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Revision Memo

12/00 Design Practices format updated to Word document. Table of Contents expanded to include additional subsections and tables.
Minor editorial revisions completed. References updated. Control of particulate emissions section expanded.

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SCOPE

This section of Design Practices discusses overall air pollution control technology and serves as an introduction to the other Design Practice sections on air pollution control. It provides background on sources of air pollution and the methodologies used to achieve compliance with regulations.

For the topics of **IMPACT ANALYSIS / AIR DISPERSION MODELING, HYDROCARBON AND AIR TOXICS EMISSIONS CONTROL,** and **COMBUSTION EMISSIONS CONTROL**, this section introduces more detailed guidance contained in **Sections XVIII-A1** through **A6, A8,** and **B1**. **Table 1** shows where to find more detailed information in the other Air Pollution Control DPs.

This introductory section also contains a description of the procedures for conducting an Emissions Inventory and for preparing an Air Permit application. Additional details on these two topics are available in the references or from the Air, Water & Solid/Hazardous Waste Section of ExxonMobil Engineering.

TABLE 1
RELATED AIR POLLUTION CONTROL DP SECTIONS

HYDROCARBONS AND AIR TOXICS	COMBUSTION EMISSIONS	IMPACT ANALYSIS / AIR DISPERSION MODELING	INDUSTRIAL HYGIENE
• Fugitives: XVIII-A2 • Tanks: XVIII-A2 • Loading: XVIII-A2 • Wastewater: XVIII-A2 • Odors: XVIII-A2 • Exposure Limits: XVIII-B1 • Toxic Effects: XVIII-B1	• Cyclones: XVIII-A3 • Fabric Filters: XVIII-A4 • Wet Gas Scrubbers: XVIII-A5 • Electrostatic Precipitators: XVIII-A6 • Nitrogen Oxides: XVIII-A8	• Dispersion Modeling: XVIII-A1	• Guidelines: XVIII-B • Exposure Limits: XVIII-B1 • Toxic Effects: XVIII-B1

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DEFINITIONS

Air Pollutant - Any substance in ambient air that is present above its normally occurring standard concentration. This pollutant may or may not be harmful and can include naturally occurring substances such as volcanic dust. Air pollutants generally include the emissions from industrial and agricultural activities; from transportation sources such as cars, buses, trains and ships; and from the treatment of human and animal wastes. Almost any human or animal activity, or any natural occurrence, can cause the generation of an air pollutant. Many regulatory agencies have developed lists of specific air pollutants, which they have the authority to control.

Ambient Air Quality - A measure of the concentration of a pollutant in air compared to a concentration limit, which may have an adverse effect on humans, animals, vegetation, materials, structures, visibility, or the quality of life. Many regulatory agencies have developed concentration limits for specific air pollutants. These limits are often different for indoor and outdoor air as well as for worker and community exposure. There may also be more than one limit based on the adverse effect being considered.

Anthropogenic Emissions - These are emissions of pollutant(s) from “man-made" sources or activities. They include industry, manufacturing, transportation, agriculture, waste treatment and all other sources that are not naturally occurring.

Biogenic Emissions - These are emissions of pollutant(s) from natural sources. They include vegetation and volcanoes.

Dispersion - The transport and dilution of emissions due to natural atmospheric phenomena such as wind and turbulence.

Ozone (Tropospheric or Ground Level) - A substance, O_3, that is a principal component of smog and can be formed in the atmosphere from the reaction of volatile organic compounds and nitrogen oxides in the presence of sunlight.

Primary Air Pollutant - An air pollutant that is in the same form as when it was released. The concentration of the pollutant will be changed, but the chemical species of the pollutant is the same as when it was emitted. Sometimes referred to as non-reactive pollutants.

Secondary Air Pollutant - An air pollutant that is present in a form other than when it was released. Secondary Air Pollutants are formed in the atmosphere by the reaction of one or more Primary Air Pollutants.

Volatile Organic Compound (VOC) - Compounds containing carbon that react with nitrogen oxides in the presence of sunlight to form ozone.

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BACKGROUND

Decisions on the design of air pollution control systems require information on plant emissions, comparison of these emissions and resulting air concentrations to standards, and cost comparison of potential control alternatives. Emissions to the air from refineries and chemical plants include products of combustion, volatile organics, air toxics, and particulate matter. An emissions inventory lists the types, quantities, and sources of air pollutants that are released. These emissions may be compared to regulatory limits or may be used in impact analysis modeling to predict community or worker exposure levels. Regulatory agencies may require some type of permit application, which describes the facility, its predicted emissions, and any control equipment that will be employed. In most cases, there is a choice among alternative technologies or methods that can achieve emissions reduction. An economic analysis is recommended in order to identify the most cost effective emissions reduction options.

