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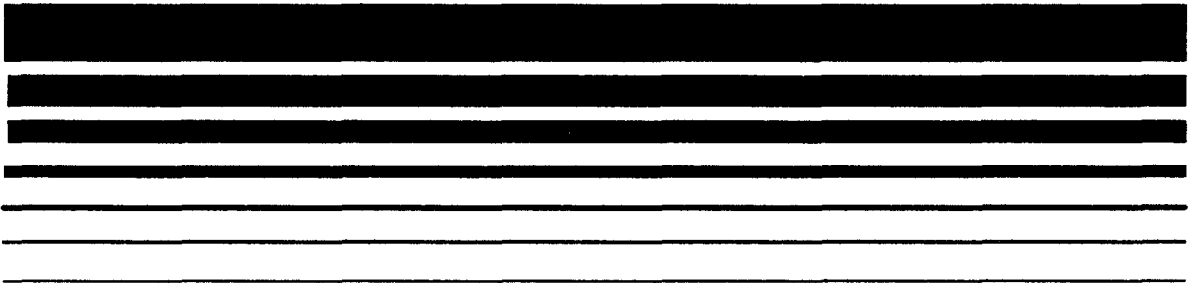
May 1994

&EPA

Emissions from Epoxy Resins Production and Non-Nylon Polyamides Production -

Background Information for Proposed Standards

NESHAP

Emissions from Epoxy Resins Production

and Non-Nylon Polyamides Production

Background Information for
Proposed Standards

Emission Standards Division

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ENVIRONMENTAL PROTECTION AGENCY

Background Information
and Draft
Environmental Impact Statement
for Epoxy Resins Production and Non-Nylon Polyamide Resins
Production

Prepared by:

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Director, Emission Standards Division   (Date)
U.S. Environmental Protection Agency
Research Triangle Park, North Carolina   27711

1. The proposed national emission standard would limit emissions
    of hazardous air pollutants from existing and new facilities
    that manufacture epoxy resins and non-nylon polyamide resins.
    The proposed standards implement Section 112 of the Clean Air
    Act as amended in 1990 and are based on the Administrator's
    determination of July 16, 1992 (57 FR 31576) that epoxy
    resins and non-nylon polyamide resins manufacturing generate
    significant emissions of certain hazardous air pollutants
    listed in Section 112(b) of the Act, primarily
    epichlorohydrin.

2. Copies of this document have been sent to the following
    Federal Departments: Labor, Health and Human Services,
    Defense, Transportation, Agriculture, Commerce, Interior, and
    Energy; the National Science Foundation; the Council on
    Environmental Quality; members of the State and Territorial
    Air Pollution Program Administrators; the Association of
    Local Air Pollution Control Officials; EPA Regional
    Administrators; Office of Management and Budget; and other
    interested parties.

3. The comment period for review of this document is 60 days.
    Mr. Randy McDonald, Chemicals and Petroleum Branch, telephone
    (919) 541-5402, may be contacted regarding the date of the
    comment period.

4. For additional information contact:

    Mr. Randy McDonald (MD-13)
    Chemicals and Petroleum Branch
    U. S. Environmental Protection Agency
    Research Triangle Park, N. C.   27711
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iii

5. Copies of this document may be obtained from:

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (continued)

1.0 SUMMARY

The draft Background Information Document (BID) chapters included in this package refer to the control of hazardous air pollutants (HAP's) from the manufacture of basic liquid epoxy resins (BLR) and wet-strength resins (WSR). These preliminary chapters provide estimates of uncontrolled and baseline HAP emissions and present information on applicable control techniques. Additionally, recommended regulatory alternatives and their economic impacts are estimated for individual facilities and entire industries. The chapters have just recently been drafted, and none of the information has yet been peer-reviewed by industry. Thus, the information contained herein is preliminary and will presumably be revised based on comments. The following paragraphs are intended to provide general information regarding the regulatory approach and provide assumptions and methods used to arrive at the information presented in the chapters. The discussion below is organized into the following sections: (1) Information Gathering, (2) Emission Data Analysis, (3) Control Device Design and Cost Analysis, and (4) Economic Impact Analysis.

1.1 INFORMATION GATHERING

Section 114 information request responses were used to establish the current level of HAP emissions for both industries. Often, telephone conversations and additional written correspondence were needed in addition to the completed Section 114 responses to establish emission levels. All such pieces of correspondence are contained in the project docket, which is designated as docket No. A-92-37. In addition, references not readily available to the public (e.g., drafts,

memoranda, and unpublished books) are also included in the docket. Published materials are referenced at the end of each BID chapter.

1.2 EMISSION DATA ANALYSIS

Emission stream characteristics of the various HAP emission events that occur in the two industries were established using data from the Section 114's and from making general assumptions based on vapor-liquid equilibrium. In some cases, the information reported in the Section 114's contained discrepancies between the total HAP emission rate reported and the characteristics of the emission streams, such as flow rate, HAP concentration, and duration. In such situations, the emission stream characteristics were used to establish the HAP emission rates. In many instances, uncontrolled HAP emissions were not reported. The stream characteristics and total emission rate were in these cases estimated by assuming that the streams were saturated with HAP's at the conditions reported. Hazardous air pollutant emissions from storage tank working and breathing losses were estimated using AP-42 emission estimation equations. Emissions from equipment leaks were estimated using Synthetic Organic Chemical Manufacturing Industry (SOCMI) emission factors.

Finally, a source of data that frequently was unavailable at WSR facilities was the exact number of fugitive components per affected unit (i.e., valves, pumps, and flanges) and the duration of contact with HAP's and the weight percent of HAP's at the time of contact. When these counts and the associated information were not furnished by a facility in the Section 114 responses, a model equipment count scenario was assumed.

1.3 CONTROL DEVICE DESIGN AND COST ANALYSIS

The following HAP control techniques were designed and costed out for either individual BLR facility emission sources or WSR model emission sources: (1) condensation systems, (2) thermal incineration systems with caustic scrubbers for acid gas emissions, (3) water scrubbers, (4) steam strippers for wastewater, (5) floating roofs for storage tanks, and (6) leak detection and repair (LDAR) programs to control HAP emissions

from equipment leaks. The first three techniques were designed and costed out according to the methodology contained in the OAQPS Cost Manual, 4th edition. Steam strippers were costed out using an OAQPS cost algorithm. The installation of floating roofs was evaluated using information provided in the Draft Volatile Organic Liquid Storage CTG (May 1992) for cleaning, degassing, and installation. Various levels of LDAR programs were evaluated for cost and emissions reductions using memoranda from the Equipment Leaks Negotiated Regulation (Reg Neg) background file.

1.4 ECONOMIC IMPACT ANALYSIS

The regulatory alternatives that are presented in BID Chapter 6 were evaluated for economic feasibility by dividing the annualized cost of control by the emission reductions achieved from baseline. A preliminary estimate of nationwide impacts of implementing these regulatory alternatives is also presented in BID Chapter 6 in the "Total" rows in Tables 6-5 and 6-6. A detailed cost analysis is contained in BID Chapter 8, Costs.

2.0 INTRODUCTION

2.1 BACKGROUND AND AUTHORITY FOR STANDARDS

According to industry estimates, more than 2.4 billion pounds of toxic pollutants were emitted to the atmosphere in 1988 ("Implementation Strategy for the Clean Air Act Amendments of 1990," EPA Office of Air and Radiation, January 15, 1991). These emissions may result in a variety of adverse health effects, including cancer, reproductive effects, birth defects, and respiratory illnesses. Title III of the Clean Air Act Amendments of 1990 provides the tools for controlling emissions of these pollutants. Emissions from both large and small facilities that contribute to air toxics problems in urban and other areas will be regulated. The primary consideration in establishing national industry standards must be demonstrated technology. Before national emission standards for hazardous air pollutants (NESHAP) are proposed as Federal regulations, air pollution prevention and control methods are examined in detail with respect to their feasibility, environmental impacts, and costs. Various control options based on different technologies and degrees of efficiency are examined, and a determination is made regarding whether the various control options apply to each emissions source or if dissimilarities exist between the sources. In most cases, regulatory alternatives are subsequently developed that are then studied by EPA as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the environment, the economics and well-being of the industry, the national economy, and energy and other impacts. This document summarizes the information obtained through these studies so that

interested persons will be able to evaluate the information considered by EPA in developing the proposed standards.

National emission standards for hazardous air pollutants for new and existing sources are established under Section 112 of the Clean Air Act as amended in 1990 [42 U.S.C. 7401 et seq., as amended by PL 101-549, November 15, 1990], hereafter referred to as the Act. Section 112 directs the EPA Administrator to promulgate standards that "require the maximum degree of reduction in emissions of the hazardous air pollutants subject to this section (including a prohibition of such emissions, where achievable) that the Administrator, taking into consideration the cost of achieving such emission reductions, and any non-air quality health and environmental impacts and energy requirements, determines is achievable ... ." The Act allows the Administrator to set standards that "distinguish among classes, types, and sizes of sources within a category or subcategory."

The Act differentiates between major sources and area sources. A major source is defined as "any stationary source or group of stationary sources located within a contiguous area and under common control that emits or has the potential to emit considering controls, in the aggregate, 10 tons per year or more of any hazardous air pollutant or 25 tons per year or more of any combination of hazardous air pollutants." The Administrator, however, may establish a lesser quantity cutoff to distinguish between major and area sources. The level of the cutoff is based on the potency, persistence, or other characteristics or factors of the air pollutant. An area source is defined as "any stationary source of hazardous air pollutants that is not a major source." For new sources, the amendments state that the "maximum degree of reduction in emissions that is deemed achievable for new sources in a category or subcategory shall not be less stringent than the emission control that is achieved in practice by the best controlled similar source, as determined by the Administrator." Emission standards for existing sources "may be less stringent than the standards for new sources in the same

category or subcategory but shall not be less stringent, and may be more stringent than--

(A) the average emission limitation achieved by the best performing 12 percent of the existing sources (for which the Administrator has emissions information), excluding those sources that have, within 18 months before the emission standard is proposed or within 30 months before such standard is promulgated, whichever is later, first achieved a level of emission rate or emission reduction which complies, or would comply if the source is not subject to such standard, with the lowest achievable emission rate (as defined by Section 171) applicable to the source category and prevailing at the time, in the category or subcategory for categories and subcategories with 30 or more sources, or

(B) the average emission limitation achieved by the best performing five sources (for which the Administrator has or could reasonably obtain emissions information) in the category or subcategory for categories or subcategories with fewer than 30 sources."

The Federal standards are also known as "MACT" standards and are based on the maximum achievable control technology previously discussed. The MACT standards may apply to both major and area sources, although the existing source standards may be less stringent than the new source standards, within the constraints presented above. The MACT is considered to be the basis for the standard, but the Administrator may promulgate more stringent standards which have several advantages. First, they may help achieve long-term cost savings by avoiding the need for more expensive retrofitting to meet possible future residual risk standards, which may be more stringent (discussed in Section 2.6). Second, Congress was clearly interested in providing incentives for improving technology. Finally, in the Clean Air Act Amendments of 1990, Congress gave EPA a clear mandate to reduce the health and environmental risk of air toxics emissions as quickly as possible.

For area sources, the Administrator may "elect to promulgate standards or requirements applicable to sources in such categories or subcategories which provide for the use of generally available control technologies or management practices by such sources to reduce emissions of hazardous air pollutants." These area source standards are also known as "GACT" (generally available control technology) standards, although MACT may be applied at the Administrator's discretion, as discussed previously.

The standards for hazardous air pollutants (HAP's), like the new source performance standards (NSPS) for criteria pollutants required by Section 111 of the Act (42 U.S.C. 7411), differ from other regulatory programs required by the Act (such as the new source review program and the prevention of significant deterioration program) in that NESHAP and NSPS are national in scope (versus site-specific). Congress intended for the NESHAP and NSPS programs to provide a degree of uniformity to State regulations to avoid situations where some States may attract industries by relaxing standards relative to other States. States are free under Section 116 of the Act to establish standards more stringent than Section 111 or 112 standards.

Although NESHAP are normally structured in terms of numerical emissions limits, alternative approaches are sometimes necessary. In some cases, physically measuring emissions from a source may be impossible or at least impracticable due to technological and economic limitations. Section 112(h) of the Act allows the Administrator to promulgate a design, equipment, work practice, or operational standard, or combination thereof, in those cases where it is not feasible to prescribe or enforce an emissions standard. For example, emissions of volatile organic compounds (many of which may be HAP's, such as benzene) from storage vessels for volatile organic liquids are greatest during tank filling. The nature of the emissions (i.e, high concentrations for short periods during filling and low concentrations for longer periods during storage) and the configuration of storage tanks make direct emission measurement

impractical. Therefore, the MACT or GACT standards may be based on equipment specifications.

Under Section 112(h)(3), the Act also allows the use of alternative equivalent technological systems: "If, after notice and opportunity for comment, the owner or operator of any source establishes to the satisfaction of the Administrator that an alternative means of emission limitation" will reduce emissions of any air pollutant at least as much as would be achieved under the design, equipment, work practice, or operational standard, the Administrator shall permit the use of the alternative means.

Efforts to achieve early environmental benefits are encouraged in Title III. For example, source owners and operators are encouraged to use the Section 112(i)(5) provisions, which allow a 6-year compliance extension of the MACT standard in exchange for the implementation of an early emission reduction program. The owner or operator of an existing source must demonstrate a 90 percent emission reduction of HAP's (or 95 percent if the HAP's are particulates) and meet an alternative emission limitation, established by permit, in lieu of the otherwise applicable MACT standard. This alternative limitation must reflect the 90 (95) percent reduction and is in effect for a period of 6 years from the compliance date for the otherwise applicable standard. The 90 (95) percent early emission reduction must be achieved before the otherwise applicable standard is first proposed, although the reduction may be achieved after the standard's proposal (but before January 1, 1994) if the source owner or operator makes an enforceable commitment before the proposal of the standard to achieve the reduction. The source must meet several criteria to qualify for the early reduction standard, and Section 112(i)(5)(A) provides that the State may require additional reductions.

2.2 SELECTION OF POLLUTANTS AND SOURCE CATEGORIES

As amended in 1990, the Act includes a list of 189 HAP's. Petitions to add or delete pollutants from this list may be submitted to EPA. Using this list of pollutants, EPA will publish a list of source categories (major and area sources) for

which emission standards will be developed. Within 2 years of enactment (November 1992), EPA will publish a schedule establishing dates for promulgating these standards. Petitions may also be submitted to EPA to remove source categories from the list. The schedule for standards for source categories will be determined according to the following criteria:

"(A) the known or anticipated adverse effects of such pollutants on public health and the environment;

(B) the quantity and location of emissions or reasonably anticipated emissions of hazardous air pollutants that each category or subcategory will emit; and

(C) the efficiency of grouping categories or subcategories according to the pollutants emitted, or the processes or technologies used."

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from these facilities may vary in magnitude and control cost. Economic studies of the source category and applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by standards, the standards may not cover all pollutants or facilities within that source category.

2.3 PROCEDURE FOR DEVELOPMENT OF NESHAP

Standards for major and area sources must (1) realistically reflect MACT or GACT; (2) adequately consider the cost, the non-air quality health and environmental impacts, and the energy requirements of such control; (3) apply to new and existing sources; and (4) meet these conditions for all variations of industry operating conditions anywhere in the country.

The objective of the NESHAP program is to develop standards to protect the public health by requiring facilities to control emissions to the level achievable according to the MACT or GACT guidelines. The standard-setting process involves three principal phases of activity: (1) gathering information, (2) analyzing the information, and (3) developing the standards.

During the information-gathering phase, industries are questioned through telephone surveys, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from other sources, such as a literature search. Based on the information acquired about the industry, EPA selects certain plants at which emissions tests are conducted to provide reliable data that characterize the HAP emissions from well-controlled existing facilities.

In the second phase of a project, the information about the industry, the pollutants emitted, and the control options are used in analytical studies. Hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emissions data, and existing State regulations governing emissions from the source category are then used to establish "regulatory alternatives." These regulatory alternatives may be different levels of emissions control or different degrees of applicability or both.

The EPA conducts studies to determine the cost, economic, environmental, and energy impacts of each regulatory alternative. From several alternatives, EPA selects the single most plausible regulatory alternative as the basis for the NESHAP for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into standards, which, in turn, are written in the form of a Federal regulation. The Federal regulation limits emissions to the levels indicated in the selected regulatory alternative.

As early as is practical in each standard-setting project, EPA representatives discuss the possibilities of a standard and the form it might take with members of the National Air Pollution

Control Techniques Advisory Committee, which is composed of representatives from industry, environmental groups, and State and local air pollution control agencies. Other interested parties also participate in these meetings.

The information acquired in the project is summarized in the background information document (BID). The BID, the proposed standards, and a preamble explaining the standards are widely circulated to the industry being considered for control, environmental groups, other government agencies, and offices within EPA. Through this extensive review process, the points of view of expert reviewers are taken into consideration as changes are made to the documentation.

A "proposal package" is assembled and sent through the offices of EPA Assistant Administrators for concurrence before the proposed standards are officially endorsed by the EPA Administrator. After being approved by the EPA Administrator, the preamble and the proposed regulation are published in the Federal Register.

The public is invited to participate in the standard-setting process as part of the Federal Register announcement of the proposed regulation. The EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standards with interested parties. All public comments are summarized and incorporated into a second volume of the BID. All information reviewed and generated in studies in support of the standards is available to the public in a "docket" on file in Washington, D.C. Comments from the public are evaluated, and the standards may be altered in response to the comments.

The significant comments and EPA's position on the issues raised are included in the preamble of a promulgation package, which also contains the draft of the final regulation. The regulation is then subjected to another round of internal EPA review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a "final rule" in the Federal Register.

2.4 CONSIDERATION OF COSTS

The requirements and guidelines for the economic analysis of proposed NESHAP are prescribed by Presidential Executive Order 12291 (EO 12291) and the Regulatory Flexibility Act (RFA). The EO 12291 requires preparation of a Regulatory Impact Analysis (RIA) for all "major" economic impacts. An economic impact is considered to be major if it satisfies any of the following criteria:

1. An annual effect on the economy of $100 million or more;

2. A major increase in costs or prices for consumers; individual industries; Federal, State, or local government agencies; or geographic regions; or

3. Significant adverse effects on competition, employment, investment, productivity, innovation, or on the ability of United States-based enterprises to compete with foreign-based enterprises in domestic or export markets.

An RIA describes the potential benefits and costs of the proposed regulation and explores alternative regulatory and nonregulatory approaches to achieving the desired objectives. If the analysis identifies less costly alternatives, the RIA includes an explanation of the legal reasons why the less costly alternatives could not be adopted. In addition to requiring an analysis of the potential costs and benefits, EO 12291 specifies that EPA, to the extent allowed by the CAA and court orders, demonstrate that the benefits of the proposed standards outweigh the costs and that the net benefits are maximized.

The RFA requires Federal agencies to give special consideration to the impact of regulations on small businesses, small organizations, and small governmental units. If the proposed regulation is expected to have a significant impact on a substantial number of small entities, a regulatory flexibility analysis must be prepared. In preparing this analysis, EPA takes into consideration such factors as the availability of capital for small entities, possible closures among small entities, the increase in production costs due to compliance, and a comparison

of the relative compliance costs as a percent of sales for small versus large entities.

The prime objective of the cost analysis is to identify the incremental economic impacts associated with compliance with the standards based on each regulatory alternative compared to baseline. Other environmental regulatory costs may be factored into the analysis wherever appropriate. Air pollutant emissions may cause water pollution problems, and captured potential air pollutants may pose a solid waste disposal problem. The total environmental impact of an emission source must, therefore, be analyzed and the costs determined whenever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made for proposed standards. It is also essential to know the capital requirements for pollution control systems already placed on plants so that the additional capital requirements necessitated by these Federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to provide the additional control equipment needed to meet the standards.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires Federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by EPA for proposed actions under the Clean Air Act. Essentially, the Court of Appeals has determined that the best system of emissions reduction requires the Administrator to take into account counterproductive environmental effects of

proposed standards as well as economic costs to the industry. On this basis, therefore, the Courts established a narrow exemption from NEPA for EPA determinations.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to Section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969" (15 U.S.C. 793(c)(1)).

Nevertheless, EPA has concluded that preparing environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by Section 102(2)(C) of NEPA, EPA has adopted a policy requiring that environmental impact statements be prepared for various regulatory actions, including NESHAP developed under Section 112 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the EPA to NEPA requirements.

To implement this policy, a separate section is included in this document that is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are discussed.

2.6 RESIDUAL RISK STANDARDS

Section 112 of the Act provides that 8 years after MACT standards are established (except for those standards established 2 years after enactment, which have 9 years), standards to protect against the residual health and environmental risks remaining must be promulgated, if necessary. The standards would be triggered if more than one source in a category or subcategory exceeds a maximum individual risk of cancer of 1 in 1 million. These residual risk regulations would be based on the concept of providing an "ample margin of safety to protect public health."

The Administrator may also consider whether a more stringent standard is necessary to prevent--considering costs, energy, safety, and other relevant factors--an adverse environmental effect. In the case of area sources controlled under GACT standards, the Administrator is not required to conduct a residual risk review.

3.0   INDUSTRY DESCRIPTION

This chapter presents a description of a segment of the polymers and resins industry.   Section 3.1 provides a general description of basic liquid epoxy resins (BLR) and wet strength resins (WSR).   Section 3.2 presents source category descriptions. Section 3.3 presents baseline hazardous air pollutant (HAP) emissions for each source category.   Finally, Section 3.4 lists the references for Chapter 3.

3.1   GENERAL

The scope of source categories to be covered by this NESHAP are defined as the manufacture of BLR (diglycidyl ether of bisphenol-A [DGEBPA]) and WSR (EPI modified non-nylon polyamides).   Basic liquid epoxy resins does not include specialty epoxy resins (epoxy resins that are not BLR) or modified epoxy resins (BLR resins that have been blended with solvents, reactive diluents, or other resins).   Wet strength resins include those resins that are made with dibasic esters, dicarboxylic acids, amines, and epichlorohydrin (EPI).

In general, BLR are plastic materials that become hard, infusible solids upon the addition of a hardening agent.[1]   These resins are characterized by the presence of a three-member cyclic ether group commonly referred to as an epoxy group.   Usually the epoxy groups are situated at the ends of the molecule, but they can be attached at other points, as in the case of specialty epoxy resins.   To become useful, epoxy resins must be cross-linked with amines, anhydrides, or other curing agents to form thermoset, three-dimensional structures.   The epoxy groups provide the points for the curing reaction to take place.   Upon addition of the curing agent, the epoxy groups open up to begin a

reaction that permanently cross-links the resin to the curing agent and to itself. It is the cross-linked structure that gives the epoxy resins desirable properties such as high chemical and corrosion resistance, good mechanical and strength properties, outstanding adhesion, low shrinkage upon curing, and flexibility.[2] These properties make the cured resin a desirable ingredient in adhesives, coatings, and other plastics applications.

Epichlorohydrin modified non-nylon polyamide resins (WSR) are used primarily by the paper industry as an additive to increase the tensile strength of paper products. Natural polymers such as cellulose and protein are not highly crosslinked; their fibers, which are composed of hydrophylic polymer chains, can change position or become completely separated upon the addition of water.[3,4] The added resins are used to form a stable polymeric web among the natural fibers. For this reason, these resins are commonly referred to as WSR.

Production methods used in the two source categories include both batch and continuous operations. The sizes of the facilities range from those that make several megagrams of resin per year (Mg/yr) to those that produce over 50 thousand Mg/yr. The HAP emissions associated with the production processes include EPI, methanol, and hydrochloric acid (HCl). This chapter presents source category, product, and process descriptions, lists of facilities, descriptions of potential emission sources, and current levels of emissions in each source category.

3.2 SOURCE CATEGORY DESCRIPTIONS

3.2.1 Source Category 1: BLR Production

Diglycidyl ether of bisphenol-A can be made from excess EPI and bisphenol-A in two different processes, the "two-step process" and the "conventional process." Current domestic production is believed to utilize the two-step process, which is described below.

3.2.1.1 Two-Step Process.[5] This process involves two major steps, coupling and dehydrochlorination. In the coupling step,

EPI is added to bisphenol-A to form dichlorohydrin ether, an intermediate, as shown in the following reaction:

$$
\underset{\substack{\text{Cl}\\ |}}{}\; 2CH_2CH \overset{O}{\underset{\diagup \diagdown}{-}} CH_2 + HO - X - OH \longrightarrow H_2C \overset{\substack{\text{Cl} \;\; \text{OH}\\ |\quad\;\; |}}{-} CHCH_2O - X - OCH_2CH \overset{\substack{\text{OH} \;\; \text{Cl}\\ |\quad\;\; |}}{-} CH_2
$$
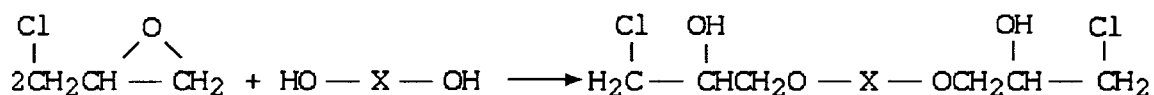
The reaction is catalyzed with either caustic soda or a compound such as methyltributyl ammonium chloride, methyltriphenyl phosphonium bromide, or trimethylsulfonium iodide.

The dichlorohydrin intermediate formed in the coupling reaction is dehydrochlorinated in the next step with caustic soda to produce BLR in the following reaction:

$$
\underset{\substack{\text{Cl}\;\; \text{OH}}}{H_2C} - CHCH_2O - X - OCH_2CH - CH_2 + 2NaOH \longrightarrow
$$

$$
H_2C \overset{O}{\underset{\diagup\diagdown}{-}} CHCH_2O - X - OCH_2CH \overset{O}{\underset{\diagup\diagdown}{-}} CH_2 + 2NaCl + 2H_2O
$$
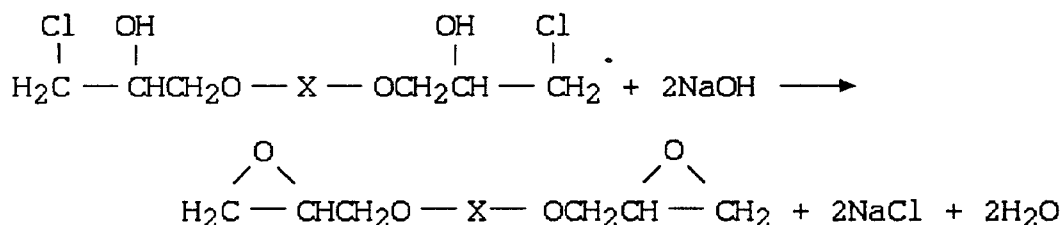
Sodium chloride (NaCl), water, and BLR are the final reaction products.

Excess EPI is removed either before or after the dehydrochlorination step. If EPI is removed prior to dehydrochlorination, it is distilled off in two stages. This two-stage process is shown in Figure 3-1, option A. After the first distillation, glycerol dichlorohydrin is added to the reaction mixture. After the second distillation, a solvent mixture of methyl isobutyl ketone and isopropanol is added to the mixture and the solution is reacted with a 15 percent caustic soda solution. The resulting organic solution is purified by neutralizing with a dilute acid solution and by washing with water. The solvent is removed by distillation. The liquid epoxy resin is filtered to remove any entrained organic salt.

If excess EPI is left in the solution during dehydrochlorination, as shown in Figure 3-1, option B, the amount of caustic solution added is carefully controlled to limit

Figure 3-1. Epoxy resin process flow diagram (two-step process).
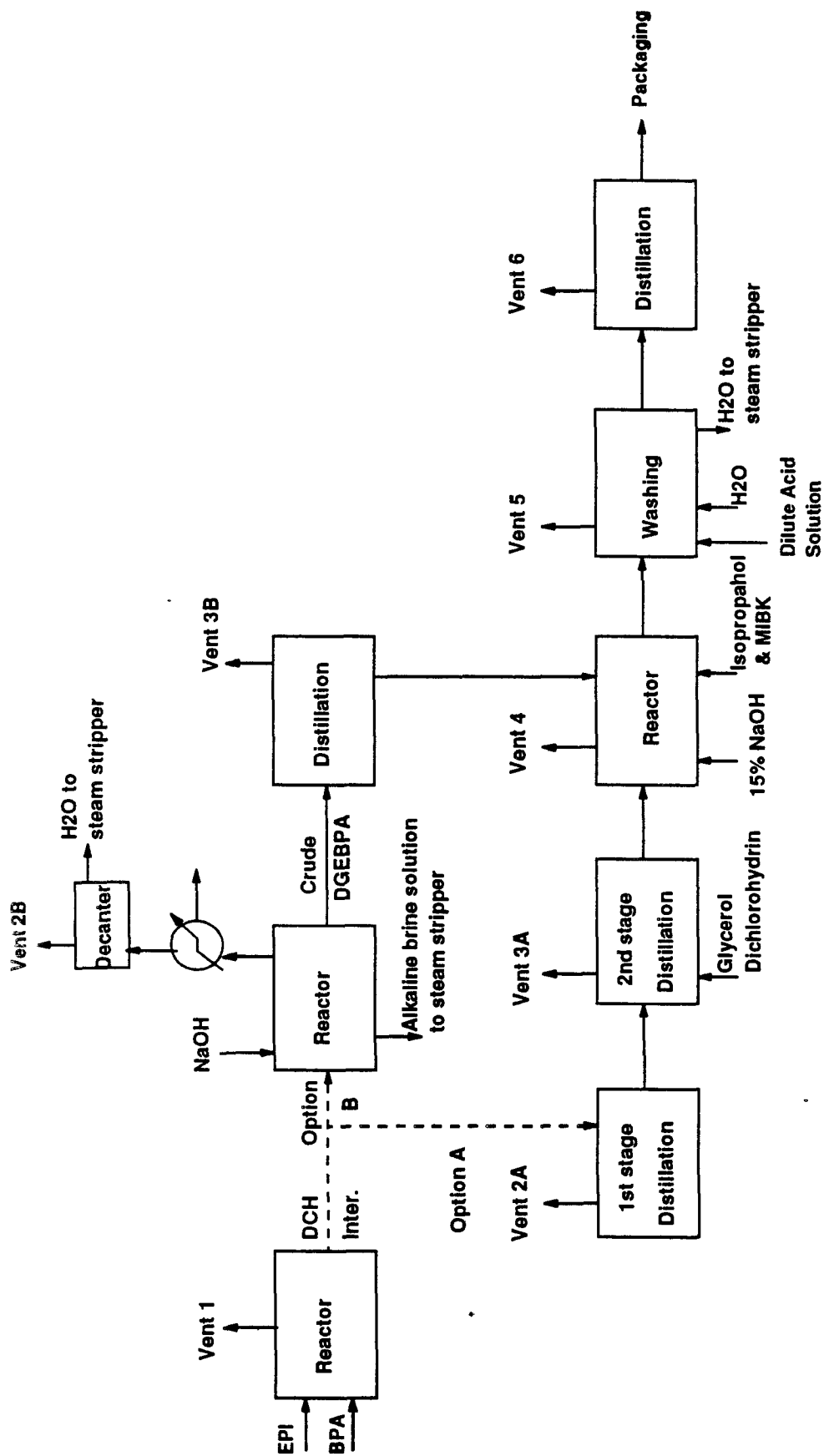
Option A
- Excess EPI removed before dehydrochloronation

Option B
- Excess EPI left in solution during dehydrochloronation

hydrolysis of EPI. After the dehydrochlorination reaction takes place, water and EPI are removed from the reaction medium as an azeotropic mixture. After condensation, this overhead mixture is separated into a water layer and an EPI layer by decantation. After distillation, the organic product is dissolved in an organic solvent such as toluene, xylene, or methyl isobutyl ketone (MIBK). The solution is further purified in the same method as described above for option A.

3.2.1.2 Product Specifications. The effect of mole ratio of EPI to bisphenol-A on the average molecular weight of the liquid resin and on the average number of repeating units (n) is shown below:[6,7]

EPI:bisphenol-A	Molecular weight	n
2:1	370	0.1
2:1	450	0.4
1.4:1	791	2
1.1:1	3,750	12

Typically, commercial BLR has an average molecular weight of 370 and consists of about 87 percent of the polymer molecules with n = 0, 11 percent of the polymer molecules with n = 1, and 1.5 percent of the polymer molecules with n = 2.[8] The molecular weight and chain length have an effect on the physical state of the resin. Pure BLR (n = 0) is a solid with a melting point of 43°C (109°F).[9] The higher the molecular weight, the higher the melting point and the more solid the resin becomes. Commercial BLR is a super-cooled liquid with the potential for crystallization depending on purity and storage conditions. By warming, the crystallized resin is restored to its original form.[10] It does not need to be dissolved in solvent for it to be liquid, although it is commonly blended with solvents or diluents to reduce the viscosity before use.

Basic liquid epoxy resins are widely used in casting, tooling, adhesives, and coatings applications. They are just one

ingredient in a formulation that includes curing agents that cross-link the epoxy resin, diluents or solvents that reduce the viscosity, inexpensive fillers that reduce the formulation cost, plasticizers that make the resin more flexible, and other resins that alter the properties of the finished resin formulation. Diglycidyl ether of bisphenol-A is used to make higher molecular weight epoxy resins to be used as ingredients in powder coatings, resin solutions, or resin dispersions. It is also used to make numerous types of modified resins by chemically attaching it to other resins such as phenolic, urea, melamine, furane, polyester, vinyl, polyurethane, and silicone; or by reacting it with other organic compounds such as oils or fatty acids to make epoxy esters or other useful polymers.[11]

3.2.1.3 Emission Sources in Source Category 1. As mentioned in Section 3.2.1.1, EPI may be removed either before or after the dehydrochlorination step. In either case, the manufacture of BLR is initiated in a reactor where EPI emissions occur during EPI charging and reaction. The dichlorohydrin intermediate formed in this reaction is dehydrochlorinated in the next step. If excess EPI is removed prior to dehydrochlorination (option A) emissions occur from the two distillation stages. If the excess EPI is left in solution (option B) a dehydrochlorination reaction takes place. Epichlorohydrin and water vapors are removed from the reactor, condensed, and sent to a decanter. In this step, potential emissions of EPI are from noncondensed EPI vapors. Further reaction, washing and distillation steps occur with potential emissions of EPI and solvent. Currently, the facilities in the source category do not report the usage of other HAP solvents (such as MIBK) in these steps.

Working and breathing losses are noted for storage tanks, and equipment leaks are potential fugitive HAP emission sources. Finally, wastewater is generated from the steam stripper bottoms and from vacuum seals; this water is routed to the wastewater treatment system, which contributes to emissions of EPI from volatilization.

3.2.1.4 **Facilities Included in Source Category 1.**
Facilities that are included in this source category have
production rates on the order of 45 gigagrams per year (Gg/yr)
(100 million lb/yr). As of 1990, only three U. S. companies
produced BLR on a large scale: Ciba-Geigy Corporation in
McIntosh, Alabama; Dow Chemical U.S.A. in Freeport, Texas; and
Shell Chemical Company in Deer Park, Texas. All three of these
facilities are considered major sources according to the EPA
criterion of having the potential to emit 10 tons per year of any
one HAP or 25 tons per year of combined HAP's. As of
January 1987, total U. S. production capacity of liquid BLR epoxy
resin was approximately 220 Gg/yr (4.8 x 10^8 lb/yr).[12] Table 3-1
presents the list of facilities that manufacture BLR and provides
information on HAP emissions related to this source category.
The emission estimates are discussed in Section 3.3.

3.2.1.5 **End-Product Uses and Future Growth.** Diglycidyl
ether of bisphenol-A is used to make higher molecular weight
epoxy resins to be used as ingredients in powder coatings, resin
solutions, or resin dispersions. It is also used to make
numerous types of modified resins by chemically attaching it to
other resins such as phenolics, urea, melamine, furane,
polyester, vinyl, polyurethane, and silicone. One 1987 reference
indicates that approximately 75 percent of the epoxy resins
currently used worldwide are derived from BLR.[13] Table 3-2
shows consumption patterns for BLR.

In recent years, the market trends have increasingly been
toward the growth of specialty epoxy resins, many of which are
not derived from BLR. Overall growth for epoxy resins is
estimated at approximately 2 to 3 percent through 1995. The
coatings segment, of which BLR is a part, has a projected growth
rate of 1 to 2 percent through this period.[14]

3.2.2 **Source Category 2: WSR Production**

3.2.2.1 **Product Description.** Wet strength resins can be
categorized into two groups: (1) dimer acid-based and (2) EPI
cross-linked. The second group of resins is identical to the
first group except that the resins in the second group are

TABLE 3-1. EMISSIONS INFORMATION FOR FACILITIES THAT MANUFACTURE BASIC LIQUID RESINS (BLR)

	Emission sources	Estimated EPI uncontrolled emissions, lb/yr	Control device	Reported removal efficiency, percent	Reported EPI Baseline emissions, lb/yr	Estimated removal efficiency, percent	Estimated baseline emissions, lb/yr
Dow Chemical Freeport, TX	Process						
	1. Resin finishing	600	Water scrubber	95	30	92	50 EPI
	2. Steam jet exhausts	59,000	Water scrubber	99.7	200	97	1,900 EPI
	3. Vapor containment from synthesis	42,000	Carbon adsorption	98	1,300	97	1,300 EPI
	4. Storage tanks	61,000	Carbon adsorption	98	1,800	97	1,800 EPI
	5. Wastewater	697,000	WW treatment (Biodegradation)	97.5	17,000	98	14,000 EPI
	6. Equipment leaks	244,000	LDAR			54	122,000 EPI
Shell Chemical Deer Park, TX	Process						
	1. Premix vent	1,800	Condenser	0	1,800	0	1,800 EPI
	2. Vacuum system manifold	500[a]	Water scrubber (ejector) and packed tower and recirculation	90	50	Not estimated	50 EPI
	3. Storage	<1[a]	Water scrubber (ejector) and packed tower and recirculation	90	<1	Not estimated	<1 EPI
	4. Wastewater	96,000	WW treatment (hydrolysis + biodegradation)		--	>99	200 EPI
	5. Equipment leaks	84,000	LDAR			16	70,000 EPI
Ciba Geigy McIntosh, AL	Process						
	1. Process manifold	176,000	Refrigerated condenser + Flare	90		90	1,000 EPI / 17,000 HCI
	2. Storage	3,000	Refrigerated condenser + Flare	90		90	10 EPI / 300 HCI
	3. Wastewater -washing -brine distillation	9,000	WW treatment (biodegradation)			93	600 EPI
	4. Equipment leaks	68,000	LDAR			48	38,000 EPI

[a] The emissions prior to the water scrubber that are considered by Shell to be a product recovery device. These emissions total 319,000 lb/yr from the process and 2,000 lb/yr from storage.

TABLE 3-2. BLR CONSUMPTION PATTERNS[a]

Market	Million lb	
	1989	1990
Bonding and adhesives	25	28
Flooring, paving, aggregates	25	26
Protective coatings	193	195

Reinforced uses
  Electrical laminates
  Other
	57
	26
		55
		31

Tooling, casting, molding	30	28
Export	86	68
Other	41	33
Total	483	464

[a]From Modern Plastics, January 1990. p. 114.

