United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park, NC 27711

EPA-453/R-94-019
March 1994

Air

Regulatory Impact Analysis for the National Emissions Standards for Hazardous Air Pollutants for Source Categories: Organic Hazardous Air Pollutants from the Synthetic Organic Chemical Manufacturing Industry and Other Processes Subject to the Negotiated Regulation for Equipment Leaks

FINAL

REGULATORY IMPACT ANALYSIS

For The
National Emissions Standards for Hazardous Air Pollutants for Source Categories: Organic Hazardous Air Pollutants from the Synthetic Organic Chemical Manufacturing Industry and Other Processes Subject to the Negotiated Regulation for Equipment Leaks

Emission Standards Division

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
MD-13, Research Triangle Park, North Carolina 27711
March 1994

This report has been reviewed by the Emission Standards Division of the Office of Air Quality Planning and Standards, EPA, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use. Copies of this report are available through the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, or from National Technical Information Services, 5285 Port Royal Road, Springfield, VA 22161.

FOREWORD

This Regulatory Impact Analysis (RIA) was initiated under the authority of Executive Order 12291. On October 1, 1993, the Order was rescinded and replaced by Executive Order 12866. The Hazardous Organic NESHAP RIA at present does not explicitly reflect this change. This is necessary due to the tight court-ordered schedule for this regulation.

EXECUTIVE SUMMARY

The Environmental Protection Agency (EPA) plans to promulgate regulations to reduce air pollutant emissions from synthetic organic chemical manufacturing industry (SOCMI) facilities in eight source categories, and facilities in seven non-SOCMI equipment leak source categories. Both new and existing facilities that meet the Clean Air Act definition of major sources will be regulated under the authority of sections 112(c) and (d). This decision is based on evidence that SOCMI facilities release air pollutants that have adverse effects on both public health and welfare, and the need for additional control of air pollutants already covered by the Act before the 1990 Amendments.

Section 112(b) lists 189 hazardous air pollutants (HAP's). The proposed regulation will reduce the emissions of approximately 150 of the organic chemicals on the list. The proposed regulation requires sources to achieve emissions limits reflecting the application of the maximum achievable control technology (MACT).

The HON regulation covers five types of emission points: process vents, wastewater, transfer operations, storage vessels, and equipment leaks. The regulation is made up of two standards, one covering the first four emission points, and the second covering equipment leaks. The standard for the first four emission points was arrived at by the usual regulatory process, while the equipment leaks standard was developed by regulatory negotiation.

This regulation is unusual in that the regulation of the emissions occurring from production of an extremely large number of chemicals is being targeted at one time. Facilities in virtually every state shall be affected by the HON. In determining the regulatory options, the Agency evaluated methods of determining what technologies should be applied for particular types of emissions, what would be the minimum level of stringency for pollutant control, and strategies for obtaining control at the lowest cost (emission averaging).

The standards will require reductions of emissions of HAP's, which are a subset of VOC's (volatile organic compounds). The level of control provided by the regulatory options chosen ranges from no control for existing small storage tanks (i.e, storage tanks with less than 10,000 gallon capacity) to 95 percent control for new process vents. The total amount of emission reduction for HAP's will be 456,000 Mg (megagrams), and for all VOC's (including HAP's) approximately 949,000 Mg.

These standards, based on the regulatory options chosen, will cost the nation $230 million annually by the fifth year after all affected sources have complied with the regulation (i.e., 1999), and will require $450 million in capital investment. The economic impacts for the regulatory options chosen are expected to be small. Price increases for a large majority (83 percent) of affected chemicals are expected to be under 2 percent, and decreases in production for a very large majority (87 percent) of affected chemicals are expected to be under 2 percent. Due to the flexible nature of the SOCMI, and the several process routes possible for production of most SOCMI chemicals, significant closures for SOCMI facilities are quite unlikely.

The regulatory alternatives under consideration will not affect a substantial number of small entities, so a Regulatory Flexibility Analysis is not required.

The absence of valuation and sufficient exposure-response information precludes a quantitative benefits analysis at this time.

Table of Contents

Chapter 9 - Weighing the Benefits and the Costs

List of Tables **Page No.**

Acronyms, Definitions, and Conversions

Acronyms

BID	Background Information Document
CAA	Clean Air Act
CAAA	Clean Air Act Amendments of 1990
CPP	Chemical Production Processes
EPA	Environmental Protection Agency
HAP	Hazardous Air Pollutant
HON	Hazardous Organic NESHAP (NESHAP is defined below)
LDAR	Leak Detection and Repair
LEL	Lower Explosive Limit
MACT	Maximum Achievable Control Technology
NAAQS	National Ambient Air Quality Standards
NESHAP	National Emission Standards for Hazardous Air Pollutants
NPDES	National Pollutant Discharge Elimination System
OAQPS	Office of Air Quality Planning and Standards
OSHA	Occupational Safety and Health Administration
POTW	Publicly Owned Treatment Works
RACT	Reasonably Available Control Technology
RFA	Regulatory Flexibility Act; also Regulatory Flexibility Analysis
SIC	Standard Industrial Classification
SIP	State Implementation Plan
SOCMI	Synthetic Organic Chemical Manufacturing Industry

TLV	Threshold Limit Value
TRE	Total Resource Effectiveness
VOC	Volatile Organic Compound
VHAP	Volatile Hazardous Air Pollutant
VOHAP	Volatile Organic Hazardous Air Pollutant
VVHAP	Very Volatile Hazardous Air Pollutant

Chemical Symbols

CO_2	Carbon dioxide
CO	Carbon monoxide
HCl	Hydrochloric acid
NH_3	Ammonia
NO_x	Nitrogen oxide
O_3	Ozone
SO_2	Sulfur dioxide

Economic, Regulatory, and Scientific Terms

Annual Cost	Annualized capital plus annual operating costs
Area Source	Any emission source emitting less than 10 tons per year of a single HAP or 25 tons or more per year of two or more HAPs, unless EPA establishes a lesser quantity cutoff
bbl	One barrel; equal to 42 gallons
Btu	One British thermal unit
C/E	Cost effectiveness, which is the net present value of cost of emission control divided by the present value of emission reductions in megagrams (defined below)

Gg	One gigagram, or 1,000,000 kilograms
Gm	One gram
kw	One kilowatt, or 1,000 watts
lpm	One liter per minute
Major Source	Any emission source emitting 10 tons or more a year of a single HAP or 25 tons or more a year of two or more HAPs
Mg	One megagram, or 1,000 kilograms
MJ	One megajoule, or .949 Btu
MW	One megawatt, or .949 Btu per second
ppmv	parts per million by volume (air)
ppmw	parts per million in water
psia	Pounds per square inch absolute
112(b)	Section of Title III in the CAAA that requires the EPA to promulgate regulations establishing emission standards for new and existing sources of HAPs on the list of 189 HAPs in the title
scfm	One standard cubic foot per minute
Title I	The first title of the CAAA; this title classifies nonattainment areas, sets attainment schedules, and prescribes control measures for O_3, CO, PM-10, and for SO_x, NO_x, and Lead
Title III	The third title of the CAAA; this title lists the 189 HAPs to be controlled with MACT, as well as the control of major and area sources, incinerator air emissions, accidental releases, and special studies

TIC	Total Industry Control; the most stringent regulatory option for each source type

Units and Conversions

This report uses metric units, some of which may not be familiar to all readers. The EPA is required by Congress to use metric measurements. The following is a short guide to the units and their conversions.

Conversions

To Approximate	As	Multiply by
Mg (megagram)	Ton (2,000 lb)	1.1
scm (standard cubic meter)	scf (standard cubic foot)	35.3
MJ (megajoule)	Btu (British thermal unit)	949
MW (megawatt)	Btu/second	949
kg (kilogram)	lb (pound)	2.2

CHAPTER 1

BACKGROUND

1.1 Introduction

The NESHAP being promulgated is commonly known as the hazardous organic NESHAP, or HON. The HON would regulate emissions of certain organic hazardous air pollutants from SOCMI process units. A SOCMI process unit is defined as a unit producing one or more of a list of SOCMI chemicals. A SOCMI process unit is only covered by the HON if it either 1) produces a HAP as a product, by-product, co-product, or intermediate; or 2) uses a HAP as a reactant or raw material to produce a SOCMI chemical. Seven non-SOCMI source categories would also be regulated under the proposed equipment leaks standard (see Section 2.1): styrene/butadiene rubber production; polybutadiene production; chlorine production; pesticide production; chlorinated hydrocarbon use; pharmaceutical production; and miscellaneous butadiene use.

1.2 Legal History

On November 15, 1990, the Clean Air Act was amended significantly. Section 112 was substantially revised at that time altering the basic framework for regulating emissions of toxic air pollutants from stationary sources.

Prior to the amendments passed in 1990, Section 112 required the Administrator to list air pollutants for which he intended to establish NESHAPs. Within 180 days after the listing of such air pollutants, regulations were to be proposed. Final regulations were to be issued in another 180 days. Thus, once the Administrator added a pollutant to the Section 112 list, a final NESHAP for that pollutant had to be issued within one year. The statute itself did not contain a list of hazardous air pollutants.

The amendments enacted in 1990 altered the preexisting scheme of Section 112 fundamentally. Instead of requiring the Administrator to determine which air pollutants ought to be listed and regulated as hazardous air pollutants, Congress provided a list of 189 hazardous air pollutants in the statute itself. EPA may revise that list only in conformance with clear statutory guidelines. The Agency is now required to develop a list of all categories and subcategories of sources emitting any of the listed pollutants, and develop technology-based standards to control such emissions. Thus, these standards are to be based on the sources of the emissions rather than being set pollutant by pollutant as in the past and are no longer to be risk based. Regulations for all source categories must be promulgated within

10 years of enactment of the amendments. Generally, assessment and control of any remaining unacceptable health risk is to occur 8 years after the technology-based standards are promulgated. However, for the HON the residual risk assessment is to be conducted 9 years after promulgation.

1.3 Retrospective on Section 111 and 112 Standards Affecting the SOCMI

The provisions of the promulgated standards incorporate data, information, and experience gained by EPA through previous rulemaking efforts involving similar sources. Information on control technology applicability, performance, and cost were available from previous NSPS and NESHAP regulatory development efforts. This information was considered in selecting MACT and in developing the proposed standards.

Under the NSPS program, EPA has promulgated NSPS for SOCMI air oxidation and distillation process vents; SOCMI emissions from equipment leaks; petroleum refinery equipment leaks; and VOC emissions from volatile organic liquid storage vessels. Similarly, under the NESHAP program, regulations were promulgated for benzene storage tanks, transfer racks and wastewater emissions , and for vinyl chlorine and benzene equipment leaks. In the development of the HON, this previously collected array of information was carefully reconsidered in light of the provisions of the CAA of 1990. This technical information is presented in detail in the HON BID.

Each of these previous efforts regulates some sources or chemicals that would be subject to the HON, but none of them comprehensively regulate emissions of all of the organic HAP's emitted from new and existing SOCMI process units from all emission points. The HON would regulate all five of the emission points at each affected SOCMI source (see Section 2.1), and would regulate emissions of any of the listed organic HAP's. The first of the HON standards (Subpart G) was developed through usual regulatory procedures, and covers four of the five emission points. An analysis of various regulatory alternatives was conducted for this standard. The second, the equipment leaks NESHAPs (Subpart H), was developed through the regulatory negotiation process, and, as a result, a formal analysis of regulatory alternatives was not conducted.

The negotiators in this process originally were to develop standards for equipment leaks for 13 source categories that would be affected by standards already under development. The standards under development would have applied to only eight organic chemicals. However, during negotiation of the amendments to the CAA, EPA expanded the scope of the standards to include all SOCMI processes that produce or use as a reactant one of the 149 organics listed in the CAA list of 189 HAP's (55 FR

8984, March 9, 1990; 55 FR 14349, April 17, 1990). Petroleum refinery processes were not to be covered, however.

1.4 Executive Order 12291

The President issued Executive Order 12291 on February 17, 1981. It requires EPA to prepare regulatory impact analyses (RIAs) for all regulations having "major" impacts. An impact is considered "major" if the annual effect on the economy is $100 million or more, and/or may result in a "significant" increase in prices. The EPA considers the HON regulations to be major and thus is issuing this RIA.

Along with requiring an analysis of benefits and costs, E.O. 12291 specifies that EPA, to the extent allowed by the Clean Air Act and court orders, demonstrate 1) that the benefits of the HON regulations will outweigh the costs and 2) that the maximum level of net benefits will be reached. Chapter 8 describes the benefits in detail. As explained in that chapter, EPA cannot quantify some of the benefits. Thus, EPA cannot show quantitatively that the benefits of the regulations will outweigh the costs. Despite this problem of quantifying benefits, EPA has determined that CAA Sec. 112 requires issuance of the HON regulations at the stringency level described in Chapter 2. For more information, refer to Chapter 9 and the Federal Register preambles to the HON.

1.5 Guide to the References

Most of this RIA is a summary of research reports, analyses, correspondence, minutes of various meetings and hearings, policy directives, legal notices, laws, regulations, and other documents relating to the development of CAA Sec. 112 regulations for SOCMI (and certain non-SOCMI) facilities. The principal references are listed in the back of the chapter on the subject of interest to you. Consult these references, as well as the preambles that accompany proposal of the HON in the Federal Register, for more detailed information. References are held in public dockets and are available for inspection and copying-the latter may require a fee-during normal business hours. For more information on the docket, contact:

Air and Radiation Docket
and Information Center (LE-131)
Room M-1500,
Waterside Mall
401 M Street, SW
Washington, DC 20460

Hours: 8:00 a.m. to 4:00 p.m.
Phone No.: (202) 382-7549
FAX: (202) 260-4000

CHAPTER 2

THE PROPOSED HON EMISSION STANDARDS IN BRIEF

The HON is organized in four subparts. Subpart F provides a description of the applicability of the standards. Subparts G, H, and I provide the control, monitoring, recordkeeping and reporting requirements for the standard.

2.1 Subpart F: Applicability of the HON

The HON will regulate certain components of new and existing major sources, as defined by Section 112(a), in the SOCMI and 7 non-SOCMI equipment leak source categories.

To define the SOCMI source category, Subpart F includes a list of organic HAP's and a list of approximately 400 synthetic organic chemicals produced by the SOCMI as commercial products. The "chemical manufacturing processes" used to produce these 400 chemicals can, but do not always, result in organic HAP emissions. Only those processes resulting in HAP emissions are subject to the standard.

As proposed, Subpart F defines "source" for the SOCMI source category as all process vents, storage vessels, transfer racks, wastewater streams, and equipment leaks in the organic HAP emitting chemical manufacturing processes that are subject to the HON. To be subject to the HON, a chemical manufacturing process must be used to produce one or more of the approximately 400 SOCMI chemicals listed in Subpart F, and have an organic HAP as either 1) a product, by-product, co-product, or intermediate; or 2) a raw material in the production of another SOCMI chemical product.

To be part of the same source, chemical manufacturing processes that are subject to the HON must also be located within a contiguous plant site under common control.

Subpart G will apply to the following kinds of emission points in SOCMI chemical manufacturing processes: process vents, wastewater operations, storage vessels and transfer operations.

Subpart H will apply to the equipment leaks in SOCMI chemical manufacturing processes, while Subpart I will apply to these non-SOCMI equipment leak source categories: styrene/butadiene rubber production; polybutadiene production; chlorine production; pesticide production; chlorinated hydrocarbon use; pharmaceutical production; and miscellaneous butadiene use.

2.2 Subpart G: Provisions for Process Vents, Wastewater Operations, Storage Vessels and Transfer Operations

Subpart G of the proposed rule would require the owner or operator of a source to limit source-wide emissions of HAP's. Subpart G provides specific instructions for determining how much emissions must be reduced at each source. The required emissions reduction is determined by how much emissions would be reduced if a "reference control technology" were applied to all the "Group 1" emission points in the source.

The proposed standard specifies the reference control technology for each kind of point. Group 1 points are those points that meet the applicability criteria included in the control requirements for the proposed standard. The reference control technologies and applicability criteria for Group 1 points are specified in Subpart G of the standard as well as the definition list in the HON preamble.

The owner or operator of a source can use two methods to comply with the emissions reduction requirement. Either method can be used exclusively, or the two can be combined.

The first method is to apply the reference control technology, or an equivalent technology, to Group 1 emission points; thereby achieving some part of the required emission reduction at each Group 1 point that is controlled.

The second method is to average emissions from two or more emission points such that the overall required emission reduction is achieved. With the second method, emissions averaging, the owner or operator does not have to apply the reference control technology to each Group 1 point, as long as an equivalent or greater emissions reduction is achieved elsewhere in the source. The proposal provides specific procedures that must be followed to utilize emissions averaging as a means of compliance with the HON. These procedures are summarized in Section III.B.6 of this notice.

Although equipment leaks are included in the definition of source for the SOCMI source category, equipment leaks can not be included in the emissions averages because: 1) the equipment leaks standard has no fixed performance level; and 2) no method currently exists for determining the magnitude of allowable emissions to assign equipment leaks for purposes of emissions averaging. When this methodology is developed, EPA will consider allowing equipment leak emissions to be included in emissions averages.

2.3 Subpart H: Provisions for Equipment Leaks in SOCMI Processes

The provisions in Subpart H of the proposed rule were developed using regulatory negotiation and represent an extension of existing equipment leak control techniques to the eight source categories regulated by this final rule.

Subpart H proposes work practice requirements to reduce emissions from equipment leaks for equipment in volatile HAP service for 300 or more hours per year. To be in volatile HAP service is to be in contact with or containing fluid that is 5 percent or more HAP.

The following types of equipment are subject to the proposed standards in Subpart H: valves, pumps, connectors, compressors, pressure relief devices, open-ended lines, sampling connection systems, instrumentation systems, agitators, product accumulator vessels, and closed-vent systems and control devices.

2.4 Subpart I: Provisions for Equipment Leaks in non-SOCMI Processes

In contrast to the sources in the SOCMI source category, sources in the non-SOCMI processes would be covered by this subpart and subpart H. For these processes, the source would include every type of equipment subject to the proposed standards in Subpart H except product accumulator vessels and closed-vent systems and control devices. The Agency is also considering regulating the other kinds of emission points in these processes in future section 112 standards.

CHAPTER 3

THE NEED FOR AND CONSEQUENCES OF REGULATORY ACTION

3.1 The Problems

One of the concerns about potential threats to human health and the environment from chemical manufacturing plants is air emissions of hazardous organics. Hazardous chemicals can also find their way into underground water supplies, and in the solid waste stream. Health risks from emissions of hazardous organics into the air include increases in cancer incidences and other toxic effects. This chapter discusses the need for and consequences of regulating of hazardous air emissions from chemical plants. Section 3.2.3 provides more detail on the health risks of these pollutants.

3.2 Need for Regulation

3.2.1 Market Failure

The U.S. Office of Management and Budget (OMB) directs regulatory agencies to demonstrate the need for a major rule.[1] The regulatory impact analysis must show that a market failure exists and that it cannot be resolved by measures other than Federal regulation. Market failures are categorized by OMB as *externalities*, *natural monopolies*, or *inadequate information*. The following paragraphs address the three categories of market failure. Chapter 5 discusses the regulatory options and makes a case for the necessity of a Federal regulation.

3.2.1.1 Air Pollution as an Externality

Air pollution is an example of a negative externality. This means that, in the absence of government regulation, the decisions of generators of air pollution do not fully reflect the costs associated with that pollution. For a chemical plant operator, air pollution from the plant is a product or by-product that can be disposed of cheaply by venting it to the atmosphere. Left to their own devices, many plant operators treat air as a free good and do not fully "internalize" the damage caused by emissions. This damage is born by society, and the receptors---the people who are the ones adversely affected by the pollution---are not able to collect compensation to offset their costs. They cannot collect compensation because the adverse effects, like increased risks of morbidity and mortality, are by and large, non-market goods, that is, goods that are not explicitly and routinely traded in organized free markets.[a]

Consider an example. It may be somewhat unreal, but it illustrates why air pollution is a market externality. A young man estimates that over his remaining lifetime he has a risk of getting cancer of, let's say, 4 chances in 10. A new chemical plant is being constructed in his neighborhood, and he pessimistically calculates that the added pollution to his own environment will boost his odds of getting cancer to, say, 5 chances in 10. He walks up to the people owning the chemical plant and offers to "sell his exposure" to the plant's air pollution for a bargain basement price of just $5 a day. For his efforts he gets no more than a laugh. What's wrong? Most young men either would be unwilling to even consider such a transaction, or, if they were willing, they would not know enough about their futures and about the effects of the pollution to set such a precise price. Furthermore, even if they were willing and did have a price, they would not have any good way of coming to terms with the plant owners.[b] The plant owners would ordinarily not attempt such a transaction for many of the same reasons the young man would not attempt it. Given that the plant owners and the young man could accept such a transaction, if transactions costs were low enough and all others parties' concerns were negligible, a transaction which would internalize the air pollution externality could occur, as explained in Coase's theorem. However, it is unusual for this type of externality to be eliminated by this route.[c]

---

[a] Litigation also is a possible route for collecting compensation. EPA recognizes that improving the legal system to facilitate environmental protection lawsuits, and the consequent reduction of negative externalities, may be as cost effective and equitable as regulation under the CAA. However, EPA has not explored this avenue for controlling hazardous organic air pollutant emissions.

[b] Again, litigation would be a possible route.

[c] An air pollution externality caused by a chemical plant outside of Port Arthur, Texas was dealt with by a market transaction. The company owning the plant purchased the homes of local residents who had complained about the pollution. However, this transaction only occurred after intense political activity instigated by the residents. See "How a Neighborhood Talked Fina Refinery Into Buying It Out," The Wall Street Journal, December 10, 1991. Other oil companies have also bought land around facilities (called "greenbelts") in order to preempt the creation of pollution externalities. However, this land buying preceded operations.

How would it help to force chemical plants either to compensate the people suffering the consequences of the pollution, or simply to reduce the pollution? Where there are negative externalities like air pollution, the market price of goods and services does not reflect the costs, borne by receptors of air pollution, generated in the course of producing the goods and services. Government regulation can be used to improve the situation. The NESHAP's will force chemical plant owners and operators to reduce the quantity hazardous organic air pollutants they emit. With the NESHAP's in effect, what chemical plant owners and operators must spend to produce chemicals will more closely approximate the full social costs of production. In the long run, chemical plants will be forced to increase prices of the products sold in order to cover total production costs. Thus, prices will rise, consumers accordingly will reduce their demand for chemical products, and hence less chemicals will be provided. The more the costs of pollution are internalized by the chemical plants, the greater the improvement in the way the market functions. If we could internalize all negative externalities---including, of course, those from chemical plants---society's allocation of resources would be improved.

3.2.1.2 Natural Monopoly

In some respects, chemical plants can tend toward "natural" monopolies. There are large economies of scale in chemical manufacturing; the heavy up-front capital needed to construct a plant acts as a barrier to entry. Due to the necessity for heavy up-front capital, most chemical market are oligopolies (i.e., dominated by a few firms). Thus, each firm in this type of market possesses more monopoly power than if each firm were operating in a more competitive market. The NESHAP's are not designed to address this circumstance, and will not reduce the tendency of chemical production markets toward monopoly or oligopoly.

3.2.1.3 Inadequate Information

The third category of potential market failure that sometimes is used to justify government regulation is inadequate information.

Some chemical manufacturing facilities can reduce costs by installing air pollution control devices, reducing leaks or recycling hazardous organic chemicals. Due to lack of information, some of these facilities do not install such systems. The NESHAP's would require the collection of information that may give a chemical plant owner enough data to make an informed decision on whether or not control devices are the best option.

3.2.2 Insufficient Political and Judicial Forces

There are a variety of reasons why many emission sources, in EPA's judgment, should be subject to reasonably uniform national standards. The principal reasons:

* Air pollution crosses jurisdictional lines.

* The people who breathe the air pollution travel freely, sometimes coming in contact with air pollution outside their home jurisdiction.

* Harmful effects of air pollution detract from the nation's health and welfare regardless of whether the air pollution and harmful effects are localized.

* Uniform national standards, unlike potentially piecemeal local standards, are not likely to create artificial incentives or artificial disincentives for economic development in any particular locality.

* One uniform set of requirements and procedures can reduce paperwork and frustration for firms that must comply with emission regulations across the country.

None of these reasons, by itself, provides overriding justification for Federal action in the case at hand. Collectively, however, the reasons argue against reliance on state and local action to control hazardous organic air emissions from chemical plants.

Citizens, as well as EPA, may sue state and local governments to force them to control hazardous organic air emissions from chemical plants. Litigation under both the CAA and RCRA is possible. However, EPA has not explored ways of improving the judicial route so that it might serve as a substitute for action under Section 111 of the CAA.

3.2.3 Harmful Effects of Hazardous Organic Air Emissions

Only health effects associated with hazardous organic air emissions are addressed in these NESHAP's. Direct exposure to air emissions can occur through inhalation, soil ingestion, the food chain, and dermal contact.

Out of the 189 hazardous air pollutants identified in the Clean Air Act Amendments, 149 chemicals are being regulated by the HON; however, of these 149, only 110 are regulated by Subpart G of the HON. Of these 110 chemicals, approximately one-third are carcinogens and approximately two-thirds are noncarcinogens. The EPA has devised a system, which was adapted from one developed by the International Agency for Research on

Cancer, for classifying chemicals based on the weight-of-evidence.[2] Three of the carcinogens, benzene, vinyl chloride, and bis(chloromethyl)ether, are classified as group A or known human carcinogens. This means that there is sufficient evidence to support that the chemical causes an increased risk of cancer in humans. One of these known human carcinogens, benzene, is a concern to the EPA because long term exposure to this chemical has been known to cause leukemia in humans. While this is the most well known effect, benzene exposure is also associated with aplastic anemia, multiple myeloma, lymphomas, pancytopenia, chromosomal breakages, and weakening of bone marrow (53 FR 28504; July 28, 1988).

Vinyl chloride is another known human carcinogen. Exposure to vinyl chloride has been known to cause angiosarcoma of the liver. It has also been associated with other forms of cancer as well as noncancerous effects. The noncancerous effects include liver damage and, potentially, chemical mutagenicity and teratogenicity (40 FR 59533; Dec. 24, 1975).

Most of the carcinogenic chemicals on the list are classified as group B or probable human carcinogens. This means that there is limited data on human carcinogenicity, but sufficient data on animal carcinogenicity to suggest possible increased human risks as well. Some examples of the twenty-five probable human carcinogens on the list are 1,3-butadiene, carbon tetrachloride, acetaldehyde, benzyl chloride, and tetrachloroethylene. In several rat studies, 1,3-butadiene caused several tumors on different organs (50 FR, pp. 41466-41468, Oct. 10, 1985). In addition, at high concentrations, it can cause coughing, fatigue, sleepiness, headache, giddiness, unconsciousness, respiratory paralysis, and death.[3] Carbon tetrachloride is known to cause cancer in animals and is thus suspected to cause cancer in humans. It may also increase stratospheric ozone depletion, which can cause a rise in the incidence of skin cancer and possibly various other effects (50 FR 32621; Aug. 13, 1985).

Twelve of the HON chemicals are considered to be group C or possible human carcinogens. A few of these are acrolein, vinylidene chloride, allyl chloride, and 1,1,2,2-tetrachloroethane. For these chemicals, there is either inadequate data or no data on human carcinogenicity, and there is limited data on animal carcinogenicity. Therefore, while cancer risk is possible, there is not sufficient evidence to support that these chemicals will cause increased cancer risks in humans.

The remaining 70 HON chemicals are noncarcinogens. Though they do not cause cancer, they are considered hazardous because of the other significant adverse health effects with which they are associated. Some examples of the noncarcinogens include chloroprene, methyl chloroform, diethyl sulfate, methyl hydrazine, and triethylamine. One of these chemicals, chloroprene, causes various effects at different lengths of exposure. Possible effects from acute exposure range from vertigo and nausea at very short exposure periods to liver damage and death after a few hours. Subchronic toxicity effects observed in human studies include fatigue, pressure and chest pain, dermatitis and hair loss. Subchronic animal studies at higher concentrations and for longer periods of time revealed effects ranging from small increases in underdevelopment and behavioral effects to lung and liver tissue damage and death (50 FR 39632; Sept. 27, 1985).

Methyl chloroform is another noncarcinogen that is a concern to the EPA. Acute exposure to this chemical may result in small changes in perception, while subchronic effects of slight histological and biochemical alterations have been observed in mice livers. At high concentrations, liver necrosis has been reported.

The following table lists the HON chemicals by CAS number and their classification by their carcinogenic effect, if any.