It is often more cost effective to prevent an emission than to add control equipment to remove it. This is the focus of “pollution prevention." Many controls tend to convert one pollutant to another (e.g., incineration of sulfur-containing waste streams produces SO_x, NO_x, CO_2, etc.) or move the pollutant from one media to another (e.g., particulate scrubber). Pollution prevention focuses on reducing or eliminating the need for the “add on," “end-of-pipe" control by modifying the process design or operation.

AIR POLLUTANTS OF INTEREST

Table 2 lists the principal Air Pollutants of interest to refineries and chemical plants as well as their potential emission sources. Process plants usually have many combustion units such as fired heaters and boilers that emit SO_x, NO_x, CO, CO_2, and particulates, as well as trace quantities of unburned fuel, metals, and other organic compounds.

Since refineries and chemical plants handle large quantities of volatile organic compounds, they will usually have emissions of these compounds. The largest sources of VOCs are valves, flanges, pumps, compressors and other “piping" components. VOC emissions also come from storage tanks, loading operations, and wastewater treating. VOCs and other air pollutants are also of interest due to their potential to cause annoying odors in the communities surrounding process plants.

The policy debate continues over concern that humans may need to limit emissions of greenhouse gasses, especially CO_2, CH_4, and N_2O, to reduce the threat of climate change. The Framework Convention on Climate Change, which took effect in 1995, requires nations to prepare and publish inventories of greenhouse gas emissions. The Kyoto Protocol, an international treaty that has not entered into force, contains targets and timetables to restrict greenhouse gas emissions in developed countries. The targets, that would take effect in the period 2008-2012, would require emissions reductions of approximately 30% from projected levels in 2010. While the Protocol may not enter into force, most nations have implemented some programs to limit emissions. These include voluntary agreements, energy efficiency standards, and taxes. The issue of public policy on climate change will continue to evolve for decades.

TABLE 2
AIR POLLUTANTS OF INTEREST TO REFINERIES AND CHEMICAL PLANTS

AIR POLLUTANT	EXAMPLE	POTENTIAL EMISSION SOURCE
Sulfur Oxides	SO_2, SO_3	Combustion
Nitrogen Oxides	NO, NO_2	Combustion
Carbon Oxides	CO, CO_2	Combustion
Particulates	FCCU Catalyst Fines	Combustion, construction, catalyst handling, land farming, unpaved roads
Volatile Organic Compounds	Hydrocarbons, Alcohols	Equipment leaks (fugitives), tanks, loading, wastewater collection and treating, relief/safety valves, combustion
Air Toxics	Benzene, H_2S 1,3 - Butadiene, Formaldehyde	Equipment leaks (fugitives), tanks, loading, wastewater collection and treating, relief/safety valves, combustion
Ozone (ground level)	O_3	Formed in the atmosphere from the reaction of nitrogen oxides, volatile organic compounds, and sunlight
Metals	Pb, Cr, As	Combustion, Land farms, Catalyst fines
Chloroflorocarbons	Freons	Refrigeration, Fire-suppression systems
“Greenhouse" Gases	CO_2, CH_4, N_2O	Combustion, equipment leaks, production operations

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BACKGROUND (Cont)

SOURCES OF AIR POLLUTION

Air pollutants can generally be classified as either anthropogenic ("man-made") or biogenic (naturally occurring). In many locations, the contribution from biogenic sources can be substantial. These natural sources include vegetation as an emitter of VOCs and volcanoes as intermittent emitters of SO_2 and particulates. In some areas of high ozone levels, VOC emissions from natural vegetation have been found to be a major contributor to local air pollution.

Anthropogenic emissions come from industrial, manufacturing, transportation, and most other activities of man. The major sources of regulated air pollutants are combustion sources, evaporation, leaks, spills, and vehicles. As previously mentioned, combustion processes are usually sources of sulfur oxides, nitrogen oxides, and particulates. Industrial facilities using organic compounds are sources of emissions from evaporation as well as leaking equipment, spills, and venting. Many consumer products such as paints and polishes contain volatile organics that evaporate during use. Some local regulatory agencies have even identified sources as small as gasoline powered lawnmowers, boat engines, and motorcycles as significant emitters of air pollutants.

The two largest sources of air pollutants in many locations are power generation and transportation. The quantity of emissions from power plants depends on the fuel type, with coal having the highest emissions, oil being lower, and gas being lower still. Combustion of oil or gas results in about 100 times less particulate emissions as compared to coal. While sulfur oxide emissions are usually much lower for oil (depending on the amount of sulfur in the fuel) as compared to coal, sulfur oxide emissions from gas-fired units is usually the lowest among the different fuels.

