TECHNOLOGIES FOR AIR POLLUTION CONTROL

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Summary

Controlling emissions of air pollutants from industrial and domestic sources is important in protecting public health and welfare. The essential planning steps that should precede these control activities include: (1) setting up an emission limit, (2) identifying all emission sources, (3) investigating process modification, (4) defining the control problem, and (5) selecting a control system. The first problem in specifying air pollution controls for air pollutants is to set an acceptable emission level. Once an emission limit has been set, attention shifts to the process envelope. It is good practice any time, and essential when dealing with air pollutants, to study the entire process and identify all emission points and all possible solutions to the control problem.

The possibility of modifying a process to reduce or eliminate a pollutant should be considered. This type of control usually offers the most economical way to reduce emissions, since little capital is normally needed to implement it. Often there are improvements in operating efficiency to be done by reducing losses, and the cost of a terminal control system is also cut, since it has to handle less material. The final step before choosing a control device is to define the properties of the vent stream. Basic data needed include physical form, flow rate of stream, concentration of material to be collected, particle size distribution, variations in flow or concentration, physical properties, chemical properties, temperature and pressure of stream, and etc. The properties of interest will depend upon the control device being considered as well as the emission conditions.

Air pollution control systems can be grouped generically into two classes: particle control systems (settling chambers, cyclones, filtration, electrostatic precipitators, wet scrubbers, etc.), and gas and vapor control systems (wet scrubbers, activated charcoal, thermal

destruction, biological oxidation, advance oxidation, etc.). These classes reflect the physical and/or chemical processes used to separate pollutants from the carrier gas. Operating fundamental, general advantages and disadvantages of the most popular types of air pollution control equipment for gases and particulates are presented separately.

1. Introduction

In recent decades, the science and engineering professions have been heavily influenced by their responsibility to society. This responsibility has been directed toward the protection of public health and welfare and is guided by a host of environmental regulations. In devising controls for atmospheric emissions of these pollutants, scientists and engineers have developed strategies for attacking air-pollution control problems. They have found that most difficulties with treatment systems stem not from improper specification or design of equipment, but rather from oversights during one of the essential planning steps that should precede these activities.

Although there is some overlap between them, these five steps include:

- Setting up an emission limit.
- Identifying all emission sources.
- Investigating process modification.
- Defining the control problem.
- Selecting a control system

In view of the relatively high cost often associated with air pollution control systems, scientists and engineers today are directing considerable effort toward process modification to eliminate as much of the pollution problem as possible at the source. This includes evaluation of alternative manufacturing and production techniques, substitution of raw materials, and improved process control methods. Unfortunately, if there is no alternative, the application of pollution control equipment must be considered. Considering the relatively high costs, proper selection of this equipment is essential. The equipment must be designed to comply with regulatory emission limitations on a continual basis, with interruptions subject to severe penalty depending on the circumstances. The requirement for design performance on a continual basis places very heavy emphasis on operation and maintenance practices. In fact, it is not unusual that favorable operation and maintenance requirements associated with a particular piece of equipment can strongly influence its selection, despite the fact that its capital cost may be higher. The rapid escalating costs of energy, labor, and materials can make operation and maintenance considerations even more important than initial cost.

There are a number of factors to be considered prior to selecting a particular piece of air pollution control hardware. In general, they can be grouped into three categories: environmental, engineering, and economic.

(1) Environmental

- Equipment location, available space, ambient conditions, availability of adequate

utilities (i.e. power, water, etc.) and ancillary system facilities (i.e. waste treatment and disposal, etc.).
- Maximum allowable emissions (air pollution regulations).
- Aesthetic considerations (i.e. visible steam or water vapor plume, impact on scenic vistas, etc.).
- Contribution of air pollution control system to wastewater and solid waste.
- Contribution of air pollution control system to plant noise levels.

(2) Engineering

- Contaminant characteristics (i.e. physical and chemical properties, concentration, particulate shape and size distribution-in the case of particulates, chemical reactivity, corrosivity, abrasiveness, toxicity, etc.).
- Gas stream characteristics (i.e. volume, flow rate, temperature, pressure, humidity, composition, viscosity, density, reactivity, combustibility, corrosivity, toxicity, etc.).
- Design and performance characteristics of the particular control system (i.e. size and weight, fractional efficiency curves in the case of particulates, mass transfer and/or contaminant destruction capability in the case of gases or vapors, pressure drop, reliability and dependability, turndown capability, power requirements, utility requirements, temperature limitations, maintenance requirements, flexibility with regard to complying with more stringent air pollution regulations, etc.).

(3) Economic

- Capital cost (equipment, installation, engineering, etc.).
- Operating cost (utilities, maintenance, etc.).
- Expected equipment lifetime and salvage value.