EPI-modified. This NESHAP considers only the manufacture of the EPI modified or "cross-linked" resin. The EPI cross-linked resins have been referred to as WSR, primarily because these resins are used to form a stable polymeric web among cellulosic or protein fibers. This web provides a permanent fiber organization without modifying the desired characteristics of the fiber and, in doing so, imparts tensile strength to paper products. One of the more important resins in this group is the EPI-modified diethylene triamine (DETA) hexanedioic acid polymer. This amino polyamide polymer can be formed from DETA and hexanedioic acid (i.e., adipic acid). In some cases, dibasic ester is substituted for adipic acid. While the polymer formed is the same, methanol, instead of water, is formed as a byproduct. Both manufacturing routes for EPI-modified diethylene triamine (DETA) hexanediodic acid polymer are shown below:

Dibasic ester route

Adipic acid route

Addition of EPI forms the cross-linked structure in the following way:

    3.2.2.2 Process Description. Figure 3-2 shows the WSR production process. For the production of the WSR, the initial reaction is carried out with adipic acid, or dibasic ester and

$$NH_2-R-NH-R-NH_2 + CH_3-\overset{\displaystyle O}{\overset{\|}{C}}-R-\overset{\displaystyle O}{\overset{\|}{C}}-CH_3 \longrightarrow$$

DETA (R: (CH)$_2$) DIBASIC ESTER

$$\left[-R-NH-R-NH-\overset{\displaystyle O}{\overset{\|}{C}}-R-\overset{\displaystyle O}{\overset{\|}{C}}-NH-\right] + CH_3OH$$

$$NH_2-R-NH-R-NH_2 + OH-\overset{\displaystyle O}{\overset{\|}{C}}-R-\overset{\displaystyle O}{\overset{\|}{C}}-OH \longrightarrow$$

DETA (R: (CH)$_2$) ADIPIC ACID (R: (CH$_2$)$_4$)

$$\left[-R-NH-R-NH-\overset{\displaystyle O}{\overset{\|}{C}}-R-\overset{\displaystyle O}{\overset{\|}{C}}-NH-\right] + H_2O$$

$$\left[R-NH-R-\underset{\displaystyle \underset{\displaystyle CH_2}{|}}{N}-\overset{\displaystyle O}{\overset{\|}{C}}-R-\overset{\displaystyle O}{\overset{\|}{C}}-NH-\right]$$

CH$_2$

CH $-$ OH

CH$_2$

$$\left[-R-NH-R-N-\overset{\displaystyle O}{\overset{\|}{C}}-R-\overset{\displaystyle O}{\overset{\|}{C}}-NH-\right]$$
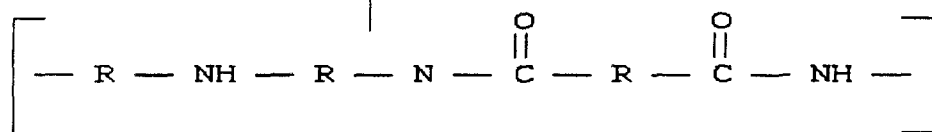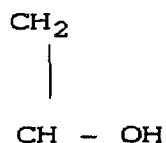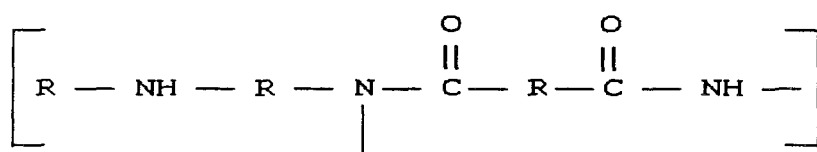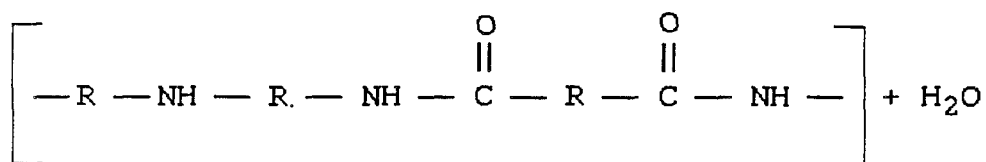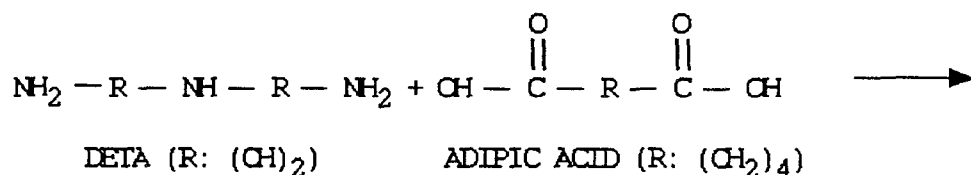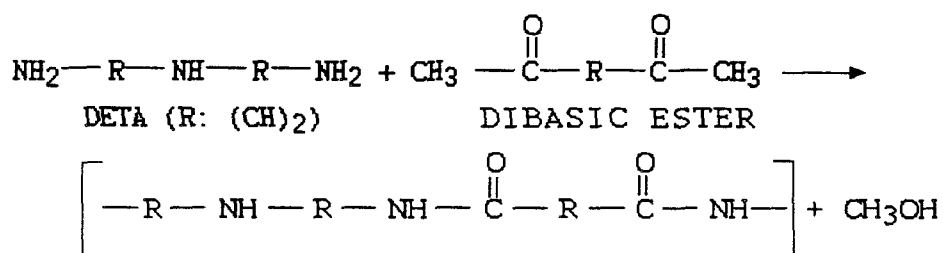
DETA. A second reaction then occurs with the addition of EPI. The second reaction between the polyamide and EPI forms EPI adducts.

Each of the feedstocks is transferred from storage tanks to dedicated weigh tanks, where the required quantities are measured. Depending upon the capacity of the production line,

1. MeOH Displacement

RECEIVER
TANK

MeOH Distillation

Prepolymer

2. Displacement
3. Heat up
4. Acid addition

To distillate storage

acid addition

REACTOR

EPI

Product to storage
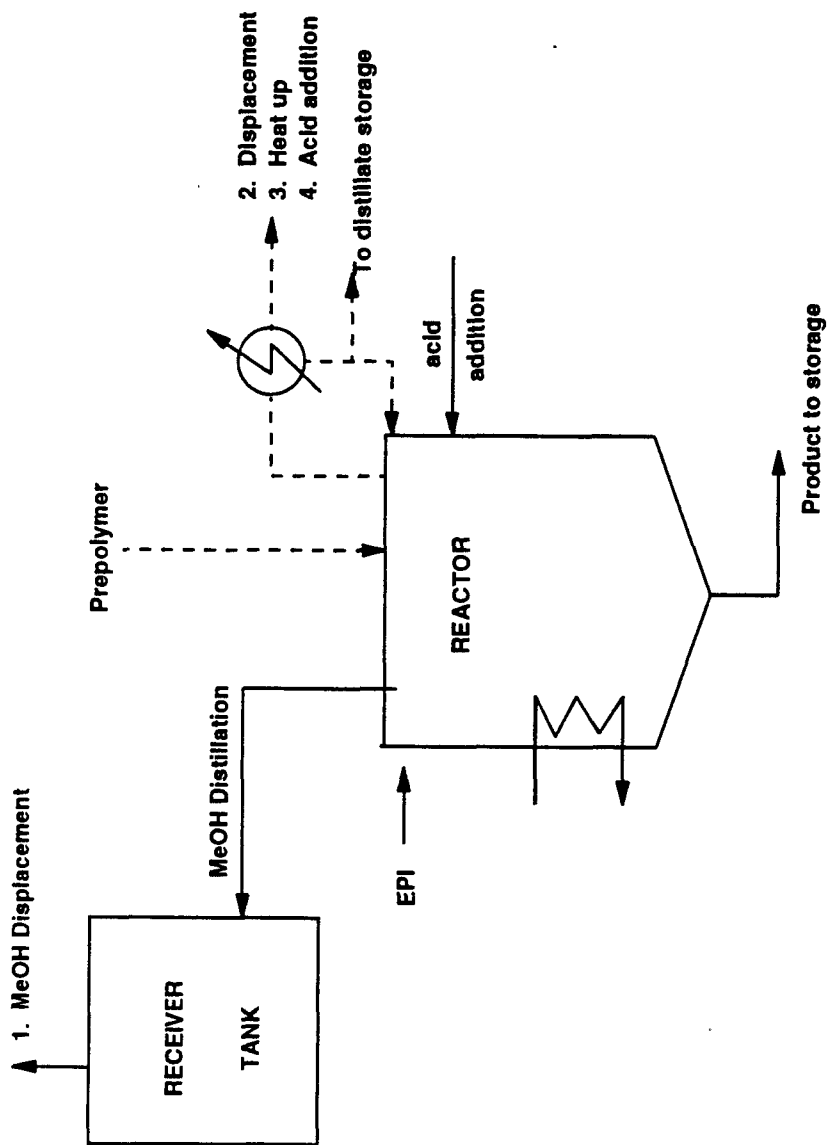
Raw materials:

Prepolymer
EPI
Acid (HCl or H2SO4)

Notes:

Prepolymer can be made during the same process and in the same reactor as the finished resin or it can be made earlier and stored until needed.

Prepolymer is formed by one of the reactions below:

dibasic ester + an amine (DETA); byproduct is MeOH

dicarboxylic acid + an amine (DETA); byproduct is H2O

Figure 3-2. Wet strength resin process flow diagram.

the volumes of the weigh tanks can range from a few hundred gallons to several thousand gallons. The process of charging the mixing tank or reactor is normally a gravity process because the weigh tanks are usually located above the mixing tank or reactor. In some instances, charging may occur by vacuum filling the reactor or by pressurizing the weigh tanks with nitrogen to force the feedstocks through piping into the receiving vessel. Charging rates are typically about 190 liters per minute (l/min) (50 gallons per minute [gal/min]). As the reaction progresses, the glycidyl groups begin crosslinking and the viscosity of the reaction mixture increases. Reaction times for each batch can range from 2 to 24 hours and reaction temperatures can range from 40° to 70°C (104° to 158°F). The reactors are generally equipped with a temperature control jacket, an agitator, sampling ports (manholes), and a pressure relief mechanism. The pressure relief system may be either a vent to the vapor recovery system or pressure relief valves equipped with rupture disks. The reactor sizes used in this process usually range from 1,900 to 7,600 l (500 to 2,000 gal). At a predetermined viscosity, sulfuric acid or hydrochloric acid is added to the reaction mixture to reduce the pH of the reaction mixture and to stop formation of glycidyl amine groups. If no acid is added, the cross-linking will continue until a gel is eventually formed. After the reaction has ceased due to the addition of acid, water and any excess acid (as well as unreacted feedstocks) are removed from the bottom of the reactor. If not used immediately, the WSR must be maintained in an acidified solution or an increase in viscosity leading to gel formation will result. The commercial WSR are shipped as acidified solutions that are reactivated by addition of base just before use in the paper mill.

   3.2.2.3 Emission Sources in Source Category 2. The manufacture of WSR typically takes place in a single batch reactor. Emissions associated with the batch reactor are charging, reaction heatup, and acid addition. Epichlorohydrin can potentially be emitted during each of these events, and HCl (a HAP) can be emitted if it is used to halt the crosslinking

reaction. Emissions of methanol are possible if a dibasic ester rather than a dibasic acid is reacted with DETA. The HAP emissions due to working and breathing losses occur from the storage tanks and displacement emissions are noted for weigh tanks dedicated to the manufacture of WSR. Equipment leaks are also a source of HAP emissions.

3.2.2.4 Facilities Included in Source Category 2.
Table 3-3 presents a summary of emissions from facilities that manufacture WSR. There are at least 17 facilities in the nation that manufacture WSR. Of these facilities, nine are considered major sources because they have the potential to emit more than 10 tons/yr of any one HAP or more than 25 tons/yr of combined HAP's from within the fenceline of the entire facility. In 1990, an estimated 198 Gg/yr (4.5×10^8 lb/yr) of resin was manufactured using approximately 14 Gg/yr (3.1×10^7 lb/yr) of combined EPI and HCl.

3.3 BASELINE EMISSIONS

3.3.1 Source Category 1: BLR Production

Based on information reported from the three facilities that make up Source Category 1 (BLR production), uncontrolled HAP emissions (i.e., ignoring existing controls) constitute approximately 700 Mg/yr (1.54×10^6 lb/yr). The baseline HAP emissions (representing the current level of control) from the three facilities are estimated to be 130 Mg/yr (2.8×10^5 lb/yr), or approximately 19 percent of the uncontrolled value. Potential wastewater emissions make up the largest fraction of uncontrolled emissions, while equipment leak emissions make up the largest fraction of controlled, or baseline, HAP emissions.

Uncontrolled emission estimates were calculated based on data reported in Section 114 information requests. Process vent streams from the resin finishing and purification stages were assumed to be saturated with EPI at the outlet conditions of the vacuum manifolds prior to the control devices. Because two of the facilities currently use water scrubbers to control these streams, the overall control efficiency was estimated considering the fate of EPI in the wastewater. Both facilities that use

TABLE 3-3. EMISSIONS INFORMATION FOR FACILITIES THAT MANUFACTUR WET STRENGTH

Major/area	No.	Facility	Resin production, lb/yr	HAP	HAP usage, lb/yr	Emission sources	HAP	HAP/uncontrolled emissions, lb/yr	Control device	Estimated efficiency, percent	Estimated baseline emissions, lb/yr
Area	1	Callaway Chemical Columbus, GA	a	EPI	a	PROCESS VENTS					
						1) EPI Charging	EPI	6	Carbon Bed	99%	0 EPI
						2) H2SO4 Addition	EPI	2	Carbon Bed	99%	0 EPI
						STORAGE	EPI	166			166 EPI
						EQUIPMENT LEAKS[b]	EPI	268			268 EPI
Major	2	Callaway Chemical Shreveport, LA		EPI	a	PROCESS VENTS					
						1) EPI Charging	EPI	42	Water Scrubber	71%	12 EPI
						2) H2SO4 Addition	EPI	10	Water Scrubber	70%	3 EPI
						STORAGE	EPI[d]	166	Water Scrubber	71%	48 EPI
						EQUIPMENT LEAKS[b]	EPI	1,091			1,091 EPI
Major	3	Georgia Pacific Crossett, AR		EPI	a	PROCESS VENTS					
						1) EPI Charging	EPI	225	Condenser	72%	63 EPI
						2) Heatup	EPI	156	Condenser	84%	25 EPI
						3) H2SO4 Charging	EPI	38	Condenser	74%	10 EPI
						STORAGE	EPI	127			127 EPI
						EQUIPMENT LEAKS[b]	EPI	1240			1,240 EPI
Area	4	Georgia Pacific Peachtree City, GA		EPI	a	PROCESS VENTS					
						1) EPI Charging	EPI	300	Condenser	72%	84 EPI
						2) Heatup	EPI	208	Condenser	84%	33 EPI
						3) H2SO4 Charging	EPI	51	Condenser	74%	13 EPI
						STORAGE	EPI	169			169 EPI
						EQUIPMENT LEAKS	EPI	301			301 EPI
Area	5	Georgia Pacific Grayling, MI		EPI	a	PROCESS VENTS					
						1) EPI Charging	EPI	225	Cat Incinerator	99%	2 EPI
						2) Heatup	EPI	156	Cat Incinerator	99%	2 EPI
						3) H2SO4 Charging	EPI	38	Cat Incinerator	99%	0 EPI
						STORAGE	EPI	127	Cat Incinerator		1 EPI
						EQUIPMENT LEAKS[b]	EPI	1501			1,501 EPI
Major	6	Georgia Pacific Columbus, OH		EPI	a	PROCESS VENTS					
						1) EPI Charging	EPI	4	Condenser	72%	1 EPI
						2) Heatup	EPI	1	Condenser	84%	1 EPI
						3) H2SO4 Charging	EPI	0	Condenser	74%	0 EPI
						STORAGE	NONE[g]				
						EQUIPMENT LEAKS[b]	EPI	613			613 EPI

TABLE 3-3. (continued)

Major/ area	No.	Facility	Resin production, lb/yr	HAP	HAP usage, lb/yr	Emission sources	HAP	HAP/uncontrolled emissions, lb/yr	Control device	Estimated efficiency, percent	Estimated baseline emissions, lb/yr
Area	7	Georgia Pacific Eugene, OR		EPI		PROCESS VENTS					
						1) EPI Charging	EPI	240	Condenser	72%	67 EPI
						2) Heatup	EPI	166	Condenser	84%	27 EPI
						3) H2SO4 Charging	EPI	41	Condenser	74%	11 EPI
						STORAGE	EPI	135			135 EPI
						EQUIPMENT LEAKS[b]	EPI	1910			1,910 EPI
Major	8	Henkel Chemicals Charlotte, NC		EPI, HCl[j]		PROCESS VENTS	EPI	129			129 EPI
							HCl	55			55 HCl
						STORAGE	EPI	109			109 EPI
							HCl	60			60 HCl
						EQUIPMENT LEAKS	EPI	1,774			1,774 EPI
							HCl	611			611 HCl
Major	9	Pioneer Plastics Auburn, ME		EPI, MeOH, HCl[j]		PROCESS VENTS	EPI	35	Condenser	77%	8 EPI
							MeOH	****	Condenser	44%	2,972 MEOH
							HCl	50	Condenser		28 HCL
						STORAGE	NONE[g]				
						EQUIPMENT LEAKS[b]	EPI	122			122 EPI
							MeOH	67			67 MeOH
							HCl	44			44 HCl
Area	10	Borden Chemicals Sheboygan, WI		EPI, MeOH, HCl[j]		PROCESS VENTS					
						1) MeOH Distillation	MeOH	330	Condenser w/vacuum pump	71	330 MeOH
						2) EPI Charging	EPI	96			28 EPI
						3) Heatup	EPI	232			232 EPI
						4) HCl Addition	EPI	20			20 EPI
							HCl	16			16 HCl
						STORAGE	MeOH	1,021			1,021 MeOH
							HCl	23			23 HCl
						WASTEWATER					
						EQUIPMENT LEAKS[b]	EPI	1,191			1,191 EPI
							MeOH	756			756 MeOH
							HCl	203			203 HCl

TABLE 3-3. (continued)

Major/ area	No.	Facility	Resin production, lb/yr	HAP	HAP usage, lb/yr	Emission sources	HAP	HAP/uncontrolled emissions, lb/yr	Control device	Estimated efficiency, percent	Estimated baseline emissions, lb/yr
Area	11	Borden Chemicals Demopolis, AL		EPI MeOH HCl[j]		PROCESS VENTS 1) MeOH Distillation	MeOH	26	Condenser w/vacuum pump	63	26 MeOH
						2) EPI Charging	EPI	16	Condenser w/vacuum pump	58	6 EPI
						3) Heatup	EPI	2.4	Condenser w/vacuum pump	78	1 EPI
						4) HCl Addition	EPI	9	Condenser w/vacuum pump	86	2 EPI
							HCl	7			1 HCl
						STORAGE	MeOH	154			154 MeOH
						WASTEWATER					
						EQUIPMENT LEAKS[b]	EPI MeOH HCl	476 154 133			476 EPI 154 MeOH 133 HCl
Major	12	Hercules Savannah, GA		EPI		PROCESS VENTS 1) EPI Charging	EPI	743	Scrubber	71	215 EPI
						2) Heatup	EPI	2548	Scrubber	71	739 EPI
						3) Acid Addition	EPI	1231	Scrubber	71	357 EPI
						STORAGE	EPI	506			506 EPI
						EQUIPMENT LEAKS	EPI	12,745			12,745 EPI
						WASTEWATER	e				
Area	13	Hercules Portland, OR		EPI		PROCESS VENTS 1) EPI Charging	EPI	454	Scrubber	71	132 EPI
						2) Heatup	EPI	160	Scrubber	71	46 EPI
						3) Acid Addition	EPI	503	Scrubber	71	146 EPI
						STORAGE	EPI	180			180 EPI
						EQUIPMENT LEAKS	EPI	1,775			1,775 EPI
						WASTEWATER	e				
Major	14	Hercules Milwaukee, WS		EPI		PROCESS VENTS 1) EPI Charging	EPI	511	Scrubber	71	148 EPI
						2) Heatup	EPI	1,328	Scrubber	71	385 EPI
						3) Acid Addition	EPI	1,073	Scrubber	71	311 EPI
						STORAGE	EPI	131			131 EPI
						EQUIPMENT LEAKS	EPI	9,361			9,361 EPI
						WASTEWATER	e				

TABLE 3-3. (continued)

Major/ area	No.	Facility	Resin production, lb/yr	HAP	HAP usage, lb/yr	Emission sources	HAP	HAP/uncontrolled emissions, lb/yr	Control device	Estimated efficiency, percent	Estimated baseline emissions, lb/yr
Major	15	Hercules Hattiesburg, MS		EPI		PROCESS VENTS					
						1) EPI Charging	EPI	471	Scrubber	71	137 EPI
						2) Heatup	EPI	165	Scrubber	71	48 EPI
						3) Acid Addition	EPI	953	Scrubber	71	276 EPI
						STORAGE	EPI	223			223 EPI
						EQUIPMENT LEAKS	EPI	9,519			9,519 EPI
						WASTEWATER	e				
Major	16	Hercules Chicopee, MA		EPI		PROCESS VENTS					
						1) EPI Charging	EPI	611	Scrubber	71	177 EPI
						2) Heatup	EPI	217	Scrubber	71	63 EPI
						3) Acid Addition	EPI	914	Scrubber	71	265 EPI
						STORAGE	EPI	167			167 EPI
						EQUIPMENT LEAKS	EPI	2,924			2,924 EPI
						WASTEWATER	e				
Area	17	Akzo Chemical		EPI		PROCESS VENTS					
						STORAGE	EPI	103			103 EPI
						WASTEWATER					
						EQUIPMENT LEAKS	EPI	527			527 EPI
			TOTAL, lb/yr					67,687			60,284

** Resin production and HAP usage for individual facilities was not included due to proprietary reasons.
*** MEOH is distilled out of kettle; Cannot assume uncontrolled MEOH emission rate is the amount leaving the kettle during distillation because the condenser is not considered a control device during distillation.

[a]Estimates were made based on a ratio of 0.08 lb MEOH/lb finished resin and 0.08 lb EPI/lb crude resin. Also assumes ratio of crosslinked resin to crude resin is 3.4.
[b]Based on a model fugitive component count developed.
[c]Estimated based on a compound-specific factor supplied in the early reductions memo.
[d]Estimates assumed to be similar to information for Callaway facility in Columbus.
[e]None, other than what is generated from process vent water scrubber.
[f]Estimated based on scale up from production data.
[g]Storage is in 55-gallon drums.
[h]Information is claimed as CBI.
[i]Control efficiencies reported in questionnaire.
[j]Pounds of HCl in 31.5 wt% HCl solution.

water scrubbers send the scrubber effluent back to the process. All wastewater is then steam stripped. Therefore, the fraction of EPI transferred from the process vents to the wastewater also includes the stripping efficiency (estimated to be 94 percent) of EPI and the subsequent disposal of the stripper bottoms.[15] Note that for the facility that uses a flare to control process emissions, the overall HAP baseline estimate includes the subsequent formation of HCl. Therefore, the net HAP reduction is much lower than the 98 percent VOC control efficiency usually assigned to a flare.

As shown in Table 3-1, emissions from wastewater do not include the fraction of EPI transferred from process vents via scrubber effluent. Other sources of wastewater include extractor (wash) water, steam stripper bottoms, and vacuum system discharges (i.e., condensed steam and water from ejectors). Control of EPI in wastewater is achieved through hydrolysis and biodegradation. Modeling of volatilization emissions was done using Chemdat 7.[16]

Uncontrolled HAP emissions from storage tanks were estimated based on AP-42 tank equations.[17] Baseline emissions from tanks were estimated using the same control efficiencies as those allowed for process vents, since the tanks were in all cases reported to be controlled by the same types of devices servicing process vents (i.e., flares and scrubbers).

Uncontrolled HAP emissions from equipment leaks were estimated based on Synthetic Organic Chemical Manufacturing Industry (SOCMI) average emission factors.[18] Baseline HAP emissions were estimated by considering the types of Leak Detection and Repair (LDAR) programs currently in use and by using the control efficiencies for various component types based on monitoring intervals specified in the Section 114 responses.[19]

3.3.2 Source Category 2: WSR Production

There are an estimated 31 Mg/yr (69,000 lb/yr) uncontrolled HAP emissions from the source category. The baseline HAP emissions representing the current level of control from these facilities is estimated to be approximately 28 Mg/yr

3-18

(61,000 lb/yr), or 88 percent of the uncontrolled value.
Equipment leaks appear to be the largest source of HAP emissions
in both cases.

Uncontrolled estimates were calculated based on data
reported in Section 114 information requests. For process vents,
such as reactor, weigh tank, and distillate receiver displacement
emissions, the volumes of gas displaced were assumed to be
saturated with HAP's at the process conditions. Controlled HAP
emissions were calculated using reported condenser outlet
conditions and assuming that the streams exiting the condensers
were again saturated with HAP's at these conditions. Emissions
of HAP's from wastewater occur only if water scrubbers are used
to control vents. Emissions of HAP's from wastewater were
estimated using the volatilization fraction of 29 percent for EPI
in the wastewater.[20] Uncontrolled emissions of HAP's from
storage tanks and equipment leaks were calculated using AP-42
fixed roof tank equations and SOCMI average emission factors,
respectively. Model process fugitive component counts were used
to estimate emissions from facilities that did not report
fugitive component counts. These model counts, and their bases,
are detailed in Chapter 5 of this document.

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4.0 EMISSION CONTROL TECHNOLOGIES

This chapter describes the technologies used to control hazardous air pollutant (HAP) emissions from the types of sources found in these industries. The chapter is structured so that each section provides descriptions of the control devices, examples of their use by polymer and resin manufacturers, and representative HAP emission control levels from test data or calculations. The following control technologies are discussed: (1) condensers, (2) scrubbers, (3) carbon adsorption beds, and (4) thermal destruction systems. In the non-nylon polyamide industry segment, the resins are manufactured using batch processing. The BLR resins are manufactured primarily in the continuous mode; therefore, the control device technologies discussed will deal with controlling emissions from both batch operations and continuous operations.

Tables 4-1 and 4-2 present information on the types of control devices used on various emission sources at facilities in each of the two source categories. The rest of this chapter presents qualitative information of control devices that are or could be used to control HAP emissions. Sections 4.1 through 4.4 describe condensers, scrubbers, carbon adsorption beds, and thermal destruction systems, respectively. Section 4.5 describes other control measures including vapor containment, operational practices, and vacuum loading. Sections 4.5 and 4.7 briefly describe leak detection and repair (LDAR) programs and storage tank controls, respectively. Section 4.8 lists the references for this chapter.

TABLE 4-1.   SUMMARY OF EXISTING BLR EMISSION CONTROL DEVICES
ON EMISSIONS SOURCES IN BLR MANUFACTURING PROCESSES

Emission sources	Control devices	*Reported efficiencies	Estimated efficiencies
1. Process vents	Water scrubbers	99%	97%[a]
	Water scrubbers with recirculation and hydrolysis	NR	>99%
	Carbon adsorption	97%	
	Refrigeration and flare	98%	90%[b]
2. Storage tanks	Water scrubbers	99%	97%[a]
	Carbon adsorption	97%	
	Flare	98%	
	Water scrubbers with recirculation	NR	97%
3. Equipment leaks	LDAR	Variable[c]	
4. Wastewater	Biological treatment	98%	93-98%

[a]Estimated by assuming that the EPI, if captured by the water scrubber, would still volatilize from the wastewater system. The fraction of EPI emitted from wastewater was estimated with WATER7.[1]
[b]Net HAP efficiency (considers formation of HCl)
[c]The reduction efficiency is different for each equipment component (i.e., pumps, valves). Reduction efficiencies range from 100% to 29%.

TABLE 4-2. SUMMARY OF EXISTING EMISSION CONTROL DEVICES
ON EMISSION SOURCES IN WSR MANUFACTURING

Emission source	Control devices	Reported efficiencies, percent	Estimated efficiencies, percent
1. Reactor vents	Condensers	~90	70[a]
	Catalytic incinerator	99	
	Water scrubbers	99-100	71[b]
	Carbon adsorption	99	
2. Storage tanks	Water scrubber	99	71[b]
3. Equipment leaks	LDAR	Variable	
4. Wastewater[c]	Biological treatment	NR[d]	71[b]

[a]The estimated efficiency of condensers were calculated based on the fraction of saturation at the condenser exit gas temperature.

[b]Estimated by assuming that the EPI, if captured by the water scrubber, would still volatilize from the wastewater system. The fraction of EPI emitted is estimated to be 29 percent for generic wastewater treatment systems.

[c]Any wastewater generated is the result of using an add-on control device for process vents that creates a wastewater effluent stream, such as a water scrubber, or a regenerative carbon adsorption unit.

[d]NR = Not reported.

4.1 CONDENSERS

Condensers can generally be classified as surface noncontact and direct contact condensers. Surface condensers are usually shell-and-tube heat exchangers, in which cooling fluid flows inside tubes and the gas condenses on the outside of the tubes. Direct-contact condensers are those which allow for intimate contact between the cooling fluid and the gas, usually in a spray or packed tower. Although direct contact condensers may also be part of a solvent recovery system, an extra separation step is usually involved in separating what was the cooling liquid from the newly-formed condensate. An exception to this situation is the direct contact condenser which uses cooling fluid identical to the desired condensate; in this case, no separation is necessary.

In principle, condensers work by lowering the temperature of the gas stream containing condensables to a temperature at which the desired condensate's vapor pressure is lower than its entering partial pressure. Typical uses for condensers in resin manufacturing are on the vents of reactors, distillation columns, solvent recovery systems, and storage tanks. Note that the function of condensers servicing reactors and distillation columns is often to reflux material. In these situations, the material in the reactor or distillation column is allowed to boil out, either at atmospheric pressure or under vacuum and is condensed by contact with surfaces that are below the boiling point of the material. If the condensers function efficiently, and if there are no noncondensables in the gas stream entering the condenser, all the material in the gas stream condenses out and is returned to the reactor. These reflux condensers or primary condensers are not considered to be emission control devices. Such applications or process steps often use secondary condensers, which operate at still lower temperatures and function primarily as product recovery and air emission control devices for the emission streams leaving the primary condensers.

HAZARDOUS AIR POLLUTANTS FROM EPOXY RESINS AND NON-NYLON
POLYAMIDE RESINS PRODUCTION

BACKGROUND INFORMATION FOR PROPOSED STANDARDS

Preliminary Draft

4.1.1 Design

The control efficiency attained by a condenser is a function of the outlet gas temperature. A typical exhaust gas from a batch reactor contains a large amount of noncondensable material, such as air or nitrogen, as well as some fraction of volatile material. Before this volatile material can condense, the gas stream must be cooled to the saturation point of the condensable material. Heat transferred from the gas stream during this stage is called sensible heat. Cooling the gas stream further, after complete (100 percent) saturation is reached, ensues condensation of the volatile material. Heat removed during the condensation process is called latent heat. Both kinds of heat, which, in refrigeration terminology, usually are summed and reported as tonnes (each ton is 12,000 Btu/hr), must be considered in the design of a condenser. The heat requirement for a surface condenser is calculated using the following equation:

$$Q = UA\Delta T_{LM},$$
(4-1)

where:

Q = heat requirement, Btu/hr;

U = overall heat transfer coefficient, which is based on the tube and shell heat transfer, Btu/hr-ft^2-°F;

A = heat transfer surface area, ft^2; and

ΔT_{LM} = log mean difference in temperature between the cooling fluid and the exhaust gas at each end of the shell and tube exchanger, °F.

The amount of heat transferred, Q, may be calculated by approximating the sensible and latent heat change when a gas stream containing condensable material is cooled:

$$Q = \overset{o}{m}C_p\Delta T + \overset{o}{m}h_v$$
(4-2)

where:

Q = heat requirement, Btu/hr;

$\overset{o}{m}$ = mass flow rate of cooling fluid, lb/hr;

4-5

C_p = heat capacity of cooling liquid, Btu/lb-°F;

ΔT = temperature difference between inlet cooling temperature and condensate temperature, °F; and

h_v = the specific latent heat associated with a phase change, BTU/lb

Based on the above discussion, the amount of material that can be condensed from a gas is limited by the following factors: (1) the emission stream properties, including the heat capacity and latent heat of condensation of the volatile material and the stream temperature and (2) the heat transfer characteristics of the condenser, most notably surface area. By controlling these factors, nearly any amount of cooling can be imparted a gas stream.

In practice, however, the design of condensers and the amount of cooling that occurs is based more on economics. Cooling fluid can range from water at ambient temperature to brine, which can be cooled to temperatures approaching or below the freezing point of pure water, to a low-temperature refrigerant. The lower the temperature of the cooling liquid, the more expensive the system becomes. In some applications, the condensing system is staged so that certain condensables that may be present in the stream, i.e., water, will be condensed out at a higher temperature, and the remainder of the gas can be cooled further to condense out lower boiling point materials without the problem of ice formation.

A second consideration when appreciable water vapor is present in the gas stream is whether the water will combine with the condensable material to form a low-boiling azeotrope. In such a situation, the saturation temperature of the azeotrope is lower than the condensing temperature of either pure compound and the system must be designed accordingly.

4.1.2 Vent Condensers

4.1.2.1 Reactor Vent Condensers. The most common application of condensers in resin manufacturing is the use of the simple shell-and-tube heat exchanger to control batch reactor

vents. Epichlorohydrin cross-linked non-nylon polyamide (wet strength) resins (WSR) are manufactured in batch reactors. Emissions of HAP's can occur from all reactor processing and transfer steps, including charging, reaction, discharging, and cleaning.

In the production of epichlorohydrin non-nylon polyamides and many small specialty resins, condensers are typically the only equipment that control HAP emissions from batch reactors. In many cases, however, the condensers serve primarily as process equipment and not control devices. Only during non-reflux conditions do the condensers function as control devices. In these non-reflux cases, the control efficiency of the condensers is often greatly increased with the substitution of refrigerant or brine for cooling water. Estimation of the expected control efficiency of a condenser is, especially for single-component systems, easier than the verification of other control technology efficiencies, such as carbon adsorption, gas absorption, incineration, etc., as these technologies require that the outlet gas pollutant concentrations be measured. To estimate condenser efficiency, the outlet gas temperature is the only value that must be known in addition to the inlet conditions. By assuming that the vapor phase of the material is in equilibrium with the liquid at condenser outlet temperature, the percent by volume HAP discharged from the condenser may be calculated by dividing its partial pressure by the total pressure.

4.1.2.2 Potential HAP Emissions Using Condensers. Listed below are some of the HAP's typically found in polymer and resin batch reactors and distillation columns and the percent by volume of a saturated gas stream at various temperatures.

	volume percent at 40°C	% volume percent at 20°C	% volume percent at 5°C
Methanol	35.4%	12.5%	5.3%
Epichlorohydrin	4.8	1.7	0.6

The percent volumes were calculated by dividing the vapor pressure by the total system pressure (atmospheric, in this

example). If a gas stream saturated in methanol enters the condenser at 40°C and atmospheric pressure, the volume percent methanol would be 35.4 percent. Cooling the stream to 20°C reduces the concentration of methanol to 12.5 percent, a reduction of 65 percent. However, dropping the temperature to 5°C would reduce the concentration to 5 percent (a reduction of 85 percent). This shows that using a colder condenser is more effective than just cooling to ambient temperature. This information also points out that different HAP's need to be cooled to different temperatures to achieve equivalent efficiencies. For example, a gas stream saturated with epichlorohydrin needs only to be cooled to 40°C to achieve the same HAP concentration as a stream saturated with methanol at 5°C.

4.1.3 <u>Application to these Source Categories</u>

Currently, the majority of facilities that manufacture WSR use vent condensers to control vapor displacement and heat up emissions in their batch reactors. Additionally, two applications for condensers exist in DGFBPA manufacturing: (1) a refrigerated condenser used to recover process vent and storage losses prior to flaring, and (2) a vent condenser to control displacement emissions for a feedstock mixing stage. This section presents information on existing condenser applications and on potential applications in these source categories.

4.1.3.1 <u>Existing Applications</u>.

4.1.3.1.1 <u>WSR</u>. Currently, seven of the seventeen facilities that manufacture WSR make use of a reactor vent condenser to control both displacement emissions and reactor heat-up emissions. All these vent condensers are operated with cooling water, which was assumed for the purposes of estimating baseline emissions to cool the gas streams to 20°C. Efficiencies for the various facility applications vary, depending on what temperature the displacement occur, on the temperature range for the reactor heat up emissions, and on what HAP's are being emitted during the emission events. For displacements, data indicate that material is fed into the reactors at approximately

45°C. Therefore, for EPI, cooling the displacement streams to 20°C result in efficiencies of 72 percent. During the exothermic reaction, the reactor temperatures range from the incoming 45° to 70°C. A control efficiency of 84 percent was estimated for a cooling water condenser, based on the net reduction from the average EPI concentration in the temperature range. It should be noted that in certain instances where methanol is formed as a by-product of the pre-polymer manufacturing process, the reactor vent condenser is used as a reflux condenser to condense the methanol distillate.

4.1.3.1.2 BLR. Currently one facility makes use of a refrigerated condenser to recover HAP compounds from a manifold of sources that include all process and storage tank vents. The plant reports that the practical temperature limit of the gas stream existing this condenser is at -8°C, due to icing. A recovery efficiency of approximately 70 percent was reported for this situation. Also, one BLR manufacturer reports the use of a cooling water condenser to control displacement emissions of EPI from a pre-mix stage. However, the temperature of the material in the pre-mix stage is also at ambient temperature (assumed to be 20°C). No control efficiency was therefore assigned to this situation.

4.1.3.2 Potential Applications.

4.1.3.2.1 WSR. Often, weigh tank displacements or methanol distillate receivers could have vapor return lines back to the batch reactors. The condensers serving the reactors would then also have some effect on emissions from these sources.

4.1.3.2.2 BLR. Emissions from the resin purification and finishing stages tend to be saturated with EPI at elevated temperatures of 60°C or more, making them ideal candidates for control using refrigeration.

4.1.3.3 Refrigeration Systems for Vapor Displacement from Process Vessels or Storage Tanks. In some situations, shell-and-tube condensers are used to control HAP emissions from vapor displacement from process vessels or storage tanks. Such applications are usually for solvent or product recovery

purposes, since it is often desirable to recover material that would otherwise be emitted as a HAP. This is especially true for products that require expensive feedstocks and solvents.

Vapor recovery systems are often designed so that the recovered material cost offsets the energy and capital costs of the systems themselves. In many cases, however, the recovered material cost is insignificant compared to the cost of purchasing and operating the recovery systems. In such a case, the decision to install a solvent recovery system as opposed to another type of system is based on other factors, such as control effectiveness and concerns about waste handling and ultimate disposal of the HAP.

While refrigeration systems are not often used solely to control single vapor displacement events such as reactor charging and extractor (mixer-settler) charging, they are often feasible for controlling collected displaced vapors from a number of sources.

It has been shown that facilities that have a large number of storage tanks, for example, can use staged refrigeration systems which employ pre-cooler sections. Often, the precooler operates at a temperature just above the freezing point of water. This condenser (usually an indirect shell and tube heat exchanger) rids the vapor stream of as much water as possible that would otherwise collect on heat transfer surfaces as ice and lower the heat transfer potential of colder surfaces. After the vapor passes through the initial indirect condenser (pre-cooler), it enters the main condenser section, which can cool the gas stream to very low temperatures, on the order of -100°F.

Low-temperature refrigeration systems such as the one described above have been used to control vapor displacement emissions from multiple sources such as working losses from a tank farm. Often, the mixtures are separated by distillation although only one or two pure components may be recovered for reuse.

