TECHNICAL BULLETIN

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CAPTURE AND CONTROL OF PROCESS FUGITIVE AIR EMISSIONS IN A BUILDING

This technical bulletin is intended to provide an overview of the management of fugitive process air emissions within a manufacturing building. A summary of the fundamental principles of ventilation system design practices, fugitive emission control and relevant operational considerations to improve their performance are presented.

1.0 INTRODUCTION

Physical and chemical processes of many manufacturing operations result in air emissions. Most air emissions are undesirable by-products and incidental to the intended purpose of the activity that creates them.

Not all processes that create air emissions are point sources. A complete inventory of activities resulting in air emissions could include both sources vented through exhaust stacks (e.g. point sources) and sources not captured and exhausted through a stack (e.g. fugitive sources). Traditionally, point sources are the focus of attention in emission inventories and dispersion modeling. However, fugitive emissions can represent a significant contribution to maximum off-site pollutant concentrations attributed to manufacturing operations. Further, the relative percentage contribution associated with fugitive emissions may increase significantly as the overall levels of point source controls are increased. Fugitive emission sources can be both inside a building and outside.

Fugitive emission sources outside a building are typically related to particulate (dust) management. Fugitive dust management is the subject of a separate Ministry Technical Bulletin that may be found in Appendix F: Review of Approaches to Manage Industrial Fugitive Dust Sources of the Ministry's "Procedure for Preparing an Emission Summary and Dispersion Modeling Report, July 2005"

Fugitive emissions released inside a building occur due to process operations performed inside a building that are not exhausted through a dedicated ventilation system or those that are equipped with dedicated ventilation but not achieving complete capture of related emissions. Typically, fugitive emissions released inside a building will be exhausted through the general ventilation system or other building penetrations (i.e. window and door openings). Either release path will result in poor predicted dispersion of pollutants as the fugitive emissions will be caught in the building wake and not well mixed in the general ambient outside air. In fact, under certain conditions building wake effect can cause pollutants to be held in an eddy and concentrated rather than disbursed. Fugitive emissions inside a building can be significant sources of both work place exposure and off-site levels.

Strategies for Minimizing Process Fumes include source elimination, source reduction and process modifications. When source elimination or reduction does not result in acceptable levels of process emissions, then modifications to isolate and exhaust the operation needs to be considered. Properly designed and operated capture systems can be highly effective at eliminating fugitive emissions within a building.

2.0 FUGITIVE EMISSION CAPTURE SYSTEMS

2.1 Enclosures

Complete enclosure of a process operation with outside building air supply and exhaust provides the highest level of fugitive emission control. When worker entry into the enclosure is not required during process operation, virtually all fugitive emissions can be eliminated.

2.2 Hoods

Ventilation hoods are used when complete enclosure of the process operation is not feasible or secondary fume capture is desirable. Hoods are typically used when close worker interaction or frequent access to the process make an enclosure impracticable. Capture efficiency of process emissions using hoods varies widely and is influenced by many collateral activities such as turbulent air flow in the process vicinity, process changes, general building HVAC performance, maintenance of ventilation system ducts, fans and control devices, to name a few. In general, hoods should be located as close to the process operation as possible and take maximum advantage of fume buoyancy and mechanical forces to assist collection.

2.3 Barriers

Seemingly minor air disturbances and turbulence can significantly affect hood capture efficiency. Cross drafts caused by opening doors, passing vehicles, even the movement of process conveyors and equipment can overwhelm a ventilation system's ability to drawn fumes into a hood. In some cases, barriers can be used to compensate for air flows that could disrupt optimal hood capture efficiency. Heavy-duty plastic curtains are widely used to shield processes from disruptive air movement and improve fume capture of hoods. More permanent barriers may also be practicable to separate processes from doors and traffic aisles. Permanent barriers are also useful in isolating bulk and loose material staged by process operations to minimize track-out and fugitive dust.

2.4 Air Management

The objective of local ventilation systems (enclosures and hoods) is to remove process fumes from the building. Ventilation equipment is sized based upon the volume of air that must be moved. Consequently, good ventilation design will seek to minimize the volume of air that is moved while achieving process fume capture and removal from the building as initial ventilation equipment cost and ongoing operation costs are directly proportional to design air volume. Importantly, building HVAC system should provide for a balance of outside air supply and building exhaust considering actual infiltrations (i.e. door and window openings) and must operate as an integrated system with local ventilation to achieve optimal fugitive emission capture efficiencies. Regular and routine inspections and maintenance of the ventilation system is necessary to assure effective operation.