Air pollution control systems can be grouped generically into the following classes, which reflect the physical and/or chemical processes used to separate pollutants from the carrier gas.

(1) Particle control systems

- Settling chambers (gravity).
- Cyclones (inertial separation).
- Filtration (inertial separation and diffusion).
- Electrostatic precipitators (electrostatic forces).
- Wet scrubbers (inertial separation and diffusion), etc.

(2) Gas and vapor control systems

- Wet scrubbers (absorption).
- Activated charcoal (adsorption).
- Thermal destruction (chemical oxidation): direct flame or catalytic.
- Biological oxidation (biofiltration and bioscrubbers).
- Advance oxidation (chemical reactions initiated by ultraviolet light (UV) augmented by ozone and hydrogen peroxide), etc.

2. Setting up an emission limit

The first problem in specifying air pollution controls for air pollutants is to set an acceptable emission level. In some cases, this has already been done by a regulatory agency. But more often, the agency will require that the owner choose an emission level and submit a request for a permit. The agency then approves or rejects the application.

If the emission is one of the materials listed in the National Emission Standards for traditional and/or hazardous air pollutants, the work of selecting a level has already been done. The National Emission Standards sets the maximum-permissible emission levels for new and existing sources. However, the degree of emission reduction should not be based on existing regulations, but rather on those that can be reasonably anticipated. Few things are as inevitable as increased taxes and lower emission limits. Those restrictions may appear excessive based on today's standards. But if the present legislative trend continues, they will be realistic within 5 to 10 years. Furthermore, technology does exist that is capable of achieving these limits.

For materials other than these, the engineer will probably have to devise his own emission levels. It usually proves easier to identify toxic materials than to set their acceptable emission levels. Those lists that have been published by governmental agencies can be of some help. Generally, these lists are not directed at atmospheric emissions, however, so their applicability is limited and care must be taken in their use. For example, although the list of 15 cancer-suspect materials contained in the Occupational Safety and Health (OSHA) standards in the United States specifies precautions to be used in handling the compounds and leaves little doubt that they are considered quite toxic, it is of little help in setting emission levels. The only reference to emission controls is a statement requiring "decontamination" of exhaust air before discharge. Decontamination is frequently, but not always, interpreted to mean that the material in question cannot be detected in the airstream by the best commonly available analytical technique. Most of these materials have limited use in the chemical industry.

Setting an emission level is not the hopeless task it might seem to be at this point. Any material will fall into one of four categories with respect to those lists cited:

- Contained in a list for which emission limits are set.
- Contained in, or meets the criteria of one of the other lists.
- Not contained in a list, but similar to a listed material.
- Not similar to any material contained in a list.

If the material falls in the fourth category, special air-pollution control precautions are seldom required except in unusual situations. The only cases where there should be a question as to the toxicity and allowable emission levels are in categories (2) and (3). In such cases, the engineer should seek the advice of a toxicologist or industrial hygienist. Specialists can frequently estimate a permissible exposure-level for the general population that accounts for the stability of the material and possible chronic effects from environmental accumulation or biomagnification. The influence of other sources of related materials, as well as any naturally occurring background concentrations, should also be considered. How much the source should be allowed to contribute to the overall concentration is then calculated from a dispersion model, based on local topography and meteorology.

3. Identifying emission sources

Once an emission limit has been set, attention shifts to the process envelope. It is normally not enough just to attach a well-designed control device to the vent emitting the pollutant. With low emission levels permitted for many types of air pollutants, especially some toxic materials, emission from sources other than the main process vent figure highly, and may sometimes overshadow even those from the main vent. It is good practice any time, and essential when dealing with toxic air pollutants, to study the entire process and identify all emission points and all possible solutions to the control problem. Some frequently overlooked emission points which have been found to contribute heavily to a process's emissions are:

(1) Accidental releases

- Spills
- Relief valve operation

(2) Uncollected emissions

- Tank breathing
- Packing-gland or rotary-seal leakage
- Vacuum pump discharges
- Sampling station emissions
- Flange leaks

(3) Re-emission of collected material

- Vaporization from water wastes in ditches or canals
- Vaporization from aeration basins
- Re-entrainment or vaporization from landfills
- Losses during transfer operations

4. Process modification

As the process is studied, the possibility of modifying it to reduce or eliminate a pollutant should be considered. This type of control usually offers the most economical way to reduce emissions, since little capital is normally needed to implement it. Often there are improvements in operating efficiency to be done by reducing losses, and the cost of a terminal control system is also cut, since it has to handle less material.