Perhaps the most important issue to consider when evaluating the need for such a system is the required size of the unit. For

a number of storage tanks or for a number of process vents from one manufacturing area, the system is most effective when it can control the stream having the maximum vapor concentration at a constant flow rate. Maintaining a constant vapor loading rate is crucial to efficient operation of the condenser. Consider a condenser which has been sized to control displacement emissions from the loading of a storage tank. At any times other than loading, the flowrate through the condenser will be virtually zero. To avoid over-cooling the coolant during these times, the compressor must go into a bypass mode which results in inefficient use of the system.

To optimize the efficiency of the system, the displaced vapors or process vents of finite duration must be staggered or controlled so that the system receives a fairly constant vapor inlet loading. The use of this system for process vents from batch processes is more difficult than for processes that have continuous emissions with constant properties. No examples in this industry have been found where multiple process or storage tank vents are routed to a refrigeration system.

4.1.3.4 <u>Combination Vapor Compression and Condensation</u>. In some situations, condensation is aided by compressing the gas stream containing VOC's to some elevated pressure in conjunction with the use of a condenser. The purpose of this compression step is to condense out the same amount of material at a higher condenser operating temperature. For example, consider the simple calculation used to estimate the vapor phase mole fraction of the HAP:

$$Y_{HAP} = \frac{P_{HAP}}{P_{TOTAL}}$$

(4-3)

A low value of Y_{HAP} is desired at the outlet of the condenser. This can be achieved by reducing the vapor pressure of the HAP (by lowering the gas temperature), by increasing the total pressure of the system, or by a combination of both.

Most applications that use a combination vapor compression-condensation system use liquid ring compressors with

4-11

recirculating ring fluid. These compressors are available for numerous ranges of flowrates and discharge pressures. Currently, no facilities in this source category use such systems for control of HAP's.

4.2 SCRUBBERS

4.2.1 General Gas Absorbers

Scrubbers, or gas absorbers, function by providing an intimate contacting environment for a gas stream containing material that is soluble in the contacting liquid. The rate of mass transfer from the gas to the liquid depends upon a driving force related to the actual HAP concentrations in the gas and liquid versus the equilibrium-defined HAP concentration in the two media at each point along the contacting path. The most common types of scrubbers found in polymer and resin industries are packed towers and spray chambers.

4.2.1.1 Liquid Gas Absorbers or Water Scrubbers. Gas absorbers are limited primarily by the solubility of the vapor in the liquid stream. Most of the scrubbers found in industry use water as the scrubbing medium, so the decision to use these devices depends largely on the solubility of the HAP's in water. In general, compounds containing nitrogen or oxygen atoms that are free to form strong hydrogen bonds, and having one to three carbon atoms are soluble; those compounds with four or five carbons are slightly soluble; and those with six carbon atoms or more are insoluble.[2] While common solvents such as methanol, isopropyl alcohol and acetone are very soluble in water, solvents like toluene and epichlorohydrin are not. However, many non-nylon polyamide producers and large producers of BLR report control of epichlorohydrin process emissions with water scrubbers.

4.2.1.2 Chemical Scrubbers. Some facilities use chemical scrubbers to control some pollutants. Instead of using a liquid medium to absorb material out of the gas phase, chemical scrubbers use the liquid medium to react with material in the gas phase. The hydrolysis of EPI is an example of a mechanism occurring in a chemical scrubber. Another good example is an

emergency destruction scrubber for a compound such as phosgene ($COCl_2$). Phosgene, when reacted with slightly basic water, hydrolyzes to HCl and CO_2. Although these product gases still require control, their toxicities are much lower than that of the initial reactant. Chemical scrubbers are often used as emergency back-up devices.

4.2.2 Design

The design of a scrubber involves the estimation of the ratio of gas-to-liquid mass flow rates and the appropriate amount of contacting area necessary to achieve the desired removal. A necessary piece of information, which can be difficult to obtain without experimental work, is the equilibrium curve depicting equilibrium mole fractions of the HAP in the solvent in the vapor and liquid phases at the contacting temperature. The equilibrium curve, as the name implies, is not a straight line, but approximations may be used and the curve may be assumed to be straight in some situations. For water scrubbers, the Henry's law constant at the water temperature is often used to define the slope of the equilibrium curve.

The estimation of the physical properties of a scrubber design, such as the number of transfer units (N_{OG}) and the height of a transfer unit (H_{OG}) for a packed tower, may be based on the reported removal efficiency of a system and the reported liquid-to-gas mass velocities. The EPA publication EPA-450/3-80-027, Organic Chemical Manufacturing Volume 5: Adsorption, Condensation, and Absorption Devices, December 1980, contains the methodology that can be used to estimate such parameters.[3] Note that verifying the efficiency of a scrubber without using test data is more difficult than verifying the efficiency of a condenser since there are more variables to consider and the equilibrium data at the required temperature are not always available. It is perhaps for this reason that unrealistically high water scrubber efficiencies may sometimes be reported.

4.2.3 Scrubber Applications

4.2.3.1 WSR. Six of the seventeen WSR facilities use water scrubbers to control reactor vent emissions. Reported control efficiency for these devices are high, at 99 percent or better. However, an overall control of 71 percent for EPI was assigned to these devices for purposes of estimating controlled (baseline) emissions to account for the fraction of EPI that will volatilize out of the wastewater during treatment.

4.2.3.2 BLR. Scrubbers are commonly used by facilities in the BLR source category to control process vent emissions containing multiple HAP's. Some producers of BLR use water scrubbers and claim control efficiencies of 98 percent or better for HAP's from process vents from resin finishing and purification stages containing epichlorohydrin. If the scrubber effluent is sent directly to wastewater treatment, the overall control efficiency for HAP's can be below 98 percent, however, since some fraction of HAP's is expected to volatilize out of the wastewater. However, specific information on facility bio-treatment units were reported from the three BLR facilities. This data, when inputted to the EPA's WATER7 model, yielded estimated destruction efficiencies ranging from 93 to 99 percent. Therefore, overall removal efficiencies from scrubbers were still estimated to be high for the BLR facilities. Additionally, one of the BLR manufacturer recycles scrubber effluent directly to the process, eliminating the majority of volatilization emissions. In this case, the scrubber effluent is used as extractor water makeup.

Based on information submitted in Section 114 responses, there are questions relating to the concentration of EPI in the scrubber effluent, which often does not agree with the amount of EPI reportedly removed. It is possible that some EPI undergoes hydrolysis to HCl and CO_2 upon contact with the scrubber water; however, no test data is available to confirm either the scrubber efficiencies or to explain the potential fate of the EPI.

4.3 CARBON ADSORPTION

Carbon adsorbers function by capturing vapor that is present in a gas phase on the surface of granular activated carbon. Adsorbers can be of the fixed-bed design or fluidized-bed design. Fixed-bed adsorbers must be regenerated periodically to desorb the collected organics from the carbon. Fluidized-bed adsorbers are continuously regenerated. Most processes that use carbon adsorbers use the fixed-bed type. Some use nonregenerative units, which are contained in 55-gallon drums and are used mostly for controlling odor from small process vents. Such units are returned to their distributors for disposal after they can no longer adsorb effectively.

4.3.1 Design

Carbon adsorption is usually a batch operation involving two main steps, adsorption and regeneration. This system usually includes multiple beds so that at least one bed is adsorbing while at least one other bed is being regenerated, thereby ensuring that emissions will be continually controlled. A blower is commonly used to force the HAP-laden gas stream through the fixed carbon bed. The cleaned gas is then exhausted to the atmosphere. A gradual increase in the concentration of organics in the exhausted gas from its baseline effluent concentration level signals it is time for regeneration. The bed is shut off and the waste gas is routed to another bed. Low-pressure steam is normally used to heat the carbon bed during regeneration, driving off the adsorbed organics, which are usually recovered by condensing the vapors and separating them from the steam condensate by decantation or distillation. After regeneration, the carbon bed is cooled and dried to improve adsorption. The adsorption/regeneration cycle can be repeated numerous times, but eventually the carbon loses its adsorption activity and must be replaced. Typically, facilities replace a portion of the carbon bed on an annual basis.

The efficiency of an adsorption unit depends on the type of activated carbon used, the characteristics of the HAP, the HAP concentration, and the system temperature, pressure, and

humidity. Overall HAP removal efficiencies depend on the completeness of regeneration, the depth of the carbon bed, the time allowed for contact, and the effectiveness of recovery of desorbed organics. Carbon adsorption is not suitable for gas streams with a high concentration of organics, with organics with boiling points greater than 250°C or molecular weights greater than 200, with relative humidities greater than 50 percent, with high levels of entrained solids, or with temperatures over 100°F. Adsorbing organics from gas streams with high concentrations of organics may result in excessive temperature rise in the bed due to the accumulated heat of adsorption; this can be a serious safety problem due to the risk of a bed fire. High molecular weight organics and organics with high boiling points are difficult to remove from the carbon under normal regeneration temperatures. The continuing buildup of these compounds on the carbon will greatly decrease the operating capacity and will result in frequent replacement of the carbon. Plasticizer or resins should also be prevented from entering the carbon bed, since they may react chemically on the carbon to form a solid that cannot be removed during regeneration.

Entrained solids in the gas stream may cause the carbon bed to plug over a period of time. These solids are generally controlled by a cloth or fiberglass filter.

Gas streams with high relative humidities will affect the adsorption capacity of the bed. Humidity control can be achieved by cooling and condensing the water vapor in the gas stream. The relative humidity can also be decreased by adding dry dilution air to the system, but this will usually increase the size and thus the cost of the adsorber required.

The adsorption capacity of the carbon and the effluent concentration of the adsorber are directly related to the temperature of the inlet stream to the adsorber. Normally, the temperature of the inlet stream should be below 100°F or the adsorption capacity will be affected. Inlet stream coolers are usually required when emission stream temperatures are in excess of 100°F.

When designing and installing carbon bed adsorber systems there are several safety factors that need to be considered. Fixed carbon beds can spontaneously combust whenever the gas stream contains oxygen and compounds easily oxidized in the presence of carbon, such as ketones, aldehydes, and organic acids. Heat generated by adsorption or by oxidation of organics in the bed is usually transported from the bed by convection. If less convection heat is removed than is generated, the bed temperature will rise. Higher temperatures will further increase the oxidation decomposition, and hot spots exceeding the autoignition temperature of the carbon may develop in the bed. If an adsorber is shut down for an extended period and not regenerated sufficiently upon startup, reintroduction of the organic-laden stream may also lead to bed combustion. There are preventive measures that can be taken to ensure safe operation of carbon adsorbers. Using adequate cooling systems, regularly inspecting valves to prevent steam leaks, and using adsorbers only on low concentration streams all will ensure safe operation. In addition, beds used for adsorbing ketones should not be dried completely after regeneration. Although not drying them may reduce adsorption capacity somewhat, it is an effective safety measure because the water acts as a heat sink to dissipate the heat of adsorption and oxidation.

Carbon adsorption systems normally are designed for gas velocities between 80 and 100 ft/min.[4] The maximum rate of recovery of organics is dependent upon the amount of carbon provided and the depth of the bed needed to provide an adequate transfer zone. The required amount of carbon may be estimated from an adsorption isotherm, which is generally available for different compounds at various partial pressures.

4.3.2 Applicability

Carbon adsorbers have a limited and varied use in the BLR industry. Emissions from reactor vents and storage tanks are known to be controlled by carbon bed adsorbers at one facility.

In one application, the adsorber is preceded by a condenser on a process vent. Since condensers are more efficient on

4-17

saturated streams and carbon bed adsorbers are more efficient on dilute streams, a condenser followed by a carbon bed adsorber may be an effective control system. Test data from one source indicated a 97 percent efficiency for removal of epichlorohydrin from a waste stream controlled with this system.

Nonregenerative carbon adsorbers are also used in this industry to control emission from storage tanks or to control displacement emissions from small reactors. These systems are extremely simple in design. When the activated carbon becomes spent, it is replaced with a new charge. The spent carbon can be reactivated offsite and eventually re-used. Carbon canisters, normally the size of 55-gallon drums, can be used to control small vent streams (less that 500 actual cubic feet per minute [acfm]) with low organic concentrations. One advantage of these systems is that they appear to be immune to normal fluctuations in gas streams that are common to batch processes.

For all practical purposes, it is difficult to estimate the efficiency of a carbon adsorption system. Although EPA has generally accepted a control efficiency of 95 percent for streams containing compounds that are considered appropriate for adsorption, the actual control efficiency attained by a particular system is largely dependent upon the amount of time elapsed and the amount of material adsorbed since the last regeneration or replacement. Note also that it is more difficult to predict the amount of material that has been adsorbed for the intermittent streams with variable characteristics typical of batch processes than for continuous emission streams with constant properties.

As mentioned previously, most applications of carbon adsorbers are as secondary control devices following condensers. Because of the highly flammable nature of many solvents, the industry trend is away from using these devices as primary control devices.

One issue that has been raised with regard to batch processing emissions in particular is the possibility of stripping VOC out of the activated carbon and back into the

emission stream during low concentration-high flowrate periods.
For example, consider a batch vent stream from a reactor entering
a carbon bed. During a processing event such as material
charging at elevated temperatures, volatile compounds will be
sorbed onto the surfaces of the activated carbon. During reactor
purge, however, a high flowrate, low VOC concentration will be
introduced into the bed that may strip volatile materials back
out of the bed and into the exit gas stream.

4.4 THERMAL DESTRUCTION

It is usually possible to route process vents to an
incinerator or flare for control. In most cases, these devices
also are not sized for peak concentrations of HAP's, but for
constant flow and concentration of HAP's. Incineration systems
are usually quite costly and must operate continuously; therefore
the use of such a system is limited to those applications where a
number of vents may be controlled. Note also that the byproduct
combustion gases in most cases must also be controlled, thereby
increasing costs.

4.4.1 Flares

Flaring is an open combustion process that destroys HAP
emissions with a high temperature oxidation flame to produce
carbon dioxide and water. Good combustion in a flare is governed
by flame temperature, residence time of components in the
combustion zone and turbulent mixing of components to complete
the oxidation reaction.

4.4.1.1 Design. There are two major types of flares:
elevated flares and ground flares.

The elevated flare is a single burner tip elevated above
ground level for safety reasons. The vented gases are burned in
the diffusion flame. The gas stream containing a HAP enters at
the base of the flame, where it is heated by already-burning fuel
and the pilot burner at the flare tip. Fuel flows into the
combustion zone, where the exterior of the microscopic gas pocket
is oxidized. The rate of reaction is limited by the mixing of
the fuel and oxygen from the air. If the gas pocket has
sufficient oxygen and residence time in the flame zone, it can be

completely burned. The diffusion flame receives its combustion oxygen by diffusion of air into the flame from the surrounding atmosphere. The high volume of fuel flow in an elevated flare requires more combustion air at a faster rate than simple gas diffusion can supply, so steam is injected to increase gas turbulence in the flame boundary zones, drawing in more combustion air and improving combustion efficiency. The steam injection promotes smokeless flare operation by minimizing the cracking reactions that form carbon. Steam flow can be controlled manually, but automatic control by sensors monitoring flame characteristics gives a faster response to the need for steam and a better adjustment of the quantity required.

Ground flares have multiple-gas-burning heads that are grouped in an enclosure and are staged to operate based on vent gas flow to the flare. The enclosure reduces the luminosity, noise, and allows the flare to be located at ground level. The size, design, number, and arrangement of the burner heads depend on the flare gas characteristics. Unlike elevated flares, an exterior source of steam or air to enhance combustion is rarely required for ground flares. Stable combustion can be obtained with some gases that have heat contents as low as 50 to 60 Btu/ft. Reliable and efficient operation can be attained at up to 100 percent of design capacity. The number of burner heads and their arrangement into groups for staged operations depend on the discharge characteristics of the emission source gas. To ensure reliable ignition, pilot burners with ignitors are provided. The burners are enclosed in an internally insulated shell and must be high enough to create enough draft to supply sufficient air for smokeless combustion of the waste gas for dispersion of the thermal plume.[5]

4.4.1.2 <u>Applicability</u>. Although flares are not as widely used for controlling emissions from batch resin processes as other control devices, they are adjustable and can be useful for these processes. In many cases, however, they require a considerable amount of auxiliary fuel to combust gases that contain dilute concentrations of organics or organics that have

low heats of combustion. Flares are capable of handling the highly variable flows that are often associated with batch process operations. Steam-assisted elevated flares may be used to control emission from high-concentration, intermittent vent streams. Elevated flares are used to control emissions during emergency venting or during process upsets, such as startup and shutdown. These intermittent emissions are characteristic of normal batch process operations with the exception that they may be more concentrated than normal batch emissions. Ground flares have less capacity than elevated flares and are usually used to burn gas continuously. Ground flares can operate efficiently at up to 100 percent of design capacity. The burner heads can also be specifically sized and designed for the materials in the flare gas.

One of the BLR manufacturers surveyed reports the use of a flare for emission control from a plant manifold. It is used to incinerate a mixture of toluene, epichlorohydrin, ethylene oxide, and propylene oxide vapors which are emitted from several streams, of which the BLR process and storage emission streams are a part of. The reported destruction efficiency is 98 percent, although the flare does create significant amounts of HCl. An overall control efficiency of 60 percent was assigned to this device to account for a net HAP reduction.

4.4.2 Thermal and Catalytic Oxidizers

Thermal and catalytic oxidizers may be used to control emission streams of VOC's and HAP's, although they are not especially suited for intermittent or noncontinuous flows, especially on an economic basis. Because they operate continuously, auxiliary fuel must be used to maintain combustion during episodes in which the organic HAP load is below design conditions. For groups of sources, however, the use of devices may be reasonable.

4.4.2.1 Design. The design and operation of incinerators is most influenced by the necessary combustion temperature, residence time and desired destruction efficiency. Most incinerators are capable of achieving better than 90 percent

control efficiency. Catalytic incinerators, which operate at low temperatures compared to thermal oxidizers (500° to 1000°F as opposed to >1000°F) generally achieve from 90 to 95 percent destruction, while thermal oxidizers usually achieve at least 98 percent. The destruction efficiency of a thermal oxidizer can be affected by variations in chamber temperature, residence time, inlet HAP concentration, compound type, and flow regime (mixing). Test results show that thermal oxidizers can achieve 98 percent destruction efficiency for most VOC compounds at combustion chamber temperatures ranging from 700° to 1300°C (1400° to 2374°F) and residence times of 0.5 to 1.5 seconds. These data indicate that significant variations in destruction efficiency occurred for C_1 to C_5 alkanes and olefins, aromatics (benzene, toluene, and xylene), oxygenated compounds (methyl ethyl ketone and isopropanol), chlorinated organics (vinyl chloride), and nitrogen-containing species (acrylonitrile and ethylamines) at chamber temperatures below 760°C (1400°F).[6] This information, used in conjunction with kinetics calculations, indicates the combustion chamber parameters for achieving at least a 98 percent destruction efficiency are a combustion temperature of 870°C (1600°F) and a residence time of 0.75 seconds (based upon residence in the chamber volume at combustion temperature). Thermal oxidizers generally can burn contaminated streams (i.e., streams that could poison catalyst in a catalytic incinerator) but may need to achieve combustion temperatures approaching 2000°F to effectively oxidize such compounds as halogenated solvents. Incinerators usually operate with excess air to ensure sufficient combustion. These devices also contain refractory linings that cannot withstand sudden warmup or cooldown periods.[7]

4.4.2.2 <u>Specific Applications</u>. Incinerators often are used to control multiple process vents that can be manifolded together. For example, processes that are contained within one building or processing area are sometimes vented together and routed to an incinerator. For some of these vents, a primary control device such as a condenser is located upstream. Note

that the stack gases resulting from combustion often contain acid such as HCl and may require an exhaust gas control device such as a caustic scrubber.

There are also some incineration units that can handle low flow rates (in the range of 10 to 500 scfm). These units can be applied to single emission streams, such as reactor vent emissions.[8]

The use of thermal and catalytic incinerators in the industry is limited. One manufacturer of WSR controls EPI emissions from reactor and storage tank vents by piping them to a manifold system with vents from other processes and sending it all to a common catalytic incinerator. This manufacturer reports a destruction efficiency of 99 percent with minimal acid gas generation.

4.5 OTHER CONTROL MEASURES

4.5.1 Vapor Containment

Vapor containment is only a control when in conjunction with a control device. It is discussed below because some of the facilities in the source category report more efficient results when these systems are used prior to existing control devices.

Probably one of the less expensive and more effective methods of controlling displaced vapors from such events as vessel charging and from storage tank working losses is to use vapor return lines to vent the vapors back to the vessel from which the liquid was originally taken. Assuming that emissions from this vessel ultimately are controlled, essentially 100 percent control of the vapors at the point sources is achieved, and there do not appear to be many adverse effects from the standpoint of safety or convenience.

The use of vapor return lines to control displacement emissions from storage tanks is fairly common in this source category. As displacement events are one of the major sources of HAP emissions, this control method has the potential to make a significant reduction in the overall emission rate.

4.5.1.1 Variable Volume Containment Devices. The use of a variable volume vessel capable of containing process vents and

continuously releasing an exhaust with constant stream properties of flowrate and HAP concentration to a control device also is a method of vapor containment. One of the BLR facilities uses an expandable vapor containment device to capture various emission streams from process and storage vents resulting from other resin processes. The exhaust from the breather balloon is routed to a control device. Presumably, the advantage to using such a containment system would be to minimize the fluctuation in emission stream characteristics that might normally occur in a manifold of vents. A disadvantage to this system is that it could be an explosive hazard.

4.5.2 Operational Practices

4.5.2.1 Limiting the Use of Inert Gas. Many applications in batch resin manufacturing require the use of inert gas for blanketing and purging of equipment for safety purposes. By eliminating purging of reactor vessel headspaces, HAP emission have been shown to decrease significantly in the WSR industry. At one facility, process emissions changed from 55,000 lb/yr EPI to 2,350 lb/yr by eliminating the nitrogen purge. There are also other practices, however, such as the blowing of lines to move material and the sparging of large volumes of liquids, that could be changed so as to reduce the amount of inert gases in the streams and thereby make the streams more suitable for control by devices such as condensers.

The blowing of lines with nitrogen to move material, for example, could be replaced by simple pumping and/or setting the lines on an incline. Blowing cannot be totally eliminated, however, because the vapor that may be contained in the vapor space in the lines may need to be purged at various times before maintenance. Reductions from these changes have not been quantified for the WSR industry.

4.5.2.2 Eliminating Direct Water-contacting Vacuum Generating Devices. The replacement of steam ejectors and vacuum pumps with vacuum generating devices that do not create an opportunity for contact of the vapor laden gas stream with seal fluid would also eliminate emissions from all wastewater

generated in WSR manufacturing and from significant portions of wastewater generated in BLR manufacturing. Recognizing that the control of HAP's with water may only "transfer" emissions to another source, the use of vacuum pumps, steam ejectors, and water scrubbers may become less viable for processing of HAP's.

4.5.3 Vacuum Loading

Vacuum loading of volatile material into process vessels such as WSR batch reactors will reduce emissions from displacement events in cases where there is no volatile residual material left in the reactor. Several facilities in the WSR source category report the use of vacuum loading as a means of limiting displacement emissions.

4.5.4 Process Changes

In WSR manufacturing, the replacement of dibasic ester with adipic acid in the initial polyamide manufacturing reaction will eliminate methanol emissions from the process. Likewise, the substitution of H_2SO_4 for HCl to halt crosslinking will eliminate HCl displacement and storage emissions. Another argument for substituting H_2SO_4 for HCl is that HCl converts any excess EPI to dichloropropenols, which are carried with the resin in aqueous solution. When base is added to activate the resin, the dichloropropenols would be converted to EPI in situ.[9] This appears to be a worker exposure concern, however.

4.6 LEAK DETECTION AND REPAIR (LDAR) AND PRESSURE TESTING PROGRAMS

Emissions of HAP's from process components such as pumps, valves, flanges, and sampling connections that happen to leak can be minimized by instituting a periodic leak detection and repair program (LDAR). Several types of LDAR programs exist; the New Source Performance Standards (NSPS) Subpart VV prescribes a quarterly monitoring program of pumps, valves, flanges, and connections. The leak definition is 10,000 ppmv. Alternatively, the Equipment Leaks Negotiated Regulation, "Reg Neg", prescribes a more stringent LDAR program.[10] A leak definition is 500 ppm, and the monitoring interval for components varies between quarterly and monthly monitoring. For batch

processes, the Reg Neg allows the substitution of pressure testing.

4.7 STORAGE TANK CONTROLS

Besides add-on controls such as refrigerated condensers and scrubbers, emissions from storage tanks (working and breathing losses) can be controlled with external and internal floating roofs. Tank sizes range from 30,000 to 200,000 gallons for BLR manufacturing, and 10,000 to 100,000 gallons in WSR manufacturing. Floating roofs are applicable to these sizes of tanks.

4.8 REFERENCES FOR CHAPTER 4

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5.0 MACT FLOORS, REGULATORY ALTERNATIVES, AND MODEL PLANTS

This chapter presents information on the current level of control of hazardous air pollutant (HAP) emissions from basic liquid resins (BLR) and wet-strength resin (WSR) manufacturing facilities and presents regulatory alternatives and associated emission reductions. Additionally, model plants were developed for both source categories to illustrate the processes typically employed by facilities located in each source category. Both source categories are small (there are three BLR facilities and 17 WSR facilities), therefore actual plant parameters were used to evaluate impacts for existing sources. Section 5-1 is a discussion of the current HAP control levels and the maximum achievable control technology (MACT) floors. Section 5-2 presents the proposed regulatory control alternatives for the industries. Section 5-3 comprises the discussion and presentation of the model plants.

5.1 MACT FLOORS

The Clean Air Act Amendments of 1990 state that HAP emission standards for existing sources cannot be less stringent than the average emission limitation achieved by either (1) the best performing 12 percent of existing sources or (2) the best performing 5 sources in the category or subcategory with fewer than 30 sources. For new sources in a category or subcategory, the amendments state that "the maximum degree of reduction in emissions that is deemed achievable for new sources in a category or subcategory shall not be less stringent than the emission control that is achieved in practice by the best controlled similar sources...." These statements define the MACT floors for existing and new sources.

According to the statute, MACT floors must be calculated for each "source". In this standard, we have chosen to define equipment leaks as a portion of the source separate from other emission points, such as process vents, storage, and wastewater volatilization emissions. Therefore, we have developed two MACT floors for each source category, one for combined emissions of process vents, storage, and wastewater, and one for equipment leaks.

The MACT floors for process vents, storage tanks, and wastewater portion of the source and the equipment leaks portion were developed for each source category in the following way:

1. For existing BLR production facilities, the pounds (lb) of HAP emitted for each portion of the source was divided by the actual BLR production rate of the facility to yield a value, in units of lb HAP emitted per million (MM) lb of product, that was then averaged across the three facilities to obtain the MACT floor. The MACT floor for new sources could not be based on lb HAP emitted per MMlb product because the MMlb product factor would correspond directly with an actual facility's value, and therefore the production rate, which is reported to be confidential in all cases, could be obtained. The MACT floor for new sources, therefore is currently set as a technology-based standard equivalent to the best performing existing source.

2. In WSR manufacturing, the MACT floor was calculated using the same method as was used in BLR. The five facilities with the lowest lb HAP emitted per MMlb product factors were averaged together and the resulting value was considered the MACT floor. As with BLR manufacturing, for new sources, the MACT floors are technology-based and equivalent to the best performing existing source.

Table 5-1 presents the MACT floors in tabular form for BLR and WSR, respectively. The development of MACT floors for both source categories is discussed in more detail below.

TABLE 5-1.   MACT FLOORS, lb HAP/MM product

Source category	Process vents, storage, wastewater	Equipment leaks	Total
1. BLR	130	570	700
2. WSR	10	120	130

5.1.1 BLR MACT Floors

The MACT floors for BLR plants were calculated based on information supplied by the three facilities that make up the source category. Currently, process vent and storage tank emissions are controlled by scrubbers at Dow and Shell, and a condenser and flare in series at Ciba-Geigy. Emission factors for individual facilities provide the rationale for the MACT floors but are considered confidential business information (CBI) and, as such, cannot be discussed in great detail in this chapter. Memoranda describing the development of the MACT floors are kept in the Emission Standard Division's CBI files. The discussion below provides a brief description of the methodology used for the estimation of the MACT floors.

Generally, process vent emissions and storage tank emissions were reported to be controlled using add-on devices (i.e., carbon adsorbers, condensers, scrubbers, etc.). In all cases, reported emission stream data was used to calculate the quantity of HAP emissions released at each facility from process and storage vents. Wastewater was assumed to have the potential to emit epichlorohydrin (EPI) in the wastewater collection and treatment system. The USEPA model WATER7 was used to estimate the level of emissions from wastewater at each of the three facilities.[1] Uncontrolled equipment leak emissions were estimated using Synthetic Organic Chemical Manufacturing Institute (SOCMI) average emission factors and by factoring typical control efficiencies of leak detection and repair (LDAR) programs.[2]

5.1.2 WSR MACT Floors

The MACT floors for the WSR plants were calculated based on data supplied by the nine facilities considered to be major sources in this source category. Process vents are generally the only emission points that are controlled by most plants, usually with scrubbers or condensers. Those facilities that are controlling emissions from process vents with scrubbers reported high control efficiencies for their devices. Because no specific information on wastewater collection and/or treatment was available, the revised wastewater enabling document was used to estimate the fraction of EPI in the scrubber liquor that is expected to volatilize from the effluent.[3] This fraction is estimated to be 29 percent. In several cases, facilities that are considered to be area sources have devices achieving the highest levels of HAP control for process vents and storage tanks in the industry. However, these efficiencies could not be factored into the MACT floors because they are associated with area sources. All storage tanks located at major sources are uncontrolled except one, which is controlled by a water scrubber. Equipment leak and wastewater emissions in the source category are not controlled by any facilities. Again, the equipment leak HAP emissions were estimated using the SOCMI average emission factors.[4]

5.2 REGULATORY ALTERNATIVES AND IMPACTS

The MACT floors, which approximate the best level of current control practices, can be perceived as the least stringent regulatory alternatives that might be chosen within the regulatory framework. Therefore, any control requirement imposed on these source categories will provide a level of control at least as stringent as the MACT floors. Beyond the MACT floors, regulatory alternatives were chosen to evaluate the costs and impacts associated with requiring increasing levels of stringency. These alternatives are discussed below for each source category.

5.2.1 BLR Regulatory Alternatives

The BLR manufacturing regulatory alternatives are presented below.

5.2.1.1 Existing Sources.

5.2.1.1.1 Process vents, storage, and wastewater. For process vent, storage, and wastewater emissions, one of the facilities currently will not meet the MACT floor of 130 lb HAP/MMlb production. The impacts associated with this facility implementing process changes to meet the MACT floor were calculated and are presented in Table 5-2. These costs and associated emission reductions are based on the replacement of a flare with a water scrubber and the treatment of the scrubber effluent at the facility's existing biological wastewater treatment system.

In order to establish a more stringent regulatory alternative than the MACT floor, the current level of control on all facilities was examined and areas where more control could be required were identified. Once the minimum MACT floor requirement was implemented, all three facilities were found to be achieving high levels of control; only one area was identified as a possible additional controlled emission point: the generation of HAP-containing scrubber effluent. The method used to control this wastewater was recirculation of scrubber effluent to the process. This measure reduced emissions down to a maximum of 125 lb HAP/MMlb production. Therefore, the regulatory alternative beyond the MACT floor corresponds to this mass emission limit.

5.2.1.1.2 Equipment leaks. For the equipment leaks portion of sources in BLR production, the MACT floor was calculated to be 570 lb HAP/MMlb production. Only one facility is below the MACT floor, and must reduce HAP emissions in order to reach the floor. This facility must comply by upgrading their current LDAR program to meet the level required by the equipment leaks negotiated regulation ("Reg Neg") as adopted from the Hazardous Organic NESHAP.

TABLE 5-2. IMPACTS OF MEETING MACT FLOORS AND REGULATORY ALTERNATIVES FOR BLR SOURCE CATEGORY

Portion of source	Uncontrolled HAP emissions, Mg/yr	Baseline emissions, Mg/yr	Emission reduction, Mg/yr	Capital costs, $/1,000	Annual costs, $	Cost effectiveness, $/Mg	Incremental cost effectiveness, $/Mg
1. Process vents, storage, and wastewater							
-- MACT floor	42	18	7	140	127,000	18,000	
-- Regulatory Option 1	42	18	9	149	139,000	15,400	5,200
2. Equipment leaks							
-- MACT floor	180	104	45	195	500	10	
-- Regulatory Option 1	180	104	88	270	13,000	150	300

One regulatory option above the MACT floor was developed for existing sources. This option requires all three facilities in the source category to meet the requirements of "Reg Neg" for equipment leaks. Table 5-2 also presents impacts for equipment leaks.

5.2.1.2 New Sources. New source MACT floor is the technology-based equivalent of the level of control achieved by the best performing source for process vents, tanks, and wastewater, and is the level of control required by "Reg Neg" for equipment leaks. This technology-based requirement will be to route all emission sources from the process and the storage tanks to a water scrubber achieving a 99 percent removal of HAP's. The scrubber effluent must then be recirculated to the process. Wastewater is also required to be controlled by 99 percent.

5.2.2 WSR Regulatory Alternatives

The WSR regulatory alternatives are presented below.

5.2.2.1 Existing Sources. For this source category as with the BLR source category, MACT floors were developed for the process vent, storage and wastewater portion of the source and for the equipment leak portion of the source. The MACT floor for process vents, storage, and wastewater was estimated to be 10 lb HAP/MMlb production, based on the average of the best performing five sources. The regulatory alternative beyond the floor was chosen as 5 lb HAP/MMlb protection for this source. As an alternative means of complying with the process vent, storage, and wastewater source MACT floor, facilities may choose to instead implement the requirements of the LDAR for equipment leaks. This alternative means of compliance has been suggested because the reductions and costs of implementation of the Reg Neg LDAR are in many cases much more reasonable than those incurred from requiring compliance with the process vent, storage, and wastewater regulatory alternatives, and the emissions reductions are much greater.

Since equipment leak emissions were calculated for each facility from a model component count and scaled on production, all sources are identical to and therefore meet the MACT floor of

5-7

120 lb HAP/MM product. The regulatory alternative above the MACT floor is 7 lb HAP/MMlb production, a level that corresponds to the level of control achieved by the Reg Neg LDAR program for a model component count and model system. The impacts estimated for facilities meeting the MACT floor and associated regulatory alternatives beyond the floors are presented in Table 5-3.

5.2.2.2 New Sources. The technology-based new source MACT floor will be equivalent to running the batch reactor with a water-cooled condenser (operating at 25°C) and to not generate methanol or use HCl or any other HAP to quench the cross-linking reaction. As with existing sources, an alternative means of compliance with the new source MACT floor for process vents, storage, and wastewater, facilities will be the implementation of a Reg Neg LDAR program.

5.3 MODEL PLANTS

Model plants have been developed for both BLR production and WSR production. Because much of the information related to the BLR manufacturing process has been claimed to be CBI, the model plant for BLR manufacturing serves to illustrate the process and the emission sources typical in BLR manufacturing. The model plant for WSR serves not only to show the process typically found in this source category, but also provides the model component counts used to calculate impacts of implementing Reg Neg LDAR. Model plants are described in Appendix G.

5.4 REFERENCES

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2. Internal Instruction Manual for ESD Regulation Development. Leaking Equipment--Pumps, Valves, Connectors, Compressors, Safety Relief Valves. July 1992.

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4. Reference 2.

TABLE 5-3. IMPACTS OF MEETING MACT FLOORS AND REGULATORY ALTERNATIVES FOR WSR SOURCE CATEGORY

Portion of source	Uncontrolled HAP emissions, Mg/yr	Baseline emissions, Mg/yr	Emission reduction, Mg/yr	Capital costs, $/1,000	Annual costs, $	Cost effectiveness, $/Mg	Incremental cost effectiveness, $/Mg
Process vents, storage, and wastewater							
1. MACT floor	8	4	2	510	520	210,000	
2. Regulatory Option 1	8	4	3	670	740	242,000	355,000
Equipment leaks							
1. MACT floor	23	23	0	0	0	0	
2, Regulatory Option 1	23	23	14	138	52	3,700	3,700

6.0 ENERGY AND ENVIRONMENTAL IMPACTS

The energy and environmental impacts associated with applying maximum achievable control technology (MACT) to HAP emission sources from basic liquid resins (BLR) and wet strength resin (WSR) manufacturing are presented in this chapter. Details of the options selected for each source category are presented in Chapter 6.

This analysis includes the national energy burden of operating the control devices used to meet various regulatory options for process vents, storage, and wastewater. Note that no energy and environmental impacts are associated with equipment leaks regulatory options. Solid waste and wastewater impacts were also evlauated because of the use of a scrubber for one of the regulatory options.

6.1 ENERGY IMPACTS

Table 6-1 presents the energy impacts for each of the process vents, storage, and wastewater regulatory options. The energy burden was estimated by calculating the electricity requirement for refrigerated condensers for WSR manufacturing, and the electricity requirement for pumps associated with water scrubbers for BLR manufacturing.

6.2 AIR QUALITY IMPACTS

No adverse air quality impacts are anticipated due to the use of the control devices examined for this NESHAP. Therefore, no air quality impacts were estimated.

6.3 SOLID WASTE AND WASTEWATER IMPACTS

Wastewater will be produced from the use of a water scrubber used for one of the regulatory options. Table 6-2 presents the wastewater impacts associated with the options.

TABLE 6-1. ENERGY IMPACTS

Source Category: BLR Manufacturing

Portion of source	Uncontrolled emissions, Mg/yr	Baseline emissions, Mg/yr	Emission reduction, Mg/yr	Energy burden, 10^6 Btu/yr
Process vents, storage, and wastewater				
-- MACT floor	42	18	7	1.5
-- Regulatory				
Option 1	42	18	9	1.5

Source Category: WSR Manufacturing

Portion of source	Uncontrolled emissions, Mg/yr	Baseline emissions, Mg/yr	Emission reduction, Mg/yr	Energy burden, 10^6 Btu/yr
Process vents, storage, and wastewater				
-- MACT floor	8	4	2	4
-- Regulatory				
Option 1	8	4	3	9

TABLE 6-2. SOLID WASTE AND WASTEWATER IMPACTS

Source Category: BLR Manufacturing

Portion of source	Uncontrolled emissions, Mg/yr	Baseline emissions, Mg/yr	Emission reduction, Mg/yr	Wastewater generated, GPY
Process vents, storage, and wastewater				
-- MACT floor	42	18	7	3,200,000
-- Regulatory Option 1	42	18	9	0[a]

[a]No wastewater will be generated this option because the scrubber liquor will be recycled back to the process.

Source Category: WSR Manufacturing

   NONE

7.0 COSTS

This chapter presents cost estimates for the application of regulatory alternatives selected for the source categories included in the Polymers and Resins II national emission standards for hazardous air pollutants (NESHAP). Control device models, assumptions, and documentation used in the development of the costs are explained in detail. Additionally, the nationwide impacts of implementing various regulatory alternatives are contained in this chapter. The costs for the application of control technologies to process vents (i.e., condensation and gas absorption) and equipment leaks are presented in Sections 7.1 and 7.2. Section 7.3 contains a summary of all analyses, and Appendix H contains the tabular costs for compliance with all the regulatory alternatives. Finally, Section 7-4 lists the references cited in this chapter.