Table 3-1. HON Chemicals by Classification

CAS Number	Chemical Name	Classification*
71432	Benzene	A
542811	Bis(choromethyl)ether	A
75014	Vinyl chloride	A
107131	Acrylonitrile	B1
75218	Ethylene oxide	B1
50000	Formaldehyde	B1
75070	Acetaldehyde	B2
79107	Acrylic acid	B2
62533	Aniline	B2
98077	Benzotrichloride	B2
100447	Benzyl chloride	B2
75252	Bromoform	B2
106990	1,3-Butadiene	B2
56235	Carbon tetrachloride	B2
67663	Chloroform	B2
111444	Dichloroethyl ether	B2
542756	1,3-Dichloropropene	B2
77781	Dimethyl sulfate	B2
123911	1,4-Dioxane	B2
122667	1,2-Diphenylhydrazine	B2
106898	Epichlorohydrin	B2
106934	Ethylene dibromide	B2
107062	Ethylene dichloride	B2
118741	Hexachlorobenzene	B2
75092	Methylene chloride	B2
75569	Propylene oxide	B2
127184	Tetrachloroethylene	B2
79016	Trichloroethylene	B2
107028	Acrolein	C
107051	Allyl chloride	C
75343	Ethylidene dichloride	C
87683	Hexachlorobutadiene	C
67721	Hexachloroethane	C
78591	Isophorone	C
79345	1,1,2,2-Tetrachloroethane	C
79005	1,1,2-Trichloroethane	C
75354	Vinylidene chloride	C
60355	Acetamide	NC
75058	Acetonitrile	NC
98862	Acetophenone	NC
79061	Acrylamide	NC
90040	0-Anisidine	NC
92524	Biphenyl	NC

HON Chemicals by Classification (Continued)

CAS Number	Chemical Name	Classification*
105602	Caprolactum	NC
75150	Carbon disulfide	NC
79118	Chloroacetic acid	NC
532274	2-Chloroacetophenone	NC
108907	Chlorobenzene	NC
126998	Chloroprene	NC
1319773	Cresols/Cresylic acid (isomers and mixture)	NC
95487	o-Cresols/Cresylic acid (isomers and mixture)	NC
108394	m-Cresols/Cresylic acid (isomers and mixture)	NC
106445	p-Cresols/Cresylic acid (isomers and mixture)	NC
98828	Cumene	NC
106467	1,4-Dichlorobenzene	NC
111422	Diethanolamine	NC
121697	N,N-Dimethylaniline	NC
64675	Diethyl sulfate	NC
119937	3,3'-Dimethylbenzidine	NC
68122	N,N-Dimethylformamide	NC
57147	1,1-Dimethylhydrazine	NC
131113	Dimethyl phthalate	NC
51285	2,4-Dinitrophenol	NC
121142	2,4-Dinitrotoluene	NC
140885	Ethyl acrylate	NC
100414	Ethylbenzene	NC
75003	Ethyl chloride	NC
107211	Ethylene glycol	NC
0	Glycol ethers	NC
123319	Hydroquinone	NC
108316	Maleic anhydride	NC
67561	Methanol	NC
74839	Methyl bromide	NC
74873	Methyl chloride	NC
71556	Methyl chloroform	NC
78933	Methyl ethyl ketone	NC
60344	Methylhydrazine	NC
108101	Methyl isobutyl ketone	NC
624839	Methyl isocyanate	NC
80626	Methyl methacrylate	NC
1634044	Methyl tert-butyl ether	NC
101688	Methylenediphenyl diisocyanate (MDI)	NC

HON Chemicals by Classification (Continued)

CAS Number	Chemical Name	Classification*
101779	4,4-Methylenedianiline	NC
91203	Naphthalene	NC
98953	Nitrobenzene	NC
100027	4-Nitrophenol	NC
79469	4-Nitropropane	NC
108952	Phenol	NC
106503	p-Phenylenediamine	NC
75445	Phosgene	NC
85449	Phthalic anhydride	NC
0	Polycyclic organic matter	NC
57578	beta-propiolactone	NC
123386	Propionaldehyde	NC
78875	Propylene dichloride	NC
106514	Quinone	NC
100425	Styrene	NC
127184	Tetrachloroethylene	NC
108883	Toluene	NC
95807	2,4-Toluenediamine	NC
584849	2,4-Toluene diisocyanate	NC
95534	o-Toluidine	NC
120821	1,2,4-Trichlorobenzene	NC
95954	2,4,5-Trichlorophenol	NC
121448	Triethylamine	NC
540841	2,2,4-Trimethylpentane	NC
108054	Vinyl acetate	NC
1330207	Xylenes	NC
95476	o-Xylene	NC
108383	m-Xylene	NC
106423	p-Xylene	NC

*The carcinogens included in this list are chemicals which have been designated as group A, B1, B2, or C by IRIS, CRAVE verification, or a Health Assessment Document. NC stands for noncarcinogenic.

3.3 Consequences of Regulation

3.3.1 Consequences if EPA's Emission Reduction Objectives are Met

3.3.1.1 Allocation of Resources

There will be improved allocation of resources associated with chemical manufacturing. Specifically, more of the costs of the harmful effects of chemical production will be internalized by chemical plants. This, in turn, will affect consumers' decisions on whether, where, how, and how much chemicals to use. To the extent these newly-internalized costs are then passed along to the people who use the chemical products, and to the extent these people are free to buy as much or as little products as they wish, they will purchase less (relative to their purchases of other competing services). If this same process of internalizing negative externalities occurs throughout the entire chemical manufacturing industry, an economically optimal situation is approached. This is the situation when the marginal cost of resources devoted to chemical production equals the marginal value of the products to the people who are using the chemical products. There are many "ifs" in this chain of events. It is easy to cite situations where the air pollution control costs will not ripple through as suggested here and affect decisions by the consumers of chemical products. Nevertheless, in the aggregate and in the long run, the NESHAP's will move society toward this economically optimal situation.

3.3.1.2 Emissions Reductions and Air Quality

Under the proposed standard, it is estimated that emissions of HAP's will be reduced by 456,000 megagrams annually by 1997 and emissions of VOC's (which includes HAP's) will be reduced by 949,000 megagrams annually by 1997. (For more information refer to Chapter 8 of this document.) Air quality will improve. (This analysis does not translate emission reductions into ambient air quality improvements.)

There will be a slight increase in emissions of carbon monoxide and nitrogen oxides resulting from the on-site combustion of fossil fuels as part of control device operations. These estimates are 1,650 megagrams per year of carbon monoxide and 16,600 megagrams per year of nitrogen oxides.

3.3.1.3 Costs and Benefits

The national annual cost of emission control, including monitoring, recordkeeping, and reporting will increase by about $226 million by 1997. Expected benefits include reduced risks for certain adverse health and welfare effects from lower levels of HAP's and VOC's emissions. (See Chapters 8 and 9.)

3.3.1.4 Energy Impacts

Increases in energy use were estimated for steam, natural gas, and electricity. These three types of energy were compared and totaled on a barrels of energy (BOE) basis. Under the standard, estimates for increases in total energy use are 2.69 billion J/yr (470,000 BOE/yr) of electricity, 6.56 billion J/yr (1,150,000 BOE/yr) of natural gas, and 2.85 billion J/yr (500,000 BOE/yr) of steam. This equates to 2.12 million BOE/yr (15.5 billion J/yr).

3.3.1.5 Solid Waste and Water Quality

Impacts for water pollution and solid waste were judged to be negligible and were not quantified. The required controls do not generate any solid waste. However, in time, as collection and control equipment is replaced, the components themselves may become part of the solid waste stream.

3.3.1.6 Technological Innovation

Section 112 of the CAA regulations serve to disseminate both pollution control and chemical manufacturing technology, and to stimulate further technological development. Chemical facility constructors have the freedom to seek the most economical way to comply with standards. The NESHAP's may promote the sharing of technology with other countries, and probably will open new directions of research in chemical manufacturing technology.

3.3.1.7 State Regulation and New Source Review

State regulatory programs will be strengthened. The NESHAP's will be delegated to the states for enforcement as part of their operating permitting programs if they are approved the EPA. Assuming states do not pull resources from other programs to handle their enlarged responsibilities, there will be a natural strengthening of state air pollution control staffs. Recognition that the NESHAP's are effectively reducing emissions will expedite the state process of reviewing applications for new chemical plants and issuing permits for their construction and operation. There will be less controversy involved. Finally, state regulations will be uniform, and the disadvantages of the piecemeal approach to emission regulation will be avoided.

3.3.1.8 Other Federal Programs

The effects of the NESHAP's on other Federal regulatory programs have not been thoroughly investigated. Under Title I there are CTGs (control technology guidelines) that specify levels of control for VOC's in nonattainment areas. Any NESHAP shall require control in attainment and nonattainment areas. While the baseline for the HON incorporates present CTGs, the effect from new CTGs is not incorporated. There is possible overlap between these new CTGs and HON for facilities in nonattainment areas. The extent of this overlap has not been defined.

3.3.2 Consequences if EPA's Emission Reduction Objectives are not Met

The most obvious consequence of failure to meet EPA's emission reduction objectives would be emissions reductions and benefits that are not as large as EPA is projecting. However, costs are not likely to be as large either. Whether it is noncompliance from ignorance or error, or from willful intent, or simply slow compliance due to owners and/or operators exercising legal delays, poor compliance can save some facilities money. Unless states respond by pouring more resources into enforcement, then poor compliance could bring with it smaller aggregate nationwide control costs. EPA has not included an allowance for poor compliance in its estimates of emissions reductions. This is because poor compliance is unlikely.

If the emission control devices degraded rapidly over time or in some other way did not function as expected, there could be a misallocation of resources. This situation is very unlikely because the NESHAP's are based on demonstrated technology. Other ways the regulations could fail are conceivable.

References

1. U.S. Office of Management and Budget. Regulatory Impact Guidance, Appendix V of Regulatory Program of the United States Government, April 1, 1991 - - March 31, 1992.

2. U.S. Environmental Protection Agency. The Risk Assessment Guidelines of 1986, Office of Health and Environmental Assessment, Washington, D.C. August 1987.

3. Sittig, Marshall. Handbook of Toxic and Hazardous Chemicals and Carcinogens, Second Edition. New Jersey: Noyes Publication, 1985. pp. 153-154.

CHAPTER 4

CONTROL TECHNIQUES

The scope of the HON is broad. The control technology and techniques involved are extensive. Combustion technology, product recovery devices, steam strippers, and vapor recovery tanks are all part of the technology requirements for the HON, and LDAR will be used to control fugitive emissions. This chapter does not attempt to be comprehensive in explaining the technology and techniques used to control air toxics emissions under the HON; it does attempt to survey what technologies and techniques are being used and how effective they are.

4.1 Combustion Technology

Combustion control devices, unlike noncombustion control devices, alter the chemical structure of the VOC. Destruction of the VOC by combustion is complete if all VOC's are converted to CO_2 and water. Incomplete combustion results in some of the VOC remaining unaltered or being converted to other organic compounds such as aldehydes or acids. If chlorinated or sulfur-containing compounds are present in the mixture, the products of complete combustion include the acid components HCl or SO_2, respectively, in addition to water and carbon dioxide.

4.1.1 Incinerators

Incineration is one of the best known methods of industrial gas waste disposal. It is a method of ultimate disposal, that is, the constituents to be controlled in the waste gas stream are converted rather than collected. Provided proper engineering design is used, incineration can eliminate the desired organic chemicals in a gas stream safely and cleanly.

The heart of an incinerator is a combustion chamber in which the VOC-containing waste stream is burned. The temperature required for combustion is much higher than the temperature of the inlet gas, so energy is usually supplied to the incinerator to raise the waste gas temperature. This is accomplished by adding auxiliary fuel (usually natural gas).

The amount of auxiliary fuel required can be decreased and energy efficiency increased by providing heat exchange between the inlet stream and the effluent stream. The effluent stream containing the products of combustion, along with any inerts that may have been present in or added to the inlet stream, can be used to preheat the incoming waste stream, auxiliary air, or both via a "primary", or recuperative, heat exchanger.

Auxiliary air may be required for combustion if the requisite oxygen is not available in the inlet gas stream. Most industrial gases that contain VOC's are dilute mixtures of combustible gases in air. With air oxidation reactor and distillation processes, the waste gas stream is deficient in air.

Important in the design and operation of incinerators is the concentration of combustible gas in the waste gas stream. Having a large amount of excess air (i.e., in excess of the required stoichiometric amounts) may be costly, but any mixture within the flammability limits, on either the fuel-rich or fuel-lean side of the stoichiometric mixture is considered a fire hazard as a feed stream to the incinerator. Therefore, some waste gas streams are diluted with air before incineration, even though this requires more fuel in the incinerator.

There are two types of incinerators: thermal and catalytic. While much of what was discussed above applies to both, there are important differences in their design and operation.

4.1.1.1 Thermal Incinerators

As is true of other combustion control devices, thermal incinerators operate on the principle that any VOC heated to a high enough temperature in the presence of sufficient oxygen will be oxidized to CO_2 and water. The theoretical temperature for thermal oxidation depends on the properties of the VOC to be combusted. There is great variation in theoretical combustion temperatures between different VOC's.

There are three requirements that must be met for a thermal incinerator to be considered efficient: 1) a high enough combustion chamber to enable oxidation of the organic compounds to proceed rapidly to completion; 2) enough turbulence for good mixing of the hot combustion products from the burner, the combustion air, and the organic compounds; and 3) sufficient residence time for oxidation to reach completion.[1]

A typical thermal incinerator is a refractory-lined chamber containing a burner or set of burners at one end. Entering gases are mixed with the process vent streams and the inlet air in a premixing chamber. Then the stream of gases passes into the main combustion chamber. This chamber is designed to allow the mixture enough time at the required combustion temperature for complete oxidation (usually from 0.3 to 1.0 second). A heat recovery section is often added to increase energy efficiency.[2] Oftentimes inlet combustion air is preheated; if this occurs, insurance regulations require the VOC concentration must be maintained below 25 percent of the lower explosive limit (LEL) to minimize the possibility of explosions. Concentrations from 25 to 50 percent are permitted given continuous monitoring by LEL monitors.

The required level of VOC control of the waste gas that must be achieved within the time it spends in the thermal combustion chamber dictates the reactor temperature. The shorter the residence time, the higher the reactor temperature must be. Once the unit is designed and built, the residence time is not easily changed, so that the required reaction temperature becomes a function of the particular gaseous species and the desired level of control. These required combustion reaction temperatures cannot be calculated a priori, although incinerator vendors can provide guidelines based on their extensive experience. Predictions of these temperatures are further complicated by the fact that most process vent streams are mixtures of compounds.[3]

Good mixing is also important, particularly in determining destruction efficiency. Even though it cannot be measured, mixing is a factor of equal or even greater importance than other parameters such as temperature. The most feasible and efficient way to improve the mixing in an incinerator is to adjust it after start-up.[4]

Other parameters affecting thermal incinerator performance are the heat content of the vent stream, the water content of the stream, and the amount of excess combustion air (the amount of air above the stoichiometric air needed for combustion). Combustion of a vent stream with a heat content less than 1.9 MJ/m^3 (52 BTU/scf) usually requires burning supplemental fuel to maintain the desired combustion temperature.

The maximum achievable VOC destruction efficiency decreases with decreasing inlet VOC concentration because combustion is slower at lower inlet concentrations. Therefore, a VOC weight percentage reduction based on the mass rate of VOC exiting the control device versus the mass rate of VOC entering the device is appropriate for vent streams with VOC concentrations above approximately 2,000 ppmv (which corresponds to 1,000 ppmv VOC in the incinerator inlet stream since air dilution is typically 1:1).[5]

4.1.1.1.1 Applicability

Thermal incinerators are technically feasible control devices for most vent streams. They are not recommended, however, for vent streams with potentially excessive fluctuations in flow rate (process upsets, for example), and for vent streams containing halogens. The former case would require a flare (see Section 4.2) and the latter case would require additional equipment such as acid gas scrubbers (see Section 4.1.3).

4.1.1.1.2 Types of Thermal Incinerators

The very simplest type of thermal incinerator is the direct flame incinerator, which is made up of only the combustion chamber. Energy recovery devices such as a waste gas preheater and a heat exchanger are not included with this type of incinerator.

A second type of thermal incinerator is the recuperative model. Recuperative incinerators use the exit (product) gas to preheat the incoming feed stream, combustion air, or both via a heat exchanger. These heat exchangers can recover up to 70 percent of the energy (or enthalpy) in the product gas. The two types of heat exchangers commonly used for this purpose and many others are plate-to-plate and shell-and-tube. Plate-to-plate exchangers can be built to achieve a variety of efficiencies and offer high efficiency energy recovery at lower cost than shell-and-tube designs. But when gas temperatures exceed 520 degrees Celsius, shell-and-tube exchangers usually have lower purchase costs than plate-to-plate designs. Moreover, shell-and-tube exchangers offer better long-term structural reliability than plate-to-plate units.[6]

Occasionally it is desired to recover some of the energy added by auxiliary fuel in the traditional thermal units (but not recovered in preheating the feed stream). Additional heat exchangers can be added to provide process heat in the form of low pressure steam or hot water for on-site application. The need for this higher level of energy recovery will be dependent upon the plant site. The additional heat exchanger is often provided by the incineration unit vendor.

A third type of thermal incinerator is the regenerative incinerator. This type of incinerator use direct contact heat exchangers constructed of a ceramic material that can tolerate the high temperatures needed to achieve ignition of the waste stream. The concept behind this incinerator type is that the traditional approach to energy recovery in thermal units still requires a significant amount of auxiliary fuel to be burned in the combustion chamber when waste gas heating values are too low to sustain the desired reaction temperature at the moderate preheat temperature employed. Under these conditions, additional fuel savings can be realized in units with more complete transfer of exit stream energy. Hence the regenerative incinerator.

In this type of incinerator, the inlet gas first passes through a hot ceramic bed thereby heating the steam to its ignition temperature. The hot gases then react and release energy in the combustion chamber and while passing through another ceramic bed, thereby heating it to the combustion chamber outlet temperature. The process flows are then switched, now feeding the inlet stream to the hot bed. This cyclic process affords very high energy recovery (up to 95 percent).[7]

4.1.1.2 Catalytic Incinerators

A catalyst promotes oxidation of some VOC's at a lower temperature than that required for thermal incineration. The catalyst increases the rate of the chemical reaction without becoming permanently altered itself. Catalysts typically used for VOC incineration include platinum and palladium. These catalysts work well for most organic streams, but are not tolerant of compounds containing halogens such as chlorine and sulfur. Among the catalysts that have been developed that are effective in the presence of these halogens are chromia/alumina, cobalt oxide, and copper oxide/manganese oxide.[8] Inert substrates are coated with thin layers of these materials to provide maximum surface area for contact with the VOC in the vent stream. Compounds containing elements such as lead, arsenic, and phosphorus should, in general, be considered poisons for most oxidation catalysts. In addition, particulate matter, including dissolved minerals in aerosols, can rapidly blind (deactivate) the pores of catalysts and deactivate them over time. Because essentially all the active surface of the catalyst is contained in relatively small pores, the particulate matter need not be large to blind the catalyst.

For optimal operation, the volumetric gas flow rate and the concentration of combustibles (in this case, VOC's) should be constant. Large fluctuations in the flow rate will cause the conversion of the VOC's to fluctuate also. Changes in the concentration or type of organic compounds in the gas stream can also affect the overall conversion of the VOC contaminants. Most changes in flow rate, organic concentration, and chemical composition are generally the result of upsets in the manufacturing process generating the waste gas stream.

4.1.1.2.1 Applicability

Applicability of catalytic incinerators for control of VOC's is limited by the catalyst deactivation sensitivity to the characteristics of the inlet gas stream. The vent stream to be combusted should not contain materials that can poison the catalyst or deposit on and block the reactive sites on the catalyst surface. In addition, catalytic incinerators are unable to handle high inlet concentrations of VOC or very high flow rates. Catalytic incineration is generally useful for concentrations of 50 to 10,000 ppmv, if the total concentration is less than 25 percent of the LEL and for flow rates of less than 2,820 m^3/min (100,000 scfm).[9] Catalytic units are also typically used for vent streams with stable flow rates and concentrations (refer to Section 4.1.1.2).

4.1.1.2.2 Types of Catalytic Incinerators

One type of catalytic incinerator is fixed-bed. Fixed-bed incinerators themselves come in two varieties, depending on the type of catalyst used: the monolith and packed-bed. The monolith catalyst is the most widespread method of contacting the VOC-containing stream with the catalyst. In this scheme the catalyst is a porous solid block containing parallel, non-intersecting channels aligned in the direction of the gas flow. Monolith catalysts offer the advantages of minimal attrition due to thermal expansion/contraction during startup/shutdown and low overall pressure drop.

A second contacting scheme is a simple packed-bed in which catalyst particles are supported either in a tube or in shallow trays through which the gases pass. The tray type arrangement is the more common packed-bed scheme due to the use of pelletized catalysts. This tray arrangement is preferred because pelletized catalysts can handle inlet streams containing contaminants such as phosphorus or silicon.[10] The tube arrangement is not used widely due to its inherently high pressure drop compared to a monolith, and the breaking of catalyst particles due to thermal expansion when the confined catalyst bed is heated/cooled during startup/shutdown.

A third contacting pattern between the gas and catalyst is a fluid-bed. Fluid-beds have the advantage of very high mass transfer rates, although the overall pressure drop is somewhat higher than for a monolith. Fluid-beds also possess the advantage of high bed-side heat transfer compared to a normal gas heat transfer coefficient. This higher heat transfer rate to heat transfer tubes immersed in the bed allows higher heat release rates per unit volume of gas processed and therefore may allow waste gases with higher heating values to be processed without exceeding maximum permissible temperatures in the catalyst bed. The catalyst temperatures depend on the rate of reaction occurring at the catalyst surface and the rate of heat exchange between the catalyst and imbedded heat transfer surfaces.

In general, fluid-bed systems are more tolerant of particulates in the gas stream than fixed-bed or packed-bed systems. This results from the constant abrasion of the fluidized catalyst pellets, which helps remove these particulates from the exterior of the catalysts in a continuous manner.

4.1.2 <u>Flares</u>

Flaring is an open combustion process in which the oxygen necessary for combustion is provided by the air around the flame. The organic compounds to be combusted are piped to a remote, usually elevated, location and burned in an open flame in the open air using a specially designed burner tip, auxiliary fuel, and sometimes steam or air to promote mixing for nearly complete (98 percent minimum) destruction of combustibles. Good combustion in a flare is governed by flame temperature, residence time of organic species in the combustion zone, turbulent mixing of the organic species to complete the oxidation reaction, and the amount of oxygen available for free radical formation. Combustion is complete if all combustibles (i.e., VOC's) are converted to CO^2 and water, while incomplete combustion results in some of the VOC's being unaltered or converted to other organic compounds such as aldehydes or acids.

Flares are generally categorized in two ways: 1) by the height of the flare tip (i.e., ground-level or elevated), and 2) by the method of enhancing mixing at the flare tip (i.e., steam-assisted, air-assisted, pressure-assisted, or unassisted). Elevating the flare can prevent potentially dangerous conditions at ground level where the open flame is located near a process unit. Further, the products of combustion can be dispersed above working areas to reduce the effects of noise, heat radiation, smoke, and objectionable odors.

In most flares, combustion occurs by means of a diffusion flame. A diffusion flame is one in which air diffuses across the boundary of the fuel/combustion product stream toward the center of the fuel flow, forming the envelope of a combustible gas mixture around a core of fuel gas. This mixture, on ignition, establishes a stable flame zone around the gas core above the burner tip. This inner gas core is heated by diffusion of hot combustion products from the flame zone.

Cracking can occur with the formation of small hot particles of carbon that give the flame its characteristic luminosity.[11] If there is an oxygen deficiency and if the carbon particles are cooled to below their ignition temperature, smoking occurs. In large diffusion flames, combustion product vortices can form around burning portions of the gas and shut off the supply of oxygen. This localized instability causes flame flickering, which can be accompanied by soot formation.

4.1.2.1 Applicability

Flares can be dedicated to almost any VOC stream, and can handle fluctuations in VOC concentration, flow rate, heating value, and inerts content. Flaring is appropriate for continuous, batch, and variable flow vent stream applications.

Some streams, such as those containing halogenated or sulfur-containing compounds, are usually not flared because they corrode the flare tip or cause formation of secondary pollutants (such as acid gases or sulfur dioxide). If these vent types are to be controlled by combustion, thermal incineration, followed by scrubbing to remove the acid gases, is the preferred method.[12]

The majority of chemical plants and refineries have existing flare systems designed to relieve emergency process upsets that require release of large volumes of gas. Often, large diameter flares designed to handle emergency releases are also used to control continuous vent streams from various process operations. Typically in refineries, many vent streams are combined in a common gas header to fuel boilers and process heaters. However, excess gases, fluctuations in flow rate in the fuel gas line, and emergency releases are sometimes sent to a flare.

4.1.2.2 Efficiency

Five factors affecting flare combustion efficiency are vent gas flammability, auto-ignition temperature, heat content of the vent stream, density, and flame zone mixing.

The flammability limits of the vent stream influence ignition stability and flame extinction. Flammability limits are the stoichiometric composition limits (maximum and minimum) of an oxygen-fuel mixture that will burn indefinitely at given conditions of temperature and pressure without further ignition. In other words, gases must be within their flammability limits to burn. If these limits are narrow, the interior of the flame may have insufficient air for the mixture to burn. Fuels, such as hydrogen, with wide limits of flammability are therefore easier to combust.

The auto-ignition temperature of a vent stream affects combustion because gas mixtures must be at a sufficient temperature and concentration to burn. A gas with a low auto-ignition temperature will ignite more easily than a gas with a high auto-ignition temperature.

The heat content of the vent stream is a measure of the heat available from the combustion of the VOC in the vent stream. The heat content of the vent stream affects the flame structure and stability. A gas with a lower heat content produces a cooler flame that does not favor combustion kinetics and is more easily extinguished. The lower flame temperature will also reduce buoyant forces, which reduces mixing.

The density of the vent stream also affects the structure and stability of the flame through the effect on buoyancy and mixing. By design, the velocity in many flares is very low; therefore, most of the flame structure is developed through buoyant forces as a result of combustion. Lighter gases therefore tend to burn better. In addition to burner tip design, the density also affects the minimum purge gas required to prevent flashback, with lighter gases requiring more purge.[13]

Poor mixing at the flare tip or poor flare maintenance can cause smoking (particulate matter release). Vent streams with high carbon-to-hydrogen ratios (> 0.35) have a greater tendency to smoke and require better mixing to burn smokelessly.[14] For this reason, one generic steam-to-vent-stream ratio is not appropriate for all vent streams. The steam required depends on the vent stream carbon-to-hydrogen ratio. A high ratio requires more steam to prevent a smoking flare.

The efficiency of a flare in reducing VOC emissions can be variable. For example, smoking flares are far less efficient than properly operated and maintained flares. Flares have been shown to have high VOC destruction efficiencies, under proper operating conditions. Up to 99.7 percent combustion efficiency can be achieved.

4.1.2.3 Types of Flares

4.1.2.3.1 Steam-Assisted Flares

Steam-assisted flares are single burner tips, elevated above ground level for safety reasons, that burn the vented gas in essentially a diffusion flame. They reportedly account for the majority of the flames installed and are the predominant flare type found in refineries and chemical plants.[15] To ensure an adequate air supply and good mixing, this type of flare system injects steam into the combustion zone to promote turbulence for mixing and to induce air into the flame.

4.1.2.3.2 Air-Assisted Flares

Air-assisted flares use forced air to provide the combustion air and the mixing required for smokeless operation. These flares are built with a spider-shaped burner (with many small gas orifices) located inside but near the top of a steel cylinder two feet or more in diameter. Combustion air is provided by a fan in the bottom of the cylinder, and the amount of combustion air can be varied by varying the fan speed. The primary advantage air-assisted flares provide is that they can be used in the absence of steam.

4.1.2.3.3 Non-Assisted Flares

The non-assisted flare is just a flare tip without any auxiliary provision for enhancing the mixing of air into its flame. Its use is limited essentially to gas streams that have a low heat content and a low carbon/hydrogen ratio that burn readily without producing smoke.[16] These streams require less air for complete combustion, have lower combustion temperatures that minimize cracking reactions, and are more resistant to cracking.

