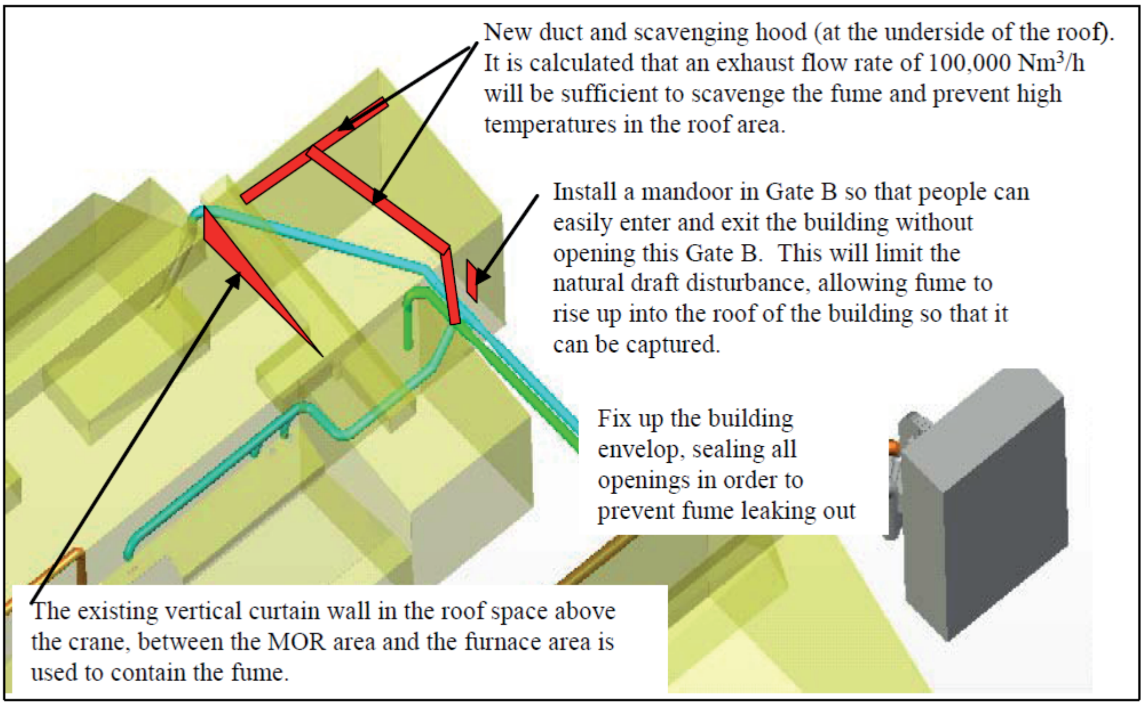

Figure 6: Proposed scavenging hood and curtain wall.

In many cases the location of the emission source and the composition of the fume pose challenges for fume control. In the present study, the slag pit emissions presented a particular challenge. The size of the emitting surface area is large, which leads to very high exhaust flow rates. Furthermore, the high quantity of steam in the fume at this location poses problems for dust handling. Dust may become "sticky" in the ductwork and consequently cannot be treated with a filter system. Wet scrubbing, which is a more costly method, is required. Given the potential expense, further study of these emissions and the potential control options is required.

6 TECHNO-ECONOMIC ANALYSIS

A cost analysis is critical to help direct cost-effective investments for improving emission control and to maximize the improvement achieved for a given budget. Order of magnitude cost estimates are prepared for the suggested modifications, which can then be ranked based on both cost and their potential impact.

Unit costs for material, labour, and installation of suggested equipment are typically available from recent experience with similar projects. Costs should be compiled based on installed costs and take into account that the modifications will be for a brownfield site. Escalation costs must also be considered, although they may not be well known.

Costs associated with a requirement for increased exhaust flow are best estimated from a unit cost per Nm^3/hr of capacity, which may also be compiled from recent project experience. This unit cost includes the filter equipment, fans, ducting, electrical, controls, and installation.

Table 3 outlines, in relative terms, the result of the techno-economic analysis preformed for ENS. Examining the cost and impact together, allows the suggested modifications to be prioritized to ensure the greatest impact for the smallest relative cost.

Table 3: Summary of techno-economic analysis.

Item	Description	Relative Cost	Relative Impact
1	Modifying and upgrading existing fume enclosures	Moderate	Moderate
2	New enclosures for slag skimming and metal transfer stations	High	Moderate
3	Replace converter gas stirring with alternative stirring	Unknown	Moderate
4	Building ventilation Improvements made by closing roof ventilators in western side of building	Low	High
5	Installation of scavenger hood above the MOR in the eastern side of the building	High	High
6	Installation of two remote hoods over the tapping pits of furnace 11 and 12 for fume control from open ladles	Very high	Low

7 CONCLUSIONS

This paper describes a systematic and comprehensive approach for analysis aimed at improvement of an existing emission control system. The analysis consists of several stages including inventory of all emissions sources, evaluation of existing emission control equipment and assessment of system performance. Combination of generated conceptual solutions for improvement of fume and dust capture and techno-economic analysis results in the most efficient and cost effective way to achieve criteria for fugitive emissions control.

This approach has been applied to identify solutions for improvement of fugitive emissions in the refining area of the smelter at ERAMET Norway Sauda (ENS). This example has demonstrated the potential benefits of this holistic approach when applied by experienced individuals. Complex interactions between plant operations, performance of the existing emission control equipment and outside factors, such as changing weather conditions were identified. This in turn has guided the proper identification of conceptual solutions for improvement. For example, a clear understanding of the building ventilation behaviour and its interaction with the local emission control system led to a low cost high impact solution to modify the building flow patterns.

8 ACKNOWLEDGEMENTS

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9 REFERENCES

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