7.1 CONTROL TECHNOLOGIES EXAMINED FOR PROCESS VENTS

Two technologies, condensation and gas absorption, were examined for controlling hazardous air pollutant (HAP) emissions from process vents in basic liquid resins (BLR) and wet strength resin (WSR) manufacturing. Documentation of the cost models for each control device, including parameters necessary for sizing the device, capital and annual costs, and any assumptions made during the development of the models, is included in this section. Sections 7.1.1 and 7.1.2 include documentation of each of the control device cost models, Section 7.1.3 contains the costs for auxiliary equipment, and Section 7.1.4 explains the process modifications available for WSR manufacturers.

7.1.1 Condenser Cost Model

Condensing HAP's was considered as a method of control for WSR production. This section explains the cost model used to develop the costs for meeting the MACT floor and regulatory alternatives using condensation. The parameters necessary for sizing the condenser, and the capital and annual costs are included in the following sections. Also, any assumptions made during the development of the cost model are included. The cost methodology presented below was taken from the OAQPS Control Cost Manual.[1]

7.1.1.1 Parameters Necessary for Sizing the Condenser. This section details the development of parameters necessary to size a condenser, including the volume fraction of HAP entering the condenser, required condenser control efficiency, noncondensables present in the emission stream, condenser heat load during events and nonevents, inlet and outlet flowrates, and required refrigeration. The development of each parameter is described below.

Volume fraction of HAP entering the condenser. All of the emission streams that were evaluated for control with condensation systems were saturated. Therefore, the volume fraction of HAP's in the inlet gas stream were estimated assuming saturation at equilibrium conditions.

Volume fraction of HAP at condenser outlet. The volume fraction of HAP at the condenser outlet is estimated using the following equation:

$$HAP_{vff} = [(1 - CE)(HAP_{vf})]/(1 - HAP_{vf} * CE)$$

where:

HAP_{vff} = Volume fraction of HAP at the exit of the condenser;

CE = Control efficiency; and

HAP_{vf} = Volume fraction of HAP at the inlet of the condenser.

Uncontrolled and Controlled emissions. The ideal gas law is used to estimate emissions on a per unit time basis as follows:

$$lb/min = (PV/RT) * HAP * MW_{HAP}$$

where:

P = pressure of emission stream at the inlet of the condenser, mmHg;

V = volumetric flowrate of emission stream, acfm;

R = gas constant, 998.97 mmHg ft^3/lbmol K;

T = temperature of emission stream at the inlet of the condenser, K;

MW_{HAP} = molecular weight of the HAP; and

HAP = HAP_{vf} (volume fraction at condenser inlet or HAP_{vff} (volume fraction at condenser outlet).

<u>Condenser exit flowrate</u>. The condenser exit flowrate is calculated by taking the inlet gas flowrate (acfm) and multiplying by the ratio of the volume fraction of noncondensables at the inlet and outlet of the condenser. This value is corrected for standard temperature and pressure at the condenser outlet. The equation is given below.

$$Exit\ FR = FR_i * (noncond._{vfi}/noncond._{vff}) * (T_f/T_i) * (P_i/P_f)$$

where:

FR_i = inlet flowrate (acfm);

$noncond._{vfi}$ = noncondensable volume fraction at the inlet of the condenser; and

$noncond._{vff}$ = noncondensable volume fraction at the outlet of the condenser.

<u>Condenser heat load during events</u>. The condenser heat load consists of sensible and latent heat, which account for the heat given off by the gas stream as it passes through to the condenser and is cooled to the condenser outlet temperature. The heat load is broken down into three parts: (1) sensible and latent heat of condensables that were condensed, (2) sensible heat of condensables that were not condensed, and (3) sensible heat of noncondensables. Each part is broken out below.

(1) Sensible and latent heat of condensables that were condensed are calculated using the following equation:

$$(E1 - E2)*[H_v + (C_p * \Delta T)]$$

where:

E1 - E2 = amount of HAP's that are condensed, lb/event;

E1 = HAP emissions at the inlet of the condenser, lb/event;

E2 = HAP emissions at the outlet of the condenser, lb/event;

H_v = heat of vaporization of the HAP, Btu/lb;

C_p = heat capacity of HAP, Btu/lb °F, and;

ΔT = change in temperature, °F.

(2) Sensible heat of the condensables that were not condensed is calculated as follows:

$$E2 * (C_p * \Delta T)$$

(3) Sensible heat of noncondensables is calculated as follows:

$$\{[cond.\ exit_{fr}*(1-HAP_{vff})*P_i]/(RT)\} * MW_{air} * C_{p\ air} * \Delta T$$

where:

$cond.\ exit_{fr}$ = condenser exit flowrate, scfm.

Heat load during nonevents. The heat load during nonevents (no emission stream going through the condenser) was assumed to be 10 percent of the heat load during an event (calculated above). Because there is no flow through the condenser unless there is an emission event occurring, the system requires only enough cooling to keep the surfaces cold.

Tons of refrigeration. Tons of refrigeration needed for a year is also calculated. This value is based on the heat load required during an event multiplied by the amount of time an event is occurring, plus the amount of heat load required during a nonevent (10 percent of heat load during an event) multiplied by the amount of time there are nonevents.

7.1.1.2 Capital Costs. The capital cost specific to the condenser is the refrigeration unit. The refrigeration unit cost is based on the required condenser exit temperature, and the

required refrigeration capacity during an emission event, as follows[2]:

$$\text{unit cost} = (9.73 - (0.012 * T_{con.}) + (0.584 * \ln R)$$

where:

$T_{con.}$ = temperature of the condenser outlet gas, °F; and

R = refrigeration capacity, tons (12,000 Btu/hr).

The above refrigeration unit cost was converted to June 1992 dollars using the <u>Chemical Engineering</u> equipment cost index. Using the refrigeration unit cost calculated above, the equipment cost of a packaged refrigeration system can be calculated. The equipment cost is estimated to be 25 percent more than the cost of the refrigeration unit. Included in the additional 25 percent is the condenser, recovery tank, and the necessary connections, piping, and instrumentation. The purchased equipment cost is 8 percent greater than the packaged equipment cost and includes sales tax and freight.

<u>Direct capital costs</u>. The purchased equipment cost of each of the control devices is assumed to be 18 percent greater than the equipment cost. Direct costs of the control device are foundation, handling, electrical, piping, insulation, and painting. These costs add 30 percent to the purchased equipment cost.

<u>Indirect capital costs</u>. Indirect capital costs add an additional 15 percent to the purchased equipment cost for engineering, startup, construction and field expenses, and contractor fees.

7.1.1.3 <u>Annual Costs.</u> The costs for the electric compressor motor used in the condensation system is calculated using the following equation:

$$C_e = R * E * \theta_s * p_e / 0.85$$

where:

C_e = electricity costs for the compressor, $/yr;

R = heat load, tons (1 ton = 12,000 Btu/hr);

E = electricity, kW/ton;

θ_s = system operating time, hr/yr; and

p_e = electricity cost, \$/kWh.

The electricity requirement used in this equation varies according to the condenser exit temperature. Below are the electricity requirements for various temperature ranges.[3]

Electricity (E, kW/ton)	Condenser exit temperature, °F
1.3	40
2.2	20
4.7	-20
5.0	-50
11.7	-100

Direct annual costs. The direct annual costs are broken into labor and utilities categories.

Labor. The direct costs are operating labor, materials, and utilities. Labor is broken up into three types of workers: operators, supervisors, and maintenance technicians. The operator and maintenance technician costs are based on the number of shifts per day, and days per year that the control device must operate. For the manufacture of BLR, these numbers were assumed to be 3 and 365, respectively. The calculation of the operator and maintenance technician labor costs are as follows:

$$\text{Costs (\$)} = 0.5 * A * \text{shifts/day} * \text{days/year}$$

where:

0.5 = 30 min. per shift; and

A = rate for operator, \$15.64/hr; or rate for maintenance technician, \$17.21/hr.

The cost for the supervisor is 15 percent of the operator's labor cost.

Materials. Material costs were estimated to be the same as the maintenance technician's labor costs.

Utilities. Electricity costs for the collection fan were estimated using the OAQPS Control Cost Manual; the electricity cost is $0.059/kwh.

Indirect annual costs. Indirect annual costs include overhead, administrative, taxes, insurance, reporting and recordkeeping requirements, and capital recovery. Overhead is 60 percent of the total labor and materials cost. Administrative, property taxes, and insurance are 2, 1, and 1 percent of the total capital investment, respectively.

7.1.1.4 Enhanced Monitoring Costs. The enhanced monitoring costs associated with condensation include both capital and annual elements.

The capital costs included the purchase of a thermocouple to measure the outlet gas temperature and a datalogger to record the measurements. The cost of these two devices was estimated to be $3,000.[4] The cost of an initial performance test of the condenser was not factored into the capital costs because the condenser was only used to estimate impacts in the WSR source category, and an initial performance test on these batch processes has not been recommended.

The annual costs associated with enhanced monitoring included labor, monitoring supplies, and reporting and recordkeeping. The labor cost was estimated to be 0.5 hours per day multiplied by the number of days per year the process was operated and the labor rate ($17.50 per hour).[5] The monitoring supplies were assumed to be $500 per year, and the reporting and recordkeeping requirements were estimated to be $17,500 per year.[6]

7.1.2 Gas Absorber Cost Model

The use of gas absorbers to control process vent emissions containing EPI was examined. This section presents the details of the design and cost calculations for scrubbers. The guidelines for these design and costing procedures are contained in the Handbook of Control Technologies for Hazardous Air Pollutants.[7]

7.1.2.1 _Parameters Necessary for Sizing the Gas Absorber_.
The major parameter that determines the sizing of the scrubber is
the ratio of moles of scrubber liquid to moles of scrubber gas,
according to the following equation:

$$L_{mol} = AF * m * G_{mol}$$

where:

  L_{mol} = liquid flowrate, lbmoles/hr;

  AF = absorption factor;

  m = slope of equilibrium curve; and

  G_{mol} = gas flowrate, lbmoles/hr.

The slope of the equilibrium curve, m, for EPI in water can
be calculated from the Henry's law constant, which is
1.8 atm/mol fraction.

The Handbook of Control Technologies for Hazardous Air
Pollutants suggests as a rule of thumb that the absorption factor
is generally in the range of 1.25 to 2.0. Because water
scrubbers are currently in use, an absorption factor ratio was
used based on reported scrubber operating data from an actual
facility. This ratio is 4.5. With the variables of AF, G_{mol},
and m, known or assumed, L_{mol} may be calculated from the above
equation.

Dimensions of the scrubber were calculated based on a
fraction of flooding conditions. The flooding correlation below
is for randomly packed towers. The abscissa value is calculated
from the equation:

$$Ab = (LG) (D_G/D_L)^{0.5}$$

where:

  L = liquid mass flowrate, lb/hr;

  G = gas mass flowrate, lb/hr;

  D_G = gas density, lb/ft^3; and

  D_L = liquid density, lb/ft^3.

Once the abscissa is known, the corresponding ordinate is read
off a chart and input into the following formula to obtain the
gas stream flowrate at flooding:

$$Ord = [(G_{area})^2 (a/\epsilon^3) (\mu_L{}^{0.2})]/D_G D_L g_c$$

where:

G_{area} = gas stream flowrate based on column cross sectional area (at flooding conditions), $lb/ft^2 \cdot sec$;

a, ϵ = packing factors;

μ_L = viscosity of solvent, cp; and

g_c = gravitational constant.

G_{area}, is then multiplied by 0.6 to obtain the optimum G_{area} (i.e., 60 percent of flooding). The column cross-sectional area and diameter are then calculated using the following equations:

$$A_{column} = G/(3600 \, G_{area})$$
$$D_{column} = (4/\pi)(A_{column})^{0.5}$$

Column height is calculated using the required removal efficiency, which was reported in excess of 99 percent for the scrubbers used in BLR manufacturing. The number of transfer units is calculated using the following equation:

$$N_{OG} = \frac{\ln[(HAP_e/HAP_o)(1 - 1/AF) + 1/AF]}{1 - 1/AF}$$

where HAP_e, HAP_o are the inlet and outlet concentrations, respectively.

H_{OG}, the height of a transfer unit, is calculated from the following mass transfer relationships:

$$H_{OG} = H_G + (1/AF)H_L$$

where:

$$H_G = [b(3,600 \, G_{area})^c/(L'')^d](SC_G)^{0.5}$$
$$H_L = Y(L''^{1}/\mu_L'')^s (SC_L)^{0.5}$$

b,c,d,Y, and s = empirical packing constants (Packing constants for 2" Rashig rings were assumed).

L" = liquid flowrate, $lb/hr\text{-}ft^2$;

$\mu L''$ = liquid viscosity, $lb/ft \cdot hr$;

SC_G = Schmidt number for the gas stream; and

SC_L = Schmidt number for the liquid stream.

The Schmidt number for EPI in air is calculated to be:

$$\frac{\mu}{\rho D_g} = \frac{(0.18cp)(2.42\ lb/hr \cdot ft/cp)}{(0.0763\ lb/ft^3)(0.3871\ ft^2/hr)} = 1.47$$

Gas diffusivity, D_g, for EPI in air was calculated to be 0.3871 ft^2/hr.

The Schmidt number for the liquid stream is calculated to be:

$$N_{SC_L} = \frac{\mu}{\rho D_L} = \frac{(1cp)(2.42)}{(6.24lb/ft^3)(3.805 \times 10^{-5})} = 1,019$$

D_L the diffusivity of EPI in water, was calculated to be 3.805×10^{-5} ft^2/hr.

Total column height and packing costs are estimated using the following correlations:

$$H_{TOT} = (N_{OG})(H_{OG}) + 2 + .25\ D_{column}$$
$$V_{packing} = (\pi/4)(D_{column})^2 \times H_{Tcolumn}$$

Pressure drop through the column is calculated from the following equations:

$$P = (g \times 10^{-8})[10^{(rL''/D_L)}](3600\ G_{area})^2/D_G$$

where:

P = pressure drop, $lb/ft^2 \cdot ft$; and

g,r = packing constants.

Total pressure drop through the column is then expressed as:

$$P_{TOTAL} = P_c \times H_{TOT}$$

7.1.2.2 <u>Capital Costs</u>. The costs of absorber columns, platforms, and ladders were estimated based on regression correlations obtained from Figures 5-6 and 5-7 of the controlling Air Toxics Handbook, 1986.[8] For the column, the cost equation is:

$$\$ = 1.6\ (\text{weight of column}) + 318$$

The column costs were adjusted to June 1992 dollars using the Chemical Engineering equipment cost indices. For the platform and ladders, the cost is:

$$\$ = 1.78 \text{ (diameter)} + 1,410.$$

Packing cost is: $9.7/ft^3 (volume packing).

Purchased equipment costs are made up of the above costs, plus instrumentation and controls, which are estimated to be 10 percent of the above costs. Total capital cost is 2.20 times the purchased equipment costs, according to the 1991 Handbook of Control Technologies for Hazardous Air Pollutants.[9]

7.1.2.3 Annual Costs. Utility costs specific to scrubbers are water ($0.30/1,000 gallons), and waste water treatment cost ($2/1,000 gallons).

7.1.2.4 Enhanced Monitoring Costs. Enhanced monitoring capital and annual costs were estimated for gas absorption.

The capital costs included an initial performance test at an estimated cost of $24,420.[10] Also, instrumentation must be purchased including a flowmeter and datalogger at an estimated cost of $3,000.[11]

The enhanced monitoring annual costs included labor at an estimated 0.5 hours per day multiplied by the labor rate ($17.50 per hour) and the number of days per year the process operated.[12] Maintenance materials were estimated to be $500 per year, and reporting and recordkeeping were estimated to be $17,500 per year.[13]

7.1.3 Auxiliary Equipment Costs

This section describes the cost methodology used to develop costs for auxiliary equipment. Auxiliary equipment costs are part of the capital costs of the control device. Auxiliary equipment that is common to both control devices considered in this analysis include costs of the fans, pumps, and manifolds. The following paragraphs describe the cost methodology for each of these auxiliary components.

Fan costs. The cost of the fan is expected to be minimal, based on the expected range of flowrates through the control

devices. Fan costs are made up of the fan, motor, and starter.
The following cost equations were used to obtain fan capital
costs.

Cost of fan: $= 57.9 \ (d_{fan})^{1.38} \ (392/363.7)$

Cost of starter and motor $= \quad 30.65 \ [(FR)(\Delta P)]^{0.256}$

where:

d_{fan} = diameter of fan, in;

FR = flowrate of stream, scfm; and

ΔP = Pressure drop across fan, in H_2O.

The cost of fan was taken from of the 1991 Handbook of
Control Technologies for Hazardous Air Pollutants, and adjusted
in June 1992 dollars using the Chemical Engineering equipment
cost indices. The starter and motor costs are from the same
reference, where

$$P_{motor} = 235 \ hp^{0.256}$$

where:

P_{motor} = cost of fan motor, belt and starter; and

hP = horsepower requirement.

The horsepower requirement for the fan was calculated using
the equation:

$$hP \quad = \quad \frac{1.17 \times 10^{-4} \ (FR)(\Delta P)}{\eta}$$

where:

ΔP = pressure drop through system, in H_2O;

FR = flowrate; and

η = efficiency, assumed to be 60 percent.

Pump costs. The pump cost was calculated from a regression
correlation developed from Perry's Chemical Engineer's Handbook,
Fifth Edition.[14] The pump cost from the regression analysis was
adjusted to June 1992 dollars using the Chemical Engineering
equipment cost indices.

Manifold costs. The manifolding costs include one automatic
stainless round damper for the collection main, two elbows per
emission source, and a cost for the estimated length of the
0.25 in. thick stainless round duct (300 ft. was the assumed

length of the collection main). The cost estimates for each of
these pieces of the manifold are based on the flowrate of the
waste gas stream. The diameter of the collection main was
calculated using the following equation:

$$\text{Velocity} = \text{Flowrate/Cross-sectional area}$$

where:

Velocity = assumed 2,000 ft/min; and

Flowrate = flowrate of the waste gas stream, acfm.

Using the relationship between the diameter and the flowrate, the
costs for the manifold equipment were estimated. The cost for
each automatic damper in June 1992 dollars is:

$$\$/\text{damper} = (3.45 * FR^{0.5}) + 1,155$$

The cost per foot for the collection main in June 1992 dollars
is:

$$\$/\text{ft} = 0.81 * FR^{0.5}$$

The cost for each elbow in June 1992 dollars is:

$$\$/\text{elbow} = 1.34 * FR^{0.5}$$

The cost of the manifold equipment is the sum of the automatic
damper cost, the cost per foot of the collection main multiplied
by the length of the collection main (300 ft), and the cost for
two elbows per emission source multiplied by the number of
sources.

7.1.4 Process Modifications

Process modifications are included as new source regulatory
alternatives for the WSR source category, and are described in
this section. In WSR manufacturing, methanol (a HAP) can be
crated as a byproduct during the production of the prepolymer
(eg., dibasic ester and diethylenetriamine create methanol), and
hydrogen chloride (HCl), a HAP, can be used to halt the
crosslinking reaction. However, several facilities have
demonstrated that the use of these HAP's in WSR manufacturing is
not essential. For example, most facilities in the source
category form the prepolymer by reacting a dicarboxylic acid and
diethylenetriamine. The byproduct of this reaction is water,
instead of methanol. Also, several facilities use sulfuric acid
rather than HCl to halt the crosslinking process. It is for

7-13

these reasons that the elimination of methanol and HCl from the WSR manufacturing process has been suggested as a regulatory alternative for new sources. No costs have been calculated for these modifications however.

7.2 CONTROL TECHNOLOGIES EXAMINED FOR EQUIPMENT LEAKS

The control technology used to estimate control of HAP emissions from equipment leaks is a formal leak detection and repair (LDAR) program that meets the requirements of the Equipment Leaks Negotiated Regulation, or "Reg Neg." All of the costs necessary for implementing an LDAR program are described below and were obtained from the Internal Instruction Manual for ESD Regulation Development.[15]

The cost model required the user to input the number of each type of component in the plant for BLR manufacturing (a model component count is used for WSR manufacturing), the weight percent of HAP in the stream, and the amount of time each plant operated (shifts per day and days per year). The amount of time each component is expected to be exposed to HAP varied for the two source categories (8 hr/shift, 3 shifts/day, 365 days/yr for BLR; 8 hr/shift, 3 shifts/day, 261 days/yr for WSR was assumed).

7.2.1 Capital Costs

The capital costs of the LDAR program included costs of a monitoring instrument, compressor vent systems, pressure relief devices, caps for open-ended lines, and sample connections. The costs for each of these were multiplied by the number of each of the components and added together. The cost of each piece of control equipment is:

Monitoring instrument = $6,500/instrument;

Compressor vent system = $6,280/system;

Pressure relief devices = $3,960/device;

Open-ended lines = $102/line; and

Sample connections = $413/connection.

7.2.2 Annual Costs

Two types of annual costs are associated with the LDAR program: Capital recovery costs and annual operating costs.

Capital Recovery Costs. Capital recovery costs are
calculated by multiplying the capital costs for each piece of
control equipment by the capital recovery factor. The capital
recovery factor for each piece of control equipment was taken
from the Internal Instruction Manual, adjusted to 7 percent
interest, and is as follows:

0.55 for pump seals;

0.21 for monitoring instruments; and

0.14 for all other equipment.[16]

For valves, sample connections, and pumps, the cost of monitoring
and repair also factor into the capital costs. The monitoring
costs for both liquid and gas valves, sample connections and
pumps includes a subcontractor monitoring fee ($2.50 per
component), and a 40 percent administrative fee, in addition to
the capital recovery costs described above. The repair costs
include an initial leak frequency (0.14 for gas valves, 0.065 for
liquid valves, 0.021 for sample connections, and 0.2 for pumps),
the fraction of the total components needing repair (75 percent
for pumps and 25 percent for all other components), four hours
for repair at $22.50 per hour, and a 40 percent administrative
fee. For pumps there is a cost for replacing seals of $180.00
per seal.

Annual operating costs. The annual operating costs are
split into three categories: maintenance, miscellaneous, and
labor costs.

Maintenance. The maintenance cost is 5 percent of the
capital cost for compressors, pressure relief devices, open-ended
lines, and sample connections. For monitoring instruments, it is
$4,280, and the annual maintenance cost for pumps is based on the
number repaired.

Annual miscellaneous costs. The annual miscellaneous costs
are 4 percent of the capital cost for monitoring instruments,
compressors, pressure relief devices, open-ended lines, and
sample connections. The cost for pumps is 80 percent of the
annual maintenance cost for pumps.

Labor. The annual labor costs are divided into monitoring and repair costs. The monitoring costs include component count, number of monitorings per year (12 for the Reg Neg, except flanges and pressure relief devices need one monitoring per year), a $2.00 monitoring fee, and a 40 percent administrative fee. For pumps an additional term for weekly visual inspections is required. The costs for this term are calculated based on the pump count, 0.5 min. per pump each week, $22.50 per hour labor charge, and a 40 percent administrative fee. The repair cost includes the component count for gas and liquid valves, pumps, and sample connections, the leak frequency of each of these components, the number of monitorings per year, the fraction requiring repair, 4 hr for a repair, $22.50 per hour labor, and a 40 percent administrative fee.

Recovery Credits. The recovery credit is calculated by multiplying the quantity of HAP's controlled by the cost per unit mass of the controlled HAP. The cost of EPI for BLR manufacturing, and EPI, methanol, and hydrogen chloride for WSR manufacturing was assumed to be $1,590 per megagram.[17]

The total annual costs are the sum of the first year annual cost and the annual operating cost minus the recovery credit.

7.3 ENHANCED MONITORING COSTS FOR WASTEWATER

Although no control technologies were evaluated for wastewater for either source category there are capital and annual costs associated with the current control technologies employed in the BLR manufacturing industry.

The capital cost includes an initial performance test to demonstrate adequate biodegradation of HAP's in the system at an estimated cost of $10,000.[18] This is the only capital cost associated with wastewater treatment and hence the only annual cost associated with wastewater is the capital recovery cost of the initial performance test. The annual cost is $1,424 per year at 7 percent interest and assuming another performance test will not be needed for 10 years.

7.4 RESULTS OF THE COSTS ANALYSIS

The nationwide impacts were estimated for both source categories using the same methodology. That is, the control devices were applied, in all cases, to baseline emission streams. This methodology allowed the emission reductions on the current level of control to match the control level specified by the individual regulatory alternatives. Details of the nationwide impacts, including capital and annual costs for each regulatory alternative, and the national costs and incremental cost effectiveness from baseline is included in Table 7-1 for BLR manufacturing and Table 7-2 for WSR manufacturing. The tabular costs associated with each regulatory alternative for the two source categories are located in Appendix H to this BID.

TABLE 7-1. BLR MANUFACTURING COST ANALYSIS RESULTS

Portion of source	Uncontrolled HAP emissions, Mg/yr	Baseline emissions, Mg/yr	Emission reduction, Mg/yr	Capital costs, $1,000	Annual costs, $	Cost effectiveness, $/Mg	Incremental cost effectiveness, $/Mg
1. Process vents storage, and wastewater							
– MACT floor	42	18	7	140	127,000	18,000	5,200
– Regulatory Option 1	42	18	9	149	139,000	15,400	
2. Equipment leaks							
– MACT floor	180	104	45	195	500	10	300
– Regulatory Option 1	180	104	88	270	13,000	150	

TABLE 7-2. WSR MANUFACTURING COST ANALYSIS RESULTS

Portion of source	Uncontrolled HAP emissions, Mg/yr	Baseline emissions, Mg/yr	Emission reduction, Mg/yr	Capital costs, $1,000	Annual costs, $1,000	Cost effectiveness, $/Mg	Incremental cost effectiveness, $/Mg
1. Process vents storage, and wastewater							
– MACT floor	8	4	2	510	520	210,000	
– Regulatory Option 1	8	4	3	670	740	242,000	355,000
2. Equipment leaks							
– MACT floor	23	23	0	0	0	0	
– Regulatory Option 1	23	23	14	138	52	3,700	3,700

7.3 REFERENCES FOR CHAPTER 7

1. OAQPS Control Cost Manual, First Supplement, U. S. Environmental Protection Agency, Research Triangle Park, NC. Chapter 8, Refrigerated Condensers. November 1991.

2. Reference 1, p. 8-21.

3. Reference 1, p. 8-30.

4. Memo to R. McDonald, CPB, from B. Shine, MRI, Polymers and Resins II NESHAP, Enhanced Monitoring Costs, July 14, 1993.

5. Reference 4.

6. Memo to D. Stackhouse, SDB, from S. Angyal, MRI Magnetic Tape NESHAP--Format of Standard, Enhanced Monitoring Requirements and Costs, July 26, 1993.

7. Handbook of Control Technologies for Hazardous Air Pollutants, U. S. Environmental Protection Agency, Cincinnati, OH. Publication No. EPA-625/6-91-014. June 1991.

8. Handbook of Control Technologies for Hazardous Air Pollutants, U. S. Environmental Protection Agency, 1986.

9. Reference 7, p. 4-52.

10. Reference 4.

11. Reference 4.

12. Reference 4.

13. Reference 6.

14. Perry, Robert H. Perry's Chemical Engineer's Handbook, Fifth Edition. New York, McGraw Hill. 1973. Figure 6-5.

15. Internal Instruction Manual for ESD Regulation Development, Leaking Equipment--Pumps, Valves, Connectors, Compressors, Safety Relief Valves, U. S. Environmental Protection Agency, Research Triangle Park, NC. July 1992.

16. Reference 15, p. 4-16.

17. Memo, to D. Markwordt, CPB, from D. Whitt, Radian, HON Equipment Leaks, May 20, 1991.

18. Reference 4.

8.0 ECONOMIC IMPACT ANALYSIS

8.1 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is reviewing National Emission Standards for Hazardous Air Pollutants (NESHAP) for the basic liquid epoxy resin (BLR) and wet strength resin (WSR) industries. These industries emit several of the hazardous air pollutants (HAPs) identified by the Clean Air Act Amendments of 1990.[1]

Section 317 of the Clean Air Act requires EPA to evaluate regulatory alternatives through an Economic Impact Analysis (EIA). Accordingly, this EIA has been conducted to satisfy the requirements of the Clean Air Act.

8.1.1 EIA Objectives

There are two primary objectives of this EIA. The first objective is to describe the distribution of adverse impacts associated with the NESHAP among various members of society. The second objective is to adjust estimated emission control costs so that these reflect the economic costs associated with the standard.

Neither the benefits nor the costs associated with the NESHAP will be distributed equally among different members of society. Since this study is focused on costs, emphasis is placed on estimating and describing the adverse impacts associated with the NESHAP. Those members of society who could potentially suffer adverse impacts include:

- Producers whose facilities require emission controls.

- Buyers of goods produced by industries requiring controls.

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[1] These HAPs are MeOH, HCl and EPI.

- Employees at plants requiring controls.

- Individuals who could be affected indirectly such as residents of communities proximate to controlled facilities, and employees of industries that sell inputs to or purchase inputs from directly affected firms.

Because of potential distributional impacts, and because of other policy issues, impacts on both energy consumption and foreign trade are also considered in this study.

Economic costs generally do not correspond to emission control costs because the latter do not reflect market adjustments that occur because of higher production costs caused by the installation, operation and maintenance of emission controls. A second purpose of this EIA is to make appropriate adjustments to estimated emission control costs so that they reflect the economic costs of the NESHAP.

8.1.2 Background

8.1.2.1 Affected Markets. EPA expects the NESHAP to affect two of the industries included in Standard Industrial Classification code 2821. They are:

- Basic Liquid Epoxy Resin (Diglycidyl Ether of Bisphenol A or DGEBPA).

- WSR (Epichlorohydrin Cross-Linked Non-Nylon polyamide resins).

8.1.2.2 Regulatory Alternatives. The Clean Air Act Amendments of 1990 stipulate that HAP emission standards for existing sources must at least match the percent reduction of HAPs achieved by either a) the best 12 percent of existing sources, or b) the best five sources in a category or subcategory consisting of fewer than 30 sources. This minimum standard is called a MACT floor.

The NESHAP considered in this EIA is the MACT floor for WSR plants. The MACT floor for these plants requires controls on storage tanks and process vents. This EIA considers an alternative to the MACT Floor for WSR plants. This alternative, which we refer to as Option I, requires controls only on equipment leaks. The NESHAP for BLR plants is the MACT floor for

storage tanks and process vents, but requires more stringent controls than the MACT floor for equipment leaks.

Both the BLR and WSR industries consist of fewer than 30 sources. Thus, definition b) was used in both cases to construct the MACT floor for existing sources. For new sources the Amendments stipulate that the MACT floor be set at the highest level of control achieved by any similar source.

There are currently three facilities producing substantial amounts of BLR. The MACT floor for existing sources was constructed by averaging the percentage reduction of HAPs achieved for each source type by each facility. A source type is a piece of equipment or component of production which produces HAPs. The MACT floor requires controls on the following BLR source types: process vents, storage tanks and equipment leaks. As noted above, the NESHAP considered in this EIA requires controls at BLR plants more stringent than the MACT floor for equipment leaks.

There are 17 existing WSR plants. The MACT floor was constructed by averaging the percentage reduction of HAPs achieved by the five best controlled sources for each source type. The MACT floor for WSR plants requires controls on storage tanks and process vents, but no additional controls on equipment leaks.

As noted earlier, Option I, which is an alternative to the MACT Floor for the WSR industry, requires controls on equipment leaks, but no controls on either storage tanks or process vents. We consider Option I because it results in larger emission reductions at considerably lower costs than the MACT floor.

8.1.3 Summary of Estimated Impacts

8.1.3.1 Primary and Secondary Impacts. Table 8-1 summarizes the estimates of the primary and secondary economic impacts associated with the NESHAP.[2] Primary impacts include price increases, reductions in market output levels, changes in

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[2] Table 9-1 summarizes the results of the MACT floor for the wet strength resin industry. We describe the impacts of Option I in the text that follows.

TABLE 8-1. SUMMARY OF ESTIMATED ECONOMIC IMPACTS

Analysis	Estimated Impacts
Primary Impacts	
Price Increases	Estimated price increases are 0.05 percent for BLR and 4.19 percent for WSR.
Market Output	Estimated reductions in market output are 0.08 percent for BLR and 3.73 percent for WSR.
Value of Domestic Shipments	Estimated changes range from a decline of 0.03 percent for BLR to an increase of 0.31 percent for WSR.
Plant Closures	No plant closures are expected in the BLR industry and one plant closure is predicted for the wet strength resin industry.
Secondary Impacts	
Employment	No significant employment losses are expected.
Energy Use	Estimated industry-wide use to decline by 0.08 percent ($8,500) in the BLR industry and by 3.73 percent ($45,000) in the wet strength resin industry.
Net Exports	Estimated trade impacts are small. Net exports of BLR predicted to decline by about $25,000. Lower volume of wet strength resin exports expected to be offset by higher post-control prices.
Regional Impacts	No significant regional impacts are expected.

the value of shipments by domestic producers, and plant closures. Secondary impacts include employment losses, reduced energy use, changes in net exports, and potential regional impacts.

The estimated primary impacts on the BLR market are small. For example, we estimate that the market price will increase by just 0.05 percent, and that market output will fall by about 0.08 percent. The estimated impacts of the MACT Floor on price and output in the WSR market are somewhat larger than those for the BLR market. We estimate an increase in price of 4.19 percent and a decrease in U.S. production of 3.73 percent. Note, however, that we expect a slight increase in the value of shipments by domestic WSR producers. This occurs because the estimated price increase more than offsets the lower production volume. Our analysis predicts no plant closures in the BLR industry, but one WSR plant closure is possible. This predicted closure, however, may be due to some "worst case" assumptions adopted in our analysis.

The analysis of the primary impacts on the WSR market under the implementation of Option I yields substantially less adverse impacts than the MACT floor. The increase in WSR price is estimated at 0.22 percent (compared to a 4.19 percent increase under the MACT floor). We estimate that market output will decrease by just 0.20 percent under Option I, with an associated increase (due to the slight increase in price) in the value of domestic shipments of $7,000 (0.02 percent). While one plant closure is possible under the MACT floor, none is expected under Option I.

The estimates of secondary impacts reported in Table 8-1 follow the estimates of primary impacts described above. We expect only small employment losses and reductions in energy use. These findings, of course, are consistent with our estimates of small impacts on market output. We estimate that the reduction in net exports of BLR will be small, about $25,000, and that higher post-control prices will offset a slightly lower volume of WSR exports. Finally, we expect no significant regional impacts.

The secondary impacts of Option I on the WSR industry are also smaller than those of the MACT Floor. Employment (production job) losses are almost negligible (0.10 production jobs) and energy use is expected to decline by 0.20 percent. The estimated trade impacts are negligible. WSR exports are estimated to fall by .21 percent. Also, no significant regional impacts are expected.

8.1.3.2 <u>Financial Analysis</u>. Our financial analysis indicates that capital and annual emission control costs are small relative to the financial resources of the firms producing BLR and WSR. As a result, we do not expect that it will be difficult for these firms to raise the capital required to purchase and install emission controls.

8.1.3.3 <u>Sensitivity Analyses</u>. In Appendix D of the report, we examine the sensitivity of the estimated primary impacts to our estimates of market demand elasticities. The results reported in Appendix D indicate that the primary impacts summarized in Table 8-1 are relatively insensitive to reasonable ranges of demand elasticity estimates. However, analysis conducted assuming a "low" elasticity of demand yields slightly less adverse impacts, including no plant closures in the WSR industry.

8.1.3.4 <u>Potential Small Business Impacts</u>. All of the affected BLR and WSR producers are large companies and none satisfies the criteria for a small business. Consequently, we do not expect any significant small business impacts to result from implementing the NESHAP.

8.1.3.5 <u>Economic Costs</u>. Table 8-2 reports estimates of the economic costs associated with the NESHAP. The estimated annualized economic costs are $120 thousand for the BLR industry and $465 thousand for the WSR industry under the MACT floor. The economic costs associated with Option I, $51 thousand, are considerably lower than those of the MACT floor. These estimates measure changes in economic surplus and include the costs associated with higher prices of imports to the U.S. economy.

TABLE 8-2.   ESTIMATES OF ANNUALIZED ECONOMIC COSTS
(thousands of 1992 dollars)

Industry	Loss in Consumer Surplus	Loss in Producer Surplus	Loss in Residual Surplus	Loss in Surplus Total
BLR	141	-3	—19	120
Wet Strength Resin MACT Floor	1,607	-841	—300	465
Option I	87	-22	-13	51

a   Economic costs are computed as the change in economic
surplus associated with the NESHAP. The estimates
include the costs of higher prices of imported products.

8.1.4 Organization of EIA

We describe the analytical methods employed to estimate the economic impacts associated with the NESHAP in Section 8-2. Section 3 contains profiles of the two affected industries. We report in Section 8-4 estimates of primary economic impacts, including those on market prices, market output levels, value of shipments by domestic producers, and plant closures. Section 8-5 presents estimates of secondary impacts, including the effects on employment, foreign trade, energy use and regional economies. We describe potential adverse impacts of small businesses in Section 8-6. In Section 8-7, we report estimates of the economic costs associated with the NESHAP.

There are four appendices to this section. We describe the model plants used in the analyses and report estimates of emission control costs and other baseline data in Appendix A. Appendix B provides a detailed technical description of the analytical methods employed to estimate economic impacts and costs. We describe an econometric model of the resin industry in Appendix C. We report in Appendix D the results of sensitivity analyses in which we consider ranges of demand elasticity estimates.

8.2 OVERVIEW OF ECONOMIC IMPACT ANALYSIS

We assess the economic impacts associated with the NESHAP by conducting studies of the affected industries. These industries are the BLR and the WSR. We describe the analytical methods employed in these studies below.

8.2.1 Overview of Distributional Impacts

As noted earlier in the introduction to this section, several groups might potentially suffer from adverse impacts associated with the NESHAP. These groups include:

- Resin producers.

- Resin buyers.

- Employees at affected plants.

- Individuals affected indirectly by the NESHAP.

We describe the potential adverse impacts affecting each of these groups below.

8.2.1.1 <u>Impacts on Producers</u>. The emission control costs associated with the standard are likely to reduce the profitability of at least some of the affected plants. Indeed, some affected plants may be forced to shutdown operations in the face of emission control costs. Ultimately, the magnitude of the adverse impacts incurred by affected plants will depend on the extent to which emission control costs can be passed on to buyers. In addition, operators of some affected plants might have difficulty acquiring the capital necessary to purchase and to install emission control equipment.

Some plants in affected industries may not suffer adverse impacts as a result of the implementation of an emission control standard. The post-control profitability of an affected plant will improve if post-control price increases more than offset the plant's emission control costs. This could occur if control costs for some plants are substantially higher, per unit of output, than those for other plants in the industry.

8.2.1.2 <u>Impacts on Consumers or Buyers</u>. Both BLR and WSR are purchased primarily by firms which use these products as inputs to produce other goods. These firms and the consumers of the goods which they produce are likely to suffer from two related adverse impacts. First, post- control prices for resins produced at the affected plants are likely to be higher as sellers attempt to pass through some of the costs of emission controls. This will cause profits to be smaller, at least in the short run, for firms which purchase BLR and WSR as inputs. It will also cause prices of final goods to be higher as firms attempt to pass through some of the increase in production costs. Second, the shift in supply caused by emission control costs is likely to reduce the amount of resin sold in affected markets, as well as the level of output sold in markets which use the resin

as an input. These two effects are related in that post-control
equilibrium prices and output levels in affected markets will be
determined simultaneously.