4.1.2.3.4 Pressure-Assisted Flares

This type of flare use vent stream pressure to promote mixing at the burner tip. If sufficient vent stream pressure is available, these flares can be applied to streams previously requiring steam or air assist for smokeless operation. Pressure-assisted flares generally have the burner arrangement at ground level, and consequently, must be located in a remote area of the plant where there is plenty of space available. They have multiple burner heads that are staged to operate based on the quantity of gas being released. The size, design, number, and group arrangement of the burner heads depend on the vent gas characteristics.

4.1.2.3.5 Enclosed Ground Flares

The burner heads of an enclosed flare are inside a shell that is insulated. This shell reduces noise, luminosity, and heat radiation and provides wind protection. A high nozzle pressure drop is usually adequate to provide the mixing necessary for smokeless operation and air or steam assist is not required. In this context, enclosed flares can be considered a special class of pressure-assisted or non-assisted flares. Enclosed flares are always at ground level.

Enclosed flares generally have less capacity than open flares and are used to combust continuous, constant flow vent streams, although reliable and efficient operation can be attained over a wide range of design capacity. Stable combustion can be obtained with lower heat content vent gases than is possible with open flare designs, probably due to their isolation from wind effects.[17]

4.1.3 Boilers and Process Heaters

4.1.3.1 Description of Boilers

Industrial boilers are combustion units that boil water to produce high and low pressure steam. Industrial boilers can also combust various vent streams containing VOC's, including vent streams from distillation operations, reactor processes, and other general operations.

The majority of industrial boilers used in the chemical industry are of watertube design, and over half of these boilers use natural gas as a fuel.[18] In a watertube boiler, hot combustion gases contact the outside of heat transfer tubes which contain hot water and steam. These tubes are interconnected by a set of drums that collect and store the heated water and steam. Energy transfer from the hot flue gases to the water in the furnace watertube and drum system can be better than 85 percent efficient.[19] Additional energy can be recovered from the flue gas by preheating combustion air in an air preheater or by preheating incoming boiler feed water in an economizer unit.

When firing natural gas, forced- or natural-draft burners throughly mix the incoming fuel and combustion air. A VOC-containing vent stream can be added to this mixture or it can be fed into the boiler through a seperate burner. In general, burner design depends on the characteristics of the fuel-- either the combined VOC-containing vent stream and fuel or the vent stream alone (when a separate burner is used).

4.1.3.2 Description of Process Heaters

A process heater is similar to an industrial boiler in that heat liberated by the combustion of fuels is transferred by radiation and convection to fluids contained in tubular coils. It is different from an industrial boiler in that process heaters raise the temperature of process streams instead of producing high temperature steam. Process heaters are used in many chemical manufacturing operations to drive endothermic reactions. They are also used as feed preheaters and as reboilers for some distillation operations. The fuels used in process heaters include natural gas, refinery offgases, and various grades of fuel oil.

A typical process heater design consists of the burner(s), the firebox, and a row of tubular coils containing the process fluid. Most heaters also contain a convective section in which heat is recovered from hot combustion gases by convective heat transfer to the process fluid.

4.1.3.3 Efficiency of Boilers and Process Heaters

Average furnace temperature and residence time determine the combustion efficiency of boilers and process heaters, just as they do for incinerators. When a vent gas is injected as a fuel into the flame zone of a boiler or process heater, the required residence time is reduced because of the relatively high temperature and turbulence of the flame zone.

Residence time and temperature profiles in boilers and process heaters are determined by factors such as overall configuration, fuel type, heat input, and excess air level.[20] A mathematical model developed to estimate furnace residence time and temperature profiles for a variety of industrial boilers predicts mean furnace residence times ranging 0.25 to 0.83 second for natural gas-fired watertube boilers that range in size from

4.4 to 44 MW (15 to 150 x 10^6 Btu/hr).[21] Boilers with a 44-MW capacity or greater generally have residence times and operating temperatures that would ensure a 98 percent VOC destruction efficiency. The required temperatures for these size boilers are at least 1,200 degrees Celsius.

Firebox temperatures for process heaters can show wide variations depending on the application. Firebox temperatures can range from 400 degrees Celsius for preheaters and reboilers to 1,260 degrees Celsius for pyrolysis furnaces. Tests conducted by EPA on process heaters using a mixture of benzene offgas and natural gas showed greater than 98 percent destruction efficiency for C_1 to C_6 hydrocarbons.[22]

4.1.3.4 Applicability of Boilers and Process Heaters

Both of these devices are used throughout the chemical industry to provide steam and heat input essential to chemical processing. Most of these devices possess sufficient size to provide the necesary temperature and residence time for VOC destruction. Furthermore, boilers and process heaters have proved effective in destroying compounds that are difficult to combust, such as PCBs (polychlorinated biphenyls). Boilers and process heaters are thus effective in reducing VOC emissions from any vent streams that are certain not to reduce the performance or reliability of the boiler or process heater.

Ducting some vent streams to a boiler or process heater can present potential safety and operating problems. The varying flow rate and organic content of some vent streams can lead to explosive mixtures or flame instability within the furnace. In addition, vent streams with halogenated or sulfur-containing compounds are usually not combusted in boilers or process heaters due to the possibility of corrosion.

Boilers and process heaters are most applicable where the potential exists for heat recovery from the combustion of the vent stream. Vent streams with a high enough VOC concentration and high flow rate can provide enough equivalent heat value to act as a substitute for fuel that would otherwise be needed. Because boilers and process heaters cannot tolerate wide fluctuations or interruptions in the fuel supply, they are not widely used to reduce VOC emissions from batch operations or other noncontinuous vent streams.

4.2 Product Recovery Devices

4.2.1 Absorbers

In absorption, a soluble vapor is absorbed from its mixture with an inert gas by means of a liquid in which the solute gas is more or less soluble. For any given solvent, solute, and operating conditions, there exists an equilibrium ratio of solute concentration in the gas mixture to solute concentration in the solvent. The driving force for mass transfer at a given point in an operating absorber is the difference between the concentration of solute in the gas and the equilibrium concentration of solute in the liquid.

Devices based on absorption principles include spray towers, venturi and wet impingement scrubbers, acid gas scrubbers, packed columns, and plate columns. Spray towers have the least effective mass transfer capability due to their high atomization pressure requirement, and are generally restricted to particulate matter removal and control of high-solubility gases such as SO_2 and NH_3 (ammonia).[23] Venturi scrubbers have a high degree of gas/liquid mixing and provide high particulate matter removal efficiency. They also require high pressure drops (i.e. high energy requirements) and have relatively short contact times. Their use is also restricted to high-solubility gases. Acid gas scrubbers are used with thermal incinerators to remove corrosive combustion products. Acid gas is formed upon the contact of halogenated or sulfur-containing VOCs with intense heat during incineration. This gas is quenched to lower its temperature and is then scrubbed in an absorber. In most cases, the type of absorber used is packed or plate columns, the two most commonly used absorbers for VOC control.

Packed towers are vertical columns containing inert packing, manufactured from materials such as porcelain, metal, or plastic, that provides the surface area for contact between the liquid and gas phases in the absorber. Packed towers are used mainly for corrosive materials and liquids with tendencies to foam or plug. They are less expensive than plate columns for small-scale or pilot plant operations where the column diameter is less than 0.6 m. They are also suitable where the use of plate columns would result in excessive pressure drops.

Plate columns contain a series of trays on which contact between the gas and liquid phases in a stepwise fashion. The liquid phase flows down tray to tray as the gas phase moves up through openings in the tray (usually perforations or bubble caps), passing through the liquid on the way.

The major design parameters for absorbing any substance are column diameter and height, system pressure drop, and required liquid flow rate. Deriving these parameters is accomplished by considering the solubility, viscosity, density, and concentration of the VOC in the inlet vent stream (all of which depend on column temperature); the total surface area provided by the packing material; and the mass flow rate of the gases to be treated.

4.2.1.1 Absorber Efficiency

Control efficiencies for absorbers can vary widely depending on the solvent selected, design parameters, and operating practices. Solvents are chosen for high solubility for the specific VOC and include liquids such as water, mineral oils, kerosenes, nonvolatile hydrocarbon oils, and aqueous solutions of oxidizing agents, sodium carbonate, and sodium carbonate.[24] An increase in absorber size (i.e., contact surface area) or a decrease in the operating temperature can increase the VOC removal efficiency of the system for a given solvent and solute. It is sometimes possible to increase VOC removal efficiency by changing the solvent.

4.2.1.2 Applicability of Absorbers

The primary determinant of absorption applicability for controlling VOC emissions is the availability of a suitable solvent.[25] Water is a suitable solvent for absorption of organic chemicals with relatively high water solubilities (e.g., most alcohols, organic acids, aldehydes, glycols). For organic compounds with low water solubilities, other solvents (usually organic liquids with low vapor pressures) are used.

Other important factors influencing absorption applicability include absorptive capacity and strippability of VOC in the solvent. Absorptive capacity is a measure of the solubility of VOC in the solvent. The solubility limits the total quantity of VOC that could be absorbed in the system, while strippability describes the ease with which the VOC can be removed from the solvent. If strippability is low, then absorption is less viable as a VOC control technique.[26]

The concentration of VOC in the inlet vent stream also determines the applicability of absorption. Absorption is usually considered only when the VOC concentration is above 200 to 300 ppm.[27] Below these gas-phase concentrations, the rate of mass transfer of VOC to solvent is decreased enough to make reasonable designs infeasible.

4.2.2 Steam Stripping

Steam stripping can be used as initial treatment of a process wastewater stream to reduce the VOC loading of that steam before it is sent to the facility-wide wastewater treatment system. There are several components in a steam stripping system: a feed tank, heat exchanger, steam stripping column, condenser, overhead receiver, and a destruction device (if necessary).

4.2.2.1 Description

Steam stripping involves the fractional distillation of wastewater to remove VOC's. The basic operating principle of steam stripping is the direct transfer of heat through contact of steam with wastewater. This heat transfer vaporizes the more volatile organic compounds. The overhead vapor contains water and organic compounds, and it is condensed and separated to recover the organic fraction. Recovered organic compounds are either recycled for reuse in the process or incinerated in an on-site combustion device for heat recovery.

Steam stripper systems may be operated in batch or continuous mode. Batch steam strippers are more prevalent when the wastewater feed is generated by batch processes, when feed characteristics are highly variable, or when small volumes of wastewater are generated. They may also be used if wastewater contains relatively high concentrations of solids, resins, or tars. In batch stripping, wastewater is charged to the receiver, or pot, and brought to the boiling temperature of the mixture. Solids and other residues remaining in the bottom of the pot (hence the term "bottoms") at the completion of the batch are nonvolatile, heavy compounds that are removed for disposal. By varying the heat input and fraction of the initial charge boiled overhead, a batch stripper can be used to treat wastewater mixtures with widely varying characteristics.[28]

In contrast to batch strippers, continuous steam strippers are designed to treat wastewater streams with relatively consistent characteristics. Continuous strippers can have several stages and achieve greater efficiencies of VOC removal than batch strippers. Other advantages offered by continuous strippers include more consistent effluent quality, more automated operation, and lower annual operating costs.

Typically, wastewater steams continuously discharged from process equipment are usually consistent in composition. A continuous steam stripper system would thus be indicated for treating the wastewater. However, batch wastewater streams can also be controlled by continuous steam strippers by incorporating a feed tank with adequate residence time to provide a consistent outlet composition.

4.2.2.2 Collecting, Conditioning, and Recovery

The controlled sewer system or hard piping from the point of wastewater generation to the feed tank controls emissions before steam stripping. The feed tank collects and conditions the wastewater fed to the steam stripper. If the feed tank is adequately designed, a continuous steam stripper can treat wastewater generated by some batch processes. In these cases, the feed tank serves as a buffer between the batch process and the continuous steam stripper. During periods of no wastewater flow from the batch process, wastewater stored in the feed tank is fed to the stripper at a relatively constant rate.

Often present in the feed tank are aqueous and organic phases. The feed tank provides the retention time necessary for these phases to separate. The organic phase is recycled to the process for recovery of organic compounds or disposed by incineration. The water phase is fed to the stripper to remove the soluble organic compounds. Solids are also separated in the stripper feed tank; the separation efficiency depends on the density of the solids dissolved in the process wastewater. The more dense solids, which settle to the bottom of the tank, are removed periodically from the feed tank and are usually landfilled or landfarmed.

After this conditioning of the wastewater, it is pumped through the feed/bottoms heat exchanger where it is preheated and then pumped into the steam stripping column. Steam is sparged into the stripper at the bottom of the column, and the wastewater feed enters at the top. The wastewater flowing down the column contacts the flowing countercurrently up the column. Both latent and sensible heat is transferred from the steam to the organic compounds in the wastewater, vaporizing them into the vapor stream. These constituents flow out the top of the column with any uncondensed steam.

The wastewater effluent leaving the bottom of the stripper is pumped through the feed/bottoms heat exchanger which heats the feed stream and cools the bottoms before discharge. After leaving the exchanger, the bottoms stream is usually either routed to an on-site wastewater treatment plant and discharged to an NPDES-permitted outfall, or sent to a publicly owned treatment works (POTW).

Recovery of both VOC's and water vapors from the gaseous overheads stream from the steam stripper is usually accomplished with a condenser. The condensed stream is fed to an overhead receiver, and the recovered VOC's are usually either pumped to storage and recycled to the process unit or combusted for their fuel value in an incinerator, boiler, or process heater (all discussed earlier in this chapter). If an aqueous phase is generated, it is returned to the feed tank and recycled through the steam stripper system.

4.2.2.3 Efficiency of Control

The degree of contact between the steam and the wastewater is the primary variable affecting the ability of a steam stripper to remove VOC's. In turn, this variable is affected by five factors: 1) column dimensions (height and diameter); 2) the contacting media (packing or trays); and 3) operating parameters such as the steam-to-feed ratio, column temperature, and wastewater pH.

Control efficiency increases as column height increases since there is greater opportunity for contact between the steam and the wastewater. The column height is determined by the number of theoretical stages required to achieve the desired removal efficiency. The number of theoretical stages is a function of the equilibrium coefficient of the pollutants and the efficiency of mass transfer in the column, and this number can be computed by either the McCabe-Thiele graphical method or the Kremser analytical method.

The column diameter determines the required cross-sectional area for liquid and vapor flow through the column. The smaller the cross-sectional area, the higher the superficial gas velocity, which increase turbulence and mixing resulting in high column efficiencies. However, the column cross-sectional area must be sufficient to prevent flooding from excessive liquid loading or liquid entrainment. This area also affects the liquid retention time, with higher retention times resulting in higher efficiencies. These factors have to be weighed in selecting the column diameter and the design velocities.

The contacting media in the column also play an important role in determining the mass transfer efficiency. Packing or trays are used to provide contact between liquid and vapor phases. Packing provides for continuous contact while trays provide staged contact. Trays are usually more effective for wastewater containing dispersed solids because of the plugging and cleaning problems encountered with packing. Tray towers can also operate over a wider range of liquid flow rates than packed towers. Packed towers, on the other hand, are often more cost effective to install and operate when treating highly corrosive wastewater since corrosion resistant ceramic packing can be used. Also, the pressure drop through packed towers may be less than through tray towers.[29]

The steam-to-feed ratio required for high removal efficiencies is affected by the wastewater temperature as it enters the column. If the feed temperature is lower than the operating temperature at the top of the column, part of the steam is required to heat the feed. With good column design, sufficient steam flow is provided to heat the feed as well as volatilize the organic constituents. Any steam in excess of this flow rate helps carry VOC's out of the top of the column with the overheads stream. Also, increasing the steam-to-feed ratio will increase the ratio of the vapor to liquid flow through the column, which increases the stripping of VOC's into the vapor phase.

Two other influences on VOC removal are the column temperature and wastewater pH. Temperature influences the solubility and equilibrium coefficients of the organic compounds. pH has an effect on the vapor liquid equilibrium characteristics of VOC's. To ensure steam stripping is successful, columns are operated at pressures slightly exceeding atmospheric, and operating temperatures are usually slightly higher than the normal boiling point of water. Wastewater pH is controlled by adding caustic to the feed.[30]

4.2.2.4 Applicability

Steam stripping is most applicable to treating wastewaters with organic compounds that are highly volatile and have a low solubility in water. The VOC's that have low volatility tend not to volatilize and thus are not easily stripped out of the wastewater by the steam. Similarly, VOC's that are very soluble in water tend to remain in the wastewater and are not easily stripped by steam. Oil, grease, solids content and pH of wastewater also affect applicability. High oil, grease, and solids levels can cause operating problems for steam strippers, and extremes in pH may prove to be corrosive to equipment. Design or wastewater preconditioning techniques can be used to mitigate these problems.

4.2.3 Carbon Adsorbers

Adsorption is a mass-transfer operation involving interaction between gas- or liquid-phase components and solid-phase components. In this operation, certain components of a gas- or liquid-phase (or adsorbate) are transferred to the surface of a solid adsorbent. The transfer is accomplished by physical or chemical adsorption mechanisms. Physical adsorption takes place when intermolecular (van der Waals) forces attract and hold the gas molecules to the solid surface. Chemisorption occurs when a chemical bond forms between the gaseous- and solid-phase molecules. A physically adsorbed molecule can be removed readily from the adsorbent (under suitable temperature and pressure conditions); the removal of a chemisorbed component is much more difficult.

Most industrial adsorption systems use activated carbon as the adsorbent. Activated carbon effectively captures certain organic vapors by physical adsorption. The vapors can then be released for recovery by regenerating the adsorption bed with steam or nitrogen. Oxygenated adsorbents such as silica gels or diatomaceous earth exhibit a greater selectivity for capturing water vapor than organic gases compared to activated carbon. They thus are of little use for high-moisture vent streams characteristic of some VOC-containing vent streams.[31]

Among the factors influencing the design of a carbon adsorption system are the chemical characteristics of the VOC being recovered, the physical properties of the inlet stream (temperature, pressure, and volumetric flow rate), and the physical properties of the adsorbent. The mass of VOC that adheres to the adsorbent surface is directly proportional to the difference in VOC concentration between the gas phase and the solid surface. In addition, the quantity of VOC adsorbed depends on the adsorbent bed volume, the surface area of adsorbent available to capture VOC, and the rate of diffusion of VOC through the gas film at the gas- and solid-phase interface (the mass transfer coefficient). It should be noted that physical adsorption is an exothermic operation that is most efficient within a narrow range of temperature and pressure.[32]

4.2.3.1 Types of Adsorbers

There are five types of adsorption equipment used in gas collection: 1) fixed regenerable beds; 2) disposable/rechargeable cannisters; 3) traveling bed adsorbers; 4) fluid bed adsorbers; and 5) chromatographic baghouses. The fixed-bed type is the one most commonly used for control of VOC's,[33] so this section addresses this type only.

Fixed-bed units can be sized for controlling continuous, VOC-containing streams over a wide range of flow rates, ranging up to several thousand cubic meters per minute (100,000 scfm). VOC concentrations in streams that can be treated by fixed-bed units can range from several parts per billion by volume (ppbv) to 10,000 ppmv.

Fixed-bed adsorbers can be operated in two modes: intermittent or continuous. In intermittent mode, the adsorber removes VOC's for a specified time (called "the adsorption time"), which corresponds to the time during which the controlled source is emitting VOC's. In continuous mode, a regenerated carbon bed is always available for adsorption, so that the controlled source can operate continuously without shutting down. While continuous operation allows for more adsorption over the same period of time because it does not need to be shut down, more carbon must be provided. This is necessary since a bed for desorbing must be provided along with the adsorbing bed in order to recover the captured VOC from the carbon.[34]

4.2.3.2 Control Efficiency

Well designed and operated carbon adsorption systems can achieve control efficiencies of 95 to 99 percent for a variety of solvents including ketones such as methyl ethyl ketone and cyclohexanone. The VOC control efficiency depends on factors such as inlet vent stream characteristics (temperature, pressure, and velocity), the physical properties of the compounds present in the vent stream, the physical properties of the adsorbent, and the condition of the regenerated carbon bed.

The adsorption capacity of the carbon and the resulting outlet concentration are dependent upon the temperature of the inlet vent stream. High vent stream temperatures increase the kinetic energy of the gas molecules, causing them to overcome van der Waals forces and release from the surface of the carbon. At vent stream temperatures above 38 degrees Celsius, both adsorption capacity and outlet concentration may be adversely affected.[35]

Increasing vent stream pressure improves VOC removal efficiency. Increased stream pressure results in higher VOC concentrations in the vapor phase and increased driving force for mass transfer to the carbon surface. Decreased stream pressure, on the other hand, is often used to regenerate carbon beds. Reduced pressure in the carbon bed effectively lowers the concentration of VOCs in the vapor phase, desorbing the VOCs from the carbon surface to the vapor phase.

Vent stream velocity entering the carbon bed must be quite low to allow time for diffusion and adsorption. Typical inlet vent stream velocities range from 15 to 30 meters per minute (50 to 100 feet per minute). If inlet VOC concentrations are low, as is expected in the SOCMI, the bed area required for the volume needed usually permits a velocity at the high end of this range.[36]

The required depth of the bed for a given compound is directly proportional to the carbon granule size and porosity and to the inlet vent stream velocity. For a given carbon type, bed depth must increase as the vent stream velocity increases. Generally, carbon adsorber bed depths range from 0.40 to 0.95 meter (1.5 to 3.0 feet).

The condition of the regenerated carbon bed will change with use. After repeated regeneration, the carbon bed loses activity, resulting in reduced VOC removal efficiency.

4.2.3.3 Applicability

Carbon adsorption cannot be used universally for distillation or process vent streams. It is not recommended under the following conditions, common with many VOC-containing vent streams: 1) high VOC concentrations, 2) very high or low molecular weight compounds, 3) mixtures of high and low boiling point VOC's, and 4) high moisture content.

Absorbing vent streams with VOC concentrations above 10,000 ppmv may result in excessive temperature rise in the carbon bed due to the accumulated heat of adsorption resulting from the VOC loading. If flammable vapors are present, insurance company requirements may limit inlet concentrations to less than 25 percent of the LEL.[37]

The molecular weight of the compounds to be adsorbed should be in the range of 45 to 130 gm/gm-mole for effective adsorption. High molecular weight compounds that are characterized by low volatility are strongly adsorbed on carbon. The affinity of carbon for these compounds makes it difficult to remove them during regeneration of the carbon bed. Conversely, highly volative materials (i.e, molecular weight less than about 45 gm) do not adsorb readily on carbon, thus adsorption is not typically used for controlling streams containing such compounds.

Adsorption systems can be very effective with homogeneous vent streams but much less so with streams containing a mixture of light and heavy hydrocarbons. The lighter organic compounds tend to be displaced by the heavier compounds, greatly reducing system efficiency.

Humidity is not a factor in adsorption at adsorbate concentrations above 1,000 ppmv. Below this level, however, water vapor competes with VOC's in the vent stream for adsorption sites on the carbon surface. In these cases, vent stream humidity levels exceeding 50 percent (relative humidity) are not desirable.[38]

4.2.4 Condensers

Condensation is a separation technique in which one or more volatile components of a vapor mixture are separated from the remaining vapors through saturation followed by a phase change. The phase change from gas to liquid can be achieved in two ways: 1) by increasing the system pressure at a given temperature or 2) by lowering the temperature at a constant pressure. The latter method is the more common to achieve the specified phase change, and it alone is addressed here.

4.2.4.1 Description

The basic equipment includes a condenser, refrigeration unit(s), and auxiliary equipment such as a precooler, recovery/storage tank, pump/blower, and piping.

The two most commonly used condenser types are surface condensers and direct contact condensers.[39] In surface condensers, the coolant fluid does not contact the vent stream; heat transfer occurs through the tubes or plates in the condenser. As the vapor condenses, a film forms on the cooled surface and drains away to a collection tank for storage, reuse, or disposal. Because the coolant from surface condensers does not contact the vapor stream, it is not contaminated and can be recycled in a closed loop. Surface condensers also allow for direct recovery of VOC's from the gas stream.

Most refrigerated surface condensers are the shell-and-tube type, which circulates the coolant fluid on the tube side. The VOC's condense on the outside of the tube (the shell side). Plate-type heat exchangers are also used as surface condensers in refrigerated systems. Plate condensers operate under the same principles as the shell-and-tube systems, for there is no contact between the coolant and vent stream), but the two streams are separated by thin, flat plates instead of cylindrical tubes.

In contrast to surface condensers, direct contact condensers cool the vapor stream by spraying a liquid at ambient or lower temperature directly into the vent stream. Spent coolant containing VOC's from direct contact condensers usually cannot be reused directly. Additionally, VOC's in the spent coolant cannot be recovered without further processing. The combined stream could present a potential waste disposal problem, depending upon the coolant and the specific VOC's.

A refrigeration unit generates the low-temperature medium necessary for heat transfer for recovery of VOC's. Typically in refrigerated condenser systems two kinds of refrigerants are used, primary and secondary. Primary refrigerants such as ammonia and chlorofluorocarbons (e.g., chlorodifluoromethane) are those that undergo a phase change from liquid to gas after absorbing heat. Secondary refrigerants, such as brine solutions, have higher boiling points and thus act only as heat carriers and remain in the liquid phase.

There are some applications that require auxilary equipment. If the vent stream contains water vapor or if the VOC has a high freezing point (e.g., benzene or toluene), ice or frozen hydrocarbons may form on the condenser tubes or plates. This will reduce the heat transfer efficiency of the condenser and thereby reduce the removal efficiency. Formation of ice will also increase the pressure drop across the condenser. In such cases, a precooler may be used to remove the moisture before the vent stream enters the condenser. Alternatively, ice can be melted during an intermittent heating cycle by circulating ambient temperature brine through the condenser or using radiant heating coils.

It is necessary in some cases to provide a recovery tank for temporary storage of condensed VOC before its reuse, reprocessing, or transfer to a large storage tank. Pumps and blowers are typically used to transfer liquid (e.g., coolant and recovered VOC) and gas streams, respectively, within the system.

4.2.4.2 Control Efficiency

The major parameters that affect the removal efficiency of refrigerated surface condensers designed to control air/VOC mixtures are: 1) Volumetric flow rate of the VOC-containing vent stream; 2) Inlet temperature of the vent stream; 3) Concentrations of the VOC's in the vent stream; 4) Absolute pressure of the vent stream; 5) Moisture content of the vent stream; and 6) properties of the VOC's in the vent stream, such as dew points, heats of condensation, heat capacities, and vapor pressures.[40]

Any operator of a condenser should remember that a condenser cannot lower the VOC concentration to levels below the saturation concentration at the coolant temperature. Removal efficiencies above 90 percent can be achieved with coolants such as chilled water, brine solutions, ammonia, or chlorofluorocarbons.

4.2.4.3 Applicability

Condensers are widely used as product recovery devices. They may be used to recover VOC's upstream of other control devices or they may be used alone for controlling vent streams containing relatively high VOC concentrations (usually greater than 5,000 ppmv). In these cases, the removal efficiencies of condensers can range widely, from 50 to 95 percent.

Since the temperature necessary for condensation depends on the properties and concentration of VOC's in the vent stream, streams having either low VOC concentrations or more volatile compounds require lower condensation temperatures. Also, depending on the type of condenser used, disposal of the spent coolant can be a problem. If cross-media impacts are a concern, surface condensers would be preferable to direct contact condensers.

Condensers used as emission control devices can process flow rates as high as about 57 m^3/min (120,000 scfm). Condensers for vent streams with greater volumetric flow rates and having high concentrations of noncondensibles will require significantly larger heat transfer areas.

4.2.5 Vapor Collection Systems for Loading Racks

When liquids are transferred into a transport vessel, vapors in the head space of that vessel can be lost to the atmosphere. The principal factors affecting emissions from transfer operations are the vapor pressure of the chemical being transferred. Other factors that influence emissions from transfer operations include the transfer rate and the purge rate of nitrogen (or other inert gas) through the vessel during transfer.

The vapor pressure of the chemical being transferred has the greatest influence on emissions from transfer operations. For pure materials, the vapor pressure gives a measure of the amount of organic compound lost during transfer. The total potential emissions from any transfer is related to the void volume of the transport vessel and the concentration of the VOC in the head space.

The mode of transfer is also an important factor in determining emissions from transfer operations. Top splash loading creates the most emissions because it enhances the agitation of the liquid being transferred, creating a higher concentration of the compound in the vapor space. With alternate loading techniques, such as submerged fill or bottom loading, the organic liquid is loaded under the surface of the liquid, which reduces the amount of agitation and suppresses the generation of excess vapor in the head space of the transport vessel.

The rate of transfer has a more subtle influence on emissions; its greatest effect is on air quality. Transfer rate will dictate the short-term emission rate of the compound being transferred, thereby influencing exposure to the worker or public.