The air pollutants emitted from transportation include the products of combustion, and evaporative losses during use, fueling, and delivery and storage of the fuel. Due to the large number of these individual sources, as well as the potential effect on the life style of the entire population, significant control of vehicular emissions has been difficult to achieve in many locations. Recent controls include more fuel efficient vehicles and changes in the composition of the fuels (e.g., lower volatility, removal of lead as an octane booster, decreases in the concentration of benzene, and reductions in fuel sulfur levels). A single, poorly performing automobile can contribute more emissions than many newer, well performing models.

Table 3 provides approximate relative emissions of various air pollutants by anthropogenic source types in the United States in 1998 (**Ref. 5**). With the exception of volatile organic compounds, the petroleum and petrochemical industries are not a significant source of air pollutants. In most cases the larger sources of SO_x and NO_x are utilities. CO emissions are primarily due to mobile sources (cars, trucks, etc.). These percentages are likely to be different in other countries since they depend on the extent of industrialization, the fuels used to generate electrical power, the climate, and the modes of transportation.

EFFECTS OF AIR POLLUTANTS

There are many potential effects from the exposure to air pollutants including those to humans, animals, vegetation, materials, structures, visibility, and the quality of life. This section contains a general description of the atmospheric, health, and other effects from exposure. For a more detailed discussion on the specific health effects of air pollutants see **Section XVIII-B1**. The effects described here may occur where the ambient concentration of an air pollutant is above a specified concentration. In many cases, however, there is considerable controversy regarding the value of this concentration. For the latest accepted exposure limits, contact your local Industrial Hygienist or ExxonMobil Biomedical Sciences in Clinton, N.J.

Atmospheric effects of air pollutants include visibility reduction, acid precipitation, stratospheric ozone depletion, and potentially, climate change. Reduced visibility is one of the most noticed effects of air pollution and is primarily due to the presence of particulates and aerosols. Sulfur oxides and nitrogen oxides react with moisture in the atmosphere and are converted into acids, which can precipitate in the form of rain, snow, or mist. Chloroflorocarbons and certain other compounds (e.g., CCl_4, $CHCl_3$) are reported to decrease the protective stratospheric ozone layer.

Basic understanding of the influence of air pollutants on atmospheric radiation suggests that the ongoing accumulation of greenhouse gases could lead to global warming and associated climate changes over the next century. Potential impacts of air pollutants include global warming; rising sea levels; changes in hydrology; shifts in the distribution of ecological systems, ranges of agricultural crops, pests and some diseases; changes in air quality; and changes in climate variability including the frequency and intensity of severe storms and drought. The issue is controversial because uncertainty and ignorance about critical aspects of the science and about future human behavior limit our ability to project both future emissions and their impacts through climate change. Much of what we project must be evaluated in large computational models. While these models are the best tools available today to make forecasts, they are known to be incomplete and unconfirmed, and they are likely to remain so for decades. Little understood natural climate variability complicates the problem of identifying a human induced component of climate change against a backdrop of significant natural climate variability.

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BACKGROUND (Cont)

Health effects due to exposure to air pollutants above certain concentrations include irritation of the eyes, nose, throat, and skin, and respiratory and cardiovascular distress. Different effects may result from either short or long term exposures. In addition, certain segments of the population, such as smokers, are much more susceptible to the effects of ambient air pollutants.

Other effects of air pollutants are those on vegetation, animals, structures, and the effect of odors on the "quality of life." In most cases these effects have received much less attention than the health effects. Sulfur oxides and ozone have been reported to cause significant injury to vegetation. Gaseous and particulate pollutants are known to effect metals, carbonate building stones, paints, textiles, rubber, leather, and paper.

TABLE 3
APPROXIMATE RELATIVE EMISSIONS OF ANTHROPOGENIC POLLUTANT SOURCE TYPES IN THE UNITED STATES, 1998
(FROM US EPA ANNUAL EMISSION REPORT, REF. 5)