8.2.1.3 Indirect or Secondary Impacts. Two countervailing
impacts on employees of affected plants are likely to result from
the implementation of the NESHAP. Employment will fall if
affected plants either reduce output or close operations
altogether. On the other hand, increases in employment
associated with the installation, operation, and maintenance of
emission controls are likely.

A number of other indirect or secondary adverse impacts may
be associated with the implementation of a standard. The
indirect impacts we consider in this study include: foreign
trade effects; impacts on regional economies; and, effects on
energy consumption.

8.2.2 Economic Impact Studies

The industry segment studies that follow in this report
include six major components of analysis. These components or
phases of analysis, which are designed to measure and describe
economic impacts, are:

- Industry profile.

- Direct impacts (market price and output, domestic
  production and plant closures).

- Capital availability analysis.

- Evaluation of secondary impacts (employment, foreign
  trade, energy consumption, and regional and local
  impacts).

- Analysis of potential small business impacts.

Each of these phases of analysis is described below.

8.2.3 Industry Profile

The industry profile provided in Section 8-3 describes
conditions in affected industries that are likely to determine
the nature of economic impacts associated with the implementation
of the NESHAP. We discuss the following seven topics in the
industry profile:

8-10

- Product descriptions.
- Prices and output.
- Market outlook.
- Market structure.
- Foreign trade.
- Financial conditions.
- Employment and energy use.

8.2.4 Primary Impacts

We employ a partial equilibrium model of the BLR and WSR
industries to estimate the primary impacts of emission control
costs, including market equilibrium price, market output, the
value of domestic shipments, and the number of potential plant
closures.[3] This analysis is so named because the predicted
impacts are driven by estimates of how the affected industries
achieve market equilibrium after the air quality standard is
implemented.

In a competitive market, equilibrium price and output are
determined by the intersection of demand and supply. The supply
function is determined by the marginal (avoidable) operating
costs of existing plants and potential entrants. A plant will be
willing to supply output so long as market price exceeds its
average (avoidable) operating costs. The installation,
operation, and maintenance of emission controls will result in an
increase in operating costs. An associated upward shift in the
supply function will occur.

The procedures employed in the market analysis are
illustrated in Figure 8-1. Constructing the model and predicting
impacts requires completing the following four tasks.

- Estimate pre-control market demand and supply
  functions.

- Estimate per unit emission control costs.

- Construct the post-control supply function.

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[3] The results of the partial equilibrium analyses are also used to esti-
mate employment, energy and foreign trade impacts and the economic costs
associated with the regulatory alternatives.

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┌──────────────────┐
│  Pre-Control     │──┐
│  Market Data     │  │    ┌───────────────────────┐
└──────────────────┘  ├────│           1           │
                      │    │                       │─────────┐
┌──────────────────┐  │    │  Estimate Pre-Control │         │
│ Specify Demand and│──┘    │  Demand and Supply    │         │
│ Supply Functions │       └───────────────────────┘         │
└──────────────────┘                                         │
                                                             │
┌──────────────────┐                                         │
│   Emissions      │──┐                                       │
│ Control Costs    │  │    ┌───────────────────────┐         │
└──────────────────┘  ├────│           2           │         │
                      │    │                       │         │
┌──────────────────┐  │    │   Estimate per Unit   │         │
│ Discounted Cash  │──┘    │       Emissions       │──┐      │
│ Flow Parameters  │       │    Control Costs      │  │      │
└──────────────────┘       └───────────────────────┘  │      │
                                                       │      │
                           ┌───────────────────────┐  │      │
                           │           3           │──┘      │
                           │                       │         │
                           │      Construct        │         │
                           │    Post-Control       │──┐      │
                           │  Supply Function      │  │ ┌────┴──────────────────┐
                           └───────────────────────┘  │ │          4            │
                                                       └─│                       │
                                                         │ Solve for Post-Control│
                                                         │ Price and Output, and │
                                                         │   Predict Closures    │
                                                         └───────────────────────┘
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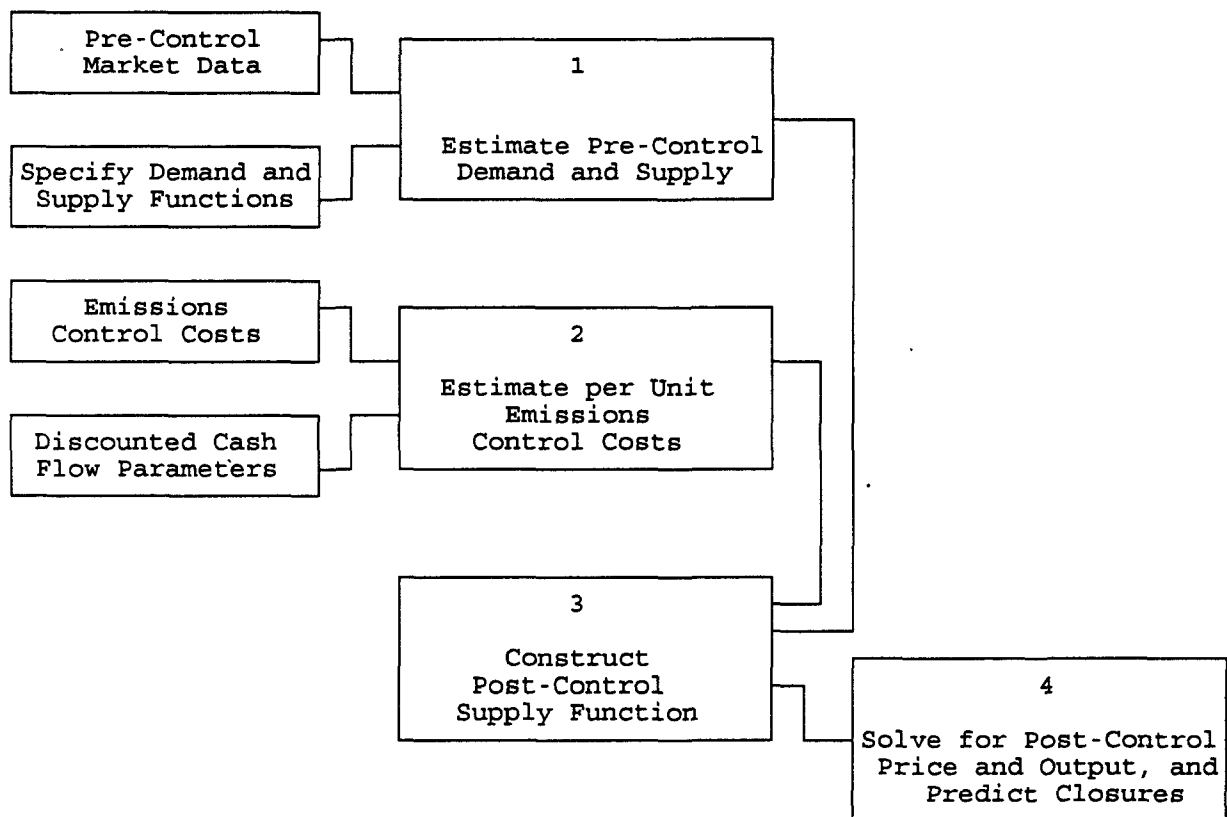
Figure 8-1.   Partial Equilibrium Analysis of BLR and
WSR Industries.

- Solve for post-control price, output and employment levels, and predict plant closures.

We briefly describe each of these tasks below.[4]

8.2.4.1 Pre-Control Market Demand and Supply Functions. Pre-control equilibrium price and output levels in competitive markets are determined by market demand and supply. Because estimates of demand and supply for the relevant industries are unavailable from the literature, we estimated these functions as part of this study. Both the market demand and domestic supply functions were estimated econometrically using time-series data.[5]

Market demand in the household segment was specified as a function of product price and a time trend to capture structural change in demand over time.[6] However, because of uncertainty regarding the demand elasticity estimates, we report the results of sensitivity analyses in Appendix D.

Market supply includes domestic supply and foreign supply of imports. We derived our estimate of domestic supply elasticity from a production function in which output of is expressed as a function of capital stock held by the industry, material and labor inputs, and time. We assume, in the absence of other information, that the supply elasticity of imports (foreign supply) is the same as that for domestic supply.[7]

8.2.4.2 Per Unit Emission Control Costs. Emission control costs will cause an upward vertical shift of the supply curves in affected markets. The height of the vertical shift for each

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[4] See Appendices A, B, and C for more detailed descriptions of the data and methods employed in the partial equilibrium analysis.

[5] See Appendix C for detailed descriptions of the data and methods employed to estimate these functions. Appendix C also reports the estimated parameters of the functions.

[6] Our estimates of demand elasticities are -1.50 for BLR and -0.92 for WSR.

[7] Given this assumption, a one percent change in price causes the same percentage increase in both domestic and foreign supply.

affected plant is given by the after-tax cash flow required to offset the per unit increase in production costs resulting from the installation, maintenance, and operation of emission control equipment.

Estimates of the capital, operating and maintenance costs associated with emission control equipment for affected plants were obtained from the draft BID document. Per unit, after-tax costs are estimated by dividing after-tax annualized costs by annual output. This cost reflects the offsetting cash flow requirement which, in turn, yields an estimate of the post-control vertical shift in the supply function.

Computing per unit after-tax control costs requires, as inputs, estimates of the following parameters:

- The useful life emission control equipment.
- The discount rate (marginal cost of capital).
- The marginal corporate income tax rate.

Estimates of the expected life of emission control equipment were obtained from the draft BID document. The results presented in this report are based on a 10 percent real private discount rate[8] and a 25 percent marginal tax rate.

8.2.4.3 <u>The Post-Control Supply Function</u>. Estimated aftertax per unit control costs are added to pre-control supply prices to determine the post-control supply prices for domestic producers. We construct the post-control domestic supply function by sorting affected plants, from highest to lowest, by per unit post-control costs. We assume that plants with the highest per unit emission control costs are marginal (highest cost) in the post-control market.[9] Because per unit control

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[8] The discount rate referred to here measures the private marginal cost of capital to affected firms. This rate, which is used to predict the market responses of affected firms to emission control costs, should be distinguished from the social cost of capital. The social cost of capital is used to measure the economic costs of emission controls. See Section 9.7 for a more detailed discussion of this issue.

[9] Note that any other construction of the post-control supply curves would result in the same or smaller vertical shifts in supply, and accordingly, the same or smaller economic impacts.

costs differ across affected plants within an industry segment, the post-control domestic supply function is segmented. Total market supply is given by the sum of domestic and foreign supply. We assume, of course, that foreign supply is unaffected by emission controls.[10]

8.2.4.4 <u>Post-Control Prices, Output, and Closures</u>. The baseline, pre-control equilibrium output in an affected market is taken as the level of observed national consumption (shipments by domestic producers minus net exports). We compute post-control equilibrium price and output levels in affected markets by solving for the intersection of the market demand curve and the market post-control, segmented supply curve. The estimated reduction in market output is given by the difference between the observed pre-control output level and the predicted post-control output level. Similarly, the estimated increase in price is taken as the difference between the observed pre-control price and the predicted post-control equilibrium price.

Because higher market prices lead to higher imports, the reduction in domestic production is larger than the reduction in market output. Specifically, the reduction in output for domestic producers is given by the reduction in market output plus the increase in imports. We estimate the number of plant closures by dividing the predicted reduction in domestic output by the production levels at plants with post-control supply prices higher than the post-control equilibrium market price.

8.2.4.5 <u>Reporting Results of Market Analyses</u>. The results of the partial equilibrium market analyses for each of the affected industries are presented in Section 8-4 of this report. In particular, estimates of the following are reported:

- Price increase.
- Reduction in market output.
- Annual change in the value of domestic shipments.

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[10] This assumption means that no shift in the foreign supply function occurs as a result of emission controls on domestic producers. The quantity supplied by foreign producers, however, increases as market price increases.

TABLE 8-3.   BIASES RESULTING IF MODEL ASSUMPTIONS
ARE VIOLATED

Assumption	Direction of Bias		
	Change in Industry Quantity	Change in Industry Price	Net Closures
i) national market	+	*	+
ii) controlled plants at margin in baseline	+	+	+
iii) no regulation-induced expansion of domestic producers	+	+	+

*   Price changes will vary depending on the locations of affected
plants and the levels of regional trade barriers and degree of
product differentiation.

- Number of plant closures.

8.2.4.6 <u>Limitations of the Market Analysis</u>. The partial
equilibrium model has a number of limitations. First, a single
national market for homogeneous output is assumed in the
analysis. However, markets may be regional. Then each region or
product type will be affected primarily by cost changes of plants
in the region, rather than all plants in the national market.
Output reductions and price effects will vary across regions
depending on locations of affected plants. In addition, the
assumption of a national market is likely to cause predicted
closures to be overstated to the extent that affected firms are
protected somewhat by regional trade barriers.

Second, the analysis assumes that plants with the highest
per unit emission control costs are marginal post-control. This
assumption produces an upward bias in estimated effects on
industry output and price changes because the control costs of
non-marginal firms will not affect market price. Predicted
closures will also be overstated.

Third, the analysis assumes that the implementation of
controls does not induce any domestic producers to expand
production. An incentive for expansion would exist if some
plants have post-control incremental unit costs between the
baseline price and the post-control price predicted by the
partial equilibrium analysis. Expansion by domestic producers
will result in reduced impacts on industry output and price
levels. While plant closures will increase as expanding
producers squeeze out plants with higher post-control costs, net
closures (closures minus expansions) will be reduced.

Table 8-3 summarizes the biases discussed above. In most
cases, the assumptions embedded in the market analyses produce an
upward bias in estimated impacts on market quantity, market
price, and net closures.

Also, statistical errors in the estimated demand and supply
functions exist. We report the statistical properties of the

8-16

estimates of these functions in Appendix C.[11] In addition, it is likely that uncertainty in the estimates of emission control costs exist, causing control costs for some plants to be either overstated or understated. The control costs used in this EIA are study estimates and are accurate within plus or minus 30 percent.

8.2.5 Capital Availability Analysis

We assume in the market analysis that affected firms will be able to raise the capital associated with controlling emissions at a specified marginal cost of capital. The capital availability analysis, on the other hand, examines the variation in firms' ability to raise the capital necessary for the purchase, installation, and testing of emission control equipment.

The capital availability analysis also serves three other purposes. First, it provides information for evaluating the appropriateness of the selected discount rate as a proxy for the marginal cost of capital of the industry; implications for bias in the partial equilibrium analysis follow. Second, it provides information on potential variation in capital costs across firms. Third, it provides measures of the potential impacts of controls on the profitability of affected firms.

8.2.5.1 Evaluation of Impacts on Capital Availability. For each model plant[12] included in the capital availability analysis, the impact of the alternative standards on the following two measures is evaluated:

- Net income/assets.
- Long-term debt/long-term debt and equity.

Net income is measured before-tax and is defined to include all operations, continued and discontinued.

The ratio of net income to assets is a measure of return on investment. The implementation of emission controls is likely to reduce this ratio to the extent that net income falls

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[11] See Appendix D for estimates of impacts associated with alternative estimates of demand elasticities.

[12] The model plants included in the analysis are described later in this section and in more detail in Appendix A.

(e.g., because of higher operating costs) and assets increase (because of investments in emission control equipment).

The ratio of long-term debt to long-term debt plus equity is a measure of risk perceived by potential investors. Other things being the same, a firm with a high debt-equity ratio is likely to be perceived as being more risky, and as a result, may encounter difficulty in raising capital. This ratio will increase if affected firms purchase emission control equipment by issuing long-term debt.

8.2.5.1.1 <u>Baseline values for capital availability analysis.</u> Baseline values for net income and net income/assets are derived by averaging data for as many years as are available between 1988 and 1991. Data from these four years are employed to reduce distortions caused by year-to-year fluctuations. Since changes in the long-term debt ratio represent actual structural changes, 1990 or 1991 data are used, whichever is the most recent year the data are available.

8.2.5.1.2 <u>Post-control values for capital availability analysis</u>. Post-control values for the two measures identified above are computed to evaluate the ability of affected firms to raise required capital. The post control values are computed as follows:

- Post-control net income — pre-control net income minus the after-tax annualized costs associated with the purchase, installation, maintenance and operation of emission control equipment.

- Post-control return on assets — post-control net income divided by the sum of pre-control assets plus investments in emission control equipment.

- Post-control long-term debt ratio — the sum of precontrol long-term debt plus investments in emission control equipment divided by the sum of pre-control long-term debt, equity, and investments in emission control equipment.

The calculations are done for a worst-case scenario of the impact of controls on the measures. First, the total investment in emission control equipment is assumed to be debt-financed.

Second, it is assumed that there is no increase in the price a company receives for its output.

8.2.5.1.3 <u>Limitations of the capital-availability analysis</u>. The capital availability analysis has limitations. First, future baseline performance may deviate from past levels. The financial position of a firm during the period 1988-1991 may not be a good approximation of the company's position later during the implementation period, even in the absence of the impacts of emission control costs.

Second, a limited set of measures is used to evaluate the impact of controls. These measures reflect accounting conventions and provide only a rough approximation of the factors that will influence capital availability.

8.2.6 <u>Evaluation of Secondary Impacts</u>

The secondary impacts that we consider in this study include:

- Employment impacts.
- Energy impacts.
- Foreign trade impacts.
- Regional impacts.

8.2.6.1 <u>Employment Impacts</u>. As equilibrium output in affected industry segments falls because of control costs, employment in the industry will decrease. On the other hand, operating and maintaining emission control equipment requires additional labor for some control options. Direct net employment impacts are equal to the decrease in employment due to output reductions, less the increase in employment associated with the operation and maintenance of emission control equipment.

Our estimates of the employment impacts associated with the NESHAP are based on employment-output ratios and estimated changes in domestic production. Specifically, we compute changes in employment proportional to estimated changes in domestic production.[13]

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[13] See Appendix B for descriptions of the data and methods used to estimate employment impacts.

Estimates of the labor hours required to operate and maintain emission control equipment are unavailable. Accordingly, the employment impacts presented in this report are overstated to the extent that potential employment gains attributable to operating and maintaining control equipment are not considered.

The estimates of direct employment impacts are driven by estimates of output reductions obtained in the market analyses. Biases in these estimates will likely cause the estimates of employment impacts to be biased in the same direction.

8.2.6.2 <u>Energy Effects</u>. The energy effects associated with the NESHAP include reduced energy consumption due to reduced output in affected industry segments plus the net change in energy consumption associated with the operation of emission controls.

The method we use to estimate reduced energy consumption due to output reductions is similar to the approach employed for estimating employment impacts.[14] Specifically, we assume that changes in energy use are proportional to estimated changes in domestic production. Estimates of the net change in energy consumption due to operating emission controls are unavailable.[15]

8.2.6.3 <u>Foreign Trade Impacts</u>. Other factors being the same, the implementation of the NESHAP will raise the production costs of domestic resin manufacturers relative to foreign producers, causing U.S. net exports of resin to decrease.

The extent to which imports to U.S. increase will depend on the supply elasticity of foreign-produced resin to the U.S. Unfortunately, we have not identified any estimates of resin import supply elasticities in the literature and the available data does not permit us to derive our own estimate. Accordingly, we assume

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[14] See Appendix B for a more detailed description of this procedure.

[15] We view these as short-run estimates of reduced energy consumption. In the long run, resources diverted from the production of BLR and WSR will likely be directed to producing other goods and services.

that the import supply elasticity is the same as that for domestically produced resin.

We report estimates of the dollar value of the increase in imports associated with the implementation of the standard. There are two sources of this increase: (1) the increase in the quantity of goods imported; and (2) increases in prices of imported goods. The estimates we report reflect the contributions from both sources.

8.2.6.4 <u>Regional Impacts</u>. Substantial regional or community impacts may occur if a plant that employs a significant percent of the local population or contributes importantly to the local tax base is forced to close or to reduce output because of emission control costs.

Secondary employment impacts may be generated if a substantial number of plants close as a result of emission control costs. Secondary employment impacts include those suffered by employees of firms that provide inputs to the directly affected industry, employees of firms that purchase inputs from directly affected firms for end-use products, and employees of other local businesses.

8.2.7 <u>Affected Plants</u>

The NESHAP is expected to affect three BLR and 17 WSR plants. Because only three BLR plants are affected, the analysis considers plant specific data for this industry. However, because of the large number of affected WSR facilities, the analysis is based on three different model plants that have been developed to represent the 17 plants in the industry. Appendix A describes the characteristics of the affected BLR and WSR plants.

8.3 INDUSTRY PROFILE

This section describes market conditions for products that will be affected by the NESHAP. The affected products are BLR made from diglycidyl ethers of bisphenol A (DGEBPA), which is a type of unmodified epoxy resin, and WSR, which are epichlorohydrin based non-nylon polyamide resins.

We cover the following topics in this industry profile:

* Product descriptions and end uses.

- Market structure.
- Market trends and outlook.
- Foreign trade.
- Financial conditions.

8.3.1 Product Descriptions and End Uses

8.3.1.1 **Basic liquid resins (BLR)**. Diglycidyl ether of bisphenol A (DGEBPA), from which BLR are made, is a type of unmodified epoxy resin. There are several types of unmodified epoxy resin, but the standard and most common commercial epoxy resin is DGEBPA. In fact, DGEBPA is often referred to as "conventional" epoxy resin. Epoxy resins are plastic materials which contain a specific molecular group that reacts with different curing agents or hardeners resulting in hard, infusible solids. These solids have useful properties including good adhesion to many substrates, low shrinkage, high electrical resistivity, and good corrosion and heat resistance. Commonly used curing agents for DGEBPA include phenolic, urea, melamine, furane, polyester, vinyl, polyurethane and silicone.

The primary application of BLR is in protective coatings. Other applications include electrical laminates, adhesives, tooling, and flooring. Industrialized nations are by far the largest producers and consumers of BLR. Table 8-4 reports patterns of consumption across end-use categories for the years 1989 and 1990.

8.3.1.1.1 **Protective coatings**. About 40 percent of domestic BLR sales go to protective coatings markets. The primary uses of these coatings are automobile primers and finishes, maintenance and marine coatings, can coatings, and other product finishes. The popularity of BLR in the coatings industry is due to the high chemical resistance, toughness, and adhesion properties.

Epoxy coatings are called high performance coatings. A high performance coating or lining is one that is superior to paint in adhesion, toughness, and resistance to continuing exposure to industrial chemicals, food products, water, sea water, weather and high humidity. These coatings are designed to protect from

TABLE 8-4. BLR END-USE CONSUMPTION
(millions of pounds)

End Use	1989	Percent of total	1990	Percent of total
Protective coatings	193	40.0	195	42.0

Reinforced uses
   Electrical laminates
   Other
	
	57
	26
		
		11.8
		5.4
			
			55
			31
				
				11.9
				6.7

Export	86	17.8	68	14.7
Tooling, casting, molding	30	6.2	28	6.0
Bonding and adhesive	25	5.2	28	6.0
Flooring, paving, aggregates	25	5.2	28	6.0
Other	41	8.5	33	7.1
Total	483		464	

Source: <u>Plastics World</u>, "Resin Report," January 1991.

corrosive or otherwise detrimental exposure, and to slow the breakdown of industrial structures. The coatings need to be safe for use with materials in which they come into contact as well as be dense and have a minimum of absorption with contacting materials. Also, they should have a high resistance to the transfer of chemicals through the coating. Finally, they should maintain a generally good appearance even though subject to severe weather and chemical conditions.

Epoxy surface coatings are the third most common type of industrial finish behind alkyds and acrylics.[16] Epoxies tend to be more expensive, but have more attractive properties than other coatings including superior adhesion, flexibility and corrosion resistance when used on metallic substrates. However, due to their tendency to chalk or discolor upon exposure to sunlight they are not often.used for architectural purposes. Solid DGEBPA low-molecular weight resins are the most common type of epoxy resin used in coatings.

There are several types of epoxy coatings.[17] Each has different properties, but all are resistant and cure by internal linkage only. This means they need not be exposed to the air to cure so that thick coatings can be achieved in a single application. The primary types of epoxy coatings are amine-cured epoxies, polyamide cured epoxies, phenolic epoxies, and coal tar epoxies. DGEBPA can also be reacted with oils or fatty acids to make epoxy esters and other polymers. The esters are used primarily in floor finishes, primers for appliances, and maintenance coatings. Epoxy esters accounted for approximately 5 percent of epoxy coating demand in 1991.

Amine-cured epoxies are the most chemically resistant of the ambient temperature cure variety (they do not require heat or other processes to cure). However, they can be brittle and chalk quickly when exposed to the weather. They are mostly used in

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[16] Chemical Economics Handbook, Epoxy Surface Coatings.

[17] The material in this section was taken from Pulp and Paper (1979), Modern Plastics mid-October Encyclopedia issue.

industry where an air-dry coating is required and the need for chemical resistance is high. Urea and Melamine are two of the curing agents used to make amine-cured epoxies.

Polyamide cured epoxies are somewhat less chemically resistant than amine-cured epoxy. However, they have much better weather resistant qualities. The coating is non brittle and fairly flexible. It has excellent resistance to alkali and to water. The uses of this type of resin are broad based and include maintenance coatings for most industries including the chemical, paper, marine, atomic power, and food industries.

Epoxy-phenolic systems offer chemical resistance along with excellent mechanical properties. When they are heat cured, they are the strongest and most resistant of the epoxy coatings. For this reason, they are used for chemically resistant coatings on process equipment, tank and drum linings, pipe linings, and for protection from direct exposure to various chemicals. They are also commonly used for exposure to solvents, vegetable and animal oils, fatty acids, foods, and alkalis.

Coal tar epoxy coatings have good chemical resistance, reasonable weather resistance, and outstanding resistance to fresh and salt water, brine, and hydrogen sulfide. More generally, they are resistant to both acidic and alkaline conditions. They are one of the most durable coatings for the protection of concrete and metal, either under water or above water, against corrosive elements. These resins are black and so have limited decorative use, and, of course, can be used only where black is acceptable. They are used throughout the chemical industry and in the marine industry, both on ships and on offshore structures.

The following is a list of some specific uses of epoxy coatings.

- Heavy duty industrial and marine maintenance coatings.
- Tank linings.
- Industrial floorings.
- Coatings for farm and construction equipment.
- Aircraft primers.

8-26

- Floor and gymnasium finishes.
- Maintenance coatings.
- Metal decorating finishes.
- Pipe coatings.
- Container coatings.
- Electrodeposition primers for automobiles.
- Solder masks.
- Beverage and food can coatings.
- Appliance primers.
- Hospital and laboratory furniture.
- Coating for jewelry and hardware.
- Impregnating varnishes.

8.3.1.1.2 <u>Bonding and adhesives</u>. Because of their excellent adhesion to many substrates, epoxy resins are widely used as high performance adhesives. For example, because of their extraordinary adhesion to metal they are used in the automobile, aircraft and construction industries. According to the September 1990 issue of Chemical Marketing Reporter, about 80 percent of epoxy adhesive sales go into the automobile and construction industries. According the Chemical Economics Handbook, production of epoxy adhesives and sealant grew at an average annual rate of 8 to 8.5 percent from 1983 through 1989.

8.3.1.1.3 <u>Molding, casting, and tooling</u>. Uses in this category include encapsulation of electrical components by epoxy molding compounds. Also, epoxy casting resins are used as prototypes and master models in the manufacture of tools. Epoxies based on ultraviolet light stable structures are used in the casting of outdoor insulators switch gear components and instrument transformers.

8.3.1.1.4 <u>Laminating and composites</u>. Epoxy-based laminates are used in printed wiring boards, such as those used in computers and complex telecommunication equipment. Epoxy compounds are used in filament-wound glass reinforced pipe in oil field applications, in the manufacture of pressure vessels and tank and rocket motor casings, chemical plants, water distribution, and as electrical conduits. In the aerospace

industry, graphite fiber-reinforced multifunctional epoxy resin composites are becoming standard.

8.3.1.1.5 Building and construction. Epoxies are used in flooring, to repair bridges, roads, and cracks in concrete, to coat reinforcing bars, and to perform as binders for patios, swimming pool decks and the soil around oil well drills.

8.3.1.2 WSR. Polyamide-epichlorohydrin or WSRs are a type of non-nylon polyamide resin sold almost exclusively in the paper additives market. Approximately 90 percent of these resins are used to improve the wet tensile strength of paper products. Other uses of these resins in the paper industry include flocculent, drainage and drying aids, dry creping aids, cationizing agent for unmodified (pearl) potato and tapioca starch (used for dry strength), and as a component of paper surface finishes.

Paper which has been treated with a WSR shows greater resistance to rupture or disintegration when exposed to water. Note that wet strength is defined as tensile strength when the paper is completely absorbed with water, not water repellency. There are three primary types of WSR: (1) Ureaformaldehyde resins, (2) melamine formaldehyde resins, (3) polyamide-polyamine epichlorohydrin and modifications. It is the third category that includes EPI-based non-nylon polyamide resins. Other wet strength additives include those made from polyacrylamide, dialdehyde starch, polyacrolein resin, and cellulosic resin. The wet strength of paper increases almost linearly with the addition of WSR up to a point. Beyond this threshold the addition of WSR has little affect on the wet strength of the paper.

There are a large number of uses for paper which retains tensile strength when wet. Examples include tea bags, paper towels, and paper groceries bags.

Demand for this type of paper is most likely inelastic because of its "necessary" nature and the small percentage of income which is typically spent on these types of products. Specifically WSR are used for protection against:[18]

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[18] This list was drawn from Pulp and Paper (1979).

- Exposure to water of paper products used as drying or wiping media. Examples are paper towels, napkins, windshield wiping tissue, industrial wiping towels, lens paper, and facial tissue.

- Exposure to weather. Examples are packing cases, outdoor posters, building papers, paper bags, maps, and mulch paper.

- Wrapping for wet materials. Examples are butcher wraps, fruit and vegetable wraps and boxes, frozen and prepared food packages, and foil wrapped wet wipes.

- Exposure to water by immersion in a processing operation. Examples are photographic paper, copy print paper, filter paper, saturating paper, and tea bag paper.

- Disposables used in place of textiles. Examples are hospital bed sheets, hospital gowns and other sanitary single-use garments.

8.3.2 Market Structure

BLR and WSR are produced by a few large corporations, and many of these are conglomerates. Accordingly, market concentration is relatively high and vertical integration is common.

8.3.2.1 BLR. The major producers of basic liquid epoxy resins (BLR) are Dow Chemical Company, Ciba-Geigy Corporation, and Shell Chemical Company. They are also the largest producers of any type of unmodified epoxy resin - each having production rates on the order of 45.4 million kilograms per year. These three large companies have been producing epoxy resin for at least 12 years. Shell and Dow Chemical are also major producers of epichlorohydrin and bisphenol-A which are the primary feedstocks for epoxy. While Ciba-Geigy is not similarly backward integrated, it is a significant player in markets for further processed epoxy products, including formulated systems, electronic materials and composite materials.[19] These facts suggest that the market is fairly concentrated. Together, these

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[19] CEH (1991) Epoxy Resins.

three producers were responsible for approximately 60 percent of unmodified epoxy resin production in 1990.[20]

BLR and other types of unmodified epoxy resin are reasonably good substitutes. For this reason, entry and exit from the entire unmodified epoxy resin industry is worth examining. Table 8-5 lists companies who produced unmodified epoxy resin at some time over the period 1980 to 1991. An "X" in the column under a given year indicates that the company produced epoxy resin in that year. These lists of manufacturers comprise only those companies which responded to inquiries from the Society of the Plastics Industry. However, SPI's Committee on Resin Statistics estimates that these manufacturers account for about 95 percent of unmodified epoxy production.[21]

Over the last 12 years the list of manufacturers has had no more than 7 companies on it, and, beginning in 1984, has had only six. Since 1980, only four companies have entered or exited. The average duration of manufacture over the 12 years from 1980 to 1991 was 8.3 years.

8.3.2.2 <u>WSR</u>. Firms which produced epichlorohydrin based non-nylon polyamide resins in either 1988 or 1990 are listed in Table 8-6. An "X" in the column under a given year means that the company produced the resin in that year, an "O" means that they did not. Over the two years of data, there were two entries into and one exit from this industry.

In 1988, Hercules accounted for approximately 80 percent of the production of EPI-based polyamide. Henkel, Georgia-Pacific, Borden and Callaway each accounted for about 5 percent of the market. Trinova produced very little. It is unclear exactly what percentage of the market is controlled by Hercules in 1990. However, two Borden plants, five Hercules plants, and one Akzo

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[20] SPI I and MRI (1992).

[21] Source: SPI II.

TABLE 8-5. COMPANIES PRODUCING UNMODIFIED EPOXY RESIN,
1980-1991

Company Name	80	81	82	83	84	85	86	87	88	89	90	91
Celanese Plastics	X	X	X	X	X	X						
Ciba-Geigy	X	X	X	X	X	X	X	X	X	X	X	X
Dow Chemical	X	X	X	X	X	X	X	X	X	X	X	X
Reichold Chemical	X	X	X	X	X	X	X	X	X	X	X	X
Shell X	X	X	X	X	X	X	X	X	X	X	X	
Union Carbide	X	X	X	X	X	X	X	X	X	X	X	X
Morton Industries	X	X	X									
Rhone Poulenc Inc.											X	X
Interez						X	X	X				
Hi-Tek Polymers*										X		

*   Hi-Tek Polymers was owned by Rhone Poulenc in 1989.

Source: Society of the Plastics Industry 1.

TABLE 8-6.   COMPANIES PRODUCING EPI BASED NON-NYLON
POLYAMIDE RESINS, 1988 AND 1990

	1988, 1990
Borden	xx
Callaway Chemical[a]	xx
Georgia Pacific Corp.	xx
Henkel of America, Inc.	xx
Hercules, Inc.	xx
Trinova Corp.	xo
Pioneer Plastics	ox
Akzo	ox

[a]A subsidiary of Exxon Corporation.

Source: Chemical Economics Handbook and MRI (1992).

plant together accounted for 80 percent of production in 1990.[22]

Raw materials for epichlorohydrin based polyamide resin include adipic acid, diethylenetriamine, and epichlorohydrin. No producer of epi-based polyamide resins also produced these feedstocks as of 1988.

As of 1991 Georgia Pacific owned or controlled over 6 million acres of timber and timberlands. They were also producing pulp and paper (8 percent of U.S. annual capacity), containerboard and packaging, uncoated free sheet paper, tissue, envelopes and other paper products. Hercules was producing various paper products in addition to WSR in 1991.

8.3.3 Market Outlook

While domestic production of both BLR and WSR has fluctuated, the long-term trend has seen increased output of both products. BLR prices have been relatively stable recently, but WSR prices have fallen. The demand for both products is expected to increase moderately over the next few years.

8.3.3.1 BLR. Domestic production of unmodified resins has fluctuated somewhat over the twenty year period 1971 to 1990. However, production has increased on average by about 7 percent annually over this time.[23] BLR comprised about 60 percent of total unmodified epoxy resin production in 1990. Nominal prices peaked at $2.89 (per kilogram) in 1984 and since then have fluctuated around $2.40.[24]

Two recently published industry reports predict that U.S. epoxy resin production will experience healthy growth to the end of the 1990's. Network Consulting Inc. (1992) expects a 4 percent annual growth in domestic production to last through 1997. The Freedonia Group (1992) predicts North American

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[22] MRI (1992).

[23] Computed from data in USITC I.

[24] USITC I.

production, which is dominated by U.S. firms, to grow at an annual rate of 4.4 percent to 1995.

The Freedonia Group attributes expected growth to an expanding export market which they predict will reach 300 million pounds by 1995. However, they expect the heavy growth in exports to be countered by a slower growth in North American consumption, which they expect to be just 3 percent per year.

Network Consulting, Inc. (1992) base their projections of growth on the recovery of the U.S. economy and the advent of environmental regulations which favor the use of epoxies in high solids and powder coatings. In recent years, environmental pressures have resulted in the rapid development of these epoxy products because they use substantially less organic solvent but retain the useful chemical and physical properties of epoxies.

The Freedonia Group expects epoxy adhesives to grow at 4.4 percent per year to 1995, reaching 37 million pounds. They expect epoxy coatings to grow four tenths of a percent faster than the overall coatings market at 2.8 percent per year to 1995. This means that by 1995, 235 million pounds of epoxy resin will be used in coatings.

Chemical Economics Handbook estimates that between 1983 and 1988 the use of epoxy resins in adhesives and sealants grew at an average rate of about 8.5 percent per year. An increase of about 7 percent occurred in 1989. Between 1989 and 1994, growth in the consumption of epoxy adhesives is expected to slow slightly to a 6 percent annual rate. They expect growth to be driven by the increasing use of resin based composites in aerospace, automotive and recreational markets. Also, there is a trend toward using epoxies instead of more expensive welds, especially in the automotive market. Technological advances may also contribute to the growth of epoxy adhesives. Improvements have been made in various properties including adhesion to plastics and toughness, and new systems have been introduced that allow faster bonding at lower initiation temperatures.

Chemical Economics Handbook estimates that epoxy surface coatings grew at an average annual rate of 3.5 to 4 percent

between 1986 and 1990. They expect this growth to slow to 3 to 3.5 percent presently. Furthermore, they report that the consumption of epoxy esters will decline due to their adverse effects on the environment. On the other hand powder coatings are projected to grow at 5 to 10 percent annually because of the high quality of the coating and the lack of adverse environmental effects. Consumption of epoxy resins in surface coatings is projected by CEH to reach 215-220 million pounds by 1995.

8.3.3.2 WSR. The growth rate of production for non-nylon polyamide was more volatile than that of epoxy over the period 1971-1990. For example, production increased by 73 percent in 1974 and fell by 49 percent in 1975. However, the average growth rate of production was somewhat greater than that of epoxy, about 10 percent annually. The nominal price reached $2.54 per kilogram (dry weight basis) in 1985, but has since declined. Production and prices both fell sharply in 1990. Production fell by about 26 percent in 1990 and price declined substantially to $1.50 — a level it had not been below since 1972.[25]

In 1987, Chemical Economics Handbook reported that the growing trend to use neutral-cure wet-strength resins as replacements for formaldehyde based (melamine and urea) resins would continue through 1992, and that it would account for strong increases in the demand for WSR. Urea formaldehyde and melamine formaldehyde resins are inferior as wet strength additives in unbleached paper production because of their acid curing characteristics. Specifically, they can cause embrittlement and deterioration of paper as well as reduce absorbency. Demand for epichlorohydrin based polyamide was predicted to continue to increase at a rate of 5 to 6 percent annually from 1987 through 1992. Production of non-nylon polyamide was somewhat erratic over the period 1987 through 1990, experiencing 10 percent decline in volume in 1990.

8.3.4 Foreign Trade

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[25] USITC I (various issues).

8.3.4.1 <u>BLR</u>. Table 8-7 shows exports and imports of epoxy
         TABLE 8-7. U.S. TRADE IN EPOXY RESIN
                    (millions of kilograms)

Year	Exports	Imports/Exports
1981	42.3	.05
1982	45.7	.05
1983	41.5	.07
1984	44.5	.09
1985	40.5	.14
1986	44.0	.18
1987	55.7	.12
1988	69.0	.09
1989	85.1	.07
1990	94.4	.09
1991	97.9	.11

Source: U.S. Department of Commerce, Bureau of the Census.

resin in millions of kilograms per year from 1981 through 1991 as reported by the U.S. Department of Commerce. The table also reports imports divided by exports.