Nonetheless, modifications of this type are frequently opposed by operating personnel, who resist even looking at inconvenient changes to the process if another control method exists. This resistance lasts until the completed study reveals the cost of add-on controls for the unmodified process to be totally unreasonable. If process modification has been ignored up to this point, redoing the study will be costly in both time and money. Thus, it is wise to insist on carrying out both types of studies from the start. Some techniques that are efficacious in reducing emissions are:

- Substitution of a less-toxic or less-volatile solvent for the one being used.
- Replacement of a raw material with a purer grade in order to reduce the amount of inerts vented from the process, or the formation for undesirable impurities and byproducts.
- Changing the process operating conditions to cut down the formation of undesirable byproducts.
- Recycling process streams to recover waste products, conserve materials, or diminish the formation of an undesirable byproduct by the law of mass action.
- Enclosing certain process steps to lessen contact of volatile materials with air.

This type of study need not be laborious. Once an engineer is acquainted with the technique, the proper questions will occur to him automatically as he studies the process. Since the process design engineer is highly familiar with the process, it is often most economical for him to perform the study.

As the study proceeds, a running count of the cumulative effects of all process modifications should be kept. When emission sources are eliminated, the remaining ones should be compared with the allowable emissions level, so that the required control efficiency can be determined. A comparison of the required control efficiencies of the control devices likely to be used will indicate how far the process study should be carried.

Often a fairly simple means of control will be uncovered. In one case, a light hydrocarbon being released from a reaction ran afoul of a hydrocarbon emission regulation. Much effort was expended in finding ways to collect, purify, and sell the material before a process modification study was permitted. In a short time, it was discovered that the cause of the emissions was a side reaction stemming from too high a temperature, and an insufficient excess of one reactant. Laboratory work was needed to set new process conditions, but the resulting changes increased product yield, decreased consumption of one reactant, and cut the hydrocarbon emission rate to a point where no further controls were required. The project netted the operator a substantial profit.

Occasionally a complex solution will be necessary. In another case, a herbicide facility required an extremely efficient control system to prevent damage to vegetation around the plant. Problems with wastewater treatment demanded the minimizing of aqueous wastes. As a solution, the strategy shown in Figure 1 was devised. The pollutants were removed from the vent gases at the wet end of the process by a packed tower, which also condensed the water given off by the dryer and recycled it to the reactor. The effluent from the scrubber and vents at the dry end of the process were passed through a bag filter to remove the bulk of the dust, and then through a high-efficiency disposable filter to remove any bleed-through from the bags. The dry area was enclosed, air-conditioned, and vented through the bag filter to avert the escape of fugitive dust through open doors and windows.

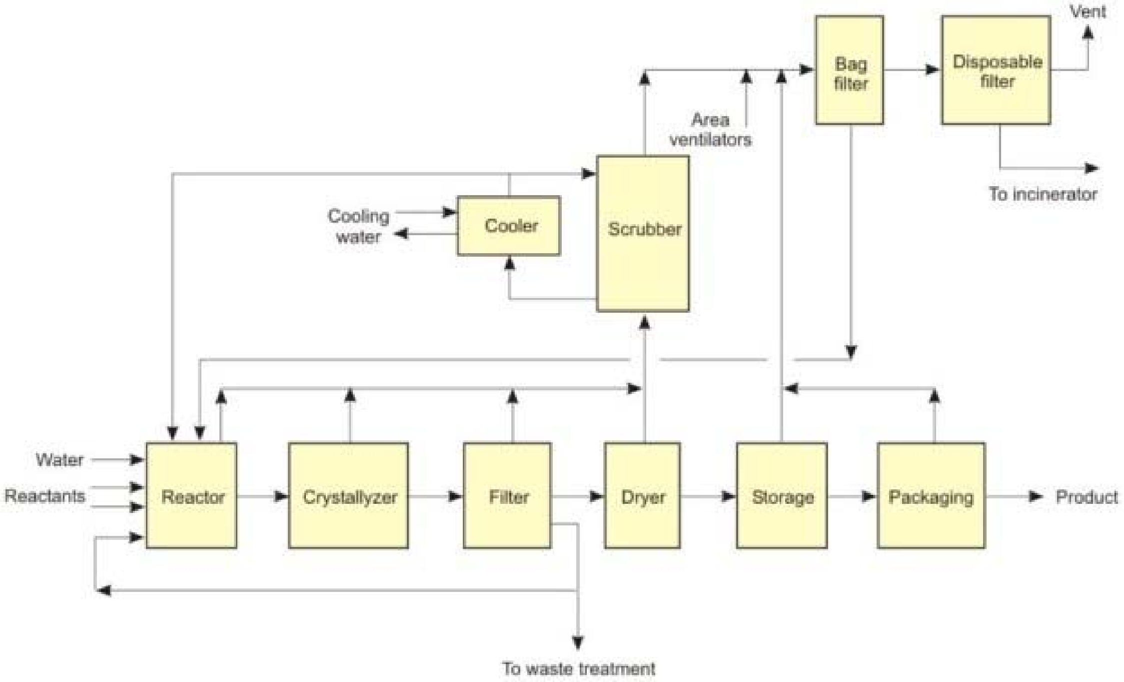

Figure 1. Controlling herbicide plant emissions: wet tower scrubs vent gasses and condenses dryer vapors; high efficiency bag filter keeps down dust