SO_x	
85%	Stationary Source Combustion (Utilities, Industrial/Residential Furnaces/Boilers)
8%	Industrial Processes (Ore Processing, Petroleum/Chemicals, Paints, Agriculture)
7%	Transportation (Cars, Trucks, Buses, Aircraft, Ships, Trains, Motorcycles)
NO_x	
54%	Transportation (Cars, Trucks, Buses, Aircraft, Ships, Trains, Motorcycles)
42%	Stationary Source Combustion (Utilities, Industrial/Residential Furnaces/Boilers)
3%	Industrial Processes (Ore Processing, Petroleum/Chemicals, Paints, Agriculture)
1%	Other Combustion (Forest Fires, etc.)
CO	
79%	Transportation (Cars, Trucks, Buses, Aircraft, Ships, Trains, Motorcycles)
10%	Other Combustion (Forest Fires, etc.)
6%	Stationary Source Combustion (Utilities, Industrial/Residential Furnaces/Boilers)
4%	Industrial Processes (Ore Processing, Petroleum/Chemicals, Paints, Agriculture)
1%	Solid Waste Disposal (Materials Handling, Incineration)
VOLATILE ORGANIC COMPOUNDS	
44%	Transportation (Cars, Trucks, Buses, Aircraft, Ships, Trains, Motorcycles)
30%	Solvent Utilization (Degreasing, Graphic Arts, Dry Cleaning, Surface Coating)
8%	Industrial Processes (Ore Processing, Agriculture, Petroleum/Chemicals, Paints)
7%	Storage and Transport (Storage Tanks, Loading, Service Stations)
5%	Stationary Source Combustion (Utilities, Industrial/Residential Furnaces/Boilers)
4%	Other Combustion (Forest Fires, etc.)
2%	Solid Waste Disposal (Materials Handling, Incineration)
PARTICULATES (PM_{10})	
85%	Fugitive Dust (Unpaved Roads, Paved Roads, Construction)
4%	Stationary Source Combustion (Utilities, Industrial/Residential Furnaces/Boilers)
4%	Other Combustion (Forest Fires, etc.)
3%	Transportation (Cars, Trucks, Buses, Aircraft, Ships, Trains, Motorcycles)
3%	Industrial Processes (Ore Processing, Agriculture, Petroleum/Chemicals, Paints)
1%	Solid Waste Disposal (Materials Handling, Incineration)
PARTICULATES ($PM_{2.5}$)	
56%	Fugitive Dust (Unpaved Roads, Paved Roads, Construction)
13%	Other Combustion (Forest Fires, etc.)
12%	Stationary Source Combustion (Utilities, Industrial/Residential Furnaces/Boilers)
9%	Transportation (Cars, Trucks, Buses, Aircraft, Ships, Trains, Motorcycles)
6%	Industrial Processes (Ore Processing, Agriculture, Petroleum/Chemicals, Paints)
4%	Solid Waste Disposal (Materials Handling, Incineration)

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BACKGROUND (Cont)

AIR POLLUTION REGULATIONS

Regulations to control air pollution may require the application of specific control equipment or practices, limitations on the emission rates of specific chemicals, and/or the assessment of risk. It is important to determine which regulations apply in each situation before selecting any air pollution controls. Contact the plant environmental coordinator for the most recent applicable regulations.

Some regulatory agencies set a standard for the maximum allowable concentration of a pollutant in ambient air at ground level. This concentration is designed to be what most individuals may be exposed to without harm. An emission source will usually be required to apply controls such that it does not cause concentrations that exceed the regulatory standard. Comparison to the standard can be determined using either ambient air monitoring or dispersion modeling. Monitoring to determine the impact of new facilities not yet built is clearly impossible. One of the difficulties with the modeling approach, however, is that there are many sources that may need to be included in the analysis in order to accurately predict the resultant concentration.

Regulations that limit emission rates may be based on total flow or on the concentration of a particular species. Some are applied to an entire plant ("bubble" approach) rather than to each individual emission source. Source testing may be required to demonstrate compliance with some regulations.

When specific equipment or practices are required, it is often possible to substitute options that result in an equivalent effect on the quality of the ambient air. In most cases, these options include alternative equipment on a specific emission source or a nearby source of the same pollutant. More recently, emissions trading between different companies and even different pollutants has been utilized. Check with the local regulatory agency to determine if these alternatives are an option.

The most recent regulatory approach for controlling the emissions of air pollutants is risk assessment. In one type of this analysis, the total emissions of a plant are included and, using sophisticated population models, concentrations of many species are compared to long term exposure limits. In another approach, various leak and/or spill scenarios are analyzed to determine the potential effects on the surrounding communities in the event of a major, accidental release of toxic chemicals.

It is clear that many regulatory agencies intend to apply more stringent regulations to control air pollution than are currently in place. These regulations tend to be copied from those locations where standards have already been applied. In this manner, requirements that may not always be the best technological solution to reducing air pollution are implemented. Early interaction with local regulatory agencies is recommended in order to ensure that the most appropriate solutions to reducing air pollution are considered.