According to the Bureau of the Census, exports in 1991 amounted to 97.9 million kilograms. In 1989 the principle destinations were: Far East countries other than Japan, which accounted for 27 percent; Canada which accounted for 23 percent; Western Europe, 21 percent; Japan, 11 percent; and Mexico, 7 percent.

Imports have been fairly stable and relatively small in volume through the eighties. In 1989, an estimated 50 percent of the imported epoxy resins were used in coatings, and the remainder went primarily into adhesives and electronic encapsulation.

8.3.4.2 WSR. Table 8-8 shows exports and imports of nonnylon polyamide resins in millions of kilograms per year from 1981 through 1991. The ratio of exports to domestic production, import to domestic production and imports to exports are also reported.

Exports fluctuated considerably during the 1980's, reaching a high of 10.2 million kilograms in 1988 and a low of 3.6 million kilograms in 1982. However, in most years exports ranged between 4 and 6 million kilograms. Imports were more stable over the period hovering around 1 million kilograms until 1988. However, in 1989 and 1990 imports of non-nylon polyamide increased.

8.3.5 Financial Data

Baseline financial data for firms producing resins are displayed in Table 8-9. The ratio of net income to assets and the ratio of long term debt to long term debt plus equity are reported in the table. In order to compensate for cyclical fluctuations, net income over assets figures were averaged over the years 1988 through 1991. The long term debt ratio is reported for 1991.

Most of the resin producers are earning between a 4 and 6 percent return on their assets. Dow is earning by far the largest return at 9 percent. Hercules and Shell show the poorest

TABLE 8-8.   U.S. TRADE IN NON-NYLON POLYAMIDE
(millions of kilograms)

Year	Exports	Imports	Imports/ Exports
1981	5.0	n.a.	n.a.
1982	3.6	n.a.	n.a.
1983	4.1	0.8	.19
1984	4.4	1.1	.24
1985	5.3	1.1	.21
1986	4.5	1.2	.26
1987	6.1	1.2	.19
1988	10.2	1.1	.11
1989	5.9	3.8	.64
1990	6.2	4.7	.76
1991	n.a.	6.1	n.a.

Sources: U.S. Department of Commerce (1992), USITC.

TABLE 8-9. FINANCIAL DATA FOR RESIN PRODUCERS

	NI/A* (average 1988-1991)	LTD/(LTD+E) (1991)
Hercules	.02	.22
Shell	.03	.11
Dow	.09	.39
Ciba Geigy	.05	.20
Borden	.05	.41
Exxon	.06	.20
Georgia Pacific	.04	.58
Henkel	.05	.14

Source: Moody's Industrial Manual 1991, Annual Reports 1991.

*   NI = net income   A = assets
      LTD = long term debt   E = equity

returns at 2 and 3 percent, respectively.

Shell and Henkel have the smallest long term debt ratios at less than 0.15 each. Hercules, Ciba Geigy and Exxon are a little larger at around 0.2 each. Dow and Georgia Pacific have the highest ratios.

8.4 PRIMARY ECONOMIC IMPACTS AND CAPITAL AVAILABILITY ANALYSIS

8.4.1 Introduction

This section presents estimates of the primary economic impacts which would result from the implementation of the NESHAP and the results of the capital availability analysis. We also present results for Option I for the WSR industry. Primary impacts include changes in market prices and output levels, changes in the value of shipments by domestic producers, and plant closures. The capital availability analysis assesses the ability of affected firms to raise capital and the impacts of control costs on plant profitability.

8.4.2 Estimates of Primary Impacts

As explained earlier in Section 8-2, we use partial equilibrium models of the affected industries to estimate primary impacts. The increase in production costs resulting from the purchase and operation of emission control equipment causes an upward, vertical shift in the domestic supply curves. The height of this shift is determined by the after tax cash flow required to offset the per unit increase in production costs. Because control costs vary across plants within each industry segment, the post-control supply curves are segmented. We assume a worst case scenario in which plants with the highest control costs (per unit of output) are marginal (highest cost) in the post-control market.

Foreign supply (net imports) is assumed to have the same elasticity as domestic supply in both markets.[26] Foreign and

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[26] The United States is a new exporter of both BLR and WSR. Trade in DGEBA is substantial. Net exports accounted for approximately 15 percent of production in 1990. However, trade in wet strength resin is insignificant. The small volume of trade is due to the custom of shipping only the polyamide and letting the receiving company complete the epichlorohydrin reaction. In 1988 exports accounted for about 1 percent of domestic wet strength resin

post-control domestic supply are added together to form total market post-control supply. The intersection of post-control market supply curve with market demand determine the new market equilibrium price and quantity. The post-control domestic output is given by post-control market output less post-control imports.

Table 8-10 presents the primary impacts predicted by the partial equilibrium analysis for the BLR and WSR industries. For example, we estimate that the NESHAP will result in a 0.12 cent per kilogram (0.05 percent) increase in the price of BLR and an annual reduction in domestic production of about 106 metric tons (0.08 percent of baseline production). We also estimate that the NESHAP will cause the annual value of domestic shipments to fall by about $108,000 (0.03 percent). No plant closures are predicted.

Table 8-10 also shows the estimated impacts on the WSR industry, both for the MACT Floor and Option I. Estimated price and output changes range from very small impacts associated with Option I to larger impacts under the MACT Floor. Under the MACT Floor, estimated increases in price and decreases in domestic production are approximately 4 percent, and about 1 plant closure is possible[27]. However, under Option I, price and output impacts are only 0.22 percent and 0.20 percent, respectively, and no plant closures are predicted.

We emphasize that the assumptions we adopt in our analysis are likely to cause us to overstate predicted plant closures. First, we assume that the plant with the highest per unit emission control costs also is the least efficient in that it has the highest baseline per unit production costs. Second, we assume a national market, but regional trade barriers might afford some protection for some plants. Finally, the production of WSR is intermittent. When our analysis predicts a plant

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production, and imports were only a small fraction of exports.

[27] Table 4-1 reports fractions of plant closures. The 0.63 plant closure predicted for the wet strength resin industry means that we estimate that the marginal plant would lose 63 percent of its annual production.

TABLE 8-10. ESTIMATED PRIMARY IMPACTS ON BLR
AND WET STRENGTH RESIN MARKETS

IMPACT	BLR	WET STRENGTH MACT Floor	RESIN Option I
Price Change ¢/kilogram[a] Percent	.12 .05	.84 4.19	.04 .22
Annual Change in Domestic Output Metric Tons[b] Percent	−106 −.08	−7347 −3.73	-404 -.20
Annual Change in Value of Domestic Shipments $1,000[a] Percent	−108 −.03	−123 −.31	7 .02
Plant Closures	.00	.63	.03

[a] 1992 dollars.   [b] Wet weight basis.

closure, it means that the plant will cease production of WSR, but not close operations altogether.

The estimated primary impacts reported above depend on a set of parameters used in the partial equilibrium model of the wet strength and BLR resin industries. One of the parameters, the elasticity of demand, measures how sensitive buyers are to price changes. The estimated impacts reported above are based on a demand elasticity of —0.92 for the wet strength market and —1.5 for the BLR market. In Appendix D, we report the results of analyses that show the sensitivity of the estimated impacts to changes in the demand elasticity. The "low" elasticity case adopts a demand elasticity of —0.5 for the WSR industry and —0.62 for the BLR industry. The results show slightly larger price increases, smaller reductions in market output and less adverse impacts on domestic producers than results reported above.[28] The "high" elasticity case uses a demand elasticity of —1.34 for the WSR industry and —3.10 for the BLR industry. In general, this case shows slightly smaller price increases but more adverse impacts on domestic producers. However, the sensitivity analysis generally shows that the estimated primary impacts are relatively insensitive to reasonable ranges of demand elasticity estimates.

Also, the estimated impacts reported in Table 8-10 is based on the assumption that plants with the highest emission control costs (per unit of output) are marginal (highest cost) producers in the post-control market. This assumption causes the adverse impacts associated with the regulatory alternatives to be overstated.

8.4.3 Capital Availability Analysis

The capital availability analysis involves examining pre- and post-control values of selected financial ratios. These ratios include net income divided by assets and long term debt divided by the sum of long term debt and equity. In order to

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[28] Also, the plant closure previously predicted for the wet strength resin industry under the MACT Floor is no longer predicted when a "low" elasticity of demand is assumed.

reduce the effects of year-to-year fluctuations in net income, a four-year average (1988 through 1991) of net income over assets was used as the baseline. Changes in the long term debt ratio represent structural changes and so are not subject to the same cyclical fluctuations. Long term debt ratios from 1991 were used as the baseline.

As explained in Section 8-2, these financial statistics lend insight into the ability of affected firms to raise the capital needed to acquire emission controls. They provide estimates of the changes in profitability which would arise from the implementation of the NESHAP.

To calculate the post-control ratio of net income to assets, annualized control costs were subtracted from pre-control net income, and capital control costs were added to pre-control assets. To calculate the post-control long term debt ratio, capital control costs were added to pre-control long term debt, both the numerator and denominator of this ratio. Note that both post-control ratios reflect a worst-case assumption that affected firms are required to absorb emission control costs without the benefit of higher market prices.

Financial data are available for all three DEGBPA producers and 5 of the 7 WSR producers. The 5 wet strength producers own 15 of the 17 facilities.

All of the companies that produce BLR and WSR are large corporations. As a result, emission controls costs, which are relatively small, have no perceptible impacts on the firm's financial ratios after rounding. Accordingly, we conclude that affected companies will not find it difficult to raise the capital necessary to purchase and install the required emission controls.

8.4.4 Limitations of Estimated Primary Impacts

Several qualifications of the estimated primary impacts presented in this section need to be made. A single market for homogeneous output is assumed in the partial equilibrium analysis. However, there may be some regional trade barriers which would protect producers. Furthermore, the analysis assumes

that plants with the highest per unit emission control costs are marginal post-control. This assumption will cause the impacts presented above to be overstated since market impacts are determined by the costs of marginal plants. Finally, some plants may find that the price increase resulting from regulations make it profitable to expand production. This would occur if a firm found its post-control incremental unit costs to be smaller than the post-control market price. Expansion by these firms would result in a smaller decrease in output and increase in price than otherwise would occur.

We have also noted that the estimated primary impacts depend on the parameters of the partial equilibrium model. The results of the sensitivity analyses presented in Appendix D, which are based on a larger (more elastic) estimate of demand elasticity, show slightly more adverse impacts on domestic producers.

The capital availability analysis also has limitations. First, future baseline performance may not resemble past levels. Second, the tools used to measure the impact of controls are limited in their scope. Finally, the financial analysis is based on a worst-case assumption that affected establishments will fully absorb emission control costs without the benefits of higher prices.

8.4.5 <u>Summary of Primary Impacts</u>

The estimated impacts of the NESHAP on the BLR industry is relatively small. Predicted price increases, reductions in domestic output and the value of domestic shipments for the BLR industry are 0.08 percent or less. The impacts estimated under the MACT Floor for the WSR industry are somewhat more adverse. Predicted price increases, reductions in domestic output and the value of domestic shipments for the MACT Floor are about 4 percent, and one plant closure is possible. Under the Option I Scenario, however, predicted price increases, reductions in domestic output and the value of domestic shipments are 0.22 percent or less, and no plant closures are expected. As noted earlier, these results are likely to overstate the true adverse impacts. Finally, because emission control costs are

very small relative to the financial resources of affected producers, they should not find it difficult to raise the capital necessary to finance the purchase and installation of emission controls.

8.5 SECONDARY ECONOMIC IMPACTS

8.5.1 Introduction

This section presents estimates of the secondary economic impacts that would result from the implementation of the NESHAP. Secondary impacts include changes in employment, energy use, and foreign trade and regional impacts.

8.5.2 Labor Impacts

The estimated labor impacts associated with the NESHAP are based on the results of the partial equilibrium analyses of the two resin industries. These estimated impacts depend primarily on the estimates of reduction in domestic production reported earlier in Section 8-4.[29] Note that changes in employment due to the operation and maintenance of control equipment have been omitted from this analysis due to lack of data. Also, the estimated employment impacts reported below do not include potential employment gains in industries which produce substitute commodities that might benefit from reduced BLR and WSR production. Thus, the changes in employment estimated in this section reflect only the direct employment losses due to reductions in domestic production of BLR and WSR.

Table 8-11 presents estimates of employment losses for each of the two industries. As Table 8-11 indicates, the estimated job losses are small (up to two production jobs). As expected, the estimated employment losses in the WSR industry are smaller for Option I than for the MACT Floor. The generally small impacts occur primarily because only small reductions in output are expected to occur as a result of the implementation of the

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[29] More specifically, we estimate employment impacts by assuming that labor use per unit of output will remain constant when the quantity of output changes. Production worker hours per dollar of output was calculated from 1989 Annual Survey of Manufactures and a producer price index for chemicals and allied products obtained from the Economic Report of the President 1991. See Appendix B for a more detailed discussion.

TABLE 8-11. ESTIMATED EMPLOYMENT LOSSES

IMPACT	BLR	Wet Strength Resin, MACT Floor	Wet Strength Resin, Option I
Lost Jobs	0.34	1.84	0.10
Percent Loss	0.08	3.73	0.20

NOTE: Estimates do not include potential employment gains due to operating and maintaining emission controls.

NESHAP. Also, the industry is characterized by a relatively high output/employment ratio or low labor intensity.

8.5.3 <u>Energy Use Impacts</u>

The approach we employ to estimate reductions in energy use is similar to the approach employed to estimate labor impacts. Again, these impacts depend primarily on the estimated reductions in domestic output reported earlier in Section 8-4. Note that the changes reported below do not account for the potential increases in energy use due to operating and maintaining emission control equipment. This omission is due to lack of data.

Table 8-12 presents changes in the use of energy by each industry. As expected, the estimated changes in energy use are minor because only small reductions in output are expected as a result of the implementation of the NESHAP. The change in the use of energy by the WSR industry differs substantially between the MACT Floor and Option I. Much smaller energy use reductions are expected under Option I.

8.5.4 <u>Foreign Trade Impacts</u>

Other factors being the same, the implementation of the NESHAP will raise the production costs of domestic resin manufacturers relative to foreign producers, causing U.S. imports of resin to increase and U.S. exports to decrease. The effects of the regulation on both the quantity and the value of net exports (exports-imports) are reported in Table 8-13.

The estimated trade impacts are small, both because of small predicted domestic price increases and because of the relatively small amount of trade that exists currently for the two products. For example, we estimate that the implementation of the standard will result in reduced BLR net exports of about 20 metric tons annually (about .12 percent of baseline net exports) or about $38,000 per year. Note that we predict only a slight change in the dollar value of WSR exports under both the MACT Floor and Option I, even though we estimate that the volume of exports will fall by about 73 metric tons annually under the MACT Floor, and 4 metric tons annually under Option I. In either case, the higher

TABLE 8-12. ESTIMATED ENERGY USE REDUCTIONS

INDUSTRY/IMPACT	
BLR	
$1,000 1992	8.51
Percent Reduction	0.08
WSR (MACT Floor)	
$1,000 1992	45.55
Percent Reduction	3.73
WSR (Option I)	
$1,000 1992	2.50
Percent Reduction	.20

NOTE: Estimates do not include potential increases in energy use due to operating and maintaining emissions controls.

TABLE 8-13.   ESTIMATED IMPACTS ON NET EXPORTS

INDUSTRY/IMPACT	

BLR
   Volume (metric tons)
   Percent Change (volume)
   Value ($1,000 1992)
	—20
	—.12
	—38

WSR (MACT Floor)
   Volume (metric tons)
   Percent Change (volume)
   Value ($1,000 1992)
	—73
	—3.73
	1.23

WSR (MACT Floor)
   Volume (metric tons)
   Percent Change (volume)
   Value ($1,000 1992)
	.
	—4
	—.21
	.06

NOTES: Dollar estimates of trade impacts are adjusted for higher
           post-control prices. Changes in trade volumes are reported on
           a wet weight basis.

8-50

post-control prices offset (approximately) the reduced physical volume of exports.

8.5.5 Regional Impacts

No significant regional impacts are expected from the implementation of the NESHAP because estimated employment impacts are small.

8.5.6 Limitations of Estimated Secondary Impacts

Our estimates of the secondary impacts associated with the NESHAP are based on changes in market equilibria predicted by the partial equilibrium models of the two affected markets. Accordingly, the caveats we discussed earlier in Section 8-4 for the primary impacts apply as well to our estimates of secondary impacts.

As noted earlier, the estimates of employment impacts do not include potential employment gains due to operating and maintaining emission control equipment or employment gains in the manufacturing of substitute products. Similarly, the estimates we report exclude potential indirect employment losses in industries that supply inputs to the resin industries. In short, the reported estimates of employment impacts include only direct production job losses in the BLR and WSR industries.

8.5.7 Summary of Secondary Impacts

The estimated secondary economic impacts of the alternative NESHAP are generally small. Estimated employment and energy impacts are small because only small reductions in industry output are expected. The estimated trade impacts are minor because only small domestic price increases are expected and because baseline trade volumes for the affected products are small. No significant impacts on regional economies are expected.

8.6 POTENTIAL SMALL BUSINESS IMPACTS

Firms in the BLR and WSR industries are classified as "small businesses" if they employ fewer than 750 employees.[30] No BLR producer satisfies the criteria for a small business.[31] The three BLR producers, Shell, Ciba-Geigy and Dow Chemical, employed over 30 thousand people in 1991. Ciba-Geigy employed over 90 thousand people in 1991. Employment data are available for 5 of the 7 wet strength facilities. Of the five, the company employing the fewest people was Hercules at approximately 15 thousand employees. No WSR producer for which we have employment data comes close to qualifying as a small business. Table 8-14 shows the total employment of resin producing companies in 1991.

The Small Business Administration defines a small business as one which is not dominant in its field. There are three producers in the DGEBA industry. Each producer has a substantial market share.

The EPA Guidelines for Implementing the Regulatory Flexibility Act state that the definition of a small business is "any business which is independently owned and operated and not dominant in its field." The three corporations producing DGEBA each have substantial market share. Similarly, the producers of WSR are typically large conglomerates which employ well over 750 people.

8.7 ECONOMIC COSTS

Estimates of the economic costs associated with the implementation of the NESHAP for the BLR and WSR industries are presented below in this section of the report.

8.7.1 Economic Costs of Emission Controls: Conceptual Issues

Air quality regulations affect society's economic well-being by causing a reallocation of productive resources within the economy. Specifically, resources are allocated to the production of cleaner air and away from other goods and services that could

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[30] EPA (1992). EPA Guidelines for Implementing the Regulatory Flexibility Act, Revised April 1992, Appendix C. Small Business Size Regulations, 13 CFR Part 121.

[31] EPA may adopt an alternative definition of a small business if an alternative size cutoff can be justified.

TABLE 8-14.   EMPLOYMENT OF RESIN PRODUCERS

Company Name	Employment in 1991
Georgia Pacific	over 52,000
Henkel	41,000
Hercules	15,000
Dow	62,000
Borden	44,000
Exxon	101,000
Ciba-Geigy	91,000
Shell	30,000

Source: 1991 Annual Reports

otherwise be produced. Accordingly, the economic costs of emission controls can be measured as the value that society places on those goods and services not produced as a result of resources being diverted to the production of improved air quality. The conceptually correct valuation of these costs requires the identification of society's willingness to be compensated for these foregone consumption opportunities that would otherwise be available.[32]

In the discussion that follows, we distinguish between emission control costs and the economic costs associated with the regulatory alternatives. The former are measured simply as the annualized capital and annual operating and maintenance costs of controls under the assumption that all affected plants install controls. As noted above, economic costs reflect society's willingness to be compensated for foregone consumption opportunities.

Estimates of emission control costs will correspond to the conceptually correct measure of economic costs only if the following conditions hold:

- Marginal plants affected by an alternative standard must be able to pass forward all emission control costs to buyers through price mark-ups without reducing the quantity of goods and services demanded in the market.

- The prices of emission control resources (e.g., pollution control equipment and labor) used to estimate costs must correspond to the prices that would prevail if these factors were sold in competitive markets.

- The discount rate employed to compute the present value of future costs must correspond to the appropriate social discount rate.

- Emission controls do not affect the prices of goods imported to the domestic economy.

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[32] Willingness to be compensated is the appropriate measure of economic costs, given the convention of measuring benefits as willingness to pay. Under this convention, the potential to compensate those members of society bearing the costs associated with a policy change is compared with the potential willingness of gainers to pay for benefits. See Mishan (1971).

8.7.1.1 <u>Market Adjustments</u>. A plant is marginal if it is among the least efficient producers in the market and, as a result, the level of its costs determine the post-control equilibrium price. A marginal plant can pass on to buyers the full burden of emission control costs only if demand is perfectly inelastic. Otherwise, consumers will reduce quantity demanded when faced with higher prices. If this occurs, estimated control costs will overstate the economic costs associated with a given air quality standard.

The emission control costs estimates do not reflect any market adjustments that are likely to occur as affected plants and their customers respond to higher post-control production costs. The estimates of economic costs presented later in this section do reflect estimates of such market adjustments.

8.7.1.2 <u>Markets for Emission Control Resources</u>. Other things being the same, estimated emission control costs will overstate the economic costs associated with an alternative air quality standard if the estimates are based on factor prices (e.g., emission control equipment prices and wage rates) which reflect monopoly profits earned in resource markets. Monopoly profits represent a transfer from buyers to sellers in emission control markets, but do not reflect true resource costs.

The extent to which sellers in emission control markets possess monopoly power has not been investigated. Consequently, we assume in this study that emission control resources are traded in competitive markets. The estimated economic costs reported in this section are overstated if this assumption does not hold.

8.7.1.3 <u>The Social Discount Rate</u>. The estimates of annualized emission control costs presented earlier in this report were computed by adding the annualized estimates of capital expenditures associated with the purchase and installation of emission control equipment to estimates of annual operating and maintenance costs. Capital expenditures were annualized using a 7 percent discount rate. The private cost of capital is appropriate for estimating how producers adjust supply

prices in response to control costs.[33] In order to estimate
the economic costs associated with the NESHAP, an appropriate
measure of the social discount rate should be used in the
amortization schedule.

There is considerable debate regarding the use of
alternative discounting procedures and discount rates to assess
the economic benefits and costs associated with public
programs.[34] The approach adopted here is a two-stage procedure
recommended by Kolb and Scheraga (1990).

First, annualized costs are computed by adding annualized
capital expenditures (over the expected life of emission
controls) and annual operating costs. Capital expenditures are
annualized using a discount rate that reflects a risk-free
marginal return on investment.[35] This discount rate, which is
referred to below as the social cost of capital, is intended to
reflect the opportunity cost of resources displaced by
investments in emissions controls. Kolb and Scheraga (1990)
recommend a range of 5 to 10 percent for this rate. We adopt a
midpoint value of 7.0 percent in this analysis.[36]

Second, the present value of the annualized stream of costs
is computed using a consumption rate of interest which is taken
as a proxy for the social rate of time preference. This discount
rate, which is referred to below as the social rate of time
preference, measures society's willingness to be compensated for
postponing current consumption to some future date. Kolb and
Scheraga (1990) argue that the consumption rate of interest

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[33] In other words, a discount rate reflecting the private cost of capital
to affected firms should be used in analyses designed to predict market
adjustments associated with emission control costs. The private cost of
capital, assumed to be 10 percent in this analysis, is higher than the 7 per-
cent social discount rate because it reflects the greater risk faced by
individual procedures related to the risk faced by society at large.

[34] See Lind, et al. (1982) for a more detailed discussion of this debate.

[35] The risk-free rate is appropriate if the NESHAP, as a program, does
not add to the variance of the return on society's investment portfolio.

[36] The 7 percent discount rate is also consistent with recent OMB recom-
mendations.

probably lies between 1 and 5 percent. We do not, however, present estimates of the present value of the costs associated with the NESHAP in this report.

The resulting estimates of the present value of the economic costs associated with the NESHAP can be compared with estimates of the present value of corresponding benefits in the BCA. The social rate of time preference should be employed to discount the future stream of estimated benefits.

8.7.1.4 <u>Costs of Imported Goods</u>. The NESHAP is expected to cause an increase in prices paid for imports. From the perspective of the world economy, higher prices paid for imported goods represent a transfer from domestic consumers to foreign producers. However, from the perspective of the domestic economy alone, higher prices on imported goods represent an economic cost.

Since we do not consider the welfare of foreign producers in this analysis, we treat expenditures on BLR and WSR due to higher prices as a cost. Note that there are two sources of this cost: (1) higher prices paid for baseline imports; and (2) higher prices paid for the additional imports induced by emission control costs faced by domestic producers.

8.7.2 <u>Other Costs Associated with NESHAP</u>

It should be recognized that the estimates of costs reported later in this section do not reflect all costs that might be associated with the NESHAP. Examples of these include administrative, monitoring, and enforcement costs (AME), and transition costs.

AME costs may be borne by directly affected firms and by different government agencies. These latter AME costs, which are likely to be incurred by state agencies and EPA regional offices, for example, are reflected neither in the estimates of emission control costs, nor in the estimates of economic costs.

Transition costs are also likely to be associated with the alternative standards. Analyses described in previous sections of this report, for example, predict that some plants will close because of emission control costs. This will cause some

individuals to suffer transition costs associated with temporary unemployment and affected firms to incur shutdown costs. These transition costs are not reflected in the cost estimates reported later in this section.

8.7.3 Changes in Economic Surplus as a Measure of Costs

As was noted earlier, willingness to be compensated for foregone consumption opportunities is taken here as the appropriate measure of the costs associated with the NESHAP. In this case, compensating variation is an exact measure of willingness to be compensated. In practice, however, compensating variation is difficult to measure; consequently, the change in economic surplus associated with the air quality standard is used as an approximation to compensating variation.

The degree to which a change in economic surplus coincides with compensating variation as a measure of willingness to be compensated depends on whether the surplus change is measured in an input market or a final goods market. The surplus change is an exact measure of compensating variation when it is measured in an input market, but it is an approximation when measured in a final goods market.[37]

The direction of the bias in the approximation of compensating variation when the surplus change is measured in a final goods market depends on whether affected parties realize a welfare gain or suffer a welfare loss, but in either case, the bias is likely to be small.[38] Affected firms (and their customers) will suffer a welfare loss as the result of the implementation of emission controls. In this case, the change in economic surplus will exceed compensating variation, the exact measure of willingness to be compensated.[39]

8.7.4 Estimates of Economic Costs

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[37] See Just, Heuth, and Schmitz (1982) for a more detailed discussion.

[38] See Willig (1974).

[39] See Appendix B for a detailed, technical description of the methods employed to compute changes in economic surplus.

Estimates of the annualized total economic costs associated with the NESHAP are reported in Table 8-15 (for a social cost of capital equal to 7.0 percent). The estimates of total annual costs of the NESHAP are $120 thousand for the BLR industry, $465 thousand for the WSR industry under the MACT Floor, and $51 thousand for the WSR industry under Option I.

We measure economic costs as net losses in economic surplus. Table 8-15 shows how losses in surplus are distributed among consumers, domestic producers and society at large. The latter is referred to as "residual" surplus in the table.

The loss in consumer surplus includes higher outlays for foreign and domestically produced BLR and WSR plus a dead weight loss due to foregone consumption. As Table 8-15 indicates, consumers in each market suffer a loss in surplus. These losses are due mostly to higher expenditures on BLR and WSR.

We compute the loss in producer surplus as annualized emission control costs incurred by plants remaining in operation plus the dead weight loss in surplus due to reduced output less increased revenue due to higher post-control prices. The estimated losses in producer surplus reported in Table 8-15 are negative, meaning that domestic producers would realize a net gain in economic surplus. This occurs because higher post-control market prices more than offset emission control costs.

Surplus losses to society at large are computed as "residual" adjustments to account for differences in private and social discount rates and transfer effects of taxes. The estimates of changes in producer surplus reflect a 10 percent real private rate on emission control capital costs. Recall that social costs are discounted at a 7.0 percent real rate.[40]

We note that the distribution of economic costs between consumers and domestic producers depends, in part, on the way we have constructed the post-control supply curve. As explained earlier, we have assumed that plants with the highest emission

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[40] Since the loss in producer surplus measures the burden of the alternative borne by producers, we calculate it using the private cost of capital.

TABLE 8-15.   ESTIMATES OF ANNUALIZED ECONOMIC COSTS
(thousands of 1992 dollars)

Industry	Loss in Consumer Surplus	Loss in Producer Surplus	Loss in Residual Surplus	Loss in Surplus Total
BLR	141	-3	—19	120
Wet Strength Resin MACT Floor	1,607	-841	—300	465
Option I	87	-22	-13	51

NOTE: Estimates are computed as the annualized reduction in economic
surplus to the domestic economy.

control costs (per unit of output) are marginal in the post-control market. This assumption is worst case in that it results in large increases in prices (relative to an alternative assumption that plants with high control costs are not marginal), thus shifting the cost burden to consumers and away from plants that continue to operate in the post-control market. Any alternative construction of the post-control supply curve would result in smaller price increases and shift a larger share of economic costs away from consumers to domestic producers. In other words, smaller price increases would reduce the economic rent realized by domestic producers in the post-control market.

Earlier, we explained that economic costs differ from emission control costs. Recall that the latter are computed simply as annualized capital costs plus annual operating and maintenance costs, assuming that all plants install controls. Table 8-16 reports estimates of annualized emission control costs. These estimates are $145 thousand for the BLR industry and range from $52 thousand under the MACT Floor to $519 under Option I for the WSR industry. The emission control costs reported in Table 8-16 exceed the economic costs reported in Table 8-15 under the MACT Floor scenario. This occurs because the estimated economic costs reflect market adjustments away from marginally expensive production.

TABLE 8-16. ESTIMATES OF THE ANNUALIZED EMISSION
CONTROL COSTS
(thousands of 1992 dollars)

BLR	Wet Strength Resin MACT Floor	Wet Strength Resin Option I	Total
145	519	N.A.	664
145	N.A.	52	197

NOTE: Estimates are computed as annualized capital costs plus annual
operating and maintenance costs, assuming all plants continue to
operate after controls are installed. Capital costs are annualized
at a 7 percent discount rate.

APPENDIX A

AFFECTED PLANTS AND EMISSION CONTROL COSTS

APPENDIX A

AFFECTED PLANTS AND EMISSION CONTROL COSTS

This appendix describes the affected BLR and WSR plants and the estimates of emissions and emission control costs used in this study.

AFFECTED PLANTS

There are three major BLR producers. Consequently, we are able to use plant specific data for baseline emissions, emissions reductions, and control costs. Data on production rates at BLR plants, however, is considered confidential and is not available to the public. We use an average annual production rate of 45,000 metric tons (wet weight) as baseline output for each of the three BLR facilities.[1]

There are 17 WSR facilities nationwide. However, only five of these plants are expected to incur emission control costs under the MACT Floor and nine under Option I. We assume that each of these plants produce 11,600 metric tons annually.[2]

EMISSION CONTROL COSTS

Table A-1 reports emission control capital costs and annualized costs for the three BLR facilities. Table A-2 shows the same information for the five affected WSR plants. Annualized costs include amortized capital costs plus the annual operating and maintenance costs associated with emission controls. Table A-3 shows capital and annualized costs for the nine WSR plants expected to be affected by Option I (estimated costs are the same for all nine plants).

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[1] Draft BID, Section 6, Appendix A (wet weight).

[2] Draft BID, Section 6, Appendix A (wet weight).

TABLE A-1.   CONTROL COSTS AT BLR PLANTS

PLANT	CAPITAL COSTS (1992$)	ANNUALIZED COSTS (1992$)[a]
DOW	254,873	31,207
Ciba-Geigy	104,778	75,461
Shell	67,618	38,266

[a] Capital costs annualized at a 7 percent discount rate.

TABLE A-2.   MACT FLOOR CONTROL COSTS AT AFFECTED WSR PLANTS

PLANT ID #	CAPITAL COSTS (1992$)	ANNUALIZED COSTS (1992$)[a]
1	24,500	86,000
2	37,400	112,000
3	360,000	91,000
12	48,000	111,000
14	39,500	119,000

[a] Capital costs annualized at a 7 percent discount rate.

TABLE A-3.   OPTION I CONTROL COSTS AT AFFECTED WET STRENGTH RESIN PLANTS

NUMBER OF PLANTS	CAPITAL COSTS (1992$)	ANNUALIZED COSTS (1992$)[a]
9	15,348	5,782

[a] Capital costs annualized at a 7 percent discount rate.

APPENDIX B

TECHNICAL DESCRIPTION OF ANALYTICAL METHODS

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TECHNICAL DESCRIPTION OF ANALYTICAL METHODS

This technical appendix provides detailed descriptions of the analytical methods employed to conduct the following analyses:

- Partial equilibrium analysis (i.e., computing post-control price, output and trade impacts).

- Estimating changes in economic surplus.

- Labor and energy impacts.

- Capital availability.

We also present the baseline values used in the partial equilibrium analysis.

PARTIAL EQUILIBRIUM ANALYSIS

The partial equilibrium analysis requires the completion of four tasks. These tasks are:

- Specify market demand and supply.

- Estimate the post-control shift in market supply.

- Compute the impact on market quantity.

- Compute the impact on market price.

- Predict plant closures.

Market Demand and Supply

Baseline or pre-control equilibrium in a market is given by:

$$Q_d = \alpha P^{\epsilon} \tag{B.1}$$

$$Q_s^d = \beta P^{\gamma} \tag{B.2}$$

$$Q_s^f = \rho P^{\gamma} \tag{B.3}$$

$$Q_d = Q_s^d + Q_s^f = Q \tag{B.4}$$

where,   Q = output;

          P = price;

          ϵ = demand elasticity;

γ = supply elasticity;

α, β and ρ are constants;

Subscripts d and s reference demand and supply, respectively; and,

Superscripts d and f reference domestic and foreign supply, respectively.

The constants α, β and ρ are computed such that the baseline equilibrium price is normalized to one. Note that the market specification above assumes that domestic and foreign supply elasticities are the same.

Market Supply Shifts

Supply price for a model plant will increase by an amount just sufficient to equate the net present value of the investment and operation of the control equipment to zero. Specifically,

$$\frac{[(C \cdot Q) - (V+D)](1-t) + D}{S} = k \qquad (B.5)$$

where   C   is the change in the supply price;

Q   is output;

V   is a measure of annual operating and maintenance control costs.

t   is the marginal corporate income tax rate;

S   is the capital recovery factor;

D   is annual depreciation (we assume straight-line depreciation);

k   is the investment cost of emissions controls.

Solving for C yields the following expression:

$$C = \frac{kS - D}{Q(1-t)} + \frac{V+D}{Q} \qquad (B.6)$$

B-2

Estimates of k and V were obtained from EPA (1991). The variables, D, I, and S are computed as follows:

$$D = k/T \tag{B.7}$$

and

$$S = r(1+r)^T/((1+r)^T - 1) \tag{B.8}$$

where   r   is the discount rate or cost of capital faced by producers;

   T   is the life of emission control equipment.

Solving for P in Equation (B.2) yields the following expression for the baseline inverse market supply function for domestic producers.

$$P = (Q_s^d/\beta)^{1/\gamma} \tag{B.9}$$

Emission control costs will raise the supply price of the ith model plant by C_i (as computed in Equation (B.6)). The aggregate domestic market supply curve, however, does not identify the supply price for individual plants. Accordingly, we adopt the worst-case assumption that model plants with the highest after-tax per unit control costs are marginal in the post-control market. Specifically, we write the post-control supply function as

$$P = (Q_s^d/\beta)^{1/\gamma} + C(C_i, q_i) \tag{B.10}$$

where q_i is the total output of all model plants of type i.

The function $C(C_i, q_i)$ shifts segments of the pre-control domestic supply curve vertically by C_i. The width or horizontal distance of each segment is q_i. The resulting segmented post-control domestic supply curve is illustrated in Figure B-1 as S_2, compared with pre-control supply S_1.[3]

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[3] The supply curves in Figure B-1 are drawn as linear functions for ease of exposition. Because the supply curves are specified as Cobb-Douglas, they are log-linear.
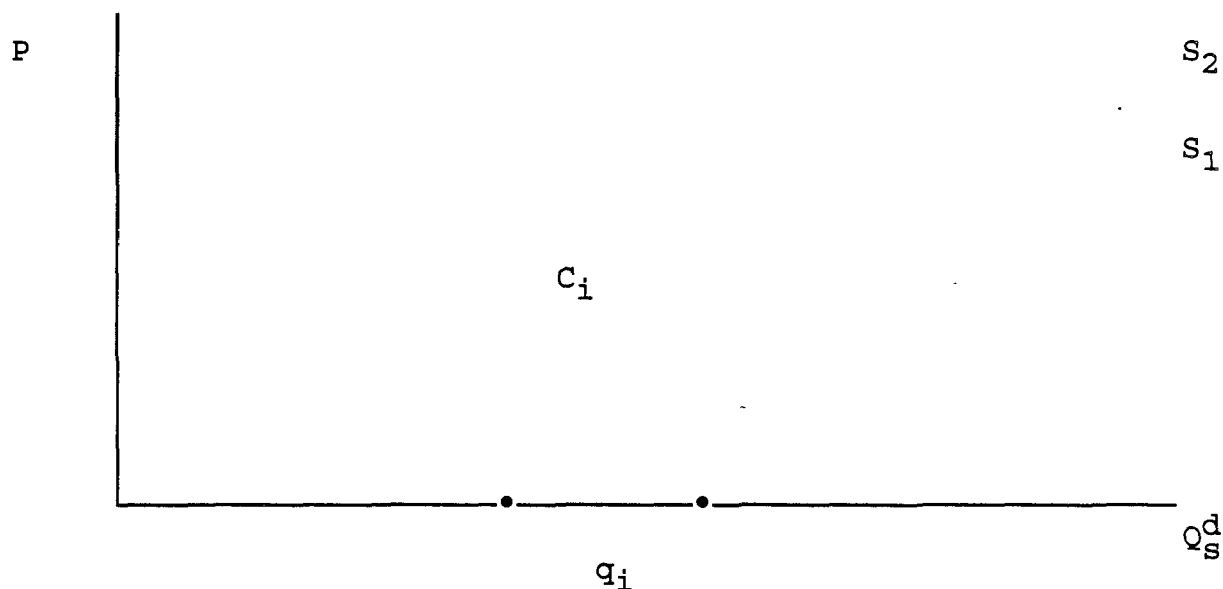
Figure B-1.

Domestic Market Supply Shift Due to Emission Control Costs

Impact on Market Price and Quantity

The impacts of the alternative standards on market output are estimated by solving for post-control market equilibrium and then comparing that output level, Q_2, to the pre-control output level, Q_1. Because post-control domestic supply is segmented, a special iterative algorithm was developed to solve for post-control market equilibrium. The algorithm first searches for the segment in the post-control supply function at which equilibrium occurs and then solves for the post-control market price that clears the market.

Since the market clearing price occurs where demand equals post-control domestic supply plus foreign supply, the algorithm simultaneously solves for the following post-control variables.

- Equilibrium market price.
- Equilibrium market quantity.
- The quantity supplied by domestic producers.
- The net quantity supplied by foreign producers.

B-4

We assess the market impacts of control costs by comparing
baseline values to post-control values for each of the variables
listed above.

Trade Impacts

We report trade impacts as the change in both the volume and
dollar value of net exports. We assume that exports comprise an
equivalent percentage of domestic production in the pre- and
post-control markets. We also assume that foreign and domestic
supply elasticities are the same. As the volume of imports rises
and the volume of exports falls, the volume of net exports will
decline. However, if demand is inelastic, it is uncertain
whether the dollar value of net exports will rise or fall. The
dollar value of imports will increase due to increases in both
volume and price. Exports will decrease in volume, but price
will increase. If demand is inelastic then the dollar value of
exports will increase. If the increase in the dollar value of
exports is greater than that of imports then the alternative will
result in an increase in the dollar value of net exports.