If the emitted pollutant tends to accumulate in the environment, it is wise to sample soil, water, and plant and animal lifer in the area of the plant site for the background level of the material. This can serve both as a defense against future accusations of contamination, and as a starting point for an ongoing monitoring program that gauges the efficiency of existing controls in preventing undesirable accumulations.

5. Defining the control problem

The final step before choosing a control device is to define the properties of the vent stream. The properties of interest will depend upon the control device being considered as well as the emission conditions. Basic data needed include physical form (gas, liquid, solid), flow rate of stream, concentration of material to be collected, particle size distribution, variations in flow or concentration (extent and time), physical properties (solubility, resistivity, ease of handling), chemical properties (reactivity, corrosivity, toxicity), temperature and pressure of stream. At this point in the study, a good deal should already be known about the properties of the emission, but most of the information will probably be based on theoretical calculation, or the results of a small-scale test. A certain amount of skepticism is required with such data. All of it should be verified, and the conditions under which it was taken should be checked against those in the plant. Even laboratory data may be inaccurate, since it is not always possible to simulate actual plant conditions in the lab, and differences often occur in agitation rates, flow velocities, and heat-loss rates. If the process has been implemented at the pilot-plant scale, sample the emission and determine its properties directly. In selected cases, conditions may be ideal enough for control equipment to be designed from theory, but care should still be taken to ensure that all variables have been accounted for. Plan the sampling procedures carefully so that all relevant information is obtained. Stack-gas sampling is not as simple as it sometimes appears, and it is easy to get inaccurate results that give no inkling of their inaccuracies. When planning a sampling program, those not well versed in sampling should seek the advice of an expert.

There are three circumstances in which inaccurate data commonly lead to major problems in the design of a control system. First is the failure to recognize the presence of another phase. If particulates, especially fines, are present when only a gas is expected or vice versa, serious control-efficiency problems can follow, since most devices designed for removing gaseous pollutants are far less efficient on particulates, and most particulate control-devices are inefficient at removing gases. Only a few devices do both jobs well.

Where the particulate is an aerosol resulting from the condensation of a relatively nonvolatile material, the problem is especially difficult, since a sample at the only available sample point may give one answer, whereas a sample further upstream could show more gaseous material and one downstream might show more particulate. Sulfur trioxide frequently offers this type of difficulty. When dry, SO_3 is gaseous and can be absorbed in 98% H_2SO_4 or 80% isopropanol. When SO_3 contacts water, either in moist air or in a water-filled absorber, it hydrates to H_2SO_4 and condenses to a submicron aerosol that is not collected well by either reagent. In this from, it should be collected with a dry filter. USEPA's method employs both an absorber and a filter, but in the plant, dual control devices are usually prohibitively expensive. The second circumstance is the failure to recognize the presence of fine particles in an emission. Until recently, this was a minor problem, but fine particulates in the atmosphere are recognized as a serious environmental hazard. A lot of material has been published on the fine particulate problem and its control, and more work is in progress.

Fine particles are particularly important in the treatment of toxic pollutants, for two reasons. First, fine particles stay airborne longer than coarse ones and increase the chances of the surrounding population being exposed to the pollutant. Second, the low emission levels normally required for toxic materials will generally force removal of most fine material from the emission. Qualitatively, the presence of fine particles can sometimes be detected by the hazy appearance of a plume, but this rule does not hold when coarse particulates or steam are present. Unless the operator has experience with a similar emission, it is advisable to check particle size distribution with one of the many cascade impactors or optical devices on the market. Take care to extend the test into sufficiently fine sizes, so that all particles that may have to be removed by the control device will be accounted for.

The third problem-causing circumstance is failure to recognize variations in the characteristics of the emission. Virtually all emissions vary from season to season, as the temperatures of both the air and the cooling water change. Most emissions—even from continuous processes—vary from day to day, and some, particularly from batch processes, vary from hour to hour. The ranges of these variations must be estimated in order to determine their effect on the control device. If the controls are designed for the worst case, they will usually handle less severe cases; even so, one should be aware of problems peculiar to the control devices, such as the sensitivity of the venturi scrubber to flowrate, or of the electrostatic precipitator to dust resistivity.

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Biographical Sketches

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