A nitrogen purge is used to reduce the potential for explosion of some chemicals in air or to keep some chemicals moisture-free. Using an inert gas purge increases the emission rate of VOC lost to the atmosphere because it creates a turnover rate of gas through the transport vessel, increasing the total volume of vapor discharged to the atmosphere.

Most vapor collection systems collect the vapors generated during transfer operations and transport them to either a recovery device for return to the process or a combustion device for destruction. In vapor balancing systems, vapors generated during transfer operations are returned directly to the storage facility for the material, and the system requires no additional controls.

4.2.5.1 Description of Vapor Collection Systems

Vapor collection systems consist of piping that captures and transports to a control device VOC's in the vapor space of transport vessels that are displaced when liquids are loaded. These systems may use existing piping normally used to transport liquids under pressure into the transport vessel or piping separate from that for transfer. Collection systems comprise very few pieces of equipment and minimal piping. The principal piece of equipment in a collection system is a vacuum pump or blower, used to induce the flow of vapors from the transport vessel to the recovery or combustion system.

Blowers can also be used to remove vapors from the head space of the tank car as liquid is transferred into the tank car. Standard recovery techniques such as condensation or refrigeration/condensation systems, or combustion can be applied to the captured vapors.

Vapor balancing is another means of collecting vapors and reducing emissions from transfer operations. Vapor balancing is most commonly used where storage facilities are adjacent to the loading facility. In this collection system, an additional line is connected from the transport vessel to the storage tank to return any vapor in the transport vessel displaced by the liquid that is loaded to the vapor space of the storage vessel left by the transferred liquid. Since this is a direct volumetric change, there are no losses to the atmosphere.

4.2.5.2 Efficiency

The three factors affecting the efficiency of a vapor collection system are:

1) Operating pressure of the collection system;

2) Volume of piping between the loading arm and the transport vessel; and

3) The efficiency of the ultimate control device.

The first factor influences the efficiency of collection through the VOC concentration remaining in the line after transfer. The VOC concentration for systems operating at low pressures or under vacuum is decreased, thus lowering the total amount of VOC in the piping. This effectively reduces the amount of VOC lost to the atmosphere when disconnecting transfer lines. The opposite occurs for systems operating at higher pressures.

The second factor establishes the quantity of VOC not delivered to the transport vessel and not collected for treatment. Systems that minimize the piping between the transfer loading arm and the transport vessel are more efficient than those with larger piping connections, because there is less open piping to the atmosphere.

The third factor is the most important, for it affects the the overall efficiency of the collection system and the control system. In the SOCMI, collection systems are generally hard-piped between the transport vessel and the control system. Thus, there is no loss of efficiency, other than losses associated with connections and disconnections.

4.2.5.3 Applicability

Applicability of vapor collection systems depends on four factors:

1) Vapor pressure of the material;
2) Value of the product;
3) Physical layout of the facility; and
4) OSHA considerations.

Materials with vapor pressures greater than atmospheric are stored and loaded under pressure. Loading under pressure eliminates the losses associated with atmospheric transfer operations and limits losses to those associated with connections and disconnections.

For purely economic considerations, expensive products are candidates for more extensive collection and recovery systems. Further, it is unlikely that combustion techniques will be used to control emissions of products whose value is high enough to warrant recovery efforts.

The third factor, physical layout of the facility, is the most important. The shorter the distance between the vapor balancing system and the storage tank, the fewer meters of piping required, and the more affordable a vapor balancing system is. Because vapor balancing is a simple and cost effective control technique for transfer operations, it is often used in RACT (reasonably available control technology) requirements and has been used in many instances as a control measure to meet the emission requirements of many state air toxic regulations.

OSHA limitations on work place exposure to chemicals being transferred are additional considerations. Some chemical compounds being transferred are more toxic than others, and thus must be more tightly controlled. Highly toxic or carcinogenic compunds require stringent control measures such as transferring VOCs under vacuum, vapor compression, refrigeration, and combustion.

4.3 LDAR

Leak detection and repair programs have been required by the EPA for a number of years. They have been undertaken to reduce emissions due to leaking equipment. These emissions occur when process fluid (liquid or gaseous) is released through the sealing mechanisms of equipment in the chemical plant. This section discusses the sources of equipment leak emissions and control techniques that can be applied to reduce emissions from equipment leaks, including the applicability of each control technique and its associated effectiveness in reducing emissions.

Many potential sources of equipment leak emissions exist in an organic chemical plant. The following sources are covered in this section: pumps, compressors, agitators, pressure relief devices, open-ended lines, sampling connections, process valves, connectors, instrumentation systems, and product accumulator vessels.

The techniques for reducing emissions from equipment leaks are as diverse as the types of sources. The three major categories for techniques are: 1) Equipment (modifications); 2) Closed vent systems; and 3) Work practices. The selection of a control technique and its effectiveness in reducing emissions depends on a number of factors including: 1) Type of equipment; 2) Equipment service (gas, light liquid, heavy liquid); 3) Process variables influencing equipment selection (temperature, pressure); 4) Process stream composition; and 5) Costs.

4.3.1 Equipment Description and Controls

4.3.1.1 Pumps

Pumps are used widely in the SOCMI for the movement of organic liquids.[41] Chemicals transferred by pump can leak at the point of contact between the moving shaft and the stationary casing. Consequently, all pumps require a seal at the point where the shaft penetrates the housing in order to isolate the pumped fluid from the environment.

4.3.1.1.1 Seals for Pumps

Two generic types of seals, packed and mechanical, are used on pumps. Packed seals can be used on both reciprocating and rotary action (centrifugal) pumps. A packed seal consists of a cavity (or "stuffing box") in the pump casing filled with packing material that is compressed with a packing gland to form a seal around the shaft. Coolant is required to remove the frictional heat between the packing and shaft. The necessary lubrication is provided by a coolant that flows between the packing and the shaft.[42] Deterioration of the packing can result in leakage of the process liquid.

Mechanical seals are limited in application to pumps with rotating shafts. There are single and double mechanical seals, with many variations to their basic design, but all have a lapped seal face between a stationary element and a rotating seal ring. In a single mechanical seal, the faces are held together by the pressure applied by a spring on the drive and by the pump pressure transmitted through the pumped fluid on the pump end. An elastomer O-ring seals the rotating face to the shaft. The stationary face is sealed to the stuffing box with another elastomer O-ring or gasket.

For double mechanical seals, two seals are arranged back-to-back, in tandem, or face to face. In the back-to-back arrangement, a closed cavity is created between the two seals. A seal liquid, such as water or seal oil, is circulated through the cavity. This seal liquid is used to control the temperature in the stuffing box. For the seal to function properly, the pressure of the seal liquid must be greater than the operating pressure of the pump. In this manner, any leakage would occur across the seal faces into the process or the environment.

Double mechanical seals are used in many process applications, but there are some conditions for which their use is not indicated. Such conditions include service temperatures above 260 degrees Celsius, and pumps with reciprocating shaft motion. Further, double mechanical seals cannot be used where the process fluid contains slurries, polymeric, or undissolved solids.

4.3.1.1.2 Sealless Pumps

Another type of pump used in the SOCMI is the sealless pump. Sealless pumps are used primarily in processes where the pumped fluid is hazardous, highly toxic, or very expensive and where every effort must be made to prevent all possible leakage of the fluid. Canned-motor, diaphragm, and magnetic drive pumps are three common types of sealless pumps.

Canned-motor pumps have interconnected cavity housings, motor rotors, and pump casings. Because the process liquid is the bearing lubricant, abrasive solids in the process lines cannot be tolerated. Canned-motor pumps are widely used for handling organic solvents, organic heat transfer liquids, and light oils.

Diaphragm pumps contain a flexible diaphragm of metal, rubber, and plastic as the driving member. The primary advantage of this arrangement is the elimination of all packing and seals exposed to the process liquid provided the diaphragm's integrity is maintained. This is important when handling hazardous or toxic liquids. Emissions from diaphragm pumps can be large, however, if the diaphragm fails.

In magnetic-drive pumps, no seals contact the process fluid. An externally-mounted magnet coupled to the pump motor drives the impeller in the pump casing.

4.3.1.2 Compressors

Compressors move gas through a process unit in much the same way that pumps transport liquid. Compressors are typically driven with rotating or reciprocating shafts. Thus, the sealing mechanisms for compressors are similar to those for pumps, i.e., packed and mechanical seals. Emissions from this source type may be reduced by improving the seals' performance or by collecting and controlling the emissions from the seal. Emissions from mechanical contact seals depend on the type of seal or control device used and the frequency of seal failure.

Shaft seals for compressors are of several different types: labyrinth, restrictive carbon rings, mechanical contact, and liquid film. All of these seal types restrict leaks, although none of them completely eliminates leakage. Compressors can be equipped with ports in the seal area to evacuate collected gases, which could then be controlled.

A buffer or barrier fluid may be used with these mechanical seals to form a buffer between the compressed gas and the environment, similar to barrier fluids in pumps. This system requires a clean, external gas supply that is compatible with the gas being compressed. Barrier gas can become contaminated and must be disposed of properly, for example by venting to a control device. Compressors can also be equipped with liquid film seals. This seal is formed by a film of oil between the rotating shaft and stationary gland.

4.3.1.3 Agitators

Agitators are used in the SOCMI to stir or blend chemicals. As with pumps and compressors, emissions from agitators can occur at the interface of a moving shaft and a stationary casing. Emissions from this source type may be reduced by improving the seal or by collecting and controlling emissions. There are four seal arrangements commonly used with agitators: packed seals, mechanical seals, hydraulic seals, and lip seals. Packed seals for agitators are similar in design and application to the packed seals for pumps (refer to Section 4.3.1.1).

While mechanical seals are more costly than other seal arrangements, they provide better leakage rate reduction. Also, the maintenance frequency of properly installed and maintained mechanical seals is one-half to one-fourth that of packed seals.[43] Mechanical seals can be designed specifically for high pressure applications (i.e., greater than 1,140 kPa or 165 psia).[44] As with packed seals, the mechanical seals for agitators are similar to the design and application of mechanical seals for pumps.

The hydraulic seal is the simplest and least-used agitator is limited to low temperatures and pressures and can only handle very small fluctuations. Process chemicals may contaminate the seal liquid and then be released into the atmosphere as equipment leak emissions.

Lip seals, which are relatively inexpensive and easy to install, can be used on a top-entering agitator as a dust or vapor seal. Once the seal has been installed, the agitator shaft rotates in continuous contact with the lip seal. Emissions can be released through this seal when it wears excessively or when the operating pressure surpasses the pressure limitation of the seal.

4.3.1.4 Pressure Relief Devices

Insurance, safety, and engineering codes require that pressure relief devices or systems be used in applications where the process pressure may exceed the maximum allowable working pressure of the process equipment. Pressure relief devices include rupture disks and safety/relief valves. The most common pressure relief device is a spring-loaded valve designed to open when the operating pressure of a piece of process equipment exceeds a set pressure. Equipment leak emissions from spring-loaded relief valves may be caused by failure of the valve seat or valve stem, improper reseating after overpressure relief, or process operation near the relief valve set pressure which may cause the relief valve to frequently open and close or "simmer."

Rupture disks are designed to burst at overpressure to allow the process gas to vent directly to the atmosphere. Rupture disks allow no emissions as long as the integrity of the disk is maintained. They must be replaced after each pressure relief episode to restore the process to an operating pressure condition. Although rupture disks can be used alone, they are sometimes installed upstream of a relief valve to prevent emissions through the relief valve stem.

Combinations of rupture disks and relief valves require certain design constraints and criteria to avoid potential safety hazards. For example, appropriate piping changes must be made to prevent disk fragments from lodging in damaging the relief valve when relieving overpressure. A block valve upstream of the rupture disk can be used to isolate the rupture disk/relief valve combination and permit in-service replacement of the disk after it bursts. Otherwise, emissions could result through the relief valve.

4.3.1.5 Open-Ended Lines

Emissions from open-ended lines are caused by leakage through the seat of an upstream valve in the open-ended line. Emissions that occur through the stem and gland of the valve are not considered "open-ended" emissions and are addressed in the section on process valves. Emissions from open-ended lines can be controlled by installing a cap, plug, flange, or second valve to the open end. Control efficiency of these control measures is assumed to be 100 percent.

4.3.1.6 Sampling Connections

Emissions from sampling connections occur as a result of purging the sampling line to obtain a representative sample of the process fluid. These emissions can be reduced by using a closed loop sampling system or disposing of the purged process fluid in a control device. The closed loop sampling system is designed to return the purged fluid to the process at a point of lower pressure. Closed loop sampling is assumed to be 100 percent effective for controlling emissions from a sample purge. This purged fluid could also be directed to a control device such as an incinerator, in which case the control efficiency would depend on the efficiency of the incinerator in removing the VOC.

4.3.1.7 Process Valves

Valves are the most common and numerous process equipment type found in the chemical industry.[45] There are many designs for valves, and most of the designs contain a valve stem which operates to restrict or allow fluid flow. Typically, the stem is sealed by a packing gland or O-ring to prevent leakage of process fluid to the atmosphere. Emissions from valves occur at the stem or gland area of the valve body when the packing or O-ring in the valve fails.

4.3.1.7.1 Seals for Valves

Valves that require the stem to move in and out or turn must utilize a packing gland. A variety of packing materials are suitable for conventional packing glands. The most common packing materials are the various types of braided asbestos that contain lubricants; other packing materials include graphite, graphite-impregnated fibers, and tetrafluorethylene. The choice of packing material depends on the valve application and configuration.[46] Conventional packing glands can be used over a wide range of operating temperatures.

4.3.1.7.2 Sealless Valves

Emissions from process valves can be eliminated if the valve stem can be isolated from the process fluid. There are two types of sealless valves available: diaphragm valves and sealed bellows valves.

Diaphragm valves isolate the valve stem from the process fluid using a flexible elastomer or metal diaphragm. The position of the diaphragm is regulated by a plunger, which is controlled by the stem. Depending on the diaphragm material, this type of valve can be used at temperatures as high as 205 degrees Celsius and in strong acid service. If the diaphragm fails, the valve can become a relatively larger source of emissions.[47] In addition, use at temperatures beyond the operating limits of the material tends to damage or destroy the diaphragm.

Sealed bellows valves are another alternative leakless design. In this valve type, metal bellows are welded to the bonnet and disk of the valve, thereby isolating the stem from the process. These valves can be designed to withstand high temperatures and pressures and can provide leak-free service at operating conditions beyond the limits of diaphragm valves. However, they are usually dedicated to highly toxic services and the nuclear industry.

The control effectiveness of both diaphragm and sealed bellows valves is essentially 100 percent, although a failure of the diaphragm or bellows could cause temporary emissions much larger than those from other types of valves.

4.3.1.8 Connectors

Connectors are flanges, threaded fittings, and other fittings used to join sections of piping and equipment. They are used wherever pipe or other equipment (such as vessels, pumps, valves, and heat exchangers) require isolation or removal.

Flanges are bolted, gasket-sealed connectors. Normally, flanges are used for pipes with diameters of 50 mm or greater and are classified by pressure rating and face type. The primary cause of flange leakage are poor installation and thermal stress, which results in the deformation of the seal between the flange faces.[48]

Threaded fittings are made by cutting threads into the outside end of one piece (male) and the inside end of another piece (female). These male and female parts are then screwed together like a nut and bolt. Threaded fittings are normally used to connect piping and equipment having diameters of 50 mm or less. Seals for these fittings are made by coating the male threads with a sealant before joining it to the female piece. Emissions from threaded fittings can occur as the sealant ages and eventually cracks. Leakage can also occur as the result of poor assembly or application of the sealant, and thermal stress of the piping and fittings.

Emissions from connectors can be controlled by regularly scheduled maintenance. Potential emissions can be reduced by replacing the gasket or sealant materials. If connectors are not required for process modification or periodic equipment removal, emissions from connectors can be eliminated by welding the connectors together.

4.3.1.9 Instrumentation Systems

An instrumentation system is a group of equipment components used to condition and convey a sample of process fluid to analyzers and instruments for the purpose of determining process operating conditions (e.g., composition, pressure, and flow rate). Valves and connectors are the predominant types of equipment used in instrumentation systems, although other equipment may be included. Emissions resulting from the components in the instrumentation system are controlled as they are for the same component in the process system.[49]

4.3.2 Closed Vent Systems

Emissions from equipment leaks may be controlled by installed a closed vent system around the leaking equipment and venting the emissions to a control device. This method of control is only applicable to certain equipment types, i.e., pumps, compressors, agitators, pressure relief valves, and product accumulator vessels. Because of the many valves, connectors, and open-ended lines typically found in chemical facilities it is not practical to use this technique for reducing emissions from all of these potential sources for an entire process unit. However, a closed vent system can be used to control emissions from a limited number of components, which could be enclosed and maintained under negative pressure and vented to a control device.

4.3.3 Work Practices

LDAR methods are used to identify equipment components that are emitting significant amounts of VOC and to reduce these emissions. The emission reduction potential for LDAR as a control technique is highly variable and depends on several factors, the most important of which are the frequency of monitoring and the techniques used to identify leaks. Repair of leaking components is required only when the equipment leak emissions reach a set level--the leak detection level. A low leak definition will initiate repair at lower levels, resulting in a lower overall emission rate.

4.3.3.1 Leak Detection Methods

Leak detection methods include individual component surveys, area (walk-through) surveys, and fixed point monitors. Individual component surveys form a part of the other methods.

4.3.3.1.1 Individual Component Survey

Each source of equipment leak emissions (pump, valve, compressor, etc.) can be checked for VOC leakage by visual, audible, olfactory, soap bubble, or instrument techniques. Visual methods are good for locating liquid leaks. A visible leak does not necessarily indicate VOC emissions, however, because the leaking material may be non-VOC. High-pressure leaks may be detected by the sound of escaping vapors, and leaks of odorous materials may be detected by smell.

Soap spraying on equipment components can be used to survey individual components in certain applications. If the soap solution forms bubbles or blows away, a leak is indicated, and vice versa. Disadvantages of this method are that 1) it does not distinguish leaks of hazardous VOC's from nonhazardous VOC's; 2) it is only semiquantitative, since it requires the observer to determine subjectively the rate of leakage based on the behavior of the soap bubbles; and 3) it is limited to sources with temperatures below 100 degrees Celsius, because the water in the soap solution will evaporate at temperatures above this figure. This method is also not suited for moving shafts on pumps or compressors, because the motion of the shaft may interfere with the motion of the bubbles caused by a leak.

The best method for identifying leaks of VOC from components is using a portable hydrocarbon detection instrument. Air close to the potential leak site is sampled and analyzed by a sampling traverse ("monitoring") over the entire are where leaks may occur. The concentration of hydrocarbons in the sampled air is displayed on the instrument meter and is a rough indicator of the VOC emission rate from the component. If the concentration is higher than a specified figure ("action level"), then the leaking component is marked for repair.

4.3.3.1.2 Area Survey

An area or walk-through survey requires the use of a portable hydrocarbon detector and a strip chart recorder. The procedure involves carrying the instrument within one meter of the upwind and downwind sides of process equipment. The instrument is then used for an individual component survey in a suspected leak area. The efficiency of this method for locating leaks is not well established. Problems with this method include the fact that leaks from overhead valves or relief valves will not be detected, and the possibility of leaks from adjacent units and adverse meteorological conditions affecting the results of the walk-through survey. Thus, the area survey is best for locating only large leaks at small expense.

4.3.3.1.3 Fixed point monitors

This method consists of placing several automatic hydrocarbon sampling and analysis instruments at various locations in the process unit. If elevated hydrocarbon concentrations are detected, a leaking component is indicated. Identifying the specific leaking component requires an individual component survey. The efficiency of fixed point monitoring is not well established, but fixed point monitoring of VOC's is not as effective as a complete individual component survey.[50] Fixed-point monitors are expensive, multiple units may be required, and the portable instrument is also needed to locate the particular leaking component. Calibration and maintenance costs may be high. Fixed-point monitors are used successfully to detect emissions of hazardous or toxic substances, and can provide an increased detection efficiency by selecting a particular compound as the sampling criterion.

4.3.3.2 Repair Methods

This section describes repair methods for possible equipment emission sources in a chemical plant. These are not intended to be complete repair procedures.

Many pumps have in-line or parallel spares that can be used while the leaking pump is being repaired. Leaks from packed seals may be reduced by tightening the packing gland. With mechanical seals, the pump must be dismantled to repair or replace the leaking seal. Dismantling pumps can result in spillage of some process fluid. If the seal leak is small, evaporative emissions of VOC from such spillage may be greater than the continued leak from the seal. Precautions must be taken to prevent or reduce these emissions.

Leakage from compressors with packed seals may be reduced by tightening the packing gland, as described for pumps. Repair of compressors with mechanical seals requires the compressor be removed from service. Since compressors usually do not have spares, immediate repair may not be practical or possible without a process unit shutdown.

Agitators, like pumps and compressors, can leak VOC's at the point where the shaft penetrates the casing, and seals are required to minimize fugitive emissions. Leaks from packed seals may be reduced by the repair procedure described for pumps, while repair of other types of seals require the agitator to be out of service. In this latter case, process shutdown or isolation of the particular agitator being repaired is required.

Leaking repair valves usually must be removed for repair. To remove the relief valve without shutting down the process, a block valve may be required upstream of the relief valve. A spare relief valve should be attached while the faultly valve is repaired and tested.

A rupture disk can be installed upstream from a pressure relief valve to eliminate leaks until an overpressure release occurs. Once a release occurs, the rupture disk must be replaced to prevent further leaks. A block valve is required to isolate the rupture disk for replacement.

Most valves have a packing gland that can be tightened while in service. Although this procedure should decrease the emissions from the valve, it can actually increase the emission rate if the packing is old and brittle or has been over-tightened. Some types of valves have no means of in-service repair and must be isolated from the process and removed for repair and replacement. Most control valves have a manual bypass loop that allows them to be isolated and removed. Most block valves cannot be isolated easily, although temporary changes in process operation may allow isolation in some cases.

In some cases, leaks from connectors can be reduced by replacing the connector gaskets, but most connectors cannot be isolated to permit gasket replacement. Tightening of connector bolts also may reduce emissions from connectors. Where connectors are not required for process modification or periodic equipment removal, emissions from connectors can be eliminated by welding them.

4.4 Internal Floating Roofs

Internal floating roofs are commonly used in the chemical manufacturing industry to control emissions of chemicals from storage tanks. As the name implies, it is a roof inside a tank that floats on the surface of the stored liquid.

The presence of a floating roof (or deck) inside a fixed roof tank significantly reduces the surface area of exposed liquid. It serves as a physical barrier between the volatile organic liquid and the air that enters the tank through vents.

Because evaporation is the primary emission mechanism associated with storage tanks, emissions from floating roof tanks as well as fixed roof tanks vary with the vapor pressure of the stores liquid. Thus, the control efficiency of retrofitting a fixed roof tank with an internal floating deck depends on the material being stored.

Other factors affecting emissions, and therefore control efficiency, are tank size, number of turnovers, and the type of deck and seal system selected. Installing an internal floating roof can reduce emissions by 61 to 98 percent.[51] The relative effectiveness of one internal floating roof design over another is a function of how well the deck can be sealed. Probably the most typical internal floating roof design is the noncontact, bolted, aluminum internal floating roof with a single vapor-mounted wiper seal and uncontrolled fittings.

4.4.1 Types of Losses and How They are Controlled

Loss of VOC's from internal floating roof tanks occurs in one of four ways:

1) Through the annular rim space around the perimeter of the floating roof (seal losses),

2) Through the openings in the deck required for various types of fittings (fitting losses),

3) Through the nonwelded seams formed when joining sections of the deck material (deck seam losses), and

4) Through evaporation of liquid left on the tank wall following withdrawal of liquid from the tank (withdrawal loss).[52]

4.4.1.1 Control of Seal Losses

Internal floating roof seal losses can be minimized by employing liquid-mounted primary seals instead of vapor-mounted seals and/or by employing secondary wiper seals in addition to primary seals.

Available emissions test data suggest that the location of the seal (i.e., vapor- or liquid-mounted) and the presence of a secondary seal are the major factors affecting seal losses. A liquid-mounted primary seal has a lower emissions rate, and thus a higher control efficiency, than a vapor-mounted seal. A secondary seal, with either a liquid- or a vapor-mounted primary seal, provides an additional level of control.

The type of seal used plays a less significant role in determining the emissions rate.[53] The type of seal is important only to the extent that the seal must be suitable for the particular application. For instance, an elastomeric wiper seal is commonly employed as a vapor-mounted primary seal or as a secondary seal for an internal floating roof. Because of its shape, this seal is not suitable for use as a liquid-mounted primary seal. Resilient foam seals, on the other hand, can be used as both liquid- and vapor-mounted seals.

4.4.1.2 Control of Fitting Losses

There are numerous fittings that penetrate or are attached to an internal floating roof. Among them are access hatches, column wells, roof legs, sample pipes, ladder wells, vacuum breakers, and automatic gauge float wells. Fitting losses occur when VOCs leak around these fittings. Fitting losses can be controlled with gasketing and sealing techniques or by the substitution of fittings that are designed to leak less.

The effectiveness of fitting controls at reducing the overall emission rate is a function of the number of fittings of each type employed on a given tank. For example, if using controlled fittings reduces total fitting loss by 36 percent, and if fitting losses are about 35 percent of the total emissions from a typical internal floating roof tank, then the controlled fittings reduce the overall emissions by (.36*.35)= .126, or 12.6 percent over a similar tank without fitting controls. The usual increase in control efficiency achieved by installing controlled fittings ranges from 0.5 to 1.0 percent.[54]

4.4.1.3 Control of Deck Seam Losses

Deck seam losses are inherent in a number of floating roof types including internal floating roofs. Any roof constructed of sheets or panels fastened by mechanical fasteners (e.g., bolts) is expected to have deck seam losses. Deck seam losses are considered to be a function of the length of the seams and not the type of mechanical fastener or the position of the deck relative to the liquid surface. This is a conclusion drawn from a 1986 study on two roof types with significantly different mechanical fasteners and differences in the amount of contact with the liquid surface.[55]

Deck seam losses are controlled by selecting a roof type with vapor-tight deck seams. The welded deck seams on steel pan roofs are vapor tight. Fiberglass lapped seams of a glass fiber reinforced polyester roof may be vapor tight as long as there is negligible permeability of the liquid through the seam lapping materials. Some manufacturers provide gaskets for bolted metal deck seams.

Selecting a welded roof (rather than a bolted roof) will eliminate deck seam losses. For a typical internal roof that has primary seals, secondary seals, and controlled fittings already, eliminating deck seam losses will raise the control efficiency as much as 1.5 percent.[56]

4.4.2 Applicability

The applicability of any storage tank improvement in order to reduce VOC emissions is dependent upon the characteristics of the particular VOC. Since floating decks are often constructed primarily of aluminum, they may not be applicable to tanks storing halogenated compounds, pesticides, or other compounds that are incompatible with aluminum. Contact between these compounds and an aluminum deck could corrode the deck and cause product contamination.

In addition, vapor pressures may affect the selection of tank improvements as an applicable control technology. For chemicals with very low vapor pressure, fixed roof tank emissions will already be so low that installing an internal floating roof may not significantly reduce emissions further. For chemicals with vapor pressures up to 65 kPa (9.4 psia), emission reductions of 95 percent and above are achievable with this technology. Above this vapor pressure, achievable emission reduction starts to decrease with increasing vapor pressure. Thus, an internal floating roof may not be indicated for chemicals with relatively high vapor pressures.

References

1. U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. Hazardous Air Pollutant Emissions from Process Units in the Synthetic Organic Chemical Manufacturing Industry -- Background Information for Proposed Standards, Volume 1B. September 1991. p. 2-8.

2. Reed, R.J. North American Combustion Handbook. Cleveland, Ohio. North American Manufacturing Company. 1979, p. 269.

3. U.S. Enviromental Protection Agency. Office of Air Quality Planning and Standards. Research Triangle Park, North Carolina. OAQPS Control Cost Manual, Fourth Edition. January 1990. p. 3-8.

4. Reference 3. p. 3-9.

5. Reference 1. p. 2-13.

6. Letter from Thomas Schmidt (ARI International, Palatine, IL) to William M. Vatavuk (U.S. EPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina). August 16, 1989.

7. Reference 3. p. 3-11.

8. Manning, P. Hazardous Waste. Volume 1 (1). 1984.

9. Kosusko, M. and Ramsey, G. Destruction of Air Emissions Using Catalytic Oxidation. U.S. Environmental Protection Agency. Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina. EPA Publication No. 600-D-88/107. May 1988. p. 3.