We use the following algorithms to compute trade impacts:

Change in volume of imports =

$$Q_{s_2}^f - Q_{s_1}^f \qquad\qquad\qquad (B.11.a)$$

Change in dollar value of imports =

$$P_2(Q_{s_2}^f - Q_{s_1}^f) + (P_2 - P_1) \cdot Q_{s_1}^f \qquad\qquad (B.11.b)$$

Change in volume of exports =

$$\frac{Q_e}{Q_{s_1}^d}(Q_{s_2}^d - Q_{s_1}^d) \qquad\qquad\qquad (B.11.c)$$

Change in dollar value of exports =

$$\frac{Q_e}{Q_{s_1}^d}(P_1 Q_{s_1}^d - P_2 Q_{s_2}^d) \qquad\qquad (B.11.d)$$

where the subscript e references exports by domestic producers.

We report the change in the volume of net exports as (B.11.c) minus (B.11.a). We report the change in the dollar value of net exports as the difference between (B.11.d) and (B.11.b).

We also report the change in the dollar value of shipments by domestic producers. This value, ΔVS, is given by

$$\Delta VS = P_2 \cdot Q_{s_2}^d - P_1 Q_{s_1}^d \qquad (B.12)$$

Plant Closures

We predict that any plant will close if its post-control supply price is higher than the post-control equilibrium price. Post-control supply prices are computed by Equation (B.10). We round fractions of plant closures to the nearest integer.

CHANGES IN ECONOMIC SURPLUS

The shift in market equilibrium will have impacts on the economic welfare of three groups:

- Consumers.
- Producers.
- Society at large.

The procedure for estimating the welfare change for each group is presented below. The total change in economic surplus, which is taken as an approximation to economic costs, is computed as the sum of the surplus changes for the three groups.

Change in Consumer Surplus

Consumers will bear a dead weight loss associated with the reduction in output. This loss represents the amount over the pre-control price that consumers would have been willing to pay for the eliminated output. This surplus change is given by:

$$\int_{Q_2}^{Q_1} (Q/\alpha)^{1/\epsilon} \, dQ - P_1 \cdot (Q_1 - Q_2) \qquad (B.13)$$

In addition, consumers will have to pay a higher price for post-control output. This surplus change is given by:

$$(P_2 - P_1) \cdot Q_2 \qquad\qquad (B.14)$$

The total impact on consumer surplus, ΔCS, is given by (B.13) plus (B.14). Specifically,

$$\Delta CS = \int_{Q_2}^{Q_1} (Q/\alpha)^{1/\epsilon} \, dQ - P_1 Q_1 + P_2 Q_2 \qquad\qquad (B.15)$$

This change, ΔCS, includes losses of surplus incurred by foreign consumers. In this report we are only concerned with domestic surplus changes. We have no method for identifying the marginal consumer as foreign or domestic.

To estimate the change in domestic consumer surplus we assume that total consumer surplus is split between foreign and domestic consumers in the same proportion that sales are split between foreign and domestic consumers in the pre-control market. That is, the change in domestic consumer surplus, ΔCS_d, is:

$$\Delta CS_d = \left[1 - \left(\frac{Q_e}{Q_{s_1}^d} + Q_{s_1}^f \right) \right] \Delta CS \qquad\qquad (B.16)$$

While ΔCS is a measure of the consumer surplus change from the perspective of the world economy, ΔCS_d represents the consumer surplus change from the perspective of the domestic economy.

Change in Producer Surplus

To examine the effect on producers, output can be divided into two components:

- Output eliminated as a result of controls.
- Remaining output of controlled plants.

The total change in producer surplus is given by the sum of the two components.

Note that post-tax measures of surplus changes are required to estimate the impacts of controls on producers' welfare. The post-tax surplus change is computed by multiplying the pre-tax surplus change by a factor of (1-t) where t is the marginal tax

rate. As a result, every one dollar of post-tax loss in producer surplus will be associated with a complimentary loss of $t/(1-t)$ dollars in tax revenues.

Output eliminated as a result of control costs causes producers to suffer a dead-weight loss in surplus analogous to the dead-weight loss in consumer surplus. The post-tax deadweight loss is given by:

$$\left[P_1(Q^d_{s_1} - Q^d_{s_2}) - \int_{Q^d_{s_2}}^{Q^d_{s_1}} (Q/\beta)^{1/\gamma} \, dQ \right] (1-t) \tag{B.17}$$

Plants remaining in operation after controls realize a welfare gain of $P_2 - P_1$ on each unit of output, but incur a per unit welfare loss of C_i. Thus, the post-tax loss in producer surplus for m model plant types remaining in the market is

$$\left[(P_1-P_2) Q^d_{s_2} + \sum_{i=1}^{m} C_i q_i \right] (1-t) \tag{B.18}$$

The total post-tax change in producer surplus, ΔPS, is given by the sum of (B.17) and (B.18). Specifically,

$$\Delta PS = \left[P_1 Q^d_{s_1} - P_2 Q^d_{s_2} - \int_{Q^d_{s_2}}^{Q^d_{s_1}} (Q/\beta)^{1/\gamma} \, dQ + \sum_{i=1}^{m} C_i q_i \right] (1-t) \tag{B.19}$$

Recall that we are interested only in domestic surplus changes. For this reason we do not include the welfare gain experienced by foreign producers due to higher prices. This procedure treats higher prices paid for imports as a dead-weight loss in consumer surplus. Higher prices paid to foreign producers represent a transfer from the perspective of the world economy, but a welfare loss from the perspective of the domestic economy.

Residual Effect on Society

The changes in economic surplus, as measured above, must be adjusted to account for two effects which cannot be attributed specifically to consumers and producers. These two effects are caused by tax impacts and differences between private and social discounts rates.

Two adjustments for tax impacts are required. First, per unit control costs C_i, which are required to predict post-control market equilibrium, reflect after-tax control costs. The true resource costs of emissions controls, however, must be measured on a pre-tax basis. For example, if after-tax control costs exceed pre-tax control costs, C_i overstates the true resource costs of controlling emissions.

A second tax-related adjustment is required because changes in producer surplus have been reduced by a factor of (1-t) to reflect the after-tax welfare impacts of emissions control costs on affected plants. As was noted earlier, a one dollar loss in pre-tax producer surplus imposes an after-tax burden on the affected plant of (1-t) dollars. In turn, a one dollar loss in after-tax producer surplus causes a complimentary loss of t/(1-t) dollars in tax revenues.

A second adjustment is required because of the difference between private and social discount rates. The rate used to shift the supply curve reflects the private discount rate (or the marginal cost of capital to affected firms). This rate must be used to predict the market impacts associated with emission controls. The economic costs of the NESHAP, however, must be computed at a rate reflecting the social cost of capital. This rate is intended to reflect the social opportunity cost of resources displaced by investments in emission controls.[4]

The adjustment for the two tax effects and the social cost of capital, which we refer to as the residual change in surplus, ΔRS, is given by:

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[4] See Section 7 for a more detailed discussion of this issue.

$$\Delta RS = -\sum_{i=1}^{m} (C_i - pc_i)q_i + \Delta PS \cdot [t/(1-t)] \tag{B.20}$$

where pc_i = per unit cost of controls for model plant type i, computed as in (B.5) with t=0 and r=social cost of capital.

The first term on the right-hand-side of (B.20) adjusts for the difference between pre- and post-tax differences in emission control costs and for the difference between private and social discount rates. Note that these adjustments are required only on post-control output. The second term on the right-hand-side of (B.19) is the complimentary transfer of the sum of all post-tax producer surplus.

Total Economic Costs

The total economic costs, EC, is given by the sum of changes in consumer and producer surplus plus the change in residual surplus. Specifically,

$$EC = \Delta CS_d + \Delta PS + \Delta RS \tag{B.21}$$

LABOR AND ENERGY IMPACTS

Our estimates of the labor and energy impacts associated with the alternative standards are based on input-output ratios and estimated changes in domestic production.

Labor Impacts

Labor impacts, measured as the number of jobs lost due to domestic output reductions, are computed as

$$\Delta L = \frac{P_1 (Q_{s_1}^d - Q_{s_2}^d) L_1}{2000} \tag{B.22}$$

where ΔL is the change in employment, L_1 is the production worker hours per dollar of output, and all else is as previously defined. The number 2000 is used to translate production worker hours into jobs (i.e., we assume a 2000 hour work year).

Energy Impacts

We measure the energy impacts associated with the alternative standards as the reduction in expenditures on energy inputs due to output reductions. The method we employ is similar to the procedure described above for computing labor impacts. Specifically,

$$\Delta E = E_1 P_1 \left(Q_{s_1}^d - Q_{s_2}^d \right) \tag{B.23}$$

where ΔE is the change in expenditures on energy inputs, E_1 is the baseline expenditure on energy input per dollar output and all else is as previously defined.

BASELINE INPUTS

The partial equilibrium model described above requires, as inputs, data on the characteristics of affected plants and baseline values for variables and parameters that characterize each market. The characteristics of affected plants have been described earlier in Appendix A. These include the number of plants by model type and a measure of output for each model plant. Appendix A also reports estimates of capital and annual emission control costs.

Table B-1 reports the baseline values of variables and parameters for each market. The baseline price of BLR is taken from the Chemical Economic Handbook (p. 580.601G); the baseline price of WSR is from Synthetic Organic Chemicals.[5][6] Baseline domestic output in each market is computed as the sum of production at all domestic plants (see Appendix A from production rates at BLR and WSR plants).

The import and export ratios reported in Table B-1 were computed from production and trade data for BLR (unmodified epoxy resins) and WSR (epi-based non-nylon polyamide) reported in

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[5] Prices were converted to 1992 dollars using the producer price index for chemicals and allied products (Economic Report of the President).

[6] Wet strength resin prices were converted from a dry weight to wet weight basis using a wet-to-dry weight conversion factor of 7.7 (computed from data in the Chemical Economics Handbook, p. 580.1000X).

TABLE B-1. BASELINE INPUTS

| Variable/Parameter | MARKET | |
	BLR	Wet Strength Resin
Price (P_1)[a]	$2.59	$.20
Domestic Output [b]	135.0	197.2
Import Ratio[c]	0.028	0
Export Ratio[d]	0.178	0.010
Supply Elasticity (ϵ)	3.76	3.76
Demand Elasticity (γ)	−1.50	−0.924
Tax Rate (t)	0.25	0.25
Private Discount Rate (r)	0.1	0.1
Social Discount Rate	0.07	0.07
Equipment Life (T)[e]	10	10
Labor (L_1)[f]	0.0025	0.0025
Energy (E_1)[g]	0.031	0.031

Notes:
[a] Dollars (1992) per kilogram (wet weight).
[b] Thousands of metric tons (wet weight).
[c] Imports divided by domestic production.
[d] Exports divided by domestic production.
[e] Years.
[f] Production worker hours per dollar of output.
[g] Energy expenditure per dollar of output.

Chemical Economics Handbook (pp. 580.601M, 580.601K and 580.1000Y). Imports of WSR were reported to have been "insignificant."

We describe the data and procedures employed to estimate supply and demand elasticities (γ and ϵ, respectively) in Appendix C. Note that we use the estimates of the demand elasticities reported in Table B-1 for the "base case" results presented in Sections 4, 5, and 7 of this report. We assess the sensitivity of the estimated impacts to demand elasticity by reporting in Appendix D results based on "low" and "high" estimates.

We use a marginal tax rate of 25 percent to assess the impacts of emission controls. We adopt a 10 percent private discount rate (real marginal cost of capital) and a 7.0 percent social discount rate. The expected life of emission control equipment is 10 years.

Finally, the values for labor hours per unit of output (L_1) and energy use per unit of output (E_1) were obtained from the Annual Survey of Manufactures. Data from the ASM used to derive these estimates include 1989 annual values for total production worker hours used, total expenditures on energy; and the value of shipments. Recall that these data are available at the 4-digit SIC code level. BLR, WSR and other resin products are included in SIC code 2821. For this reason, L_1 and E_1 are the same in both resin markets.

CAPITAL AVAILABILITY ANALYSIS

Pre- and post-control values of the following financial measures are compared in the capital availability analyses:

- Net income/assets.

- Long-term debt/long-term debt plus equity.

Pre-Control Financial Measures

Pre-control measures of net income and net income/assets are computed by averaging data for the period 1988 through 1991 where these data are available. The long-term debt ratio is computed from 1991 data, or the most recent year available.

All figures are adjusted to 1991 dollars by the producer price index for chemicals and allied products. Then, pre-control values are estimated by:

i) $\quad n \quad = \quad \sum\limits_{i=1988}^{1991} n_i/4$ $\qquad$ (B.24)

ii) $\quad r \quad = \quad \sum\limits_{i=1988}^{1991} (n_i/a_i)/4$ $\qquad$ (B.25)

iii) $\quad l \quad = \quad l_{1991}/(l_{1991} + e_{1991})$ $\qquad$ (B.26)

where $\quad n \quad = \quad$ average net income

$\qquad n_i \quad = \quad$ net income in year i

$\qquad r \quad = \quad$ average return on assets

$\qquad a_i \quad = \quad$ assets in year i

$\qquad l \quad = \quad$ long-term debt ratio

$\qquad l_{1987} \quad = \quad$ long-term debt in 1991

$\qquad e_{1987} \quad = \quad$ equity in 1991

Post-Control Values

To determine the impact of controls, an estimate of the cost of controls is made. In order to get an idea of the steady-state cost, an annualized cost is used. The annualized cost, AC, for a plant is:

$\qquad$ AC $\quad = \quad$ V + kS $\qquad\qquad\qquad\qquad$ (B.27)

where the variables are as defined previously.

Annualized costs and capital costs are estimated for each model plant type. For each establishment, post-control measures are given by:

$$pn = \sum\limits_{i=1988}^{1991} \frac{n_i - AC}{4} \qquad (B.28)$$

where pn $\quad = \quad$ post-control average net income

$$pr = \sum_{i=1988}^{1991} \frac{(n_i - AC)/(a_i + k)}{4} \qquad\qquad \text{(B.29)}$$

$$pl = \frac{l_{1991} + k}{l_{1991} + e_{1991} + k} \qquad\qquad \text{(B.30)}$$

AC = annualized cost for the company

pr = post-control return on assets

 k = capital cost for the company

pl = post-control long-term debt ratio

APPENDIX C

ESTIMATION OF INDUSTRY SUPPLY AND DEMAND

APPENDIX C
ESTIMATION OF INDUSTRY SUPPLY AND DEMAND

INTRODUCTION

This appendix describes the analytical approach and the data we employed to estimate the supply and demand elasticities used in this EIA. We also report and evaluate the statistical properties of the estimates.

APPROACH

The approaches we adopt to estimate supply and demand elasticities are consistent with economic theory and, at the same time, exploit the available data. Briefly, we derive an industrywide estimate of supply elasticity from an estimated production function. Because the data required to estimate the production function are available only at a four-digit SIC level (SIC 2821 which includes both the epoxy and WSR industries), we obtain a single estimate of supply elasticity. We adopt this single estimate for both the BLR and WSR industries, implicitly assuming that the two industries face similar production functions.

Because both BLR and WSR are used as intermediate inputs to produce other goods, the demand for these inputs is derived from the goods they are used to produce. The data required to estimate the derived demand functions are available separately for both BLR and WSR. As a result, we obtain estimates of demand elasticities for each of the two industry segments.

Supply Elasticity

As noted above, we derive an estimate of the market supply elasticity from an industry-wide estimate of the production function. Given the production function, we solve for the dual cost function. Then, exploiting the result that market price is established at marginal production cost, we derive the inverse supply curve as the derivative of the cost function with respect to output. The important result is that the parameters of the supply function can be stated in terms of the parameters of the estimated production function.

C-1

We assume that the industry is economically efficient in that production costs are minimized subject to a production constraint. In equation form, this can be written as:

$$\underset{x_i}{\text{minimize}} \quad \Sigma \; r_i x_i \tag{C.1}$$

$$\text{subject to:} \quad Q = f(x_i)$$

where x_i = factor inputs (used to produce resins)

r_i = factor prices

Q = output (of resins)

The solution to this problem is a set of input demand functions:

$$x_i^* = g(r_i, Q) \tag{C.2}$$

If the input demand functions are substituted back into the objective function, one obtains a cost function in terms of input prices and output.

$$C = h(r_i; Q) \tag{C.3}$$

Equilibrium in the market is established at the point where price equals marginal cost. That is:

$$P = \partial C / \partial Q = h'(r_i; Q) \tag{C.4}$$

where P is output price. Equation (C.4) is a relationship between output and output price and thus represents the industry supply curve.

An explicit functional expression for the right-hand side of (C.4) can be determined if one makes a specific assumption on the form of the production function. For this analysis, we assume a multiplicative form for the production function with two variable inputs and a capital factor. Because we use time series data to estimate the production function, we also include a time factor to account for changes in technology. Specifically,

$$Q_t = A K_t^{\alpha_K} t^\lambda L_t^{\alpha_L} M_t^{\alpha_M} \tag{C.5}$$

where Q_t is industry output in year t

K_t is real capital stock in year t

L_t is production man-hours in year t

M_t is an index of materials input in year t

t   is   time in years

A, $\alpha_L, \alpha_M, \lambda$ are parameters to be estimated.

Equation (C.5) can be written in linear form by taking the natural logarithms of both sides. Thus, linear regression techniques can be applied.

Given a particular form for the production function, the steps described by Equations (C.2) to (C.4) can be used to derive the implied supply function. For this analysis, we assume that capital stock is fixed.[7] The derived supply function can be written as:

$$\ln Q = B_0 + \gamma \ln P + B_2 \ln K \qquad (C.6)$$
$$+ B_3 \ln P_L + B_4 \ln P_M + B_5 \ln t$$

where P_L =   factor price of labor input

P_M =   factor price of material input

K   =   fixed real capital stock

The B_i and γ coefficients are functions of the α_i, the coefficients of the production function. For example, γ, the supply price elasticity, can be shown to be equal to

$$\gamma = \frac{\alpha_L + \alpha_M}{1 - \alpha_L - \alpha_M} \qquad (C.7)$$

It is clear from (C.7) that it may be necessary to place restrictions on the estimated coefficients of the production function in order to have well-defined supply function coefficients. For example, the sum of the coefficients for labor and materials should be less than one. Otherwise, γ is undefined or, if both coefficients are positive, γ would be negative. For this reason, the production function is estimated with the ·

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[7] This specification, which treats in place capital as sunk, is consistent with our objective of modeling how supply adjusts to price changes in the post-control market. This response will depend on the behavior of avoidable production costs and emission control costs.

restriction that the sum of coefficients for the inputs should equal one. This is equivalent to assuming long-run constant costs in the industry, an assumption that seems reasonable on a priori grounds and appears to be consistent with the data.[8]

Demand Functions

WSR is used primarily in the production of pulp and paper products (SIC 2851). BLR is used to produce a variety of products; about 50 percent of industry output is used to sealants and adhesives (SIC 2621) and coatings and paints (SIC 2891). As intermediate inputs, the demand for both WSR and BLR are derived from the demand for the products they are used to produce.

We assume that firms using WSR and BLR as inputs attempt to maximize profits subject to a production constraint. The profit function can be written

$$\underset{Q,W}{\text{Max}} \ \pi = P_e \cdot g(Q,W) - P \cdot Q - r_w \cdot w \qquad (C.8)$$

where π =   profit;

       P_e =   the price of the final good (e.g., pulp and paper products);

       Q =   input use of WSR or BLR;

       W =   a vector of other inputs

       P =   the price of WSR or BLR; and,

       r_w =   a vector of prices of other inputs.

Note that the function $g(Q,W)$ defines the production function for the end product, say Q_e.

The solution to C.8 yields a system of input demand equations of the form

$$Q = h(P, P_e, r_w) \qquad (C.9)$$

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[8] The unrestricted estimates of the production function coefficients summed nearly to unity. Thus, the restriction on the coefficients is only marginally binding.

In words, C.9 states that the derived demand for WSR or BLR depends on its own price, the price of the final good, and the prices of other inputs.

We adopt a multiplicative function form for equation C.9. Specifically, we write the derived demand function as

$$Q_e = BP^\beta \cdot P_e^{\beta_e}$$ (C.10)

where Q = the quantity demanded of WSR or BLR;

P = the price of WSR or BLR;

P_e = the price of the end product; and,

B, β, β_e are parameters to be estimated.

The parameter β, of course, is the demand elasticity for the input — either WSR or BLR.

Note that equation C.10 excludes variables for the prices of other inputs (r_w of equation C.9). Unfortunately, data on these prices are unavailable. This requires us to adopt the implicit assumption that the use of WSR and BLR in end products is fixed by technology.

Because the markets for WSR and BLR are simultaneous in P and Q, it is necessary to apply a systems estimator in order to obtain consistent estimates of the coefficients for the demand equations. We employ a two-stage least squares estimator (2SLS) to estimate the demand equations. In order to estimate consistent demand equation coefficients, one uses as instruments the exogenous variables included in the system of demand and supply equations. The supply-side instruments used to estimate the demand functions include capital stock (K), a cost index (P_v) measuring the weighted-average cost of variable inputs (labor and materials), and time.

DATA

Table C-1 identifies the variable names, units of measure, and variable descriptions for the data available for the analysis. Those variables directly related to a specific SIC

TABLE C-1. VARIABLES AND DEFINITIONS OF PRIMARY DATA

	Variable[a]	Unit	Description
1.	YEAR	—	Observation identifier, 1958-1989
2.	SIC	4-digit	Industry identifier
3.	PISHIP	index	Producer price index for Value of Shipments (SICs 2821, 2891 and 2851)
	VSHIP	millions $	Value of industry shipments
5.	CAP	millions 1972 $	Real capital stock (SIC 2821)
6.	COSTMAT	millions $	Cost of materials inputs (SIC 2821)
7.	PIMAT	index	Price index for materials inputs (SIC 2821)
8.	PRODW	millions $	Production worker wages (SIC 2821)
9.	PRODH	millions hours	Production worker hours (SIC 2821)
10.	PRICE	dollars per kilogram	Price per kilogram (Type A Liquid Resin, BLR Resin and Non-Nylon Polyamide Resin)
11.	SALES	millions of kilograms	Quantity sold by domestic producers annually (BLR use in protective coatings, BLR use in bonding and adhesives and Non-Nylon Polyamide Resin)
12.	IPD	index	Implicit Price Deflator (1.0 in 1972)

a   Items 1-9 obtained from the ASM. Items 10 and 11 obtained from the ITC and the SPI. Item 12 obtained from 1991 Economic Report of the President.

were obtained from the Annual Survey of Manufactures (ASM).[9] These data are defined for 4-digit SICs and represent annual values which cover the years 1958-1989. Recall that both BLR and WSR belong to SIC 2821 code. Industry segment price and output data, obtained from the ITC and SPI, were used to estimate demand elasticities. These data are available for the years 1971-1990.

Items 1 through 9 of Table C-1 were used to estimate the production function (see Equation C.5) for SIC 2821. We formed the industry output variable, Q, as VSHIP/PISHIP; this ratio yields the real value of shipments in SIC 2821. The capital stock variable, K, is measured as CAP, the real value of capital stock in millions of 1972 dollars. Labor input, L, is measured as PRODH, millions of production worker hours. The time trend, t, is measured by the variable YEAR. Finally, we measure materials use, M, as the ratio of COSTMAT/PIMAT; this ratio yields the real cost of material inputs for SIC 2821 in millions of 1972 dollars.

Items 3, 10, 11 and 12 were used to estimate the derived demand equations. The dependent variable for the WSR equation, quantity demanded, is measured as sales of nonnylon polyamides in millions of kilograms per year. The "real" price variable for this equation is measured as the nominal price of non-nylon polyamides (item 10) divided by IPD (item 12). The "real" price of the end-product good is measured as PISHIP for SIC 2821 (pulp and paper) divided by IPD.

We estimate two derived demand functions for BLR — one for BLR use in coatings and paints and another for BLR use in sealants and adhesives. The dependent variables for each equation are measured as sales for the respective use in millions of kilograms annually. The real price variable for BLR use in coatings and paints is measured as the nominal price of Type A liquid resin divided by IPD; the real price for BLR use in coatings and adhesives is measured as the nominal price of BLR

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resin divided by IPD. Both price variables are expressed as dollars per kilogram. Finally, the real prices of end-products are formed by the ratios of PISHIP/IPD for SICs 2891 (coatings and paints) and 2621 (sealants and adhesives).

The 2SLS estimates of the derived demand equations require data for three instrumental variables — time, capital stock and a cost index for variable inputs. Time and capital stock are measured as the variables YEAR and CAP (for SIC 2821). We form the cost index for variable inputs as a weighted index of PIMAT and PRODH (for SIC 2821), expressed in constant 1972 dollars.

STATISTICAL RESULTS

Production Function/Supply Equation

A restricted least squares estimator was used to estimate the coefficients of the production function shown in Equation (C.5). A log-linear specification was estimated with the sum of the α_i restricted to unity. The results are shown in Table C-2. The equation explains about 96 percent of the variation in the output variable. While the coefficients on labor and time are significant at the 99 percent confidence level, the coefficients on capital and materials are not statistically significant at conventional confidence levels.

Using the estimated coefficients reported in Table C-2 and the result shown in Equation C.7, we derive a supply elasticity estimate of 3.76. Note that the calculation of statistical significance for the elasticity is not straightforward since it is a non-linear function of the production function coefficients. No attempt has been made to assess the statistical significance of the estimated elasticity.

Demand Equations

Table C-3 reports estimates of the derived demand equations for WSR and BLR. The reported coefficients are 2SLS estimates of the parameters of Equation C.10. We have also corrected the estimates of all three equations for first-order serial

TABLE C-2.   ESTIMATED PRODUCTION FUNCTION COEFFICIENTS
(t-ratios in parentheses)

Industry	Time	Capital	Labor	Materials	Adjusted R^2
SIC 2821	.323 (7.118)	.211 (.632)	.485 (3.036)	.304 (1.552)	.96

TABLE C-3. 2SLS ESTIMATED DERIVED DEMAND COEFFICIENTS
(t-ratios in parentheses)

Industry	Own Price (β)	End-Product Price (β_e)
Wet strength resin	−.924 (4.363)	1.136 (1.023)
BLR (in coatings and paints)	−1.474 (1.780)	.097 (.115)
BLR (in sealants and adhesives)	−1.481 (2.620)	2.040 (2.445)

correlation using the Prais-Winston algorithm[10] and the two BLR equations for heteroschedasticity.

We have estimated the derived demand function for WSR consistently with the approach described earlier in this appendix. The estimated own-price coefficient is correctly signed and highly significant. The estimated coefficient on the end-product price (SIC 2621) is correctly signed but not statistically significant.[11]

The estimated own-price coefficients for BLR are sensitive to the instruments used in the two-stage procedure and to corrections for autocorrelated errors. As a result, it was necessary to modify the general approach described earlier in this appendix. Specifically, the estimated equation for BLR used in coatings and paints includes only the cost index for variable inputs and includes a time trend variable as an explanatory variable.[12] The estimated equation for BLR used in sealants and includes both time and the variable cost index as instruments, but not the capital stock variable.

The estimated own-price coefficients are -1.474 and -1.481, respectively, for BLR used in coatings and paints, and in sealants and adhesives. Accordingly, we adopt a mid-point demand elasticity of -1.5 for BLR. We caution, however, that this estimate is not robust. As noted above, the estimates for BLR are sensitive to the specification of instrumental variables and to corrections for autocorrelated errors.

We acknowledge the uncertainty in our estimate of demand elasticities for WSR and especially for BLR. Accordingly, we

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[10] The Prais-Winston algorithm is similar to the more familiar Cochrane-Orcutt estimator. However, unlike the Cochrane-Orcutt method, the Prais-Winston algorithm does not skip the first observation and uses the full generalized least squares (GLS) transformation.

[11] Note that we do not report adjusted R^2 for the derived demand equations. First, Basemann (1962) warns that low multiple correlation coefficients for simultaneous equation estimators are not evidence of poor fit or lack of joint significance of the set of explanatory variables. Second, the correction for autoregressive errors renders R^2 meaningless.

[12] The estimated coefficient for the time trend variable is .468 and the associated t-ratio is 5.104.

assess the sensitivity of our estimated economic impacts by reporting in Appendix D results corresponding to "low" and "high" demand elasticity cases. The low demand elasticities are —.50 and —.62, respectively, for WSR and BLR; the corresponding high demand elasticities are —1.34 and —3.10. The low and high demand elasticities are, respectively, minus and plus two standard deviations of the mid-point estimates.[13]

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[13] We use the standard error of the estimate for DGEBPA used in coatings and paints for the high demand elasticity case and the standard error for DGEBPA use in sealants and adhesives for the low demand elasticity case. This procedure causes us to use relatively higher demand elasticities for both cases, thus representing "worst" case scenarios.

APPENDIX D

SENSITIVITY ANALYSES

APPENDIX D

SENSITIVITY ANALYSES

INTRODUCTION

This appendix presents the results of a sensitivity analysis that explores the degree to which the results presented earlier in this report are sensitive to estimates of demand elasticity.

SENSITIVITY ANALYSIS: DEMAND ELASTICITY

The "base case" results presented earlier in this report are based on demand elasticities of −1.50 for BLR and −.92 for WSR. Below, we report results for "low" and "high" demand elasticity cases. These alternative cases use the following values for demand elasticities:

- Low demand elasticity: −.62 for BLR and −0.50 for WSR.

- High demand elasticity: −3.10 for BLR and −1.34 for WSR.

The greater the elasticity of demand (in absolute value), the more consumers will reduce the quantity they purchase in response to a given change in price. Therefore, we expect that when we use a higher demand elasticity in the partial equilibrium analysis, the reduction in market output will be greater and the price change will be smaller than in the base case. Similarly, when we use a lower elasticity, we expect the change in price to be greater, and the change in market quantity to be smaller, relative to the base case.

Tables D-1 through D-4 present estimates of the primary economic impacts associated with the NESHAP for each of the two industry segments in the case of low and high demand elasticities. Tables D-1 and D-2 report results based on low demand elasticities and Tables D-3 and D-4 report results based on high demand elasticities.

In general, the results of the sensitivity analysis are consistent with the base case results presented earlier in this report. For the BLR industry, no plant closures are predicted,

TABLE D-1. SENSITIVITY ANALYSIS: ESTIMATED PRIMARY IMPACTS ON THE BLR MARKET WITH LOW ELASTICITY OF DEMAND

		Change in Value of Domestic Shipments		
Price Change (%)	Market Output Change (%)	($1,000 1992)	(%)	Plant Closures
.06	-.04	51	.01	.00

Note: Results are based on a demand elasticity of -.62.

TABLE D-2.   SENSITIVITY ANALYSIS: ESTIMATED PRIMARY IMPACTS
ON THE WSR MARKET WITH LOW ELASTICITY OF DEMAND

Regulatory Option	Price Change (%)	Market Output Change (%)	Change in Value of Domestic Shipments		Plant Closures
			($1,000 1992)	(%)	
MACT Floor	4.60	-2.23	897	2.28	.02
Option I	0.24	-.12	48	.12	.38

Note: Results are based on a demand elasticity of -0.50

D-3

TABLE D-3. SENSITIVITY ANALYSIS: ESTIMATED PRIMARY IMPACTS
ON THE BLR MARKET WITH HIGH ELASTICITY OF DEMAND

		Change in Value of Domestic Shipments		
Price Change (%)	Market Output Change (%)	($1,000 1992)	(%)	Plant Closures
.04	-.12	-293	-.08	.00

Note: Results are based on a demand elasticity of -3.10

TABLE D-4.   SENSITIVITY ANALYSIS: ESTIMATED PRIMARY IMPACTS
ON THE WSR MARKET WITH HIGH ELASTICITY OF DEMAND

| Regulatory

Option | Price
Change
(%) | Market
Output
Change
(%) | Change in Value of
Domestic Shipments | | Plant
Closures |
			($1,000 1992)	(%)	
MACT Floor	3.86	-4.95	-505	-1.28	.84
Option I	.20	-.27	-27	-.07	.05

Note: Results are based on a demand elasticity of -1.34.

D-5

and even in the high demand elasticity case, the estimated reduction in market output is just 0.12 percent. However, for the sensitivity analysis of the WSR market, when a low elasticity of demand is employed, the plant closure predicted in the previous analysis is less probable. Also, when a "low" elasticity of demand is assumed, the impacts on domestic production, the value of domestic production, net exports, employment and energy are reduced. The estimated impacts of Option I on the WSR industry are very small, even when a high elasticity of demand is assumed.

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APPENDIX E.

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

APPENDIX E.

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

The purpose of this study was to provide data to support the development of the proposed national emission standard for hazardous air pollutants (NESHAP) for the production of basic liquid epoxy resins (BLR) and non-nylon polyamide resins, also known as wet strength resins (WSR). To accomplish the objectives of this program, technical data were gathered on the following aspects of the industry: (1) the operation of process equipment, storage tanks, wastewater treatment, and transfer equipment (piping), (2) the release and controllability of hazardous air pollutants (HAP's) emitted into the atmosphere from the above emission points, and (3) the types and costs of demonstrated emission control technologies. The bulk of the information was gathered from the following sources:

1. Technical literature;

2. Plant visits;

3. Questionnaires sent to industry;

4. Industry representatives;

5. State and regional air pollution control agencies; and

6. Equipment vendors.

Significant events relating to the evolution of the background information document are itemized in Table E-1.

TABLE E-1. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

Date	Company, consultant, or agency/location	Nature of action
6/13/91	Georgia-Pacific (Ukiah, CA, Eugene, OR, Crossett, AR, Peachtree City, GA) CPS Chemicals Old Bridge, NJ Sonoco Holyoke, MA Henkel Corporation Charlotte, NC Callaway Chemical Company Columbus, GA	Section 114 information request sent by the U. S. EPA
7/12/91	Callaway Chemical Company Shreveport, LA	
7/17/91	Georgia-Pacific Columbus, OH, Albany, OR, Grayling, MI	
7/29/91	Pioneer Plastics Corporation Auburn, ME	
9/13/91	The Dow Chemical Company Freeport, TX	
4/23/92	Shell Chemical Company Deer Park, TX	
6/1/92	The Dow Chemical Company Freeport, TX	Information sent from plant regarding the concentration of epichlorohydrin in wastewater
10/1/92	Mailed to all known industry members and selected vendors	Request from U. S. EPA for comment on draft BID chapters 3, 4, and 6
5/13/93	Shell Chemical Company Deer Park, TX	Emission test data sent from plant

APPENDIX F.

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

APPENDIX F.

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

This appendix consists of a reference system which is cross-linked with the October 21, 1974, Federal Register (39 FR 37419) containing the Agency guidelines concerning the preparation of environmental impact statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

TABLE F-1.   CROSS-INDEXED REFERENCE SYSTEM TO HIGHLIGHT THE
ENVIRONMENTAL IMPACT PORTIONS OF THE DOCUMENT

Agency guidelines for preparing regulatory action environmental impact statements (39 FR 37419)	Location within Background Information Document
1. **Background and summary of regulatory alternatives**	
Statutory basis for proposing standards	The statutory basis for proposing standards is summarized in Chapter 2, Section 2.1.
Industries affected by the regulatory alternatives	A discussion of the industries affected by the proposed standards is presented in Chapter 3. Further details covering the business and economic nature of the industry are presented in Chapter 8, Section 8.1
2. **Regulatory alternatives**	
Control techniques	The alternative control techniques are discussed in Chapter 4.
Regulatory alternatives	The various regulatory alternatives are defined in Chapter 5, Section 5.2.
3. **Environmental impact of the regulatory alternatives**	
Primary impacts directly attributable to the regulatory alternatives	The primary impacts on mass emissions and ambient air quality of the regulatory alternatives are discussed in Chapter 5, Section 5.2. Tables summarizing the environmental impacts are included in Chapter 6.
Secondary or induced impacts	Secondary impacts for the various regulatory alternatives are presented in Chapter 6.
4. **Other considerations**	Potential socioeconomic and inflationary impacts are discussed in Chapter 8, Section 8.2.

APPENDIX G. MODEL PLANT CHARACTERISTICS

APPENDIX G.   MODEL PLANT CHARACTERISTICS - BLR PRODUCTION

1.   Production Characteristics

   (a) BLR Production

   68,000 Mg/yr (150 x 10^6 lb/yr) design capacity
   45,000 Mg/yr (100 x 10^6 lb/yr) actual capacity

   (b) HAP Feedstock Usage

   25,000 Mg/yr (56 x 10^6 lb/yr) EPI actual usage

2.   Operating Time

   Continuous occurring over 8,400 hr/yr

3.   Emission Stream Characteristics - Process Vents

Emissions	Flowrate	Temperature	Composition (Vol %)
1) Dilute[a]	40 scfm	25°C	0.6 EPI, 1.4 IPA, 0.8 H_2O
2) Rich[b]	30 scfm	60°C	12 EPI, 40 IPA, 8 H_2O

[a]Emissions from reaction and premix stages
[b]Emissions from resin finishing and purification

4.   Storage Information - EPI

   6   100,000-gallon fixed roof tanks
   10   turnovers/yr each

5.   Equipment Leaks

   Duration: 7,350 hr/yr   % EPI

Component counts:	1-25	26-50	51-75	>75
Pump seals	13	13	9	8
Valves -Liquid -Gas	444 0	783 10	520 16	296 37
Flanges	463	898	1,158	406
Open-ended lines	5	0	23	0
Sampling connections	4	3	22	8
PRV's	26	1	18	2

6. Wastewater

From steam stripper bottoms and extractor: 40,000 gal/day,
1,000 mg/L concentration of EPI.

MODEL PLANT CHARACTERISTICS - WET STRENGTH RESIN (WSR) PRODUCTION

1. Production Characteristics

(a) WSR Production

11,600 Mg/yr (25.6 x 10^6 lb/yr) actual capacity

(b) HAP Feedstock Usage

900 Mg/yr (2 x 10^6 lb/yr) EPI actual usage
663 Mg/yr (1.4 x 10^6 lb/yr) MeOH actual production
233 Mg/yr (0.5 x 10^6 lb/yr) HCl actual usage

2. Operating Time

12 hours/batch
1 batch/day
175 days/year

3. Emission Stream Characteristics - Process Vents

(a) MeOH Distillation Receiver Displacement

Potential HAP's emitted	=	MeOH
Flowrate (scfm)	=	1.5
T (°C)	=	20
Composition (vol. %)	=	16 MeOH
Duration (minutes)	=	120

(b) Reactor Displacement

Potential HAP's emitted	=	EPI
Flowrate (scfm)	=	7.35
T (°C)	=	20
Composition (vol. %)	=	1.8 EPI
Duration (minutes)	=	15

(c) Heatup (Crosslinking Reaction)

Potential HAP's emitted	=	EPI
T_1 (°C)	=	20
T_2 (°C)	=	50
Flowrate (scfm)	=	1.4 x 10^{-2}

Composition (vol % @ T_1) = 1.8 EPI
                Composition (vol % @ T_2) = 7.9 EPI
                Duration (minutes)   = 180

    (d) Acid Addition

                Potential HAP's emitted = HCl, EPI

                Flowrate (scfm)   = 8.6
                T (°C)   = 50
                P (mm Hg)   = 760
                Composition (vol %)   = 18.5 HCl
                                          7.9 EPI
                Duration (minutes)   = 5

4.   Storage Information

    EPI   1   20,000-gallon fixed roof tank
            11   turnovers/yr

    MeOH   1   20,000-gallon fixed roof tank
            12   turnovers/yr

    HCl   1   10,000-gallon fixed roof tank
            7   turnovers/yr

5.   Equipment Leaks

    Duration = 2,100 hr/yr
    Component Counts:

Component	No./Plant	% HAP
Pump seals	2	100
Flanges	64	100
Liquid valves	14	100
Gas valves	1	100
Pressure relief devices	2	100
Sample connections	2	100
Open-ended lines	1	100

6.   Wastewater

        None

Model Plant Designations

    Model Plant 1: Describes plants which only emit EPI as a
HAP; there are no HCl or MeOH emissions. Therefore, the
applicable process vent emission stream characteristics are 3(b),
(c), and (d) with EPI only. Also, no storage of MeOH or HCl is
considered.

