The Effect of Air Pollutant and Control Device Characteristics on Emission Rates

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Abstract

Emissions from processes with control devices must be determined as part of development of a point source emission inventory. There are many difficulties in this determination. Single pollutant emissions are, in reality, actually heterogeneous combinations. All oxides of nitrogen must be reported together as NO_2 . Devices control the individual constituents differently and this may affect the emission rate on a throughput or time basis. Mechanisms of control for different devices also vary for the same emission.

Different emission control devices may have very different removal mechanisms. Collection by some types of devices can be characterized by efficiency. The operating mechanisms of other control devices may cause emissions to approach a different basis, such as a constant concentration in the cleaned gas. Operation of both types of devices is affected by dust characteristics, flue gas parameters, unit design, maintenance and operation in different ways. Particulate control systems are examined as an example of controlling a heterogeneous emission and control mechanisms of different devices.

Introduction

Evaluating control device operation is an important part of point source emission inventory evaluation. Calculation of emissions within an emission inventory storage computer database has promoted the concept of characterizing device operation with estimated collection and operational periods. In reality, collection by many devices is not based on efficiency. In the database, a factor for the portion of time that the control device operated while the process emitted was expanded to account for periods of unusual operation. Actual operation is much more complex than the collection device percent collection/percent operational model used in an “AIRS” type (EPA’s Aerometric Information Retrieval System) database. Additional care during evaluation will produce a more accurate estimate of emissions.

Additional care is also needed because no control device collects at a constant efficiency unless all conditions of the pollutant, flue gas and the device are constant or its performance is regulated to that level. Testing may only define operation of a control device operating under specific process operational and emission conditions at a specific time.

Furthermore, identical particles entering an electrostatic precipitator have the same probability of being collected by a specific unit, but the mechanisms of collection in a fabric filter are very different. Filters function as a relatively “constant emitter” of dust in operation. This means that emissions from a fabric filter have little variation due to due to the amount of dust entering the device.

There is also a potential for additional emissions during startups and shutdowns. The control unit may be bypassed during these periods or conditions may be very unusual. Operation may be modified during these periods to protect the control equipment. This may cause emissions to be very high. Operation of control units degrades with time. This may be due to short-term effects such as decay of filter media or long-term such as corrosion. Plant monitoring, inspection and maintenance mitigate these effects

The use of corrections to deal with emissions during startup/shutdown/malfunctions should be based on the best available information for the individual unit. A general correction factor, such as Rule Effectiveness, may generate emission estimates that are much greater than actual for high efficiency controls. The Point Source Committee of the Emission Inventory Improvement Program (EIIP) has been collecting data to help determine the relationship between these effects and emissions.

Definition of Pollutants

Many pollutants, possibly most, are heterogeneous in form, as defined. CO is homogenous in form, but NO_x is a combination of at least NO and NO_2. Test methods sometime help define pollutants. For example, Reference Test Method 25C for VOC defines volatility with its requirement of a specific temperature for the filter prior to the analyzer.

Particulate can have many different characteristics, including mean particle size, distribution of sizes, cohesion, adhesion, particle surface resistivity, density and shape. Condensable particulate is generally a gas in the flue. All of these characteristics have an effect on emissions from control devices.

Metals and other pollutants can be in the flue gas in many forms. Mercury can be a metallic gas, an oxide form, bonded with chlorine or chemically bound into more complex compounds. Solid forms can be physically bound in different ways into particulate, which has its own complexities. Removal of mercury ranges from simple to very difficult depending on the forms it takes in the flue gas.

Pollutants are generally viewed in a singular form. The complexities described above may require different methods of control. This should be taken into account during a point source emission inventory evaluation to the best possible extent.

Control Device Characteristics

The collection mechanism can be very different for various control devices of the same pollutant. The possible range of characteristics for a single pollutant, combined with the collection mechanism, may produce very different results. Particulate control will be used as an example.

The three most common devices used for particulate collection are cyclonic separation, filtration and electrostatic precipitation. The following describes their characteristics and the effect of particulate properties on their operation.

Cyclonic Control Device

Cyclones are based on forcing the flue gas to spin in the device. Since particulate has a higher density, it does not turn with the gas as well and moves toward the walls of the cyclone, where it is removed from the device and the gas stream. Removal efficiency is the same for identical particles. Collection of individual particles increases with dust density and the diameter of the particles. This is because the mass of the particle increases with the cube of the diameter, increasing force due to inertia. The aerodynamic forces of the gas on the particle, turning it inward, are based on the particle cross-section (particle diameter) and particle surface area (diameter squared).

Some cyclones may only collect particulate larger than PM_{10} and have little effect on smaller particles. Other versions may also collect smaller particles, removing some PM_{10}, but little $PM_{2.5}$. It not possible to collect condensable particulate, since it is a gas in the flue.