10. Letter from Robert M. Yarrington (Englehard Corporation, Edison, NJ) to William M. Vatavuk (U.S. EPA, OAQPS, RTP, NC). August 14, 1989.

11. Reference 3. p. 7-5.

12. Reactor Processes in SOCMI -- Background Information for Proposed Standards. U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. Preliminary Draft. EPA Publication No. 450/3-90-016a. June 1990.

13. Letter from David Shore (Flaregas Corp., Spring Valley, NY) to William M. Vatavuk (U.S. EPA, OAQPS, RTP, NC). October 3, 1990.

14. Reference 12.

15. Guide for Pressure-Relieving and Depressuring Systems. Refining Department, API Recommmended Practice 521, Second Edition. September 1982.

16. Reference 13.

17. Kalcevic, V. (IT Enviroscience). "Control Device Evaluation Flares and the Use of Emissions as Fuels," Organic Chemical Manufacturing Volume 4. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. EPA Publication No. 450/3-80-026. December 1980. Report 4.

18. Devitt, T., Spaite, P. and Gibbs, L. (PEDCo Environmental, Inc.) Population and Characteristics of Industrial/Commercial Boilers in the U.S. Prepared for the U.S. Environmental Protection Agency. Washington, D.C. EPA Publication No. 600/7-79-178a.

19. Reference 1. p. 2-17.

20. Castaldini, C., Willard, H.K., Wolbach, D., and Waterland, L. (Acurex Corporation). A Technical Overview of the Concept of Disposing of Hazardous Waste in Industrial Boilers. Prepared for the U.S. Environmental Protection Agency. Cincinnati, OH. EPA Contract No. 68-03-2567. January, 1981. p. 44.

21. Reference 20. p. 73.

22. U.S. Environmental Protection Agency. Benzene -- Organic Chemical Manufacturing, Ethylbenzene Styrene. Emission Test Report, El Paso Products Company (Odessa, TX). Research Triangle Park, North Carolina. EMB Report No. 79-OCM-15. April 1981.

23. U.S. Environmental Protection Agency. Office of Air and Waste Management. Control Techniques for Volatile Organic Emissions from Stationary Sources. Research Triangle Park, North Carolina. EPA Publication No. 450/2-78-002. May 1978. p. 72.

24. Reference 23. p. 76.

25. U.S. Environmental Protection Agency. Air and Energy Engineering Research Laboratory. Handbook -- Control Technologies for Hazardous Air Pollutants. Research Triangle Park, North Carolina. EPA Publication No. 625/6-86-014. September 1986. pp. 26-27.

26. Standifer, R.L. (IT Enviroscience). Control Device

Evaluation: Gas Absorption. In: Organic Chemical Manufacturing Volume 5: Adsorption, Condensation, and Absorption Devices. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. EPA Publication No. 450/3-80-027. December 1980. Report 3. p. I-7.

27. Reference 26. p. I-1.

28. Reference 1. p. 2-34.

29. Reference 1. p. 2-41.

30. Trip Report. R.H. Howls and M.A. Vancil, Radian Corp., to file. 7 pgs. Report of May 12, 1987 visit to Allied Fibers.

31. Stern, A.C. Air Pollution, Third Edition. Volume IV. New York, Academic Press, 1977. p. 336.

32. Reference 1. p. 2-43.

33. Calvert, Seymour and Englund, Harold M., eds. Handbook of Air Pollution Control Technology. John Wiley and Sons. New York, 1984. pp. 135-172.

34. Reference 3. p. 4-5.

35. Basdekis, H.S. and Parmele, C.S. (IT Enviroscience). Control Device Evaluation: Carbon Adsorption. In Organic Chemical Manufacturing Volume 5: Adsorption, Condensation, and Absorption Devices. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. EPA Publication No. 450/3/80/027. December 1980. Report 1. p. II-1.

36. Reference 35. p. II-7..

37. Reference 25. p. 28.

38. Barnett, K.W., May, P.A., and Elliott, J.A. (Radian Corporation). Carbon Adsorption for Control of VOC Emissions: Theory and Full Scale System Performance. Prepared for the U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. EPA Contract No. 68-02-4378. June 6, 1988. p. 2-2.

39. Vatavuk, W.M. and Neveril, R.B. Cost File Part XVI. Costs of Refrigeration Systems. Chemical Engineering. May 16, 1983. pp. 95-98.

40. Reference 1. pp. 2-31, 32.

41. Erikson, D.G. and Kalcevic, V. (Hydroscience, Inc.) Emissions Control Options for the Synthetic Organic Chemicals Manufacturing Industry. (Prepared for U.S. Environmental Protection Agency.) Research Triangle Park, North Carolina. EPA Contract No. 68-02-2577. February 1979. p. II-2.

42. Reference 41. p. II-2.

43. Ramsey, W.D. and Zoller, G.C. How the Design of Shafts, Seals, and Impellers Affects Agitator Performance. Chemical Engineering. 83 (18): pp. 101-108. August 30, 1976.

44. Reference 43. p. 105.

45. Reference 1. p. 2-73.

46. Lyons, J.L. and Askland, C.L. Lyons' Encyclopedia of Valves. New York, Van Nostrand Reinhold Company, 1975. p. 290.

47. Pikulik, A. Manually Operated Valves. Chemical Engineering. 85(7): p. 121. April 3, 1978.

48. McFarland, I. Preventing Flange Fires. Chemical Engineering Progress. 65(8): 59-61. August 1969.

49. Reference 1. p. 2-76.

50. Hustvedt, K.C. and Weber, R.C. (U.S. Environmental Protection Agency.) Detection of Volatile Organic Compound Emissions from Equipment Leaks. (Presented at the 71st Annual Meeting of the Air Pollution Control Association. Houston, Texas. June 25-30, 1978.)

51. Memorandum from Probert, J.A., Radian Corporation, to Project File. August 7, 1991. Achievable emission reduction for internal floating roofs.

52. Reference 1. p. 2-52.

53. U.S. Environmental Protection Agency. Office of Air Quality Planning and Standards. VOC Emissions from Volatile Organic Liquid Storage Tanks -- Background Information for Promulgated Standards. Research Triangle Park, North Carolina. EPA Publication No. 450/3-81-003b. January 1987.

54. Reference 1. p. 2-61.

55. Reference 53. Appendix C.

56. Reference 1. p. 2-62.

CHAPTER 5

REGULATORY OPTIONS

5.1 Introduction

This chapter is devoted to briefly explain the decision process for choosing a regulatory option. The rationale for regulation versus no regulation will be discussed as well as a MACT floor analysis, cost effectiveness, and economic incentives.

5.2 No Additional EPA Regulation

5.2.1 Judicial System

In the absence of governmental regulation, market systems fail to make the generators of pollution pay for the costs associated with that pollution. For an individual firm, pollution is an apparently unusable by-product that can be disposed of cheaply by venting it to the atmosphere. However, in the atmosphere pollution causes real costs to others. The fact that producers, consumers, and others whose activities result in air pollution do not bear the full costs of their actions leads to a divergence between private costs and social costs. This divergence is considered a market failure since it results in a misallocation of society's resources. Too many resources are devoted to the polluting activity when polluters do not bear the full cost of their actions.

Also, if there was no regulation, the previous regulations would be relied upon as the basis for making judicial decisions regarding excess emissions.

5.2.2 State and Local Action

The Clean Air Act requires each state to develop and implement measures to attain and maintain EPA's standards. Each state assembles these measures in a document called the State Implementation Plan (SIP). SIP's must be approved by the EPA, and the EPA is empowered to compel revision of plans it believes are inadequate. The EPA may assume enforcement authority over air pollution control programs any state fails to implement. The standards will become parts of each state's SIP, and enforcement authority will be delegated to the states. If the EPA were not to promulgate the standards, states would be responsible for making case-by case MACT decisions under Section 112 (g) and (j) whenever there is a major modification or when the date for MACT promulgation has passed without action on EPA's part.

The EPA believes that reliance on state and local action is not a viable substitute for the standards. This belief holds even if the EPA were to step up research and technology transfer programs to assist state and local governments.

5.3 EPA Regulation

5.3.1 Categories, Emission Points, and Floors

The EPA source category list identifies source categories for which NESHAP's are to be established. This list implements Section 112 (c) of the Act and reflects the EPA's determination that listed source categories include major sources of hazardous air pollutants. The source category list includes SOCMI chemical production as well as the seven non-SOCMI equipment leak source categories.

The SOCMI is a segment of the chemical manufacturing industry that includes the production of many high-volume organic chemicals. The products of SOCMI production processes are derived from approximately 10 petrochemical feedstocks. Of the hundreds of organic chemicals that are produced by the SOCMi, some are final products and some are the feedstocks for production of other chemicals or synthetic products. For example, large quantities of SOCMI products are used in the production of plastics, fibers, surfactants, pharmaceuticals, synthetic rubber, dyes, and pesticides. Production of these end products is not considered to be part of SOCMI production.

In the source category list, EPA identified the SOCMI with a list of chemical products whose production is believed to involve emissions of organic HAP's. This list of chemicals was identified from the literature describing SOCMI production processes, reactants, and products. A chemical was listed if organic HAP's could be used as reactants or produced in the production of the SOCMI chemical. The EPA recognizes that these chemical products can be produced using other reaction sequences and that not all plants producing the listed chemicals use a process that involves organic HAP emissions. Thus, the standard will only apply to those chemical production processes from which organic HAP's can be emitted.

The equipment leak standard would apply to the SOCMI and to processes within seven other non-SOCMI source categories: styrene/butadiene rubber production; polybutadiene production; chlorine production; pesticide production; chlorinated hydrocarbon use; pharmaceutical production; and miscellaneous butadiene use.

For this SOCMI component of the regulation, the EPA is proposing to define source as all the process vents, storage vessels, transfer operations, wastewater collection and treatment operations, and equipment leaks in the subject industrial processes used to manufacture synthetic organic chemicals that are located in a single facility covering a contiguous area under common control.

As the entire production process is contained within a single source that is part of one source category, a single floor, as defined in Section 112 (d)(3), is applicable to the entire operation.[1] The five kinds of emission points as stated above are process vents, storage vessels, transfer operations, wastewater collection and treatment operations, and equipment leaks.

Though equipment leaks are included in the definition of source, they cannot be included in emissions averaging because there is no method that currently exists for determining the magnitude of allowable emissions to assign equipment leaks for purposes of emissions averaging. When methods are developed to assign allowable emission levels to particular leak points, the EPA will consider revising the HON to allow the inclusion of equipment leaks in emissions averages.

In order to develop the MACT standards, the floor must be established for the source category. This is due to the fact that the Act specifies that the standard be at least as stringent as the floor. Since there were no readily available data to determine the floor for the source as a whole, each kind of emission point was examined to determine the floor. Controls that comprise the best 12 percent of performance for existing sources determine the existing source floor. For new sources, the best controlled similar source is used to determine the floor. For SOCMI, what distinguishes a well-controlled facility is not only the type of control equipment used, but also the number of emission points that are controlled. The EPA used existing Federal and State regulations to determine current control levels on the emission points. Using this process to establish a floor for the part of the source regulated by Subpart G ensures that the control level of the standard will be equivalent to the emission control level on the best controlled 12 percent of SOCMI facilities.

For Subparts H & I, the negotiating committee agreed that the requirements of the negotiated standards constitute MACT for equipment leaks. The standards for equipment leaks were determined under the regulatory negotiation process. The committee that negotiated the equipment leak rule considered the many factors and uncertainties associated with regulating equipment leaks at a wide variety of chemical plants and developed an acceptably balanced approach. The negotiators weighted the need to be flexible, the technical uncertainties, the requirement for MACT standards, and the data limitations. At the final negotiating session, the committee members conceptually resolved all outstanding major issues and over the following several months reached final agreement on the draft regulation and preamble.

All committee members agreed to support the standard providing that EPA proposes and promulgates a regulation and preamble with the same substance and effect as what was contained in the final agreement. Consequently, there were no other regulatory alternatives for equipment leaks evaluated under the HON rule.

5.3.2 **Development of MACT and the Regulatory Alternatives**

The SOCMI standards potentially represents the greatest emissions reduction likely to be achieved by any air toxics source category being regulated under Title III. As such, regulating this industry represents a significant first step toward fulfilling the mandate of Title III to reduce emissions of toxic air pollution to the greatest feasible extent. In addition, SOCMI facilities tend to be large individual emitters of toxic air pollutants, which are generally suspected to pose potential health hazards at the local level (i.e. close to individual sources).

The EPA recognizes that the 110 HAP's regulated by Subpart G of the HON represent a wide range of toxicities associated with a variety of potential toxic effects at a variety of exposure levels. However, Title III does not contemplate quantifying the specific health and environmental risks associated with different chemicals in MACT standard setting. While MACT decisions are thus not risk-based, and risk information specific to the SOCMI industry has not been developed, the EPA nevertheless recognizes clear public interest in reducing toxic emissions from the SOCMI industry as much as is feasible, based upon the potential for health and environmental benefits from toxic emissions reduction of this magnitude.

Aside from the general goal of maximum feasible emissions reduction, the EPA has endeavored to structure this first major MACT rule to incorporate several other goals: overall administrative simplicity, allowing flexibility in implementation (in order to reduce costs), encouraging pollution prevention and source reduction, and enforceability. Some goals reinforce each other (e.g. ensuring flexibility and encouraging pollution prevention). Where different goals may tend toward opposing outcomes (e.g. flexibility vs. enforceability), the EPA has striven to find workable resolution of issues, and will be requesting comment on our proposed solutions.

The EPA has devised a standard for sources in this category that permits compliance either by applying reference technology (MACT or an approved alternative) to all points specified by the standard, or alternatively by using emissions averaging, including Pollution Prevention/ Early Reduction credits.

Once the floor level of control was established, as required by the Act, the EPA considered the floor level of control for every kind of emission point and the options for control requirements beyond the floor. Bearing in mind all relevant statutory criteria, the EPA considered the magnitude of the emissions reduction to be obtained at a plant, the relative costs of different levels of controls and the general characteristics of this source category compared to other sources of hazardous air pollution when considering control requirements.

The alternative options were structured for each emission point. The same technology was used for each alternative but different parameters of emission points were generated which would result in a broader coverage as alternatives became more stringent.

5.3.3 **Description of MACT and the Regulatory Alternatives**

The options and floors chosen for each source are as follows: (See Tables 1 and 2 for details)

Process Vents

Using the TRE calculations, the EPA determined that the existing source floor level of control for process vents is equivalent to a cost effectiveness value of $1,500. The new source floor level of control is a TRE based cost effectiveness value of $11,000. The proposed standard would require combustion with 98 percent control efficiency for existing and new source process vents with TRE cost effectiveness values of less than $3,000 and $11,000, respectively.

Storage Vessels

For purposes of selecting control requirements, storage vessels were divided by capacity as follows: 10,000 to 20,000 gallons (small); 20,000 to 40,000 gallons (medium); and greater than 40,000 gallons (large). These size divisions are commonly used in regulations for storage vessels. The existing source floor level of control is a vapor pressure of 13.1 kPa (1.9 psia) for both large and medium storage vessels. The floor analysis for small storage vessels indicates that less than 12 percent of all small vessels are controlled to the efficiency of the reference control, and thus there is no floor control for existing source small storage vessels. The new source floor level of control is a vapor pressure of 13.1 kPa (1.9 psia) for small and medium storage vessels.

The control requirements for storage vessels apply to existing source medium and large storage vessels storing liquids of vapor pressures more than 13.1 kPa (1.9 psia) and 5.2 kPa (0.7 psia), respectively. The proposed applicability criterion for new source small and medium storage vessels is storage of liquids with vapor pressures greater than 13.1 kPa (1.9 psia). There is no proposed control requirement for existing source small storage vessels. The proposed applicability criterion for new source large vessels is vapor pressures above 0.7 kPa (0.1 psia). The control requirements are the same for new and existing source vessels in the medium and large size divisions.

Transfer Operations

The existing and new source floor levels of control for transfer operations are a vapor pressure and throughput combination of 10.3 kPa (1.5 psia) and 0.65 million liters/yr (0.17 million gal/yr), respectively.

Wastewater Streams

The floor level of control for new source wastewater streams is 10 ppmw for very volatile HAP's (VVHAP). The control requirements for new source wastewater streams are to be applied to those streams with 0.02 lpm flow and 10 ppmw volatile HAP. The applicability criteria for control of existing source wastewater streams are 10 lpm flow and 1000 ppmw volatile HAP. There is no floor for existing wastewater streams.

Equipment Leaks

The regulation would apply to both existing and new process units. It categorizes the regulated processes into five groups and uses a staggered implementation scheme, requiring some process units to comply 6 months after promulgation, while others would have to comply as late as 18 months after promulgation.

The regulation applies to those pieces of equipment currently regulated in the existing equipment-leak rules, including all valves, pumps, compressors, pressure relief devices, open-ended valves or lines, connectors, closed-vent systems and control devices, sampling connection systems, and product accumulator vessels.

These standards are estimated to reduce emissions by about 60-70 percent and after control, leak frequencies (i.e. the percentage of equipment components within a process unit that leak) would be approximately 5 percent.

The standard only applies to equipment containing or contacting process materials that are five percent VHAP or greater. In certain chemical plants, particularly those with batch processes that produce a number of different products, some equipment is used in VHAP service only occasionally. In such cases, implementation of the standard could be difficult and would achieve very little emission reduction. For these situations, equipment that is operated in VHAP service for 300 h/yr is exempt.

The HON will establish a control requirement for each kind of emission point regulated by Subparts G, H and I. To facilitate emissions averaging, the standard will also establish an allowable emissions level for the emission points regulated by Subpart G at each source. The allowable emissions level will be equal to the sum of the emissions from each point in the source excluding equipment leaks, after the required controls have been applied. As such, the allowable emissions level is set for a given mix of emission points, and the emissions limit will change as the number of each kind of emission point in the source changes.

Both Group 1 and 2 emission points as defined in Subpart G must be included in the calculation of the source's allowable emissions level. However, emission points associated with equipment that is no longer operational are not to be included in the calculation of the emissions limit because these points are not subject to the standard. Though the form of the standard established in Subpart G of the HON is an allowable emissions level, the EPA does not anticipate that any owner or operator will actually calculate emissions estimates for every point in order to comply with the standard. Actual emissions estimates will only be required for those emission points that are included in emissions averages. For emission points that are not included in emissions averages, compliance will be determined on a point by point basis. For these points, the use of an appropriate and well maintained control serves as a surrogate for an emissions estimate in determining compliance with the allowable emissions level.[2]

Table 5-1

Regulatory Options

Process Vents

- Existing - C/E ≤ $3,000/Mg
- New - C/E ≤ $11,000/Mg

Transfer Operations

- Existing and New - Control for racks with vapor pressure ≥ 10.3 kPa (1.5 psia) and throughput > 0.65 million liters/yr (0.17 million gallons/yr)

Wastewater Operations

- Existing - control for flow > 10 liter/min and > 10 ppmw total VOHAP
- New
  - Control for flow > 0.02 liter/min and > 10 ppmw total VOHAP

Storage Vessels

- Small Tanks
  - Existing - no control
  - New - control for vapor pressure > 13.1 kPa (1.9 psia)
- Medium Tanks
  - Existing - control for vapor pressure > 13.1 kPa (1.9 psia)
  - New - same as existing
- Large Tanks
  - Existing - control for vapor pressure > 5.2 kPa (0.75 psia)
  - New - control for vapor pressure > 0.7 kPa (0.1 psia)

Table 5-2

Floor Elements

Process Vents

- Existing - control vents with cost effectiveness of < $1,500/Mg
- New - control vents with cost effectiveness of < $11,000/Mg

Wastewater Operations

- Existing - No control required
- New - control for streams > 10 ppmw VVHAP

Transfer Operations

- Existing - control for racks loading liquid HAP's with vapor pressure > 10.3 kPa (1.5 psia) and throughput > 0.65 million liters/yr (0.17 million gallons per year)
- New - same as existing

Storage Vessels

- Small Tanks
  - Existing - no control required
  - New - control for tanks storing HAP's with vapor pressure > 13.1 kPa (1.9 psia)
- Medium Tanks
  - Existing - control for tanks storing HAP's with vapor pressure > 13.1 kPa (1.9 psia)
  - New - same as existing
- Large Tanks
  - Existing - control for tanks storing HAP's with vapor pressure > 5.2 kPa (0.75 psia)
  - New - control for tanks storing HAP's with vapor pressure > 0.7 kPa (0.1 psia)

5.3.4 **Role of Cost Effectiveness**

EPA has often used cost effectiveness (C/E) analysis as a guide for selecting among regulatory alternatives. Regulatory alternatives can sometimes be ranked based on stringency of control. All else equal, alternatives yielding the same level of control but higher average C/E (usually control cost per ton of pollutant reduced) could be eliminated from consideration. Incremental C/E can then be calculated for each step up the stringency ranking. The selection of a regulatory alternative could then be made by selecting the most stringent alternative below some agreed upon C/E cutoff. The level of such a C/E cutoff would generally depend on the pollutant being controlled and other factors.

However, since the HON regulation is to be a MACT standard, the role of C/E analysis for selecting a regulatory alternative for this regulation is somewhat limited. A MACT floor level of control stringency is required regardless the C/E at this control level. At stringency levels beyond the MACT floor, cost effectiveness can be legally considered, and EPA believes cost-effectiveness of controls is a primary consideration for stringency levels beyond the MACT floor.

5.3.5 **Economic Incentives: Subsidies, Fees, and Marketable Permits**

Economic incentive strategies, when designed properly, act to harness the marketplace to work for the environment. Such strategies influence, rather than dictate producer and consumer behavior, in order to achieve environmental goals. They make environmental protection of economic interest to producers and consumers. When feasible, properly designed systems can be employed to achieve any environmental goal at the least cost to society.

Several types or categories of economic incentive strategies exist. One broad category of incentive programs is based of the use of fees or subsidies. Fee programs establish and collect a fee on emissions, providing a direct economic incentive for emitters to decrease emissions to the point where the cost of abating emissions equals the fee.[3] Similarly, subsidy programs provide a direct incentive for emitters to decrease emissions by providing subsidy payments for emission reductions beyond some baseline.

A second broad category of economic incentive strategies is based on the concept of emissions trading. A wide range of variations in emissions trading programs exist. The common idea in such programs is to allow sources with low abatement cost alternatives to trade or sell emission allowances to higher abatement cost alternatives so that the cost of meeting a given total level of abatement is minimized.

There are two important constraints regarding the workability of economic incentive programs. The first constraint concerns the problem of emissions monitoring. Without an effective emissions monitoring system it is not possible to charge fees or use other economic incentive strategies. Only the traditional "command and control" approach of requiring employment of specific control technologies is feasible in this circumstance.

The second problem constraining the potential value of economic incentive strategies is legal. Various legal restrictions imposed by the CAAA limit the applicability of economic incentive strategies to reduce air pollution.

Legal constraints imposed by Title III of the Act severely limit the usefulness of economic incentive strategies for reducing HAP emissions. Title III requires the implementation of MACT. Thus sources have little or no choice as to the type or level of control they implement except perhaps if going beyond the MACT floor control level. As a limited economic incentive, it may the be possible to impose, for example, and emissions fee on residual emissions after the MACT technology is employed to encourage additional control.

Hence the applicability of economic incentive programs for the HON regulation is very limited. However, limited emissions at the facility level may be feasible and legal given that each facility is considered an emissions source. This emissions averaging strategy allows facilities to trade emission reductions across emission points so as to minimize control costs for any given facility level emission reduction requirement. Thus, to this extent, an economic incentive strategy may be implemented for the HON regulation.

The analysis of control costs (Chapter 6) does not incorporate emission averaging. It is recognized that if facilities were to use this strategy their costs of control should fall. Thus, the costs calculated are an overestimate. It also should be noted that the economic impacts and benefits analyses (Chapters 7 and 8) are only for the TIC option due to data paucities. These analyses are therefore overestimates of the impacts and benefits of the regulation. The control costs calculated in Chapter 6 do, however, include data for the MACT floor and more stringent options up to TIC for each emission point.

References

1. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Draft Preamble for the HON. December 1993.

2. Reference 1.

3. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Municipal Waste Landfills - Regulatory Impact Analysis. March 1991.

CHAPTER 6

CONTROL COST AND COST EFFECTIVENESS

Due to the unavailability of complete information upon which to base emission and control impacts to the desired degree of accuracy for all chemicals, estimates were developed in the following manner. As much information gathering and analysis as possible was completed for those chemical production processes (CPP) used in the manufacture of SOCMI chemicals.[1] Emissions and control impacts were then estimated for each CPP involved in the manufacture of those chemicals for which complete information was available.[2] For those chemicals with incomplete information, generic estimates of emissions and control impacts were developed.

Section 6.1 of this chapter presents and discusses the cost and cost effectiveness for controlling each of the five HON emissions source types. Section 6.2 presents the method for and results of estimating the cumulative control cost of producing SOCMI chemicals. Section 6.3 addresses control costs in light of the regulatory alternatives, and Section 6.4 presents the estimated national costs of the HON.

6.1 Cost Impacts of Control Technologies

In developing facility level and national costs for the HON, source emission models and appropriate control technologies were paired with the CPP units in the HON database. Control impacts were determined for each modeled emission source at a process unit that was required to implement additional control.

The costs, emission reductions, and cost effectiveness on a model plant basis, are shown in Tables 6-1 through 6-5. Table 6-1 shows the annualized costs, emission reductions, and cost effectiveness for controlling 12 model process vent streams. These model vent streams were selected to illustrate a range of impacts as well as a range of production processes and control

---

[1] For a detailed explanation of the methodology used to assess emission and control impacts, refer to Volume 1A, Chapter 4 of the HON BID.

[2] The chemicals for which sufficient information was found account for more than 90 percent of total SOCMI production capacity.

technologies.[3] For this analysis it was assumed that each production process would be equipped with a dedicated combustion device. Some cost savings would be achieved at larger facilities if a common combustion device was used to control multiple production process vent streams. As shown, the annualized costs range from $8 to $2,630,000.

Tables 6-2 and 6-3 show annualized costs, emission reductions, and cost effectiveness for controlling equipment leaks for 6 model units. The model units represent combinations of numbers of equipment components and existing control levels.[4] The recovery credit values are determined by multiplying VOC emission reductions by the average chemical price of $1,590/Mg. Table 6-2 presents annualized costs, emission reduction, and cost effectiveness when quarterly valve monitoring is required. Quarterly monitoring is required if less than 2 percent of all valves are leaking at or above a leak definition of 500 ppmv. Table 6-3 presents annualized costs, emission reduction, and cost effectiveness when monthly valve monitoring is required. Monthly monitoring is required if more than 2 percent of all valves are leaking at or above a leak definition of 500 ppmv. The costs range from a savings of $246,539 to a net cost of $390.

---

[3] For a detailed explanation of the development and use of model process vent streams see Volume 1C, Chapter 2 of the HON BID. The model streams are subsets of all the process vent streams in the database.

[4] For a detailed explanation of the development and use of equipment leak model units see Volume 1C, Chapter 6 of the HON BID.

Table 6-1. Annualized Control Cost Estimates

Model Vent Number	Total Annualized Cost ($/yr)	Total HAP/VOC Emission Reductions (Mg/yr)	Cost Effectiveness ($/Mg)[a]	VOC Emission Reductions (Mg VOC/yr)	Cost Effectivenss ($/Mg VOC)[a]
1	1310	79.4	16.5	79.5	16.5
2	1100000	2710	407	7380	150
3	152000	759	200	758	200
4	2630000	5980	439	5980	439
5	8.33	6.76	1.23	8.10	1.03
6	56400	6.23	9060	12.0	4720
7	46100	3.32	13900	3.32	13900
8	46000	0.136	337000	0.136	337000
9	65800	90.4	728	116	568
10	45800	13.4	3420	17.1	2670
11	109000	14.7	7400	18.8	5770
12	45500	0.331	138000	0.424	107000

[a] Cost Effectiveness ($/Mg) = Total Annual Cost ($/yr) ÷ Total HAP/VOC Emission Reduction (Mg/yr)

Table 6-2. Cost Effectiveness For Model Units (Quarterly Valve Monitoring)

	Unit A	Unit B	Unit C	Unit D	Unit E	Unit F
Total annual cost ($/yr)	(26,639)[a]	(108,882)	(246,539)	(6,021)	(27,037)	(76,844)
Emission reductions (Mg VOC/yr)	36.47	149.19	306.11	21.39	92.57	187.98
Average HAP/VOC ratio	0.78	0.78	0.78	0.78	0.78	0.78
Emission reductions (Mg HAP/yr)	28.45	116.37	238.77	16.68	72.20	146.62
Cost effectiveness ($/Mg VOC)	(730)	(730)	(810)	(280)	(290)	(410)
Cost effectiveness ($/Mg HAP)	(940)	(940)	(1,030)	(360)	(370)	(520)

[a] Parentheses indicate negative values (i.e., savings).