3.0 FUGITIVE EMISSION CONTROL SYSTEMS

3.1 Particulate Emission Controls

A wide range of particulate emission control technologies can be employed including cyclones, various scrubbers, wet and dry electrostatic precipitators and a variety of fabric filter types. All have their place and each presents a particular attribute that uniquely recommends their use.

3.1.1 Cyclones

In general, cyclones are easy to operate and maintain and are effective at removing large particulate but not capable of achieving removal efficiencies required for fine particulate. Cyclones are currently used in conjunction with fabric filters mostly for grinding and cutting operations.

3.1.2 Wet Scrubbers

Water scrubbers can be very effective at removing both coarse and fine particulate emissions. They have the added benefit of being relatively insensitive to inlet exhaust temperature which makes them well suited to controlling furnace exhaust. However, provision must be made to separate particulate from water for disposal and they are relatively maintenance intensive. .

3.1.3 Electrostatic Precipitators

Wet and dry electrostatic precipitators are highly efficient at removing particulate emissions. They are also very durable and well suited to corrosive environments. However, they are capital and energy intensive, and can have relatively high maintenance demands.

3.1.4 Fabric filters

Fabric filters have emerged as the dominant particulate control device. Advancements in fabric filter efficiency, durability, heat tolerance, moderate capital and operating cost, and relatively low maintenance demand have moved the technology to the forefront, especially in heavy metal industries. The type of granular particulate emissions typical in heavy metal industries is conducive to relatively easy removal and collection from filter media by shaking, vibrating and other mechanical means. A variety of filter types including bags, panels, tubes, socks, cartridges, etc. and media including spun-bound, woven-fabric, ceramic and others are available each claiming some special attribute.

Specialty filters such as High Efficiency Particulate Air (HEPA) filters and Ultra Low Penetration Air (ULPA) filters have found niches as upset safeguards for hazardous activities involving chemical, biological and radioactive PM. The HEPA and ULPA filters require high pressure drops and low flows and foul quickly making them currently inappropriate for heavy industry.

3.2 Volatile Emission Controls

Control of volatile organic compound emissions is relatively straight forward in metal working industries. Thermal oxidation is the only reliable technology currently available. Afterburners are used when volatile concentrations are high enough to self-sustain combustion (such as with high CO concentrations with some metal melting furnaces). Other volatile organic compound control devices such as catalytic oxidizers, adsorption and absorption (carbon, zeolite, etc.) are prone to blinding and fouling and are not well suited to metal working and related emissions.

4.0 FUGITIVE EMISSION EXHAUST SYSTEMS

Capture and removal of process fugitive emissions from within a building only to exhaust them in such a fashion that they re-enter the building through air supply should be avoided.

4.1 Exhaust Stack Locations

Exhaust stacks should generally not be located close to building air intake structures. Practical experience suggests that exhaust stacks should be no closer than 9 to 15 meters (30 to 50 feet) from the nearest building air intake. The objective is to prevent exhaust from re-entering the building.

4.2 Height of Release

It is desirable that exhaust stacks discharge vertically unobstructed and outside the building wake and zone of influence. Ambient air flow turbulence created by complex terrain, buildings in the vicinity and other obstructions can make simple predictions of necessary exhaust height unreliable. Certain design guides have been useful when better data is lacking. The guidance of 1.3 to 2.0 times the building height has been used in the past. Exhaust velocity can significantly increase the effective stack height. Conical stack restrictors can be used as a relatively quick and inexpensive method to increase stack discharge velocity to partially correct a less than adequate height of release (care must be taken to assure exhaust fans are capable of overcoming the required pressure increase a conical restrictor will create). Today, a variety of relatively simple dispersion models are available to make estimating appropriate stack heights more reliable.

4.3 Rain Protection

Rain caps deflect exhaust air from vertical to horizontal creating the opportunity for exhaust to be re-entrained into building supply air or captured in the building wake and should therefore be avoided. Instead rain sleeves which provide adequate protection to prevent rain from entering the stack especially when used in conjunction with appropriate exhaust velocity should be employed.