STEPS IN SELECTING CONTROL SYSTEMS

Table 4 provides a step-by-step procedure for selecting air pollution control systems when emissions reductions are needed. Not all of these steps are required for all projects and only those that are applicable need be included. The first step is to identify the need for applying the air pollution control equipment. This is done by identifying the applicable regulations that may set limits on the emissions of specific pollutants by either rate or concentration. For new projects, it is important to consider future as well as current regulations so that the plant can continue to remain in compliance as the new regulations become effective and are enforced. This may also serve as a good opportunity to review all regulations covering the plant air emissions to ensure compliance.

In addition to meeting the applicable environmental regulations, a check should be made to ensure that potential exposure levels for plant personnel are within allowable limits. In some cases there may be a need to apply more restrictive controls on emissions of potentially toxic materials.

To determine the need for air pollution control equipment, it is necessary to compare the current emissions to the regulatory limits. In order to do this, an emissions inventory is required. An inventory lists all the individual sources of each air pollutant in the plant and the quantity of the emissions. Various emissions estimating methods may be utilized and, in some cases, emissions measurements may be required. These results are then compared to the allowable emission limits and any required reductions are noted.

The results of the emissions inventory can be used in the next step, dispersion modeling, to predict the ground level ambient concentration of the pollutants for the area surrounding the plant. There are often limits on the ambient concentration of each pollutant in the local air, and this step will allow comparison of the predicted concentration to those limits and determine the need for emissions controls to achieve compliance.

- The final step in selecting an air pollution control system is to identify the potential control options that may be used to come into compliance and to evaluate their cost. Cost effectiveness is a concept that regulators use. Project teams focus on capital cost and, to a lesser extent, O&M costs.

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STEPS IN SELECTING CONTROL SYSTEMS (Cont)

TABLE 4
STEPS IN SELECTING AIR POLLUTION CONTROL SYSTEMS

STEP 1	Identify current and future applicable regulations which may limit emission rates and/or concentrations or specify specific control equipment. Include all air pollution regulations that may impact operations.
STEP 2	Determine the sources and emissions rates of each air pollutant using estimating methods or by actual measurements if appropriate. Include new, planned, and existing sources (also those outside the facility) which may have an impact on meeting regulatory or health limits. Determine potential exposure levels for plant personnel and the need for more restrictive controls.
STEP 3	For each pollutant, predict the impact on ground level ambient air concentrations for the area surrounding the plant and compare these to the appropriate regulatory or health standards. Determine the area impacted by releases from the plant.
STEP 4	From comparisons of the estimated emissions and predicted ambient concentrations to the regulatory requirements, determine the required emissions reductions, if any.
STEP 5	Identify the potential control options for reducing emissions of each pollutant. Analyze the technical feasibility and cost effectiveness of each option.

EMISSIONS INVENTORIES

An emissions inventory is an estimate of the emissions from a facility, or part of one, over a fixed period of time, usually one year. This section contains a general description of why an inventory might be required and provides guidance in how to conduct an emissions inventory. For specific instructions in estimating emissions from various sources, reference is made to a number of ExxonMobil technical manuals.

REASONS FOR CONDUCTING AN EMISSIONS INVENTORY

The scope and purpose of the emissions inventory will largely determine the methodology employed to generate the emissions estimate. An inventory can be a very detailed assessment of the emissions from the facility using measurement data or can be an approximation based upon simple emission estimating factors. Most inventories will fall somewhere between these two extremes. The resources and effort required to produce an inventory are closely related to the level of accuracy required. Thus, a primary step in any inventory process is to determine the intended use of the emission estimates.

The most common reasons for conducting an emissions inventory are:

- **Regulations** - National or local regulations may require an emissions inventory. Guidance on the extent of the inventory and acceptable approaches may be available from the regulatory agency.
- **Company Policy or Initiative** - Company initiatives to track emissions may require regular inventories even where none are required by local regulations.
- **Permitting and Health Risk Assessments** - Emission estimates for the entire or affected parts of the facility or a proposed facility, are often required in permit applications and health risk assessments.
- **Determining Baseline Emissions** - The relative magnitude of the types and sources of emissions can help prioritize emissions reduction projects. Also, the inventory can be used as a baseline to allow emissions reduction progress to be monitored.

The level of accuracy depends on the purpose of the inventory.

INVENTORY FOCUS

An emissions inventory is often focused on a specific compound or type of emission such as benzene, volatile organic compounds, or products of combustion. The inventory focus may be emissions to a single media, such as air, or multi-media, including emissions to the air, water, and land (waste disposal). Potential emission sources to air include tanks, stacks and flares, piping components, cooling towers, and waste water treatment equipment. A detailed list of potential sources can be found in the *EMRE Emission Estimating Guide* (**Ref. 1**).

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