Table 6-3. Cost Effectiveness For Model Units (Monthly Valve Monitoring)

	Unit A	Unit B	Unit C	Unit D.	Unit E	Unit F
Total annualized cost ($/yr)	(14,099)[a]	(65,171)	(154,369)	6,519	16,675	15,327
Emission reductions (Mg VOC/yr)	36.47	149.19	306.11	21.39	92.57	187.98
Average HAP/VOC ratio	0.78	0.78	0.78	0.78	0.78	0.78
Emission reductions (Mg HAP/yr)	28.45	116.37	238.77	16.68	72.20	146.62
Cost effectiveness ($/Mg VOC)	(390)	(440)	(500)	300	180	80
Cost effectiveness ($/Mg HAP)	(500)	(560)	(650)	390	230	100

[a] Parentheses indicate negative values (i.e., savings).

Table 6-4 summarizes the annualized costs, emission reductions, and cost effectiveness for controlling each of 17 model storage tank farms.[5] The costs depend on the emission rate of the storage vessel and the specific control device used. For this analysis it was assumed that each individual tank would be equipped with a dedicated control device. However, some cost savings could be achieved at larger facilities if, for instance, a single condenser serves all the tanks in one farm. The product recovery credit shown is the value in dollars per year of the recovered product. It is calculated by multiplying the emission reduction by the unit price of the individual chemical. The total annualized costs for the model tank farms range from a savings of $280,000 to a net cost of $556,000.

Table 6-5 summarizes the annualized cost, emission reductions and cost effectiveness for controlling 18 model waste water streams with steam strippers. A total of 84 model wastewater streams were created from various combinations of flow rate, VOHAP concentration, and strippability.[6] Although impact estimates were made based on specific stream characteristics of all 84 streams, a subset of 18 examples were selected from the 84 model streams to illustrate the potential cost and environmental impacts. These 18 were selected to provide a manageable number of examples while still illustrating the full range of impacts. For calculating treatment costs, it was assumed that facilities would combine wastewater streams for treatment whenever technically feasible. Accordingly, steam strippers were sized and costed for combined wastewater feed rates of 50 and 500 liters per minute (lpm). As shown in table 6-5, the annualized costs per facility range from $121,000 to $418,000.

---

[5] For a detailed explanation of the development and use of model storage tank farm farms see Volume 1C, Chapter 4 of the HON BID.

[6] For a detailed explanation of the development and use of model wastewater streams see Volume 1C, Chapter 5 of the HON BID.

Table 6-4. Annualized Control Cost Estimates for Example Model Tank Farms

Model Tank Farm Number	Control Technology[a]	Annual Cost Without Product Recovery Credit ($/yr)	Product Recovery Credit ($/yr)	Total Annual Cost ($/yr)[b]	Total HAP/VOC Emission Reductions (Mg/yr)	Cost Effectiveness ($/Mg)[c]
1	Condenser	111,513	1,298	110,215	1.03	107,000
2	Condenser	57,283	4,490	52,793	3.74	14,110
3	Install floating roof	7,907	5,590	2,317	2.23	1,040
4	Install floating roof	7,907	19,676	(11,769)	16.4	(720)
5	Install floating roof	39,483	93,442	(53,959)	37.2	(1,450)
6	Install floating roof	39,483	73,848	(34,365)	151	(210)
7	Install floating roof	151,117	37,749	113,368	51.7	2,190
8	Install floating roof	151,117	431,283	(280,166)	172	(1,630)
9	Condenser	167,967	577	167,390	2.55	65,640
10	Condenser	139,737	23,274	116,463	44.5	2,620
11	Condenser	558,758	2,422	556,336	8.74	63,650
12	Condenser	554,657	7,130	547,527	32.0	17,110
13	Condenser	350,715	11,279	339,436	57.5	5,900

Model Tank Farm Number	Control Technology[a]	Annual Cost Without Product Recovery Credit ($/yr)	Product Recovery Credit ($/yr)	Total Annual Cost ($/yr)[b]	Total HAP/VOC Emission Reductions (Mg/yr)	Cost Effectiveness ($/Mg)[c]
14	Upgrade floating roof	6,630	1,152	5,478	1.31	4,180
15	Upgrade floating roof	6,630	7,944	(1,315)	6.62	(200)
16	Upgrade floating roof	37,436	10,249	27,187	34.2	790
17	Upgrade floating roof	19,966	31,555	(11,589)	26.3	(440)

[a] Each storage tank has a dedicated control device. Thus, the costs for Model 11 represent the costs of seven condensers, one for each tank.

[b] Total Annual Cost = (Annual Cost w/o Recovery Credit) - (Recovery Credit).

[c] Cost Effectiveness ($/Mg) = Total Annual Cost ($/yr) ÷ Total HAP/VOC Emission Reductions (Mg/yr).

Table 6-5. Cost Effectiveness of Wastewater Model Streams

Model Stream	Total Annual Facility Cost ($/yr)	Total Annual Stream Cost ($/yr)	Uncontrolled HAP Emissions (Mg/yr)	HAP Emission Reductions (Mg/yr)	Cost Effectiveness ($/Mg)
4	121,000	24,200	0.02	<0.01	2,400,000
5	121,000	24,200	0.41	0.02	1,200,000
6	121,000	24,200	8.3	0.41	59,000
46	121,000	24,200	0.02	0.01	2,400,000
47	121,000	24,200	0.41	0.29	83,000
48	121,000	24,200	8.3	5.8	4,200
67	121,000	24,200	0.02	0.02	1,200,000
68	121,000	24,200	0.41	0.41	59,000
69	121,000	24,200	8.3	8.1	3,000
19	418,000	83,600	0.17	0.01	8,400,000
20	418,000	83,600	4.1	0.21	400,000
21	418,000	83,600	82.8	4.1	20,000
61	418,000	83,600	0.17	0.12	700,000
62	418,000	83,600	4.1	2.9	29,000
63	418,000	83,600	82.8	58.0	1,400
82	418,000	83,600	0.17	0.16	500,000
83	418,000	83,600	4.1	4.1	20,000
84	418,000	83,600	82.8	81.1	1,000

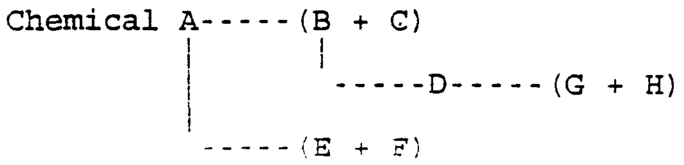
Table 6-6 shows the annualized cost, emission reduction and cost effectiveness for controlling 20 model transfer operations.[7] The costs depend on the transfer rate for a given loading rack and the combustion device selected for control. For this analysis a single control device was assumed to service the entire facility. The annualized costs of the control systems for model transfer racks range from $9,630 to $84,400.

6.2 Cumulative Control Cost Analysis

In addition to addressing the cost of the HON on a facility level, the HON economic impact analysis requires an estimate of the potential impact of the HON on SOCMI chemical prices. To better facilitate this assessment, an analysis of the potential cumulative control cost associated with each chemical's production was performed. The basis for this analysis was chemical use trees developed specifically for the HON.

A chemical tree conveys the production relationship between chemicals, indicating the possible precursor evolution of a SOCMI chemical. For instance, the tree in Figure 6-1 depicts the relationship between chemical A and its precursors. Chemical A can be produced by either combining chemicals B and C, or combining chemicals E and F. Chemical B can be produced from chemical D, and D by combining chemicals G and H.

Figure 6-1 Hypothetical Chemical Tree



---

[7] For a detailed explanation of the development and use of model transfer loading operations see Volume 1C, Chapter 3 of the HON BID.

Table 6-6. Annual Control Cost Estimates[a]

Model Rack Number	Total Annualized Cost ($/yr)	Total HAP/VOC Emission Reduction (Mg/yr)	Cost Effectiveness ($/Mg)[b]
1	9,630	$3.56 * 10^{-6}$	$2.70 * 10^{9}$
2	63,800	$6.32 * 10^{-4}$	$1.01 * 10^{8}$
3	9,650	$1.42 * 10^{-4}$	$6.81 * 10^{7}$
4	66,000	$3.08 * 10^{-2}$	$2.14 * 10^{6}$
5	10,600	$9.19 * 10^{-2}$	$1.16 * 10^{5}$
6	84,400	3.39	$2.49 * 10^{4}$
7	22,600	$9.63 * 10^{-1}$	$2.35 * 10^{4}$
8	25,900	1.67	$1.55 * 10^{4}$
9	39,000	6.39	$6.11 * 10^{3}$
10	28,100	5.65	$4.98 * 10^{3}$
11	6,870	$2.34 * 10^{-6}$	$2.93 * 10^{9}$
12	63,800	$6.32 * 10^{-4}$	$1.01 * 10^{8}$
13	10,100	$2.96 * 10^{-4}$	$3.42 * 10^{7}$
14	15,600	$9.72 * 10^{-4}$	$1.61 * 10^{7}$
15	63,800	$2.08 * 10^{-1}$	$3.06 * 10^{5}$
16	16,800	$2.11 * 10^{-1}$	$7.97 * 10^{4}$
17	14,300	$8.55 * 10^{-1}$	$1.68 * 10^{4}$
18	74,300	4.46	$1.67 * 10^{4}$
19	67,200	4.22	$1.59 * 10^{4}$
20	38,400	19.3	$1.99 * 10^{3}$

[a] Each transfer rack has a dedicated control device.

[b] Cost Effectiveness ($/Mg) = Total Annual Cost ($/yr) ÷ Total HAP/VOC Emission Reduction (Mg/yr).

6.2.1 Building Chemical Trees

Chemical trees are formed by linking together individual CPPs. A CPP is identified by its chemical inputs and outputs. The chemical output of one process is matched to the chemical input of another to form a chain. Additional processes that match are linked to the chain to form the tree. The HON trees begin with a "root" chemical and identify all the chemicals that can be used to produce the root chemical. Each root chemical can be associated with a producer, and the cost of controlling the process that makes each precursor chemical can be introduced into the tree framework.

6.2.2 Cumulative Control Cost Methodology

Cumulative control cost refers to the price increase for the root chemical that is necessary to recover HON compliance cost, given that the root chemical and its precursor chemicals incur additional production costs as a result of regulation. In simple form, the cumulative cost of controlling a root chemical is the sum of all control costs for each link in the root chemical's production chain. Because the market relationships between production process links are not fully characterized by a chemical tree, each link is assumed to denote an imaginary common marketplace where output chemicals of one process are sold as inputs to another process. One limitation of the cumulative control cost methodology is that market quantity adjustments are not considered. There are hundreds, possibly thousands, of market interactions that would have to be characterized in order to incorporate the chemical production quantity changes that result from the HON into the analysis, and this was not deemed feasible. Therefore, the chemical trees cumulative control cost analysis only addresses for each chemical the probable price increase necessary to recover the HON compliance cost when all other variables are held constant.[3]

Another limitation already alluded to is that the chemical trees represent possible market interactions, not actual interactions. Not all process links in the chemical trees are technically or economically viable. Without an indepth investigation of individual circumstances, an interaction determination cannot be made with certainty.

6.2.3 Cumulative Control Cost Results

The cumulative control cost analysis was performed for the HON options representing total industry control (TIC). This analysis, therefore, represents an upper-bound, or worst-case cost impact scenario. Table 6-7 shows the results of the

---

[8] For a summary of the indepth economic impact analysis of the representative HON chemicals, refer to Volume 1A, Chapter 6 of the HON BID, or Chapter 7 in this document.

cumulative control cost analysis for the TIC options. The average percentage cost increase for all HON chemical products appears prohibitively high due to the extremely low cost effectiveness of controlling some small (less than 1.00 Gg/yr) production process units. Of course, many of these units would be unaffected by options less stringent than TIC. The chemical percent price increase necessary to recover HON compliance costs is relatively insignificant for chemicals whose annual production exceeds 1 Gg.

6.3 Costs and Regulatory Options

Tables 6-8 through 6-19 present the total annual cost, emission reductions, and cost effectiveness for the control options considered for each source type (with the exception of equipment leaks which is governed by a negotiated regulation). It is important to note that the information in these tables pertains only to those CPPs for which sufficient information was available. Recall from this chapter's introduction that these CPPs account for over 90 percent of total SOCMI production. Tables 6-8 and 6-9 present the control options for existing and new process vents. Tables 6-10 and 6-11 present the control options for existing and new wastewater sources. Tables 6-12 and 6-13 present the control options for existing and new transfer operations. Tables 6-14 and 6-15 present the control options for existing and new 10,000 to 20,000 gallon storage vessels. Tables 6-16 and 6-17 present the control options for existing and new 20,000 to 40,000 gallon storage vessels. Tables 6-18 to 6-19 present the control options for existing and new storage vessels with greater than 40,000 gallon capacity.

6.4 National Costs

6.4.1 Monitoring, Recordkeeping, and Reporting Costs

The annualized costs of monitoring, recordkeeping, and reporting for compliance with this standard were calculated. All estimates were prepared in consultation with people who routinely work with or consult for major chemical firms, air pollutant regulators in several states, and environmental groups. They are also based on experience with similar estimates based on the information collection requirements in the SOCMI NSPS.

[9]

---

[9] For more information, refer to U.S. Enviromental Protection Agency, "Reporting and Recordkeeping Requirments for the Hazardous Organic NESHAP for the Synthetic Organic Chemical Manufacturing Industry and Other Processes Subject to the Negotiated Regulation for Equipment Leaks." Part A of the Hazardous Organic NESHAP Supporting Statement, December 1993.

To compute the costs associated with the burden estimates, the Agency used labor rates developed for the 1989 Comprehensive Assessment and Information Rule (CAIR) economic analysis. The estimated rates are: technical at $33, management at $49, and clerical at $15. These rates are in 1989 dollars to remain consistent with the base year for the control costs.

6.4.1.1 Costs to Regulated Sources

The annual burden estimates and associated costs for existing sources from reporting and recordkeeping are presented in Table 6-20, and the same estimates for new sources are shown in Table 6-21. These estimates are shown seperately because the calculation of technical hours required at new sources must include compliance at startup and periodic records burdens in addition to pre-compliance requirements. Generally, with the exceptions of new sources and some equipment leaks provisions, periodic reports and recordkeeping requirements begin after the date of compliance, which is three years after promulgation (Feburary 1997).

The requirements include both periodic reports and reports required only once. Burden estimates for the latter are treated as average annual burdens by dividing the cumulative three year total technical hour estimate by three before inclusion in the column entitled, "technical hours per year per source."

Estimates of total technical-hours per year per source and the number of activities per respondent per year listed in each table are based upon experience with similar estimates computed for the SOCMI NSPS in particular and the number of emission points in each source. It is important to note that an average was taken of costs covering a period of three years for the burden to a typical source.

6.4.1.2 Costs to the Federal Government

Because the monitoring, recordkeeping, and reporting requirements were developed as a normal part of standards development, no costs are attributed to the development of the requirments. Also, because these requirements are required under Section 112 of the Clean Air Act, no operational costs will be incurred by the Federal Government.

Examination of records to be maintained by the respondents will occur incidentally as part of the periodic inspection of sources that is part of the Agency's overall compliance and enforcement program and, therefore, is not an additional cost to the Government. The only costs the Federal Government will occur are user costs associated with the analysis of the reported information, as presented in Table 6-22. The labor rates used to compute these costs are the same as in the CAIR economic analysis.

The total of all monitoring, recordkeeping, and reporting costs comes to $69.1 million per year for the first three years after promugation. The estimated burden is approximately 2,150,000 hours (1,870,000 technical, 93,500 managerial, and 186,500 clerical hours) per year. Virtually all the costs (99 percent), not surprisingly, will be borne by the affected sources.

6.4.2 Summary

Table 6-23 shows the national total annual control cost and average cost effectiveness for the options currently proposed for the HON. These costs include all the costs associated with the monitoring, recordkeeping, and reporting requirements. The national annual control cost and cost effectiveness are estimated for the fifth year following proposal, or the third year following promulgation. This date is used to approximate the date by which all affected sources will have complied with the regulation. The estimated total annual cost of the standard is $227 million.

Table 6-7. Cumulative Control Cost Analysis Results For Total Industry Control (TIC) Options

Chem. Production (Gg/yr)	% of HON Chem.	Percent of Total HON Production	Average Cumul. Cost Increase ($/kg)	Median Cumul. Cost Increase ($/kg)	Average Percent Cost Increase	Median % Cost Increase
> 0	100	100.00	19.85	0.016	1,158	1.12
> 1	87	99.99	0.069	0.014	3.74	0.94
> 5	79	99.89	0.066	0.012	3.55	0.85
> 10	66	99.41	0.020	0.009	1.35	0.71

Table 6-8. Control Options For Process Vents
Existing Sources

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	235,000	93	55,000	234	
2	236,000	93	58,000	245	1,808
3	238,000	94	62,000	260	2,500
4	239,000	94	66,000	276	3,900
5	241,000	95	97,000	404	23,000

[a] Option 1 - (MACT floor) control vents with cost effectiveness < $1,500/Mg.

Option 2- control vents with cost effectiveness < $2,000/Mg.

Option 3- control vents with cost effectiveness < $3,000/Mg. This was the regulatory option chosen.

Option 4- control vents with cost effectiveness < $5,000/Mg.

Option 5- control of all process vents (i.e., TIC).

[b] Baseline emissions are 261,600 Mg/yr of HAP.

Table 6-9. Control Options For Process Vents
New Sources

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	46,000	95	14,000	300	
2	46,000	95	18,000	400	47,000

[a] Option 1- (MACT floor) control vents with cost effectiveness <$11,000/Mg. This was the regulatory option chosen.

Option 2- control of all process vents.

[b] Baseline emissions are 48,400 Mg/yr of HAP.

Table 6-10. Control Options For Wastewater Existing Sources

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	68,400	79	29,200	430	430
2	69,100	80	32,100	470	4,300
3	69,600	81	39,100	560	13,400
4	71,200	82	51,600	720	7,600

[a] MACT floor is no control. All options listed are for control levels above the MACT floor.

Option 1 - control streams > 10 lpm and > 1000 ppmw volatile HAP's. This was the regulatory option chosen.

Option 2- control streams > 5 lpm and > 800 ppmw volatile HAP's.

Option 3- control streams > 1 lpm and > 500 ppmw volative HAP's.

Option 4- control of all wastewater streams (i.e., TIC).

[b] Baseline emissions are 86,500 Mg/yr of HAP.

Table 6-11. Control Options For Wastewater New Sources

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	10,300	63	10,000	975	
2	13,500	82	12,800	948	860
3	13,900	85	23,500	1,690	27,700

[a] Option 1 - (MACT floor) control streams > 10 ppmv volatile HAP's. This was the regulatory option chosen.

Option 2- control streams > 0.02 lpm and > 10 ppmw highly volatile HAP's.

Option 3- control all wastewater streams (i.e., TIC).

[b] Baseline emissions are 16,300 Mg/yr of HAP.

Table 6-12. Control Options For Transfer Existing Sources

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	360	65	3,100	8,700	
2	424	77	6,500	15,000	54,000

[a] Option 1 - (MACT floor) control racks loading liquid HAP's with vapor pressure > 10.3 kPa (1.5 psia) and throughput > 0.65 million liters/yr (0.17 million gallons per year). This was the regulatory option chosen.

Option 2- control of all transfer racks (i.e., TIC).

[b] Baseline emissions are 550 Mg HAP/yr.

Table 6-13. Control Options For Transfer Operations New Sources

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	68	65	590	8,700	
2	80	77	1,200	15,000	54,000

[a] Option 1 - (MACT floor) control racks loading liquid HAP's with vapor pressure > 10.3 kPa (1.5 psia) and throughput > 0.65 million liters/yr (0.17 million gallons per year). This was the regulatory option chosen.

Option 2- control all racks loading liquid HAP's (i.e., TIC).

[b] Baseline emissions are 105 Mg HAP/yr.

Table 6-14. Control Options For Storage Vessels: Existing Sources 10,000 to 20,000 Gallon Capacity

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	0	0	0	0	
2	360	95	21,000	58,000	58,000

[a] MACT floor is no control. The MACT floor was the regulatory option chosen.

Option 1- MACT floor

Option 2- control of all storage vessels (i.e., TIC).

[b] Baseline emissions are 360 Mg/yr of HAP.

Table 6-15. Control Options For Storage Vessels: New Sources 10,000 to 20,000 Gallon Capacity

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	61	85	1,600	26,800	
2	68	95	4,000	58,000	336,000

[a] Option 1- (MACT floor) control tanks storing HAP's with vapor pressure > 13.1 kPa (1.9 psia). This was the regulatory option chosen.

Option 2- control of all small storage vessels (i.e., TIC).

[b] Baseline emissions are 72 Mg/yr of HAP.

Table 6-16. Control Options For Storage Vessels: Existing Sources 20,000 to 40,000 Gallon Capacity

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	330	70	2,400	7,400	
3	410	88	6,400	16,000	48,000

[a] Option 1 - (MACT floor) control tanks storing HAP's with vapor pressure > 13.1 kPa (1.9 psia). This was the regulatory option chosen.

Option 2- control of all medium storage vessels (i.e., TIC).

[b] Baseline emissions are 464 Mg/yr of HAP.

Table 6-17. Control Options For Storage Vessels: New Sources 20,000 to 40,000 Gallon Capacity

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	62	70	395	6,370	
2	78	88	766	9,870	23,780

[a] Option 1 - (MACT floor) control tanks storing HAP's with vapor pressure >1.9 psia. This was the regulatory option chosen.

Option 2- control of all medium storage vessels (i.e., TIC).

[b] Baseline emissions are 88 Mg/yr of HAP.

Table 6-18. Control Options For Storage Vessels: Existing Sources 40,000 Gallon Capacity And Greater

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	1,700	16	5,000	2,900	
2	4,800	46	10,000	2,100[c]	1,600
3	8,629	83	25,000	2,900	3,900
4	8,644	83	27,000	3,100	122,000

[a] Option 1 - (MACT floor) control tanks storing HAP's with vapor pressure > 13.1 kPa (1.9 psia).

Option 2- control tanks storing HAP's with vapor pressure > 5.2 kPa (0.75 psia). This was the regulatory option chosen.

Option 3- control of all large storage vessels (i.e., TIC).

[b] Baseline emissions are 10,000 Mg/yr of HAP.

[c] Average cost effectiveness decreases due to credits from controlling several large tanks.

Table 6-19. Control Options For Storage Vessels: New Sources 40,000 Gallon Capacity And Greater

Option[a]	Emission Reduct. (Mg HAP per yr)	Percent HAP Reduct.[b]	Annual Cost ($1000)	Avg. Cost Effectiveness ($/Mg)	Incremental Cost Effectiveness ($/Mg)
1	558	46	1,500	1,700	
2	1,640	87	2,900	1,800[c]	1,900
3	1,642	87	3,100	1,900	88,900

[a] Option 1 - (MACT floor) control tanks storing HAP's with vapor pressure > 5.2 kPa (0.75 psia).

Option 2- control tanks storing HAP's with vapor pressure > 0.7 kPa (0.1 psia). This was the regulatory option chosen.

Option 3- control of all large storage vessels (i.e., TIC).

[b] Baseline emissions are 1,900 Mg/yr of HAP.

[c] Average cost effectiveness decreases due to credits from controlling several large tanks.

Table 6-20. Existing Source Annual Respondent Burden and Cost of Reporting and Recordkeeping Requirements of the HON Provisions

Burden Item	Average Hours per Activity (a)	Number of Activities per year per source (b)	Technical Hours per year per source (c)	Est'd. Number Existing Sources (d)	Estimated Technical Hours per year (e)	Estimated Managerial Hours per year (f)	Estimated Clerical Hours per year (g)	Annual Cost in $Thousandsper year (h)
1) Read Rule and Instructions	3.6	47	167	371	61,957	3,098	6,196	2,289.32
2) Plan Activities	5.9	47	276	371	102,396	5,120	10,240	3,783.55
3) Training	5.8	19	111	371	41,181	2,059	4,118	1,521.63
4) Create, Test, Research & Development	17.9	140	2,499	371	927,129	46,356	92,713	34,257.40
5) Gather Info., Monitor/Inspect	2.5	500	1,250	371	463,750	23,188	46,375	17,135.59
6) Process/Compile & Review	20.0	1	20	371	7,420	371	742	274.17
7) Complete Rep'ts	75.5	2	151	371	56,021	2,801	5,602	2,069.97
8) Record/Disclose	17.5	2	35	371	12,985	649	1,299	479.79
9) Store/File	6.8	4	27	371	10,017	501	1,002	370.14
TOTAL BURDEN AND COST					1,682,856	84,143	168,287	62,181.56

Table 6-21. New Source Annual Respondent Burden and Cost of Reporting and Recordkeeping Requirements of the HON Provisions

Burden Item	Average Hours per Activity (a)	Number of Activities per year per source (b)	Technical Hours per year per source (c)	Est'd. Number of New Sources (d)	Estimated Technical Hours per year (e)	Estimated Managerial Hours per year (f)	Estimated Clerical Hours per year (g)	Annual Cost in $Thousandsper year (h)
1) Read Rule and Instructions	2.7	94	250	18	4,500	225	450	166.28
2) Plan Activities	3.8	94	355	18	6,390	320	639	236.14
3) Training	3.5	38	132	18	2,376	119	238	87.81
4) Create, Test, Research & Development	2.4	1,780	4,266	18	76,788	3,839	7,679	2,837.30
5) Gather Info., Monitor/Inspect	1.4	2,047	2,943	18	52,974	2,649	5,297	1,957.40
6) Process/Compile & Review	0.8	48	40	18	720	36	72	26.60
7) Complete Rep'ts	11.4	49	557	18	10,026	501	1,003	370.45
8) Record/Disclose	10.0	49	489	18	8,802	440	880	325.23
9) Store/File	5.2	51	264	18	4,752	238	475	175.60
TOTAL BURDEN AND COST					167,328	8,367	16,733	6,182.81

Table 6-22. Annual Burden and Cost for the Federal Government

Burden Item	Average Hours per Activity (a)	Number of Activities per year (b)	Estimated Technical Hours per year (c)	Estimated Managerial Hours per year (d)	Estimated Clerical Hours per year (e)	Annual Cost in $Thousandsper year (f)
PERFORMANCE TESTS:						
1) Initial	40	14	560	28	56	20.69
2) Repeat	40	3	120	6	12	4.43
LITIGATION:	2,080	3	6,240	312	624	230.57
REPORTS REVIEW:						
1) Initial	2	124	248	12	25	9.15
2) Implementation Plan or Permit	20	124	2,480	124	248	91.64
3) Compl. status	40	124	4,960	248	496	183.27
4) Review equip. leak monitoring	7	742	5,194	260	519	191.93
5) Notification of const./recon.	6	6	36	2	4	1.35
6) Notification of anticipated startup	6	6	36	2	4	1.35
7) Notification of actual startup	6	6	36	2	4	1.35
8) Notif. of performance test	6	6	36	2	4	1.35
9) Review of test results	24	6	144	7	14	5.31
10) Review periodic reports	4	18	72	4	7	2.68
TOTAL BURDEN AND COST (Salary)			20,162	1,009	2,017	745.07
TRAVEL EXPENSES						15.30
TOTAL ANNUAL COST						760.37

Table 6-23. National Control Cost Impacts In The Fifth Year after Proposal[a]

Emission Source Type and Other Cost Categories	Total Capital Cost (10^6 $)	Total Annual Cost (10^6 $)	Average HAP Cost Effectiveness ($/Mg HAP)[b]	Average VOC Cost Effectiveness ($/Mg VOC)
Equipment Leaks	120	(0.26)	(5)	(4)
Process Vents	100	86	290	170
Storage Vessels	74	20	2,900	2,900
Wastewater Collection and Treatment	140	50	490	130
Transfer Operations	12	5	10,000	10,000
Monitoring, Recordkeeping and Reporting	N/A	69	N/C	N/C
Total	450	230	350	170

[a] Existing emission points account for 84 percent of the total. Emission points constructed or modified in the first five years account for the additional 16 percent.

[b] Average cost effectiveness values are determined by dividing total annual costs by total annual emission reduction.