4.4 Exhaust Velocity

Exhaust velocity of about 13 m/s (2,500 fpm) or greater will overcome vertical rainfall and prevent water from entering the stack. Discharge velocity of 15 m/s (3,000 fpm) or higher is better to achieve improved dispersion. Care must be taken to avoid noise (whistling and roaring) as exhaust velocities are increased.

5.0 FUGITIVE EMISSION CONTROL PLANS

Fugitive emission control plans should incorporate at a minimum the following key elements;

1. A process ventilation system schematic for each manufacturing building indicating duct size and location, enclosure and hood sizes and locations, control device types, sizes and locations, and exhaust locations.

2. The process ventilation system schematic should be annotated with the location and size of each building air supply unit and each building exhaust fan.

3. A baseline survey shall be conducted to establish actual air flow and static pressure values before and after each emission control device and in each branch of the process ventilation system after each enclosure or hood. Similarly, actual air flow and static pressure values shall be determined for each building air supply and exhaust device. A demonstration shall be made that air supply and exhaust are balanced.

4. Static pressure readings shall be recorded every six months following completion of the baseline survey to verify operational conditions remain unchanged. Deviations shall be corrected promptly.

5. The baseline survey shall be repeated at least every five years or following significant ventilation system changes.

6. An emission control device monitoring plan that includes at least daily physical measurement of device operation such as pressure drop across the unit, leak detection, operating temperature or similar. Deviations from expected performance shall be corrected promptly.

7. The plan shall identify critical maintenance actions, schedule to complete, and verification record of completion.

8. The plan shall contain a description of each enclosure and hood with explanation demonstrating that adequate control of the process source is being achieved or actions planned to improve performance.

6.0 OPERATIONAL ISSUES

The operational issues presented below are for three industrial sectors namely, Iron and Steel Mills, Non-Ferrous Metal Smelting and Refining, and Foundries. Each sector includes a range of significantly different facilities having broadly similar process activities with multiple sources of process fugitive emissions utilizing an array of capture and control systems to reduce releases. The processes and equipment necessary to capture fugitive emissions and remove particulate and volatile pollutants are well understood and available. Industrial ventilation practices and control devices necessary to remove fugitive emissions are integral components of their operations. The challenge faced by these sectors in controlling process fugitive emissions does not appear to be related to technology but rather operational issues and cost of retrofit.

6.1 Retrofits

Challenges exist is older existing installations with retrofit capture systems added and modified as facility changes and needs occur. Retrofit of capture hoods and ventilation equipment is often restricted by existing process equipment design and layout.

6.2 Furnaces

A core activity of all three industrial sectors is furnaces to melt metal. A variety of furnace types exist and all are used by each industrial sector as needed to achieve their individual metal melting requirements. Common to all, is a high temperature furnace with enclosure or close fitting hood for primary ventilation. Periodic penetration of the primary enclosure or hood during furnace operation for charge addition, tapping of molten metal and removing slag create sources of fugitive emission losses.

6.3 Secondary Hoods

Each industrial sector has the same restrictions and limitations in attempting to provide secondary hoods to control fugitive emission losses.
Importantly, each faces a similar design dilemma that may not be practically resolvable. Namely, addition of relatively cool charge to an operating furnace creates a high intensity, short duration surge in air volume (a puff) as chemical and physical reaction occur that exits the charge door. A secondary capture hood can be relatively easily sized to capture the plume, but the ventilation fan must be sized to move a high volume of air in a relatively short period of time or spillage of fumes from the hood will occur (i.e. fugitive emissions).

6.4 Control Device Size

If the ventilation system is exhausted through a control device, then the control must be significantly increased in size to accommodate the short duration flow and that can add significant capital and operating expense to the device.

6.5 Short Duration High Intensity Flows

In practice, capture and control systems are rarely designed to accommodate short duration high intensity flow and consequently hood spillage occurs resulting in fugitive emissions released within the building.

Similar short duration, high intensity flow events occur throughout the three industrial sectors that challenge the design capacity of ventilation systems for short durations resulting in uncontrolled fugitive emissions. Conditions like freeing plugged tap holes in basic oxygen furnaces, addition of reactive fluxes to adjust metal chemistry, oxygen lancing in steel furnaces, “slip” in a blast furnace, etc. may not be practically resolvable to prevent fugitive emission. However, circumstances leading to (or contributing to) these events should be evaluated to minimize or prevent their occurrence.