Fabric Filtration

Filtration collectors are an effective method of dust removal. They can also remove acid gases with use of basic (high pH) compounds or adsorb some pollutants.

The cake of dust already built up on the filter media filters most dust removed by filter collection devices. Dust actually emitted must be released by the backside of the filter cake or travel directly through the media just after dust cleaning when there is no dust cake on the media. Different filter media provide varying amounts of dust collection. If the filter media is a simple woven cloth, dust can easily work its way through to be emitted. Felt will provide additional collection. Media with a porous Teflon surface coating provides very good additional filtration. Media filtration is most necessary during and after cleaning dust from the filter, when there is no filter cake.

Additional dust in the gas does not increase dust emissions. It does cause additional cleaning cycles, but it also speeds creation of the filter cake following cleaning. Therefore a fabric filter is best described as a “constant emitter.) This means that emissions are generally proportional to gas flow through the collector, not the amount of dust entering it. Emissions should be calculated by multiplying the total amount of gas passing through the unit by the Estimate of Outlet Dust Concentration in the flue gas.

Emission Rate = (Hours of Operation x ft^3/hour) x Estimate of Outlet Dust Concentration

The best estimate of outlet dust concentration probably results from testing. Other sources are the manufacturer’s guarantee or design tables.

Control decreases for smaller particles, but differences due to particle size in fabric filters are the least of the three types of collectors described in this paper. There is also some variation in emissions due to other particulate properties. The most significant of these actually produces a secondary effect. Dusts that tend to stick to the media require more aggressive and frequent filter cleaning. This shortens filter life and causes tears in filter bags that exhaust unfiltered gas. The fast moving dirty gas may cause damage to adjoining bags, greatly increasing excess emissions. Monitoring, such as with broken bag detectors or an opacity monitor, and proper maintance procedures are necessary to determine and minimize excess emissions from this cause. Excess emissions estimation due to this impaired operation must take into account the time, type of plant response, and the ability of sensors to indicate a problem.

Electrostatic Precipitation

Dust collection by electrostatic precipitation (ESP) is strongly affected by particulate properties. Results of operation are very different than those achieved with a fabric filter. Unlike a fabric filter, an ESP collects only a fixed proportion of dust entering it so the outlet loading will vary with the inlet loading. Collection efficiency is constant for defined device, operational and dust conditions.

A very simplified explanation of ESP operation follows. Flue gas travels slowly through the larger cross section of the ESP box. Electrically grounded vertical flat plates separated about a foot from each other split the gas stream. They also provide the collection surface for dust removed from the flue gas. Electrical current emanating from discharge surfaces charges passes through the flue gas to the dust. The discharge surfaces are located between the collecting plates and consist of sharp edged wires or a rigid structure with sharp edges. These surfaces are charged to several tens of thousands DC volts.

Some dust conditions have a major impact on collection efficiency. Magnetic forces attracting particles to the collecting surfaces are proportional to the charge on the particles. Some dusts with high surface resistivity can be very difficult to charge. Other dusts with very low surface resistivity travel to collecting surfaces, but discharge on contact and then re-entrain into the flue gas at that time or during plate cleaning. This can cause major differences in dust control.

There are several effects of particle diameter on dust collection in an ESP. It changes both attractive and aerodynamic forces. Electrical charge collects on the particle surface. Forward inertia tends favor collection of smaller particles. Smaller particles are much more likely to be re-entrained into the gas stream when the collecting surfaces are cleaned. Brownian motion of submicron particles also promotes movement back into the gas stream. Dust collection in an ESP decreases for smaller particle sizes more than a fabric filter but much less than in a cyclone.

Conclusions

The descriptions above for pollutants and control devices show how variable collection can be for a given pollutant and control device. Test data for the source can be a very useful tool in emission estimation. The best emission estimate from a fabric filter should use tested dust concentration in the cleaned flue gas and operating time.

Testing can be used for an ESP along with dust input to the control unit. An understanding that it operates on an efficiency control basis should also help estimate other operating conditions.

Accuracy of emission evaluation for processes with control devices is based on understanding of the specific unit and the care taken by the inventory evaluator in performing the evaluation. The EIIP has started to provide background in this area through its Chapter 12 document.

Unless operation of the process, control device and process composition is always at the conditions tested, there is some difference in conditions that would improve the emission estimate if taken into consideration. Basic understanding of the control device involved may enable a more accurate estimate.

Estimating a small change in efficiency in a highly effective control device can produce a massive change in controlled emissions. As an example, the old EPA guidance for Rule Effectiveness could tremendously overestimate controlled emissions. More work is necessary to provide additional assistance methods on this subject.

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Keywords

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