N/A = Not Available

N/C = Not Calculated

CHAPTER 7

ECONOMIC IMPACT ANALYSIS

7.1. Introduction

The purpose of this chapter is to summarize the economic impacts of the Hazardous Organics NESHAP (HON). HON chemical compounds are produced by the synthetic organic chemicals manufacturing industry (SOCMI), a complex and diverse industry that produces thousands of chemical compounds, with ultimate uses in nearly every consumer and industrial market. For purposes of analyzing the SOCMI, chemical trees have been constructed for 490 synthetic organic chemical compounds, which identify the various routes by which a particular compound is produced. Many different production processes can be used to produce the same compound. Since in-depth analysis of all 490 compounds is not possible, 21 compounds have been chosen for detailed analysis. Furthermore, five additional compounds, all of which incur control costs significantly higher than average, were chosen for a high-cost analysis. These compounds will be referred to as high-cost compounds.

Control costs have been analyzed for controls option one. Option one controls are estimates of the actual control costs that facilities and industries are likely to incur.

This chapter proceeds in four sections. Section 7.2 examines the extent to which the 21 selected compounds are representative of the population of regulated chemicals. Subsequently, section 7.3 reviews the economic impact analysis and examines the implications of the study for the SOCMI as a whole. Section 7.4 examines the economic impacts on high-cost compounds only. Finally, section 7.5 analyzes the small business impacts.

7.2 Representativeness of Selected Chemical Compounds

The representativeness of the 21 selected chemical compounds and the five high-cost compounds is assessed based on three criteria; annual production levels, HON control costs, and the extent to which the selection is drawn from the range of basic feedstock chemicals.

At the outset of the analysis, it was immediately clear that an examination of the initial 21 compounds was not sufficient to depict the range of impacts in the SOCMI. Specifically, in order to perform detailed analysis on particular chemicals, an adequate amount of information is needed. Little or no information was available for compounds with annual production levels of less than 10 million kilograms, which account for 32.7 percent of the regulated compounds. In addition, it was found that these same low-volume production compounds also tended to incur high compliance costs, primarily due to economies of scale in compliance. Thus, it was necessary to select a group of low volume, high-cost compounds for which there existed sufficient information for profiles and analysis. While this analysis is not nearly as detailed as for the initial 21 selected compounds, it nevertheless provides a broad overview of low-volume, high-cost impacts.

7.2.1 Annual Production and Control Costs

Percentage cost increases have been computed for each facility producing the 21 compounds analyzed, as well as the five high-cost compounds.

The percentage cost increase is calculated by dividing the cumulative compliance cost per kilogram by the per-unit revenue, or price, for each compound, as shown in equation one:

$$\left(\frac{CC_i}{P_i}\right) \times 100 \qquad (1)$$

where CC_i = cumulative compliance cost for compound i

P_i = price of chemical i

7.2.1.1 Option One Control Costs

Table 7-1 compares the distribution of the 490 chemical compounds with those 21 selected for analyses, for option one control costs, in terms of both annual production and control costs. The percentage cost increases presented represent the 50th percentile of costs for each compound. The comparison by annual production demonstrates the aforementioned drawback of the initial selection. Specifically, only one compound with annual production less than 10 million kilograms has been selected for detailed analysis, and zero less than five million kilograms. In the population, 32.7 percent of the compounds have annual production of less than 10 million kilograms, and 20.8 percent less than 5 million kilograms. Clearly, the selection is biased towards large volume compounds.

The population of compounds is under-represented in several ranges of option-one cost increases. Compounds are absent in the four highest cost ranges of control costs. Compounds in these cost ranges account for 9.9 percent of the regulated compounds.

The selection encompasses the other four cost ranges, which account for 90 percent of the regulated compounds. For the range of cost increases less than 2 percent, coverage is the best.

Table 7-1. Distribution Of HON Compounds By Percentage Cost Increase And Annual Production (10^6 kg): Option One

	All Regulated Compounds					
			Distribution By Annual Production (10^6 kg)			
% Change In Cost[a]	Number	% Of Total	<1	1-5	5-10	>10
Less than 1.00	351	71.6%	43	26	35	284
1.00 - 2.00	65	13.3%	0	2	18	28
2.00-3.00	17	3.5%	0	3	4	4
3.00-4.00	8	1.6%	0	2	0	2
4.00-5.00	6	1.2%	0	0	2	2
5.00-7.00	10	2.0%	1	3	2	4
7.00-10.00	2	0.4%	0	1	1	0
Greater than 10.00	31	6.3%	20	1	1	1
Total	490	99.9%[b]	64	38	63	325
% Of Total	100%		13.1%	6.7%	12.9%	67.3%

	Selected Compounds					
			Distribution By Annual Production (10^6 kg)			
% Change In Cost[a]	Number	% Of Total	<1	1-5	5-10	>10
Less than 1.00	14	66.7%	0	0	1	13
1.00 - 2.00	3	14.3%	0	0	0	3
2.00-3.00	1	4.8%	0	0	0	1

3.00-4.00	3	14.3%	0	0	0	3
4.00-5.00	0	0%	0	0	0	0
5.00-7.00	0	0%	0	0	0	0
7.00-10.00	0	0%	0	0	0	0
Greater than 10.00	0	0%	0	0	0	0
Total	21	100.1[b]	0	0	1	20
% Of Total	100%		0%	0%	5%	95%

---

[a] Cost increase based on control costs at the 50th percentile of industry output.

[b] Does not sum to 100 due to rounding.

Eighty-five percent of the population is included in this range, as compared with 81 percent of the selection. Cost increases ranging from two to three percent include 3.5 percent of the population and 4.8 percent of the selection. Cost increases ranging from three to four percent include 1.6 percent of the population and 14.3 percent of the selection.

7.2.3 Basic Feedstock Chemicals

Synthetic organic chemical compounds are ultimately derived from eight basic feedstock chemicals, which serve as the building blocks for the SOCMI. These eight feedstock chemicals are derived from petroleum refineries, natural gas plants, and coal tar distillers. Table 7-2 presents the selected compounds, grouped by the basic feedstocks from which they are derived. As illustrated, each basic feedstock chemical is represented. Thus, the selected compounds are a satisfactory representation the scope of the SOCMI as measured by basic feedstock chemicals.

7.2.4 Summary

In general, the selection under-represents compounds with costs greater than four percent, as well as compounds with annual production less than ten million kilograms. However, the large-volume chemicals, which make up 67.3 percent of the population, are represented in terms of annual production, control costs in the lower ranges, and basic feedstock chemicals. Since these compounds represent the lion's share of SOCMI production, an examination of the impact of HON control costs on the industry as a whole is not unreasonable.

7.3 Overview of Economic Impacts

7.3.1 Nature of Impacts

The economic impacts of HON controls on the SOCMI derive from several possible outcomes. Primary attention is paid to price and output adjustments, since these estimates are likely to be the most accurate. Impacts stemming from these adjustments are the closure of a facility and the substitution of one production process for another.

7.3.2 Price Adjustments and Reductions In Output

Installation of control equipment will lead to increases in production costs which will in turn spur price increases in the industry. Price increases have been estimated by calculating a production-weighted cost increase for each compound, and dividing it by industry revenue.[*] These production-weighted cost increases are employed for estimating economic impacts.

[*] For a detailed discussion of methodology, see Chapter two of the HON Economic Analysis, section 2.3.2.3.

The distribution of HON compounds by percentage cost increases, shown previously in Table 7-1, are used only for comparison's sake, and differ from the one's used for the economic impact analysis.

Market structure has important implications for the size of the price increase that will occur as a result of HON controls. In general, it can be said that if a market structure is not perfectly competitive, firms in the industry will raise prices less than they would in the perfectly competitive case. The market structure in the SOCMI is characterized by the following attributes:

- a limited number of firms producing each chemical
- a large degree of market concentration
- a large degree of vertical integration
- a large degree of horizontal integration
- barriers to entry and exit in the form of high capital and raw materials costs

Table 7-2. Selected Chemicals Compounds Grouped By The Eight Basic Feedstock Chemicals From Which They Are Derived

Benzene

Styrene-Butadiene Rubber
Cyclohexylamine
Hydroquinone
Styrene
Acetone
Bisphenol-A
Propylene Glycol

Toluene

Benzoic Acid

Xylenes

Terephthalic Acid
Phthalic Anhydride

Ether

Naphthalene

Acetone
Phthalic Anhydride

Ether

Methane

Formaldehyde
Chloroform
Methyl Tertiary Butyl Ether
Methyl Chloride

Ethylene

Butadiene
Polybutadiene
Styrene-Butadiene Rubber
Ethylene Dichloride
Ethylene Oxide
Ethylene Glycol
Styrene
Triethylene Glycol
Propylene Glycol

Propylene

Cyclohexylamine
Acetone
Bisphenol-A
Propylene Glycol
Methyl Tertiary Butyl

Acrylonitrile

Butylenes

Butadiene
Methyl Tertiary Butyl

Thus, the SOCMI can be characterized as oligopolistic, and firms will absorb a portion of HON control costs. Thus, the price increases are likely to be lower than estimated. Moreover, price increases are apt to be felt in end-use markets, due to the considerable amount of captive consumption in the industry.

Since the industry demand curve is downward sloping, each price increase will be accompanied by a reduction in output. While these quantity adjustments derive directly from the control costs and the price elasticity of demand for each chemical, it is not readily apparent how these changes will be experienced at the facility level. As data on average cost of production and plant vintage are not available, identifying the marginal facility is difficult. If there are notable differences in production cost and plant vintage, the quantity adjustment could be absorbed by those firms which are marginal. If the facilities have similar cost structures, the output reduction could be distributed across the industry.

Given the way in which the SOCMI is organized, it seems likely that quantity adjustments will be distributed across the industry, rather than falling on any one facility. Most facilities are owned by large parent corporations, which could subsidize plants which might be less efficient. In addition, the industry is dynamic, and cost increases will stimulate alternative production processes to offset competitive disadvantages. Also, chemical production will be driven by the economics of coproducts and byproducts. Facilities will often have the flexibility to step up production of more profitable compounds to offset the burden of compliance.

7.3.3 Closure

In general, closure of a facility might be predicted if a significant percentage of output were to be wrested from the marginal plant, i.e. the plant with the highest average cost of production. In the SOCMI, however, there is reason to believe that, even with significant price increases, closure is highly unlikely.

The primary explanation for this is the flexibility of chemical producers. In most cases, several chemicals other than the sample chemicals are produced at facilities producing sample chemicals. Table 7-3 presents this information, and indicates the lowest number of chemicals produced at a given facility, the highest number of chemicals, and the average number of chemicals. In only one case is the average number of chemicals produced at a site equal to one.

In two cases, as many as 20 chemicals are produced at the same facility. Therefore, revenue at a given facility is shared among a number of chemicals, and the reduction in output of one of them is unlikely to lead to closure. It is also possible that a decline in output of one chemical could be cross-subsidized by another chemical. There is flexibility in other areas as well. Some facilities have the ability to use different production processes for the same chemical if economic conditions dictate. Constructing new plants with the ability to use different feedstocks is becoming more common in the industry. Also, plants can vary capacity utilization, idle parts of the plant, and run inventories up and down to cope with changes in demand. In some cases, it is difficult to close facilities, as different production processes are dependent on the same feedstock. In addition, the SOCMI is a dynamic industry in which new processes and chemical formulations are constantly being explored. The prospect of control costs could stimulate a changes of these types rather than closure of a facility.

If the impacts are large, it is important to note that ceasing production of one chemical does not always necessitate closing the entire facility. Employment might be kept at the same level, or production might be stepped up for another chemical at the same facility.

Table 7-3. Number Of HON Chemical Compounds Produced On The Same Site As Facilities Producing Selected Compounds[a]

Sample Chemical (Number of Facilities)	Number Of Chemicals Produced On Same Site		
	Low	High	Average
Butadiene (9)	1	10	5
Styrene-Butadiene Rubber (5)	N.A.	N.A.	N.A.
Polybutadiene (4)	N.A.	N.A.	N.A.
Ethylene Dichloride (15)	2	17	5
Ethylene Oxide (13)	1	15	6
Cyclohexylamine (2)	1	1	1
Hydroquinone (2)	2	9	6
Ethylene Glycol (11)	1	15	6
Styrene (9)	1	17	4
Formaldehyde (46)	1	5	1
Acetone (13)	2	9	5
Chloroform (6)	2	20	9
Triethylene Glycol (11)	1	15	6
Bisphenol-A (4)	2	18	8
Terephthalic Acid (7)b	1	2	2
Propylene Glycol (5)	3	20	10
Methyl-Tertiary Butyl Ether(18)	1	7	2
Phthalic Anhydride (6)	1	7	2
Benzoic Acid (3)	2	3	3
Acrylonitrile (6)	1	6	3
Methyl Chloride	1	11	7

---

[a] May not include coproducts and byproducts.

[b] Includes dimethyl terephthalate.

N.A. - not available.

Finally, the SOCMI is an oligopolistic industry dominated by large parent corporations. While this assures that a portion of compliance costs will be absorbed by producers, it also assures the ability to finance purchase of control equipment. Also, high capital and raw materials costs provide barriers to exit. As long as firms are covering these large fixed costs, closure will not ensue, even if the facility is unprofitable in the short run.

For all of these reasons, closure due to HON controls is in general, unlikely.

7.3.4 Process Changes

It is quite possible that HON controls will stimulate a shift to an already existing chemical production process, usher in a process which was previously uncompetitive, or stimulate research and development into new production processes. Given the dynamic and flexible nature of the SOCMI, it is likely that each of these will take place in response to HON controls.

7.3.5 Economic Impacts

Table 7-4 illustrates the summary of market adjustments for the selected compounds. The output changes are based on the upper bound of the estimated price elasticity of demand, which forecasts the maximum reduction in output. It should be noted that the change in price is an increase, and the change in output is a decrease. These market adjustments are derived from a production-weighted average price increase. Each compound is accompanied by one price adjustment and quantity adjustment, except for benzoic acid. Since the facilities in this industry cater to three separate markets, it was necessary to calculate three impacts. Thus, 23 price and quantity adjustments are presented.

Table 7-5 categorizes the selected compounds in three ranges of percentage price increases for the option one costs. The categories: low; less than two percent, intermediate; two to five percent, and high; greater than five percent, respectively. Since these percentages are derived from the production-weighted average price increase, they differ from those presented in Table 7-1, which are based on costs at the 50th percentile of control. Production-weighted averages have not been calculated for all 490 regulated compounds, so direct comparison is not possible. However, general conclusions can be drawn from those chemicals analyzed.

Table 7-6 extends these market adjustments to the possibility for closure and process substitution. The possibility for closure is based solely on the percentage output reduction as compared with the smallest size facility in the industry. It was stated in section 7.3.3 that closure in any case is unlikely. Thus, Table 7-6 displays only the most conservative, i.e. severe, case.

Table 7-4. Summary Of Market Adjustments

Chemical Name (CAS Number)	Option One Control	
	% Δ Price[a]	% ΔQuantity[b]
Butadiene (106990)	0.74	(0.73)
Styrene-butadiene rubber (00043)	0.28	(0.28)
Polybutadiene (00045)	0.30	(0.30)
Ethylene Dichloride (107062)	1.03	(0.69)
Ethylene Oxide (75218)	0.31	(0.10)
Cyclohexalyamine (108918)	0.64	(0.43)
Hydroquinone (123319)	0.61	(0.61)
Ethylene Glycol (107211)	0.40	(0.27)
Styrene (100425)	0.34	(0.34)
Formaldehyde (50000)	2.51	(1.65)
Acetone (67641)	0.72	(0.48)
Chloroform (67663)	1.09	(0.37)
Triethylene Glycol (112276)	0.11	(0.07)
Bisphenol-A (80057)	0.56	(0.38)
Terephthalic Acid (100210)	1.29	(0.36)
Propylene Glycol (57556)	0.25	(0.25)
Methyl-Tertiary Butyl Ether (1634044)	0.24	(0.08)
Phthalic Anhydride (85449)	3.36	(2.50)
Benzoic Acid		
Facility 1A	0.75	(0.74)
Facility 2A	0.88	(0.87)
Facility 3A (65850)	3.78	(3.64)
Acrylonitrile (107131)	0.57	(0.38)
Methyl Chloride	3.17	(2.07)

(74873)

---

[a] The percentage price increase is based on the production-weighted average compliance cost. (See Chapter 2 A for methodology).

[b] The percentage change in quantity is based on the most elastic estimate of demand elasticity, which forecasts the higher percentage change in quantity.

Δ = Change in

Table 7-5. Summary Of Percentage Price Increases For The Selected Compounds

Price Range/ Chemical Name	Percentage Price Increase Option One Controls
High Increase: Over 5	
None	
Intermediate Increase: 2 to 5 Percent	
Phthalic Anhydride	3.86%
Benzoic Acid 3A	3.78%
Methyl Chloride	3.17%
Formaldehyde	2.51%
Low Increase: Below 2 Percent	
Terephthalic Acid	1.29%
Chloroform	1.09%
Ethylene Dichloride	1.03%
Benzoic Acid 2A	0.88%
Benzoic Acid 1A	0.75%
Butadiene	0.74%
Acetone	0.72%
Cyclohexalyamine	0.64%
Hydroquinone	0.61%
Acrylonitrile	0.57%
Bisphenol-A	0.56%
Ethylene Glycol	0.40%
Styrene	0.34%
Ethylene Oxide	0.31%
Polybutadiene	0.30%
Styrene-butadiene rubber	0.28%
Propylene Glycol	0.25%
Methyl-Tertiary Butyl Ether	0.24%
Triethylene Glycol	0.11%

7.3.6 Low Range Impacts

7.3.6.1 Option One Control Costs

For option one control costs, the low cost range includes 82.6 percent, or 19 of the 23 price increases shown. Since this range represents the majority of the SOCMI, it is useful to extend the results of these impacts to the population of regulated compounds. In this category, maximum quantity adjustments range from .07 percent to .87 percent of industry output. For 14 of these compounds, closure is unlikely even in the most extreme scenario. Closure is possible for the remaining five compounds.

Nine compounds in this range are produced by more than one production process. For two of these, the cost differential is large enough to predict possible process changes. However, it is quite possible that HON controls will stimulate research and development into new production processes.

7.3.7 Intermediate Range Impacts

7.3.7.1 Option One Control Costs

The intermediate range includes 17.4 percent, or four of the 23 price increases displayed. Maximum quantity adjustments range from 1.65 percent to 3.64 percent of industry output. Closure is possible for three of the four. Again, closure is possible only in the most extreme case, and is in general unlikely.

Three of the four intermediate-cost compounds are produced by more than one process. In each case, the cost differential is large enough to predict process changes.

7.3.8 High Range Impacts

No compounds in the selection are high-cost and so no conclusions can be drawn for this range for either control option.

Table 7-6. Likelihood Of Closure And Process Change Under Option One Controls[a]

Chemical Name	Likelihood Of Closure	Likelihood Of Process Change
Butadiene	Possible	Unlikely
Styrene-butadiene rubber	Unlikely	N.A.
Polybutadiene	Unlikely	N.A.
Ethylene Dichloride	Possible	N.A.
Ethylene Oxide		
Unlikely	N.A.	
Cyclohexalyamine	Unlikely	Possible
Hydroquinone	Unlikely	Unlikely
Ethylene Glycol	Unlikely	N.A.
Styrene	Possible	Possible
Formaldehyde	Possible	Probable
Acetone	Unlikely	Unlikely
Chloroform	Possible	Unlikely
Triethylene Glycol	Unlikely	Unlikely
Bisphenol-A	Unlikely	N.A.
Terephthalic Acid	Possible	Unlikely
Propylene Glycol	Unlikely	N.A.
Methyl-Tertiary Butyl Ether	Unlikely	Unlikely
Phthalic Anhydride	Possible	Possible
Benzoic Acid	Unlikely	N.A.
Acrylonitrile	Unlikely	N.A.
Methyl Chloride	Possible	Possible

N.A. - not applicable, since only one process is used.

[a] Closure is in general unlikely. This table presents only the most extreme case.

7.4 High Cost Compounds

Five high-cost compounds were selected for purposes of analyzing high-cost impacts. Option one controls are analyzed for this group of compounds. These compounds, along with their respective price and output adjustments, are presented in Table 7-7.

The economic impact of HON controls on high-cost compounds appears to be only a little more exacting than the impact for the SOCMI on average. Of the five compounds examined, only one is likely to experience closure, and one process could be phased out. Given the magnitude of the percentage price increases, this outcome might be expected.

Nevertheless, several qualifications are warranted that would mitigate against such severe impacts. First, as noted above, the control cost estimates are probably too large.[1] Second, these impacts assume no cost absorption at previous links in the chemical tree. Third, impacts are based on the lowest available price estimate. To this it is added that these producer's seem to have quite a degree of pricing discretion that would allow them to alleviate the impact of compliance. Fourth, as with the SOCMI as a whole, it is assumed here that many products are produced at sites along with the high-cost compounds, and that the dynamic nature of the SOCMI makes it difficult to predict closure with any certainty.

Table 7-7. Summary Of Price And Output Adjustments For High-Cost Compounds

	Elasticity = -.0		Elasticity = -.34	
Chemical Name	% Δ P	% Δ Q	% Δ P	% Δ Q
Benzil Benzoate	90.42	(0.64)	90.42	(19.7)
Phthalimide	530.9	(1.8)	530.9	(46.5)
Diphenyl Methane	1,878.93	(2.58)	1,878.93	(63.8)
Gluteraldehyde	2,378.67	(2.75)	2,378.67	(66.4)
Diisooctyl Phthalate	9.46	(.090)	9.46	(3.03)

7.5 Small Business Impacts

The RFA (Public Law 96-354, September 19, 1980) requires Federal agencies to give special consideration to the impact of regulation on small businesses.

The RFA specifies that a regulatory flexibility analysis must be prepared if a proposed regulation will have (1) a significant economic impact on (2) a substantial number of small entities. Regulatory impacts are considered significant if:

- Annual compliance costs increase total costs of production by more than 5 percent,
- Annual compliance costs exceed 10 percent of profits for small entities,
- Capital cost of compliance represent a significant portion of capital available to small entities,
- The requirements of the regulation are likely to result in closures of small entities.

A "substantial number" of small entities is generally considered to be more than 20 percent of the small entities in the affected industry.

A first step in determining small business impacts is assigning an appropriate definition for what constitutes a small entity in the SOCMI. The Small Business Administration (SBA) defines small businesses in the chemical industry as having employment from under 500 to under 1,000, depending on the SIC.[2] For this analysis, the upper bound of 1,000 employees will be used as the cutoff for assessing small business impacts.

Table 7-8 lists 1990 sales and employment figures for those companies in the SOCMI that produce the 20 chemicals selected for the HON analysis. This is a comprehensive list of sample chemical producers, totaling 66 companies. Data was compiled from a collection of 1991 annual reports, the 1991 Million Dollar Directory, and Standard and Poor's Register of Corporations, Directors, and Executives.

As shown, only 10 of the 66 companies falls below the 1000 employee cut-off. Thus, given this sample, only 15 percent of the SOCMI can be classified as small.

The 1988 Handbook of Small Business Data, which provides information on the nature of businesses which typify different SIC categories, supports this assertion. Each of the SIC categories affected by the HON are listed as "Large-Business-Dominated." This classification is based on the more conservative definition of small entities that the SBA uses.

Therefore, the standard is not expected to have a significant economic impact on a substantial number of small firms, and a RFA is not required.

Table 7-8. 1990 Sales And Employment Of Selected SOCMI Members

Company	Sales ($\$10^6$)	Number of Employees
Air Products	2,895	14,000
Allied Signal	12,343	105,800
American Cyanamid	4,574	32,012
American Petrofina	3,978	3,997
American Synthetic Rubber Corp.	93	311
American Synpol	N.A.	2,600
AMOCO	31,581	54,524
ARCO	18,808	27,300
Ashland Oil, Inc.	8,994	33,400
Atlantic Richfield	1,590	26,600
BASF	4,023	133,759
B.F. Goodrich	2,470	11,892
Borden	7,633	46,300
British Petroleum	33,039 (£ mil.)	118,050
BTL Specialty Resins Corp.	64	200
Champlin Refining	374	800
Chevron	41,540	54,208
Citgo	4,940	3,300
Conoco	12,330	19,000
Copolymer Rubber and Chemical	250	710
Deltech	20	200
Diamond-Shamrock	2,708	6,000
Dow	19,773	52,100
DuPont	40,028	
Eastman-Kodak	18,908	134,450

TABLE 7-8. (CONTINUED)

Company	Sales ($\$10^6$)	Number of Employees
Exxon	115,794	104,000
Firestone	3,867	53,500
Formosa Plastics	625	1,700
GE	55,300	292,000
General Tire	1,300	9,600
Georgia Gulf	1,110	1,350
Georgia Pacific	12,665	63,000
Goodyear	11,273	107,671
Hanlin Group	1,110	1,350
Hercules	3,200	19,867
Hill Petroleum	4	1,070
Hoechst Celanese	1,500	2,400
Kalama	N.A.	N.A.
Koppers	426	1,900
Marathon (USX)	20,659	51,523
Mobil	64,472	67,300
Monsanto	8,995	41,081
Mt. Vernon Phenol[a]	56,279	292,043
Occidental Petroleum	1,500	12,500
Olin	25,300	15,400
Oxy Petrochemicals	322	1,320
P.D. Glycol	26	185
Pfizer	6,406	42,500
Phillips Petroleum	12,500	21,800
Polysar	643	1,200
PPG	5,820	35,500
Quantum	2,656	N.A.
Questra (Rhone-Poulenc Data)	2,278	91,571
Rexene	553	1,300
Shell Oil	24,460	

TABLE 7-8. (CONTINUED)

Company	Sales ($\$10^6$)	Number of Employees
Spurlock	11	41
Stepan Co.	346	1,150
Sterling Chemical	581	926
Sun Co.	13,270	20,926
Texaco	41,822	39,000
Texas Olefins	300	300
Union Carbide	8,740	45,000
Velsicol	100	500
Vista Chemicals	779	1,750
Vulcan Materials	1,080	6,250

7.6 Conclusions

For the 21 compounds selected for detailed analysis, the majority of estimated price increases -- 83 percent -- are below two percent. Eighty-seven percent have estimated ranges of reductions in output of below two percent. In general, impacts on the selected compounds are small. Since the selection does not adequately represent the population of controlled compounds, the same cannot be said for all controlled compounds. Nevertheless, given the cost increases from Table 7.1, it is safe to say that impacts for the SOCMI are, in general, small.

Given the dynamic and flexible nature of the SOCMI, as well as the oligopolistic market structure, closure in the majority of cases is unlikely.

The notable impact of the HON will the stimulation of a shift to already existing chemical production processes, the ushering in of processes that were previously uncompetitive, or stimulation of research and development into new production processes. It is likely that each of these will take place in response to HON controls.

In conclusion, the SOCMI is a dynamic industry which responds quickly to changes in the economic environment. Increasing costs driven by the HON will serve to reinforce moves to lower-cost production processes, plants engineered for flexibility in feedstock choice, and facilities capable of producing a variety of chemical substitutes depending on costs and market demand.

7.7 References

1. U.S. Environmental Protection Agency. Economic Impact Analysis of the Hazardous Organic NESHAP. December 1993. p. 26-4.

2. "Small Business Administration: Small Business Size Standards; Final and Interim Final Rules"; 13 CFR Part 121, Federal Register, December 21, 1989.

CHAPTER 8

BENEFITS

8.1 Introduction

This chapter discusses the potential benefits associated with air toxics regulation under the HON regulation. Various limitations prevent a formal, quantitative benefits analysis. A formal benefits assessment requires analysis of the full pollutant path, tracing from the change in emissions to atmospheric dispersion through population exposure, effective dose, physical effect manifestation considering mitigating and averting behavior, and ultimately to economic valuation. Ideally, this analysis should be conducted for each of the air toxic chemicals regulated under the HON. Lack of information on an individual chemical basis, such as the quantity and location of emissions and chemical-specific physical effect and exposure data, as well as a significant time requirement preclude such a detailed benefit analysis.

Because of the above limitations, a qualitative analysis of the potential benefit categories is given that identifies the direct use and non-use benefits of the regulation. The physical effect categories that are associated with HON emission reductions include health and welfare responses that have been documented for HAPs, ozone, and particulate matter. Furthermore, option value, existence value, and bequest value are potential benefits creditable to this rule making.