6.6 Operation and Maintenance Plans

Most facilities have existing operating and maintenance plans that address at least the emission control equipment portion of the emission control system. The existence of a operating and maintenance plan does not appear to be adequate to assure good fugitive emission management. It appears appropriate to specify the development of fugitive emission control plans, as presented in Section 5.0 of this technical bulletin.

7.0 EMERGING TRENDS

7.1 Regulatory Developments

Capture and control of fugitive emissions has received increased regulatory attention in the developed industrial world over the past several years. This may be attributed to the acknowledgement that fugitive releases represent a significant source of emissions from the heavy metal working industries and increasing attention towards reducing toxic heavy metal emissions.

Regulatory agencies in the US, Europe and Australia have each adopted new requirements over the past ten years aimed at reducing fugitive emissions from the three industrial sectors. The focus has been on improving operating and maintenance procedures and specifying best management practices for existing capture and control systems

It is reasonable to anticipate that the effectiveness of operating practices will come under increasing scrutiny by regulatory agencies over the coming years. Stepped up performance monitoring and specified minimum content requirements for operating and maintenance plans will likely emerge to address potential deficiencies.

7.2 Process Equipment Developments

Pyrometallurgical processes used in ore refining and metal melting have undergone slow evolutionary changes over the past couple hundred years until about fifty years ago when revolutionary change occurred. After World War II, technology became available to generate large quantities of oxygen at moderate cost. Oxygen is the critical element needed to smelt and refine ore into useful metal. Up until this point, air has been the only source of oxygen and it brought with it unneeded inert gases like nitrogen. Replacing oxygen for air in smelting and refining furnaces has dramatically improved reaction efficiencies, reduced energy requirements, substantially reduce NOx and particulate emissions, and enabled the recovery of sulfides for beneficial use that would have otherwise been air emissions.

Steel mills and non-ferrous metal refineries have broadly adopted furnace technologies to take advantage of oxygen and developments continue. The full potential of oxygen use has yet to be realized. As the cost of fuel and electricity continue to increase, it is reasonable to expect that the use of oxygen to replace air and oxygen/fuel blends will enter the secondary metal refining and foundry industries. The resultant beneficial effect of reduced fuel burning, lower NOx and particulate emissions and reduced air flow from furnaces (reducing control costs) will emerge in coming years.

Some other emerging technologies for capture and control of fugitive emissions to note are as follows:

1. The use of intelligent damper controls can improve fume capture and reduce fan sizes and hence costs.
2. Sealed charging cars or skips used with a reverberate furnace at a secondary aluminum smelter have been shown to reduces fugitive emissions to air significantly by containing emissions during charging.
3. The use of modern fabrics for bag filters, that more effective and robust and a modern housing design can allow bag life to extended significantly, improving performance and reducing costs at the same time.
4. Techniques for separation of aluminum scrap into different types of alloy have been tested using laser and eddy current technology. The benefits of this will be easier selection of materials for recycling and the ability to more easily produce desired alloys in recycling plants.
5. Catalytic filter bags to control dioxin releases. The catalyst will destroy dioxins rather than simply collecting them.
6. The injection of fine material via the tuyeres of a blast furnace has been successfully used and reduces the handling of dusty material and the energy involved in returning the fines to a sinter plant.
7. Control parameters such as temperature are used for melting furnaces and kettles and reduce the amount of zinc and lead that can be fumed from a process.

7.3 Continuous Equipment Monitoring

We are on the threshold of technology breakthroughs that will make robust, reliable, and affordable continuous process and emission monitoring linked to data acquisition systems for real time reporting on equipment performance a reality. Properly applied, these systems will allow the application of limited operating and maintenance resources in the most efficient manner to minimize fugitive emission losses attributed to out of control operations. Continuous particulate monitors are already being required in some U.S. rules and permits. The monitor is designed to alert operators when particulate matter levels in the gases exiting the bag house are above those seen during normal bag cleaning cycles.

A couple examples of technologies that may emerge in coming years and take the lead in the monitoring technology revolution are Laser emissions monitoring systems that involve “sniffer” lasers, the size of a pinhead, provide real time infrared (IR) detection of fugitive emissions. They detect gases in the air and produce a chemical fingerprint to identify the substance and a technology generally referred to as optical leak imaging, which offers an operator the ability to view leaking gas as a real-time video image. The remote sensing and instantaneous detection capabilities of optical imaging technologies allow an operator to scan areas of potentially leaking components much more quickly, eliminating the need to measure all of the components individually.