The HON rule regulates 149 of the 189 hazardous air pollutants listed in Section 112(b). A general understanding of the physical and chemical nature of these compounds, including their potential toxicity and environmental fate, makes possible the categorization of physical effects from HAP emissions. Hazardous air pollutant emissions may occur in both gaseous and particulate form. Of the gaseous HAPs, the majority are volatile organic compounds (VOCs), which are precursors in the formation of ozone. The VOC HAPs may also condense or react to form particulate matter. HAPs may enter terrestrial and aquatic ecosystems through atmospheric deposition. HAPs can be deposited on vegetation and soil through wet or dry deposition. HAPs may also enter the aquatic environment from the atmosphere via 1) gas exchange between surface water and the ambient air, 2) wet or dry deposition of particulate HAPs and particles to which HAPs adsorb, and 3) wet or dry deposition to watersheds with subsequent leaching or runoff to waterbodies.[1]

Human exposure to HAPs may occur directly through inhalation or indirectly through ingestion of food or water contaminated by HAPs or through dermal exposure. In general, the reduction of

HAP emissions resulting from promulgation and implementation of the HON will reduce human and environmental exposure to these pollutants and thus, reduce potential health and welfare effects. This chapter provides a general discussion of the various components of total benefits that may be gained from a reduction in HAPs through the HON rule. Figure 8-1 lists the range of potential physical health and welfare effects categories that may be associated with HAP emissions and also with ambient concentrations of ozone and particulate matter secondarily formed by VOC HAPs.

Figure 8-1. **POTENTIAL PHYSICAL EFFECTS CATEGORIES FOR HON**

Categories may be applicable for hazardous air pollutants and ozone and PM secondarily formed by VOC HAPs.

Human Health Effects

Mortality Due to Chronic Exposure
Mortality Due to Acute Exposure
Morbidity Due to Chronic Exposure
Morbidity Due to Acute Exposure

Human Welfare Effects

Worker Productivity Losses
Odors

Non-Human Biological Effects

Agriculture
Forestry
Recreational/Commercial Fishing
Ecosystem

Soiling and Materials Damage

Residential/Commercial/Industrial Facilities
Miscellaneous Materials

Climate and Visibility Effects

Local Visibility
Non-local Visibility
Climate
Visibility at Parks
Transportation Safety

8.2 Hazardous Air Pollutant Benefits

8.2.1 Health Benefits of Reduction in Hazardous Air Pollutants

The HON will regulate 149 of the 189 air toxics listed under Title III. Exposure to ambient concentrations of these pollutants may result in a variety of adverse health effects considering both cancer and noncancer endpoints. In an effort to better understand the "big picture" of hazardous air pollutant exposures, EPA undertook broad studies in the 1980s to evaluate the releases of these pollutants and the relative implication of the resulting exposures to human health.

The first study assessed the magnitude and nature of potential cancer risks associated with exposure to hazardous air pollutants. Originally conducted in 1985[2] and updated in 1990[3], the work broadly assessed long-term exposures to HAPs and estimated potential cancer risks associated with these pollutants. Without chemical and site specific exposure and risk assessment, it is not possible to estimate the excess expected cancer cases attributable to HON emission sources.

A second EPA study[4] assessed ambient concentrations of HAPs in relation to their potential to elicit adverse noncancer effects. This project utilized several approaches to characterizing potential noncancer risks including review of case reports, evaluation of State, local and Federal agencies' experiences, and review of available health and exposure data. Although the magnitude of noncancer risks could not be estimated, the broad implications of this study indicated that areas of concern may be the following: short-term as well as long-term exposures, multiple chemical exposures, and the combined impact of an individual chemical emitted from multiple sources in the same geographic area. The major health endpoints of concern in this study were respiratory effects, developmental and reproductive toxicity, and neurotoxicity.

In general, noncancer health effects can be grouped into the following broad categories[5]:

- Genotoxicity - a broad term that usually refers to a chemical that has the ability to damage DNA or the chromosomes.
- Developmental toxicity - adverse effects on a developing organism that may result from exposure prior to conception (either parent), during prenatal development, or postnatally to the time of sexual maturation. Adverse developmental effects may be detected at any point in the life span of the organism. Major manifestations of developmental toxicity include:

death of the developing organism; induction of structural abnormalities; altered growth; and functional deficiency.

- Reproductive toxicity - harmful effects on fertility, gestation, or offspring, caused by exposure of either parent to a substance.
- Systemic toxicity - affects a portion of the body other than the site of entry.
- Irritant - causes irritation of eyes, skin, and respiratory tract.

Exposure to HAPs may occur directly through inhalation as well as indirectly through oral or dermal exposure to food or water contaminated through deposition of HAPs. The Lake Michigan Fish-Eating Study provides evidence of adverse health effects due to indirect exposure to HAPs. Atmospheric deposition of HAPs into the Great Lakes is a major cause of the deteriorated water quality of this aquatic system. High concentrations of toxics have been observed in a number of commercial and recreational fish species. The Lake Michigan Fish-Eating Study revealed that the total amount of fish consumed by mothers in all years prior to conception and the amount of PCBs measured in umbilical cord serum is associated with decreased visual recognition memory--a measure of neurological development--in offspring. There is also evidence of developmental effects such as reduced birth weight and smaller head and skull circumference when compared to controls.[6]

Exposures related to routine emissions of HAPs may be acute (isolated or repeated events) or continuous in nature. Most commonly, populations are exposed to more than one pollutant at a given time. Consideration must be given to potential additive, synergistic, or antagonistic effects resulting from exposures to chemical mixtures. Adverse effects resulting from these exposures may be reversible or irreversible depending upon the magnitude of the exposure and the mechanism of action eliciting the effect. A wide range of responses may be seen from mild irritation to mortality.

For the 149 HAPs covered under the HON, evidence on the potential toxicity of the pollutants varies tremendously. Given sufficient exposure conditions, all of these pollutants have the potential to elicit adverse health or environmental effects in the exposed populations. It can be expected that emission reductions achieved through the HON regulation will decrease the incidence of adverse health effects.

8.2.2 Welfare Benefits of Reduction in Hazardous Air Pollutants

Environmental Impacts

Emissions of hazardous air pollutants may also bring about adverse, non-human biological effects such as ecosystem and recreational and commercial fishery impacts. Atmospheric deposition of toxics is believed to significantly contribute to the presence of hazardous compounds in the environment. The presence of toxic compounds in relatively pristine areas and around large point sources such as smelters provides a strong linkage between long and short-range transport of HAPs and the bioaccumulation of these compounds in terrestrial and aquatic systems. For example, atmospheric loading is estimated to account for approximately 80 - 90% of all pollutant inputs to the upper Great Lakes, an area considered relatively pristine and with few major sources of toxics. Similarly, short-range atmospheric deposition is thought to be responsible for 90 - 99% of lead inputs to the mid-lower Chesapeake Bay.[7]

Hazardous air pollutants may be directly harmful to organisms due to their presence in the ambient air. For example, experts believe that major declines in the lichen flora of urban and industrial areas worldwide are caused by atmospherically-derived metals and gaseous phytotoxicants.[8]

Atmospheric deposition of HAPs directly to land may affect terrestrial ecosytems. For example, there is documented evidence of terrestrial ecosystem impacts such as plant toxicity, changes in species composition, bioaccumulation, and inhibition of enzyme activity due primarily to atmospherically-derived metals . These effects may result in the loss of sensitive species and declines in ecosystem productivity.[9] Specifically, there is evidence of impacts on mammal populations near to and downstream of a mining-smelting complex in northern Idaho. Population declines in mink, muskrat, and other small mammals are believed to be due to the direct toxicity of atmospherically-derived metals as well as secondary effects on cover and food supply.[10]

Atmospheric deposition of HAPs also contributes to adverse aquatic ecosystem effects. Much of the documentation on the aquatic impacts of HAPs has focused on the Great Lakes. Many of the HAPs deposited to the Great Lakes are persistent toxics that, through the process of biomagnification, tend to accumulate in toxic concentrations in the tissues of species high on the food chain. This not only has adverse implications for individual wildlife species and ecosystems as a whole, but also the humans who may ingest contaminated fish and waterfowl. The Great Lakes is the largest freshwater fishery in the world. In 1985, more than 4 million people fished in the Great Lakes basin.[11] Recreational and commercial fishing is estimated to be worth $4.2 billion annually.[12] High tissue contaminant levels, however, have forced the closure of some commercial fisheries and the issuance of fish advisories for some recreational fish species. Therefore, atmospheric deposition of HAPs to the Great Lakes may impose significant costs to the area's recreational and commercial fishing industries.

Toxic pollutants in the Great Lakes ecosystem are believed to be responsible for a number of specific problems in organisms at the top of the Great Lakes food web such as the following[13]:

- reproductive problems and population decline
- metabolic changes
- birth deformities
- hormonal changes
- tumors
- generational effects
- behavioral changes.

Additionally, large increases (outside normal variation for vertebrate species) in the populations of cormorants and ring-billed gull indicate the occurrence of fundamental changes in the balance of the Great Lakes ecosystem.[14] Experts believe that these ecosystem changes are indirectly due to the presence of toxic compounds in the Great Lakes ecosystem.

The extent to which other ecosystems outside of the Great Lakes are adversely impacted by hazardous air pollutants is not yet known, although toxics loading appears significant. For example, loadings to the Chesapeake Bay are at least as high or higher than loadings to the Great Lakes on a per unit area basis. Because there is a proportionally larger watershed around the Chesapeake Bay than the Great Lakes, there is greater potential for indirect loading of HAP's into the Chesapeake Bay. In general, HAP emission reductions achieved through the HON should reduce the associated adverse environmental impacts.

Additional Welfare Effects

There is evidence of materials damage that may occur as a result of emissions of hazardous air pollutants. Acidic compounds may corrode or decay metals, stone, and automotive finishes.[15] Additionally, odor threshold concentrations have been reported for a number of hazardous air pollutants.[16] However, without site specific air quality modeling, it is not known the extent to which ambient concentrations of these air toxic compounds exceed the odor threshold level.

8.3 Ozone Benefits

8.3.1 Health Benefits of Reduction in Ambient Ozone Concentration

Ozone benefits may be attributable to this regulation as ozone is a product of VOC and nitrogen oxide emissions reacting in the presence of sunlight. VOCs are a major pollutant for those sources/processes that will be regulated under HON. Consequently, reductions in the emissions of VOCs will also lead to reductions in the types of health and welfare impacts that are associated with elevated concentrations of ozone.

Approximately 47.7 million people live in nonattainment areas (classified as marginal, moderate, serious, severe and extreme) that contain a HON process unit and are potentially exposed to ozone levels above the standard. VOC emissions from HON process units therefore may contribute to some degree to the adverse health effects experienced by exposed individuals in those nonattainment areas. Furthermore, it is estimated that approximately 57% of the VOC reductions achieved by the HON may occur in ozone nonattainment areas.

There are sensitive subpopulations that are more at risk of adverse health effects from elevated ozone concentrations. These groups include people with the following conditions[17]:

- chronic bronchitis (3.5 percent of US population);
- asthma (3.5 - 5 percent of US population);
- allergies (7 percent of US population);
- emphysema (1 percent of US population);
- any individual exercising heavily during ozone exposure. Heavy exercise increases breathing frequency and depth of breathing resulting in a larger ozone dose to lungs and deeper penetration of ozone to the most sensitive lung tissue.

The health effects associated with increased ambient ozone concentrations have been well documented in EPA's recent review of the ozone standard and presented in the Office of Air Quality Planning and Standards Staff Paper on ozone. The major ozone health effects of concern to health scientists are the following[18]:

- Alterations in Pulmonary Function - modifications in such pulmonary measurements as forced expiratory volume, total lung capacity, and breathing frequency;
- Symptomatic Effects - eye, nose and throat irritation, chest discomfort, cough, headache, chest pain on deep inspiration, chest tightness, wheezing, lassitude, malaise and nausea;
- Exercise Performance - reduced workload and performance;
- Bronchial Reactivity - increased sensitivity of airway to agents such as histamines with subsequent initiation of an inflammatory response;

- Aggravation of Existing Respiratory Disease - aggravation of existing asthma, chronic bronchitis or emphysema conditions;
- Morphological Effects - occurrence of lesions in lung tissue of exposed animals;
- Altered Host Defense System - alteration of host defense system rendering sensitivity to respiratory infection;
- Extrapulmonary Effects - blood enzyme, central nervous system, liver, endocrine, cardiovascular, reproductive and teratological effects.

8.3.2 Welfare Benefits from Reduction in Ambient Ozone Concentration

Elevated concentrations of ambient ozone are also associated with adverse welfare (non-health) impacts. The welfare effects of concern are the following[19]:

- decreased worker productivity;
- crop damage resulting in yield losses and undesirable quality effects[20];
- forest damage manifested as growth retardation or foliar injury;
- materials damage of elastomers, textile fibers, dyes, and paints.

Reduction of VOCs through the HON regulation is another mechanism - in addition to Title I and II control measures - by which the ambient ozone concentration may be reduced and in turn reduce the incidence of the adverse health and welfare effects discussed above.

8.4 Particulate Matter Benefits

In addition to acting as precursors to ozone formation, VOC emissions may also condense or react to generate secondarily-formed aerosols, elevating ambient concentrations of particulate matter (PM). Based on available conversion factors, approximately 1 to 2 percent of VOC emissions condense or react to form secondary particulate matter. The 949,000 Mg of VOC emissions reduction under the HON will therefore cause a reduction of 9,490 Mg to 18,980 Mg of secondary PM formation. These particles are respirable and contribute to impairment of visibility.

PM-related health effects include chronic and acute morbidity and mortality. PM-related welfare impacts encompass soiling and materials damage and climate and visibility effect.[21] Therefore by reducing VOC emissions, decreases in the adverse health and welfare effects associated with elevated PM concentrations may be achieved.

8.5 Additional Benefits

There are additional benefits that may be attributable to the HON regulation above and beyond the direct use value as represented by the health and welfare benefits associated with HAP reductions as discussed above. Theoretical analysis of the value of non-market environmental amenities (i.e. air quality, visibility) or disamenities (i.e. Superfund sites, nuclear power plants) has led to the decomposition of willingness to pay into several components. One important distinction relevant to the HON that is made in the literature is that some portion of the value one places on air toxics reductions is related to one's own exposure to air toxics while some portion of the value may not be related to one's own exposure to air toxics. Use values are the values associated with an individual's desire to avoid his or her own exposure to an environmental risk, or in the case of the HON, toxic air pollutants. Non-use values are values an individual may have for lowering the concentration of toxic air pollution or level of risk *unrelated to his or her own exposure.* Non-use values may be related to the desire that a clean environment be available for the use of others now and in the future, or may be related to the desire to know that the resource is being preserved for its own sake, regardless of human use.

Several different categories of use and non-use values have been developed and rigorously defined in the literature.[22] These include:

- Option price. Option price is a measure of total value that reflects uncertainty regarding future use of a resource. It equals the expected value of current and future use plus a risk premium, which may be positive, negative, or zero. The risk premium is related to uncertainty regarding desired future use and its sign (positive or negative) depends on whether the individual prefers to err toward preserving the resource (reduced-toxic atmosphere) that may not be wanted for use in the future, or toward losing the resource that may be wanted for use in the future. The risk premium associated with option price is referred to as option value.

- Bequest value. This is the component of non-use value that is related to the use of the resource by others now and in the future. This value is typically thought of as altruistic in nature. Bequest value may be more significant to the HON regulation when considering the value an individual may have to reduce the risk of air pollutant exposure to others (outside of one's family and friends) now living rather than future generations.

- Existence value. This is the component of non-use value that is related to preservation of the resource for its own sake, even if there is no human use of the resource. In practice, bequest and existence values are difficult to distinguish and are often together referred to as existence value. In the case of the HON regulation, existence value would incorporate an individual's willingness to pay for the preservation of a reduced-toxic atmosphere.

These value categories may apply to changes in the quality of a resource. Freeman explicitly included this in his analysis.[23] With air emissions under the HON regulation, the issue is typically the concentration of air emissions to which people are exposed, not whether or not any emissions exist at all. These value categories may also be components of the total use and non-use values of a reduction in ambient ozone and PM concentrations that may also be achieved through the HON.

Option price differs from use value because it is an ex ante measure rather than an ex post measure of value related to exposure. As the ex ante measure, option price is the appropriate measure for analysis of proposed regulatory decisions that may affect the availability or quality of a resource. Option price may differ from use value due to differences between expected and actual use of the resource as well as due to any risk premium.

8.6 Conclusion

Because of various limitations, the benefits associated with the HON regulation have not been monetized. However, there are health and welfare improvements that could be gained through a reduction in air pollutants regulated under HON that have been qualitatively discussed. In summary, air toxic reductions may reduce mortality and morbidity from exposure directly to HAP's and secondary PM. Similarly, VOC reductions in ozone nonattainment areas will decrease ambient concentrations of ozone and therefore reduce morbidity effects. Because approximately 47.7 million people reside in ozone nonattainment areas with at least one HON process unit, any decrease in ambient ozone concentrations as a result of HON control will directly benefit these individuals. In fact, it is estimated that approximately 57% of the VOC reductions achieved by the HON will occur in ozone nonattainment areas. Human welfare benefits from HON control may include improvements in worker productivity and a decrease in odors.

The HON regulation may also result in beneficial biological effects such as agricultural crop yield increases, and beneficial forestry, fishing, and ecosystem impacts. A decrease in soiling and materials damage is another potential benefit of this rulemaking. Climate and visibility may also be improved through decreases in secondary PM associated with HAP reductions.

Finally, potential benefits from the HON regulation may also include existence value, bequest value, and components of option price.

References

1. ICF, Inc. "Focus Chemicals for the Clean Air Act Amendments Great Waters Study." Draft Report. Prepare for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC. August 1991.

2. U.S. EPA, Offices of Air and Radiation and Policy Planning and Evaluation. The Air Toxics Problem in the United States: An Analysis of Cancer Risks for Selected Pollutants. EPA 450/1-85-001. May 1985.

3. Office of Air Quality Planning and Standards, Cancer Risk From Outdoor Exposure to Air Toxics. EPA-450/1-90-004a. U.S. Environmental Protection Agency, Research Triangle Park, NC. September 1990.

4. Office of Air Quality Planning and Standards. Toxic Air Pollutant and Noncancer Health Risks: Screening Studies. External Review Draft. U.S. Environmental Protection Agency, Research Triangle Park, NC. September 1990.

5. U.S. EPA. Air Risk Information Support Center. Glossary of Terms Related to Health, Exposure, and Risk Assessment. EPA/450/3-88/016. March 1989.

6. Colborn, Theordora E. Great Lakes Great Legacy? The Conservation Foundation and The Institute for Research on Public Policy, Washington, DC. 1990. pp. 172-173.

7. ICF, Inc. Atmospheric Deposition of Toxic Chemicals to Surface Waters: Identification and Summary of Recent Literature. Draft Report. Prepared for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC. August 1991. p. ES-7.

8. Ref. 13, p. ES-10.

9. Ref. 13, p. ES-10.

10. Ref. 13, p. ES-12.

11. Environment Canada. Toxic Chemicals in the Great Lakes and Associated Effects. Toronto, Ontario. March 1991.

12. Personal Communication with Wayne Wilford, Great Lakes National Program Office, U.S. EPA. January 1992.

13. Ref. 17.

14. Ref. 12, pp. 132-140.

15. U.S. National Acid Precipitation Assessment Program. Acidic Deposition: State of Science and Technology, Volume III, Terrestrial, Materials, Health and Visibility Effects. 1991.

16. Office of Research and Development. Reference Guide to Odor Thresholds for Hazardous Air Pollutants Listed in the Clean Air Act Amendments of 1990. EPA/600/R-92/047. March 1992.

17. Environmental Criteria and Assessment Office. Air Quality Criteria for Ozone and Other Photochemical Oxidants. U.S. Environmental Protection Agency, Research Triangle Park, NC. 1986.

    Office of Air Quality Planning and Standards, "Summary of Selected New Information on Effects of Ozone on Health and Vegetation: Draft Supplement to Air Quality Criteria for Ozone and Other Photochemical Oxidants," U.S. Environmental Protection Agency, Research Triangle Park, NC. November 1988.

18. Ref. 4.

19. Adams, R.M., et. al. The Economic Effects of Ozone on Agriculture. Office of Research and Development, U.S. Environmental Protection Agency, Corvallis, OR. EPA-600/3-84-090. 1984.

20. Shortle, James S., et. al, "Economic Assessment of Crop Damages Due to Air Pollution: The Role of Quality Effects." Environmental Pollution 53:377-385. 1988.

21. Office of Air Quality Planning and Standards, "Regulatory Impact Analysis of the National Ambient Air Quality Standard for Particulate Matter," U.S. Environmental Protection Agency, Research Triangle Park, NC. December 1983.

22. Office of Air Quality Planning and Standards, Regulatory Impact Analysis of a Revision of the Federal Implementation Plan for the State of Arizona to Include SO2 Controls for the Navajo Generating Station, U.S. Environmental Protection Agency, Research Triangle Park, NC. January 1991.

23. Freeman, A.M., III. "Non-use Values in Natural Resource Damage Assessment." Paper prepared for the Resources for the Future Conference on Assessing Natural Resource Damages, Washington, D.C., June 16-17, 1988.

CHAPTER 9

BENEFIT-COST ANALYSIS

9.1 Introduction

This chapter provides an illustration of the economic efficiency framework for evaluating regulatory options under the promulgated HON rulemaking. Unfortunately data paucities and time constraints preclude a formal quantification of the allocative efficiency aspects of this rule.

This chapter also identifies the overlap of the HON rulemaking with VOC emission reduction requirements for ozone nonattainment areas. The complementarity of these regulatory requirements may result in control cost savings in these areas.

9.2 Economic Efficiency Considerations

The adoption and implementation of air toxics regulations is not free. There is a reallocation of society's resources to address the negative spillover of air pollution. In the course of internalizing the air pollution externality, the cost of reducing emissions through the HON rulemaking is reflected in the production, distribution, and consumption of synthetic organic chemicals. This additional cost is in contrast to the improvement in society's well being from a cleaner environment and concomitant reductions in adverse health effects and other risks.

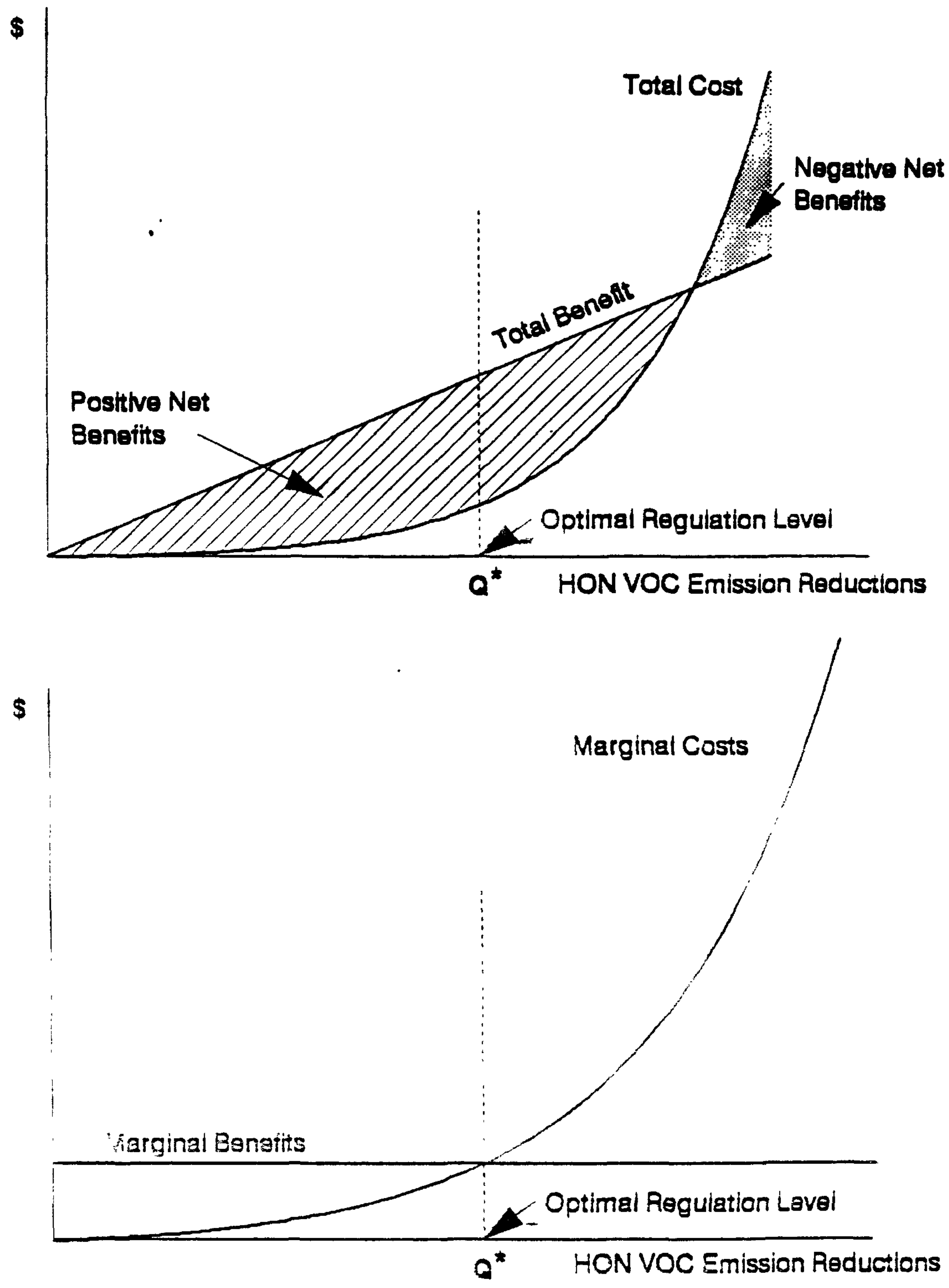
As displayed in Figure 9.1, the existence of a regulation to internalize the air pollution externality does not guarantee an allocatively efficient outcome. An allocatively efficient regulation maximizes the net benefits to society. In a mathematical sense, allocative efficiency requires that the marginal benefits of the rule be equal to the marginal cost and that marginal costs are rising at a rate greater than marginal benefits.

Because of the inability to compare in a quantitative sense both the benefits and the costs of the regulatory alternatives, the economic efficiency aspects of this rule cannot be assessed.

9.3 Cost-Effectiveness of HON VOC Emission Reductions in Ozone Nonattainment Areas

Environmental quality enhancement programs are not always independent of one another. In the course of accomplishing the objectives of Title III through the HON requirements, the regulation also reduces emissions of ozone precursors (VOC's) in ozone nonattainment areas. In the year 1996, HON VOC emission reductions for the most stringent regulatory option (TIC) are

Figure 9.1 Optimal Regulation and Net Benefit Levels



estimated to be 56 percent of the total VOC emission reductions required in nonattainment areas (classified as marginal, moderate, serious, severe, and extreme) for the ozone NAAQS.

Some of the VOC emission reductions for ozone nonattainment areas are achieved through nondiscretionary control measures. Some of these control measures include VOC emission reduction requirements based on new control techniques guidelines documents. One of the source categories for these new documents is the SOCMI. Consequently, there is some overlap between the HON VOC emission reductions and those reductions from nondiscretionary control requirements for ozone nonattainment areas.

There are additional VOC emission reductions from the HON rulemaking that will occur in moderate, serious, severe and extreme ozone nonattainment areas. Further emission reductions are required in these areas; however, the means of achieving these additional VOC emission reductions is discretionary. Consequently, the prudent regulatory authority may use the additional VOC emission reductions from the HON rules to replace the emission reductions from high cost discretionary controls. This replacement may result in a "savings" or avoided cost of the discretionary controls that are replaced by HON controls.

For example, the average cost of the HON VOC emission reductions for total industry control in nonattainment areas is estimated at $1,061 per Mg. The average cost of discretionary controls in the moderate, serious, severe, and extreme nonattainment areas is estimated to be $4,540 per Mg.[1] If a megagram of HON VOC emission reductions replaced a $4,540 discretionary control measure megagram, the savings would be $3,479. This is a potential control cost savings of nearly 77 percent.

The exact amount of savings resulting from the HON rule cannot be calculated due to uncertainties regarding the potential overlap of emission reductions resulting from rules derived from the control techniques guidelines documents for SOCMI sources and the HON rulemaking.

9.4 Conclusion

The economic efficiency aspects of HON regulatory options cannot be assessed because of the inability to quantify the benefits associated with the rule.

There is overlap between the emission reductions and environmental quality enhancement objectives of the nonattainment and air toxics titles of the Clean Air Act. This overlap may result in a potential cost savings in selected ozone nonattainment areas.

References

1. E.H. Pechan and Associates, Inc.,"Ozone Nonattainment Analysis Clean Air Amendments of 1990," report for Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC. September 1991.