Model Plant 2: Describes facilities that use HCl in acid addition stages. Storage of HCl and the process vent emission stream characteristics 3(b), (c), and (d) with EPI and HCl are considered.

Model Plant 3: Describes plants which use HCl and also produce methanol. All emission streams are considered.

APPENDIX H

TABULAR COSTS

TABULAR COSTS FOR

EXISTING SOURCES

BLR SOURCE CATEGORY

Equipment Leaks Options

EQUIPMENT LEAKS COST MODEL
Facility: DOW

INPUT:

Time in PRD (min):	480
Time in all other components (min):	480
Time variables:	
Events/8 hour shift	1
Shifts/day:	3
days/year:	365

ASSUMED VALUES:

	TOTAL	wt % HAP			
		0-25%	26-50%	51-75%	76-100%
Pump seals (#/plant):	61	19	26		16
Flanges (#/plant):	3345	750	1796		799
Liquid valves (#/plant):	2640	489	1566		585
Gas valves (#/plant):	93		20		73
Sample connections (#/plant):	29	7	6		16
Liquid pressure relief devices (#/plant):	0				
Gas pressure relief devices (#/plant):	51	45	2		4
Open-ended lines (#/plant):	0				
Compressors (#/plant):	0				

COST CALCULATIONS:

Capital Costs/TCC:

$ for monitoring instrument	$6,500.00
$ for compressor vent system:	$0.00
$ for pressure relief device:	$176,838.75
$ for open-ended line:	$0.00
$ for sample connections:	$11,849.69
TCC ($):	$195,188.44

1st Year annualized charges:

Capital recovery factors:	0.55
Pump seals, rupture disks:	0.21
Monitoring instruments:	0.14
All other equipment:	

Monitoring instruments ($):	$1,365.00	
Compressor vent systems ($):	$0.00	
PRD ($):	$26,194.20	
Open-ended lines ($):	$0.00	
Sample connections ($):	$1,658.96	
Gas valves:		
-Repair ($):	$0.00	Dow already controlling to Reg Neg levels
-Monitoring ($):	$0.00	Dow already controlling to Reg Neg levels
Liquid valves:		
-Repair ($):	$0.00	Dow already controlling to Reg Neg levels
-Monitoring ($):	$0.00	Dow already controlling to Reg Neg levels
Pumps:		
-Repair ($):	$148.18	
-Monitoring ($):	$6.86	
-Replacement seals ($):	$207.90	
Sample connections:		
-Repair ($):	$1.34	
-Monitoring ($):	$14.21	
TOTAL 1st year annualized charges ($):	$29,596.65	

Annual Operating Costs:

Annual maintenance charges:
Monitoring instruments ($):	$4,280.00
Compressors ($):	$0.00
PRD ($):	$8,842.16
Open-ended lines ($):	$0.00
Sample connections ($):	$592.48
Pump seals ($):	$2,268.00
TOTAL annual maintenance charges ($):	$15,982.65

Annual miscellaneous charges:
Monitoring instruments ($):	260
Compressors ($):	$0.00
PRD ($):	$7,073.73
Open-ended lines ($):	$0.00
Sample connections ($):	$473.99
Pump seals ($):	$1,814.40
TOTAL annual miscellaneous charges:	$9,622.12

Annual labor charges:
Gas valves:		
-Monitoring ($):	$0.00	Dow already controlling to Reg Neg levels
-Repair ($):	$0.00	Dow already controlling to Reg Neg levels
Liquid valves ($):		
-Monitoring ($):	$0.00	Dow already controlling to Reg Neg levels
-Repair ($):	$0.00	Dow already controlling to Reg Neg levels
Pumps ($):		
-Monitoring ($):	$470.40	
-Repair ($):	$6,350.40	
Flanges ($):		
-Monitoring ($):	$9,366.00	
-Repair ($):	$263.42	
-Monitoring ($):	$126.00	
-Repair ($):		
PRD monitoring ($):		
TOTAL annual labor charges ($):	$16,576.22	

Capital recovery ($/yr):	$71,257.20
TOTAL ANNUAL COSTS + 1st year labor charges ($):	$520.43

		hr/yr
TRANSFER TIME for all pump seals (min-source/yr):	17,739,000	4846.72
TRANSFER TIME for all liquid valves (min-source/yr):	783,275,400	4944.92
TRANSFER TIME for all gas valves (min-source/yr):	43,624,800	7818.06
TRANSFER TIME for all flanges (min-source/yr):	990,493,200	4935.119
TRANSFER TIME for all open-ended lines (min-source/yr):	0	ERR
TRANSFER TIME for all sample connections (min-source/yr):	10,906,200	6267.93
PROCESSING TIME in applicable unit operations:		
-includes PRDs only (min-source/yr):	8,341,000	2791.18

Emissions:

Emission Factors:

w/ current control measures:		w/ current control measures:
Pump seals (kg/yr):	2762.63	Pump seals (kg/hr/source): 0.0199
Valves:		Valves:
-liquid (kg/yr):	6318.42	-liquid (kg/hr/source): 0.00484
-gas (kg/yr):	349.00	-gas (kg/hr/source): 0.00048
Flanges (kg/yr):	3021004	Flanges (kg/hr/source): 0.00183
Open-ended lines (kg/yr):	0.00	Open-ended lines (kg/hr/source): 0.0017
Sample Connections (kg/yr):	2726.55	Sample Connections (kg/hr/source): 0.015
Pressure relief devices (kg/yr):	13062.71	Pressure relief devices (kg/hr/source): 0.104
Reg Neg Controlled:		Reg Neg Controlled:
-control level after above LDAR program implemented		-control level after above LDAR program implemented
Pump seals (kg/yr):	1833.03	Pump seals (kg/hr/source): 0.0062
Valves:		Valves:
-liquid (kg/yr):	6318.42	-liquid (kg/hr/source): 0.000484
-gas (kg/yr):	349.00	-gas (kg/hr/source): 0.00048
Flanges (kg/yr):	2113.05	Flanges (kg/hr/source): 0.000128
Open-ended lines (kg/yr):	0.00	Open-ended lines (kg/hr/source): 0
Sample Connections (kg/yr):	0.00	Sample Connections (kg/hr/source): 0
Pressure relief devices (kg/yr):	0.00	Pressure relief devices (kg/hr/source): 0

Uncontrol-control = Mg controlled/yr:	44.82
Cost effectiveness ($/Mg):	$11.61

EQUIPMENT LEAKS COST MODEL
Facility: CIBA-GEIGY

INPUT:

Time in PRD (min): 480
Time in all other components (min): 480
Time variables:
Events/8 hour shift: 1
Shifts/day: 3
days/year: 365

ASSUMED VALUES:

	0-25	26-50	51-75	76-100
Pump seals (#/plant):	23	9	4	10
Flanges (#/plant):	1348	376	184	614	174
Liquid valves (#/plant):	352	78	55	164	55
Gas valves (#/plant):	64	44		20	0
Sample connections (#/plant):	0	0			
Liquid pressure relief devices (#/plant):	0		2	5	2
Gas pressure relief devices (#/plant):	9	0	0	5	1
Open-ended lines (#/plant):	7	0			
Compressors (#/plant):	0	1			

COST CALCULATIONS:

Capital Costs/TCC:

$/monitoring instrument: $0.00
$/compressor vent system: $0.00
$/pressure relief device: $35,367.75
$/open-ended line: $711.62
$/sample connection: $0.00
TCC ($): $36,079.37

1st Year annualized charges:

Capital recovery factors:
Pump seals, rupture disks: 0.55
Monitoring instruments: 0.21
All other equipment: 0.14

Monitoring instruments ($): $0.00
Compressor vent systems ($): $0.00
PRD ($): $5,238.84
Open-ended lines ($): $99.63
Sample connections ($): $0.00
Gas valves:
-Repair ($): $32.18
-Monitoring ($): $47.04
Liquid valves:
-Repair ($): $100.90
-Monitoring ($): $0.00
Pumps:
-Repair ($): $243.43
-Monitoring ($): $0.00
-Replacement seals ($): $341.55
Sample connections:
-Repair ($): $0.00
-Monitoring ($): $0.00
TOTAL 1st year annualized charges ($): $6,103.57

b.

Annual Operating Costs:

Annual maintenance charges:
Monitoring instruments ($):	$0.00
Compressor ($):	$0.00
PRD ($):	$1,768.43
Open-ended lines ($):	$35.58
Sample connections ($):	$0.00
Pump seals ($):	$3,726.00
TOTAL annual maintenance charges ($):	$5,530.01

Annual miscellaneous charges:
Monitoring instruments ($):	0
Compressor ($):	$0.00
PRD ($):	$1,414.75
Open-ended lines ($).	$28.46
Sample connections ($):	$0.00
Pump seals ($):	$2,980.80
TOTAL annual miscellaneous charges:	$4,424.01

Annual labor charges:
Gas valves:	
-Monitoring ($):	$2,150.40
-Repair ($):	$483.84
Liquid valves ($):	
-Monitoring ($):	$0.00
-Repair ($):	$0.00
Pumps ($):	
-Monitoring ($):	$0.00
-Repair ($):	$0.00
Flanges ($):	
-Monitoring ($):	$3,774.40
-Repair ($):	$106.16
-Monitoring ($):	$25.20
PRD monitoring ($):	
TOTAL annual labor charges ($):	$6,539.99

Capital recovery ($/yr):	$23,175.17

TOTAL ANNUAL COSTS + 1st year labor charges ($):	($577.58)

		hr/yr
TRANSFER TIME for all pump seals (min-source/yr):	6,175,800	4475.22
TRANSFER TIME for all liquid valves (min-source/yr):	118,260,000	5599.43
TRANSFER TIME for all gas valves (min-source/yr):	13,665,600	3558.75
TRANSFER TIME for all flanges (min-source/yr):	431,254,800	332.03
TRANSFER TIME for all open-ended lines (min-source/yr):	2,628,000	625.14
TRANSFER TIME for all sample connections (min-source/yr):	0	ERR
PROCESSING TIME is applicable unit operations:		
-include PRDs only (min-source/yr):	3,547,800	6570.00

Emissions:

		Emission Factors:	
w/ current control		w/ current control measures:	
Pump seals (kg/yr):	614.49	Pump seals (kg/hr/source):	0.00597
Valves:		Valves:	
-liquid (kg/yr):	2069.55	-liquid (kg/hr/source):	0.00105
-gas (kg/yr):	1359.73	-gas (kg/hr/source):	0.00597
Flanges (kg/yr):	13153.27	Flanges (kg/hr/source):	0.00183
Open-ended lines (kg/yr):	0.00	Open-ended lines (kg/hr/source):	0
Sample Connections (kg/yr):	0.00	Sample Connections (kg/hr/source):	0
Pressure relief devices (kg/yr):	0.00	Pressure relief devices (kg/hr/source):	0
Reg Neg Controlled:		Reg Neg Controlled:	
-control level after above LDAR program implemented		-control level after above LDAR program implemented	
Pump seals (kg/yr):	638.17	Pump seals (kg/hr/source):	0.0062
Valves:		Valves:	
-liquid (kg/yr):	953.96	-liquid (kg/hr/source):	0.000484
-gas (kg/yr):	109.32	-gas (kg/hr/source):	0.00048
Flanges (kg/yr):	920.01	Flanges (kg/hr/source):	0.000128
Open-ended lines (kg/yr):	0.00	Open-ended lines (kg/hr/source):	0
Sample Connections (kg/yr):	0.00	Sample Connections (kg/hr/source):	0
Pressure relief devices (kg/yr):	0.00	Pressure relief devices (kg/hr/source):	0

Uncontrol-control=Mg controlled/yr:	14.58
Cost effectiveness ($/Mg):	($39.63)

EQUIPMENT LEAKS COST MODEL

Facility: SHELL

INPUT:

Time in PRD (min):	480
Time in all other components (min):	480
Time variables:	
Events/8 hour shift:	1
Shifts/day:	3
days/year:	350

ASSUMED VALUES:

		wt % HAP		
		25	40	6	76-100
Pump seals (#/plant):	32	25	40	6
Flanges (#/plant):	5645	19	2308	13	2316
Liquid valves (#/plant):	1666	1021	780	467
Gas valves (#/plant):	33	419		19
Sample connections (#/plant):	44	14	16	13
Liquid pressure relief devices (#/plant):	0	15		
Gas pressure relief devices (#/plant):	4			4
Open-ended lines (#/plant):	0			
Compressors (#/plant):	0			

COST CALCULATIONS:

Capital Costs/TCC:

$/monitoring instrument:	$6,500.00
$/compressor vent system:	$0.00
$/pressure relief device:	$15,719.00
$/open-ended line:	$0.00
$/sample connection:	$17,978.84
TCC ($):	$40,197.84

1st Year annualized charges:

Capital recovery factor:	0.55
Pump seals, rupture disks:	0.21
Monitoring instrument:	0.14
All other equipment:	
Monitoring instruments ($):	$1,365.00
Compressor vent systems ($):	$0.00
PRD ($):	$2,328.37
Open-ended lines ($):	$0.00
Sample connections ($):	$2,517.04
Gas valves:	
-Repair ($):	$16.59
-Monitoring ($):	$24.26
Liquid valves:	
-Repair ($):	$477.56
-Monitoring ($):	$816.34
Pumps:	
-Repair ($):	$338.69
-Monitoring ($):	$15.68
-Replacement seals ($):	$475.20
Sample connections:	
-Repair ($):	$2.04
-Monitoring ($):	$21.56
TOTAL 1st year annualized charges ($):	$8,398.32

Annual Operating Costs:

Annual maintenance charges:

Monitoring instruments ($):	$4,280.00
Compressors ($):	$0.00
PRD ($):	$785.97
Open-ended lines ($):	$0.00
Sample connections ($):	$898.94
Pump seals ($):	$5,184.00
TOTAL annual maintenance charges ($):	$11,148.91

Annual miscellaneous charges:

Monitoring instruments ($):	260
Compressors ($):	$0.00
PRD ($):	$628.78
Open-ended lines ($):	$0.00
Sample connections ($):	$719.15
Pump seals ($):	$4,147.20
TOTAL annual miscellaneous charges:	$5,755.13

Annual labor charges:

Gas valves:	
-Monitoring ($):	$92.40
-Repair ($):	$20.79
Liquid valves ($):	$4,664.80
-Monitoring ($):	$1,049.38
-Repair ($):	
Pumps ($):	
-Monitoring ($):	$1,153.60
-Repair ($):	$9,676.80
Flanges ($):	
-Monitoring ($):	$15,806.00
-Repair ($):	$444.54
-Monitoring ($):	$11.20
PRD monitoring ($):	
TOTAL annual labor charges ($):	$32,919.71

Capital recovery ($/yr):	$45,009.92
TOTAL ANNUAL COSTS + 1st year labor charges ($):	$13,212.16

		hr/yr
TRANSFER TIME for all pump seals (min-source/yr):	2,787,120	1451.63
TRANSFER TIME for all liquid valves (min-source/yr):	224,164,080	2242.54
TRANSFER TIME for all gas valves (min-source/yr):	2,338,560	1181.09
TRANSFER TIME for all flanges (min-source/yr):	663,974,640	1960.36
TRANSFER TIME for all open-ended lines (min-source/yr):	0	ERR
TRANSFER TIME for all sample connections (min-source/yr):	5,508,720	2086.64
PROCESSING TIME in applicable unit operations:		
-include PRDs only (min-source/yr):	120,960	504.00

Emissions:

Current Control:

Pump seals (kg/yr):	508.65
Valves:	
-liquid (kg/yr):	9489.61
-gas (kg/yr):	95.49
Flanges (kg/yr):	20251.23
Open-ended lines (kg/yr):	0.00
Sample Connections (kg/yr):	1377.18
Pressure relief devices (kg/yr):	117.41

Reg Neg Controlled:
-control level after above LDAR program implemented

Pump seals (kg/yr):	288.00
Valves:	
-liquid (kg/yr):	1808.26
-gas (kg/yr):	18.71
Flanges (kg/yr):	1416.48
Open-ended lines (kg/yr):	0.00
Sample Connections (kg/yr):	0.00
Pressure relief devices (kg/yr):	0.00

Uncontrol control = Mg controlled/yr:	28.31
Cost effectiveness ($/Mg):	$466.73

Emission Factors:

Current Control:
w/ current control measures

Pump seals (kg/hr/source):	0.01095
Valves:	
-liquid (kg/hr/source):	0.00254
-gas (kg/hr/source):	0.00245
Flanges (kg/hr/source):	0.00183
Open-ended lines (kg/hr/source):	0
Sample Connections (kg/hr/source):	0.015
Pressure relief devices (kg/hr/source):	0.05824

Reg Neg Controlled:
-control level after above LDAR program implemented

Pump seals (kg/hr/source):	0.0062
Valves:	
-liquid (kg/hr/source):	0.000484
-gas (kg/hr/source):	0.00048
Flanges (kg/hr/source):	0.000128
Open-ended lines (kg/hr/source):	0
Sample Connections (kg/hr/source):	0
Pressure relief devices (kg/hr/source):	0

Process Vents, Storage, and

Wastewater Options

Costs for Ciba-Geigy and Dow recycling
scrubber liquor back to process

Ciba-Geigy and Dow

	Cost/Plant
Capital Costs:	
Pump with the following specifications (a): 50 GPM, 50 ft head, 1.5 hp, 3550 RPM, S.G. = 1.0, discharge pipe size = 1"	$1,112
Piping with the following specifications (b): 400 ft of stainless steel piping, pipe racks, 1" diameter, schedule 10	$2,239
Installation Costs (materials & labor) (c): Assumed the pump installation cost would be the same as the piping installation costs.	$4,444
TOTAL CAPITAL COSTS:	$7,795
Annual Costs:	
Electricity:	$1,039
Capital Recovery Costs: Assumed 10 year life of pump and piping, and 7 percent interest.	$1,110
TOTAL ANNUAL COSTS:	$2,149

Facility	Emission Reduction (lb/yr)
Ciba-Geigy	3,195
Dow	1,930

(a) Richardson's Cost Manual, Volume IV, p. 100-280, 1984.
(b), (c) Richardson's Cost Manual, Volume III, p. 15-47, 1984.

SCRUBBER CALCULATIONS

Ciba Geigy

INPUT:

		COST EFFECTIVENESS:
GAS FLOW RATE (ACFM):	133	3496.84
GAS TEMPERATURE (C):	20	
SCRUBBING LIQUOR:	H2O	ENERGY(BTU):
MOL WT	18	1469419.31
MOLECULAR WEIGHT OF VOC:	92	
REQUIRED EFFICIENCY:	0.99	Mass Flux (lbs/yr)
GAS VOC CONCENTRATION (PPM):	11050	46107
SLOPE OF EQUILIBRIUM LINE:	1.8	
ABSORPTION FACTOR:	4.5	Time Var:
EMISSION DURATION (MIN):	60	0.24987872351939
EMISSIONS/SHIFT:	8	
SHIFT/DAY:	3	Mg Controlled: 20.723252
DAY/YEAR:	365	
TIME VAR	0.24987872352	

OUTPUT:

GAS MOLAR FLOW RATE (LBMOLE/HR):	20.7203180368
GAS MOLECULAR WEIGHT:	29.69615
GAS DENSITY (LB/FT3):	0.0771069765
LIQUID MOLAR FLOW RATE (LBMOLES/HR):	167.834576098
LIQUID DENSITY (LB/FT3):	62.4
CALCULATED ABSCICCA:	0.17258852531

READ ORD:	0.09690833382	
GAREA AT FLOODING (LB/SECFT2):	0.47377735865	USING 2 INCH CERAMIC RASCHIG RINGS
GAREA:	0.28426641519	
ACOLUMN (FT2):	0.60126858271	
DCOLUMN (FT):	0.98593738324	
NOG:	5.60148277717	
L DOUBLE PRIME(LB/HR.FT2):	5024.41414142	
SCHMIDT NO. GAS:	1.47	**MUST ENTER THESE VALUES***
SCHMIDT NO. LIQ:	1019	**MUST ENTER THESE VALUES***
HG:	1.71531975393	**PACKING CONSTANTS FOR 2 IN RASCHIG RINGS**
HL:	2.21914209153	
HOG:	2.20846244094	
H COLUMN:	12.370664327	
H TOTAL (FEET):	14.6171486728	
WEIGHT COLUMN (LB):	729.667307441	
V PACKING (FT3):	9.45750571483	**PACKING CONSTANTS FOR 2IN RASHIG RINGS***
PRESS DROP (LB/FT2.FT):	1.51183666295	**PACKING CONSTANTS FOR 2IN RASHIG RINGS***
DELT P TOTAL (IN H20):	3.36643629741	**PACKING CONSTANTS FOR 2IN RASHIG RINGS***

COST CALCULATIONS

Capital Costs

Direct Costs
ABSORBER PRICE:	$1,803.36
PLATFORM AND LADDERS:	$1,713.87
PACKING COST:	$111.37
Enhanced Monitoring Capital Equipment Cost	$3,000.00

DUCTWORK:

DUCT PRICE ($ for 100 FT):	$934.14
FAN PURCHASED COST:	$1,485.11
FAN MOTOR	$146.25
PUMP (GAL/MIN)	$6.04
PUMP HP	$0.02
PUMP HE (FT)	$14.62
COST	$348.38
STACK PRICE:	$1,401.21
PURCHASED EQUIPMENT COSTS:	$10,943.67
10 % INSTRUMENTATION AND CONTROLS:	$1,094.37
TOTAL DIRECT CAPITAL COST (7/92) DOLLARS:	$26,483.68

Indirect Costs

Enhanced Monitoring
Initial Performance Test:	$24,420.00
Total Indirect Capital Cost	$24,420.00
TOTAL CAPITAL COST	$50,903.68

ANNUALIZED COSTS:

WATER COST:	$951.69	JUNE'85
ELECTRICITY:		
FAN KWH/yr	$177.39	
PUMP KWH	$8,744.71	
TOTAL ELECTRICITY COST	$526.40	

OPERATING LABOR:	$8,562.90
MAINTENANCE LABOR:	$9,422.48
SUPERVISORY LABOR:	$1,284.44
MATERIALS:	$9,422.48
Enhanced Monitoring Supplies:	$500.00
Enhanced Monitoring Labor:	$3,150.00
DIRECT OPERATING COSTS:	$33,820.38
OVERHEAD:	$11,861.89
PROP TAX:	$509.04
INSURANCE:	$509.04
ADMINISTRATION:	$1,018.07
Reporting and Recordkeeping Requirements	$17,500
CRF:	$7,247.56
TOTAL ANNUALIZED COST:	$72,465.98
AMOUNT CONTROLLED (MG/YR):	20.72325222
COST EFFECTIVENESS ($/MG):	3496.84390787

DOW
Enhanced Monitoring Costs for Process Vents and Storage

Capital Cost Components:

Indirect Capital Costs

	Cost
Initial performance tests	
Process Vents	
1. scrubber ($)	$24,420
2. carbon adsorber ($)	$14,470
Storage	
All costs included in process vents	
Total Indirect Cost:	$38,890

Direct Capital Costs

Instrumentation	
1. flowmeter and datalogger ($)	$3,000
Total Direct Cost:	$3,000

TOTAL CAPITAL INVESTMENT (TCI):	$41,890

Annual Cost Components:

Direct Costs

Labor	
Labor rate ($/hr)	$17.50
hr/d	0.5
d/yr	360
Total Labor	$3,150
Maintenance materials	
Flowmeter and CEM	$500
Total Direct Cost:	$3,650

Indirect Costs

Capital recovery costs

Capital recovery factor	
years (n)	10
interest rate (i)	7%
Capital recovery factor value	0.142378
Capital recovery cost	$5,964

Reporting and Recordkeeping Requirements	$17,500
(This cost is applied only once to a facility	
because the cost of the requirements will not	
increase substanially with the addition of	
generic source types or control devices.)	

Total Indirect Cost	$23,464
TOTAL ANNUAL COST	$27,114

Shell
Enhanced Monitoring Costs for Process Vents and Storage

Capital Cost Components:

Indirect Capital Costs

Cost

Initial performance tests

Process Vents
1. scrubber ($) $24,420

Storage
All costs included in process vents

Total Indirect Cost: $24,420

Direct Capital Costs

Instrumentation
1. flowmeter and datalogger ($) $3,000

Total Direct Cost: $3,000

TOTAL CAPITAL INVESTMENT (TCI): $27,420

Annual Cost Components:

Direct Costs

Labor
Labor rate ($/hr) $17.50
hr/d   0.5
d/yr   360
Total Labor $3,150

Maintenance materials
Flowmeter and CEM $500

Total Direct Cost: $3,650

Indirect Costs

Capital recovery costs

Capital recovery factor
years (n)   10
interest rate (i)   7%
Capital recovery factor value   0.1423775

Capital recovery cost $3,904

Reporting and Recordkeeping Requirements $17,500
(This cost is applied only once to a facility
because the cost of the requirements will not
increae substantially with the addition of
generic source types or control devices.)

Total Indirect Cost $21,404

TOTAL ANNUAL COST $25,054

DOW
Enhanced Monitoring Costs for Wastewater

Capital Cost Components:

Indirect Capital Costs

Cost

Initial performance tests

Wastewater	$10,000
Total Indirect Cost:	$10,000

Direct Capital Costs

Total Direct Cost:	$0
TOTAL CAPITAL INVESTMENT (TCI):	$10,000

Annual Cost Components:

Direct Costs

Labor	
Labor rate ($/hr)	$0.00
hr/d	0
d/yr	0
Total Labor	$0
Maintenance materials	
Flowmeter and CEM	$0
Total Direct Cost:	$0

Indirect Costs

Capital recovery costs

Capital recovery factor	
years (n)	10
interest rate (i)	7%
Capital recovery factor value	0.14238
Capital recovery cost	$1,424
Total Indirect Cost	$1,424
TOTAL ANNUAL COST	$1,424

Ciba-Geigy
Enhanced Monitoring Costs for Wastewater

Capital Cost Components:

Indirect Capital Costs

	Cost
Initial performance tests	
Wastewater	$10,000
Total Indirect Cost:	$10,000

Direct Capital Costs

Total Direct Cost:	$0

TOTAL CAPITAL INVESTMENT (TCI):	$10,000

Annual Cost Components:

Direct Costs

Labor	
Labor rate ($/hr)	$0.00
hr/d	0
d/yr	0
Total Labor	$0

Maintenance materials	
Flowmeter and CEM	$0
Total Direct Cost:	$0

Indirect Costs

Capital recovery costs

Capital recovery factor	
years (n)	10
interest rate (i)	7%
Capital recovery factor value	0.14238
Capital recovery cost	$1,424
Total Indirect Cost	$1,424
TOTAL ANNUAL COST	$1,424

TABULAR COSTS FOR

EXISTING SOURCES

WSR SOURCE CATEGORY

Equipment Leaks Options

EQUIPMENT LEAKS COST MODEL

INPUT:

Time in PRD (min):	480
Time in all other components (min):	480
Time variables:	
Events/8 hour shift:	1
Shifts/day:	3
days/year:	261.4167

ASSUMED VALUES:

	wt % HAP			
	0-25%	26-50%	51-75%	76-100%
Pump seals (#/plant):				2
Flanges (#/plant):				64
Liquid valves (#/plant):				14
Gas valves (#/plant):				1
Sample connections (#/plant):				2
Liquid pressure relief devices (#/plant):				
Gas pressure relief devices (#/plant):				2
Open-ended lines (#/plant):				1
Compressors (#/plant):				

	TOTAL
Pump seals (#/plant):	2
Flanges (#/plant):	64
Liquid valves (#/plant):	14
Gas valves (#/plant):	1
Sample connections (#/plant):	2
Liquid pressure relief devices (#/plant):	0
Gas pressure relief devices (#/plant):	2
Open-ended lines (#/plant):	1
Compressors (#/plant):	0

COST CALCULATIONS:

Capital Costs/TCC:

$/monitoring instrument:	$6,500.00
$/compressor vent system:	$0.00
$/pressure relief device:	$7,920.00
$/open-ended line:	$102.00
$/sample connection:	$826.00
TCC ($):	$15,348.00

1st Year annualized charges:

Capital recovery factor:	0.55
Pump seals, rupture disks:	0.21
Monitoring instrument:	0.14
All other equipment:	
Monitoring instruments ($):	$1,365.00
Compressor vent systems ($):	$0.00
PRD ($):	$1,173.58
Open-ended lines ($):	$14.28
Sample connections ($):	$115.64
Gas valves:	
-Repair ($):	$0.50
-Monitoring ($):	$0.49
Liquid valves:	
-Repair ($):	$4.01
-Monitoring ($):	$6.86
Pumps:	
-Repair ($):	$21.17
-Monitoring ($):	$0.98
-Replacement seals ($):	$29.70
Flanges:	
-Repair ($):	$2.96
-Monitoring ($):	$31.36
TOTAL 1st year annualized charges ($):	$2,766.54

Annual Operating Costs:

Annual maintenance charges:

Monitoring instruments ($):	$4,260.00
Compressors ($):	$0.00
PRD ($):	$396.00
Open-ended lines ($):	$5.10
Sample connections ($):	$41.30
Pump seals ($):	$324.00
TOTAL annual maintenance charges ($):	$5,046.40

Annual miscellaneous charges:

Monitoring instruments ($):	260
Compressor ($):	$0.00
PRD ($):	$316.80
Open-ended lines ($):	$4.08
Sample connections ($):	$33.04
Pump seals ($):	$259.20
TOTAL annual miscellaneous charges:	$873.12

Annual labor charges:

Gas valves:	
-Monitoring ($):	$11.20
-Repair ($):	$2.52
Liquid valves ($):	$156.80
-Repair ($):	$35.28
Pumps ($):	
-Monitoring ($):	$94.50
-Repair ($):	$907.20
Flanges ($):	
-Monitoring ($):	$179.20
-Repair ($):	$5.04
Open-ended lines ($):	
-Repair ($):	$5.60
PRD monitoring ($):	
TOTAL annual labor charges ($):	$1,397.34

Capital recovery ($/yr):	$4,301.76
TOTAL ANNUAL COSTS + 1st year labor charges ($):	$5,781.64

		hr/yr
TRANSFER TIME for all pump seals (min-source/yr):	752,880	6274.00
TRANSFER TIME for all liquid valves (min-source/yr):	5,270,161	6274.00
TRANSFER TIME for all gas valves (min-source/yr):	376,440	6274.00
TRANSFER TIME for all flanges (min-source/yr):	24,092,163	6274.00
TRANSFER TIME for all open-ended lines (min-source/yr):	376,440	6274.00
TRANSFER TIME for all sample connections (min-source/yr):	752,880	6274.00
PROCESSING TIME in applicable unit operations:		
-includes PRDs only (min-source/yr):	752,880	6274.00

Emissions:

Uncontrolled:

Pump seals (kg/yr):	249.71
Valves:	
-liquid (kg/yr):	353.98
-gas (kg/yr):	37.46
Flanges (kg/yr):	734.81
Open-ended lines (kg/yr):	10.67
Sample Connections (kg/yr):	188.22
Pressure relief devices (kg/yr):	1304.99

Reg Neg Controlled:
-control level after above LDAR program implemented

Pump seals (kg/yr):	77.41
Valves:	
-liquid (kg/yr):	42.48
-gas (kg/yr):	3.00
Flanges (kg/yr):	51.44
Open-ended lines (kg/yr):	0.00
Sample Connections (kg/yr):	0.00
Pressure relief devices (kg/yr):	0.00

Uncontrol-control=Mg controlled/yr:	2.71
Cost effectiveness ($/Mg):	$2,136.99

Emission Factors:

CTG Controlled:

Pump seals (kg/hr/source):	0.0199
Valves:	
-liquid (kg/hr/source):	0.00403
-gas (kg/hr/source):	0.00597
Flanges (kg/hr/source):	0.00183
Open-ended lines (kg/hr/source):	0.0017
Sample Connections (kg/hr/source):	0.015
Pressure relief devices (kg/hr/source):	0.104

Reg Neg Controlled:
-control level after above LDAR program implemented

Pump seals (kg/hr/source):	0.006169
Valves:	
-liquid (kg/hr/source):	0.0004836
-gas (kg/hr/source):	0.0004776
Flanges (kg/hr/source):	0.0001281
Open-ended lines (kg/hr/source):	0
Sample Connections (kg/hr/source):	0
Pressure relief devices (kg/hr/source):	0

Process Vents and Storage Options

Tabular Costs for MACT Floor Option (Process Vents and Storage)

Plant #3

Currently have condenser at 20°C. The costs for this facility include cooling the exit gas temperature of the condenser currently on the process vents, and installation of a new condenser on the storage vessel.

So, the cost of condenser on process vents (turning the temperature down [from 20°C to 10°C]) is:

    Capital: $500

    Annual: $22,000[a]

[a]Enhanced monitoring costs only.

and, the costs of a condenser at 10°C for storage are:

    Capital: $24,000

    Annual: $64,000

Total costs for this facility are:

    Capital: $24,500

    Annual: $86,000

The control device was applied to uncontrolled streams. However, only the incremental control above the baseline was considered.

So,

$$[(225 * (1-.72))+(156 * (1-.84))+(38 * (1-.72))+127]$$

$$-[(225 * (1-.84))+(156 * (1-.91))+(38 * (1-.84))+(127 * (1-.44))]$$

$$= 225 - 127 = 98 \text{ lb/yr emission reduction}$$

Plant #8

Currently no control.

Costs of condenser at -10°C for process vents are:

Capital: $24,400

Annual: $47,000

Costs of condenser at -10°C for storage are:

Capital: $31,000

Annual: $65,000

The total costs for this facility are:

Capital: $37,400

Annual: $112,000

So,

353-[(56*(1-.085))+(37*(1-.089))+(56*(1-.085))+(56*(1-.085))+(12*(1-0.91))

+(5+(1-0.94))+(18*(1-0.96))+(109*(1-0.85))+(60*(1-0.89)]

=353 - 46 = 307 lb/yr emission reduction

Plant #9

Currently have condenser at 20°C. Cool the condenser down from 20°C to -50°C.

So, the cost of condenser on process vents (turning the temperature down [from 20°C to -50°C]) is:

    Capital: $360,000

    Annual: $91,000

Emission reduction = 3,008 lb/yr

Plant #12

Currently have scrubber. The costs below assume the scrubber is removed from the batch reactor and a condenser is added to control process vent emissions. A condenser is also added to the storage tank.

So, condenser at -10°C on process vents costs:

    Capital: $24,400

    Annual: $47,000

Condenser at 10°C on storage tank costs:

    Capital: $24,000

    Annual: $64,000

The total costs for this facility are:

    Capital: $48,400

    Annual: $111,000

$$1,817 - [(743*(1-0.94)) + (2,548*(1-0.97)) + (1,231*(1-0.98))$$
$$+ (506*(1-0.44))]$$

$$= 1,817 - 429 = 1,388 \text{ lb/yr emission reduction}$$

Plant #14

Currently have scrubber. same situation as Plant #12.

So, costs for condenser at 10°C on process vents:

   .Capital: $15,500

   Annual: $45,000

Costs for condenser at 10°C on storage are:

   Capital: $24,000

   Annual $64,000

The total costs for this facility are:

   Capital: $39,500

   Annual: $119,000

   975 - [(511*(1-0.77))+(1,328*(1-0.89))+(1,073*(1-0.95))

                  + (131*(1-0.44))]

      975 - 391 = 584 lb/yr emission reduction

Tabular costs for Regulatory Option #1 for
Process Vents and Storage

Plant #2

Currently have scrubber on process vents and storage vessels. This facility needs 2 * 8.8 = 18 lb emission reduction to meet the 5 lb HAP/MM lb product cutoff for this regulatory alternative. The costs below assume the scrubber currently in use at the facility will be disconnected and a condenser installed.

$$63 - [(42 * ((1 - .85) + (10 * (1 - .91)) + (166 * (1 - .85))]$$

$$63 - 32 = 31 \text{ lb/yr emission reduction}$$

So, costs for process vent condenser are:

    Capital: $24,400

    Annual: $47,000

Costs for storage tank condenser are:

    Capital: $31,000

    Annual: $65,000

Total costs for this facility are:

    Capital: $55,400

    Annual: $112,000

Plant #3

With MACT floor option a condenser at 10°C is in place on process
vents and a separate condenser is on storage tanks. To achieve
the 5 lb HAP/mm lb product cutoff the exit gas temperature of the
condenser already in place was lowered to -10°C.

So,

225 - [(225*(1-.96))+(156*(1-.98)+(38*(1-.96)) + (127*(1-.85))]

225 - 33 = 192 lb/yr emission reduction

Costs for condenser on process vents are:

Capital: $3,800

Annual: $22,000[a]

Costs for condenser on storage are:

Capital: $31,000

Annual: $65,000

Total costs for this facility are:

Capital: $34,800

Annual: $87,000

[a]Enhanced monitoring costs only.

Plant #6

Currently have condenser at 20°C

$$2-[(4*(1-.96)+(1*(1-.98))+(0*(1-.99))]$$

2 - .18 = 1.82 lb/yr emission reduction

So, costs for condenser for process vents are:

Capital: $3,800

Annual: $22,000[a]

[a]Enhanced monitoring costs only.

Plant #8

Currently no control.

So,

$$353-[(56*(1-.85)+(37*(1-.89))+(56+(1-.85))+$$

$$(12*(1-.91))+(5*(1-.94))+(18*(1-.96))+$$

$$(109*(1-.85))+(60*(1-.89))]$$

$$= 353 - 46 = 307 \text{ lb/yr emission reduction}$$

Costs of condenser for process vents are:

    Capital: $24,400

    Annual: $47,000

Costs of condenser for storage are:

    Capital: $31,000

    Annual: $65,000

Total costs for this facility are:

    Capital: $55,400

    Annual: $112,000

Plant #9

Currently have condenser at 20°C.

                    3,008 lb/yr emission reduction

The costs of the condenser on process vents is:

    Capital: $360,000

    Annual: $91,000

Plant #12

Currently have scrubber. The costs below assume the scrubber is disconnected and 2 condensers are installed to control process vent and storage emissions, respectively.

$$1,817 - [(743*(1-.94))+(2548*(1-.97)+(1231*(1-.98))$$

$$+ (506 * (1 -.85))]$$

$$1817 - 222 = 1595 \text{ lb/yr emission reduction.}$$

So, costs for condenser at -10°C on process vents are:

Capital: $24,400

Annual: $47,000

Costs for condenser at -10°C on storage are:

Capital: $31,000

Annual: $65,000

Total costs for this facility are:

Capital: $55,500

Annual: $112,000

Plant #14

Currently have scrubber.   Same situation as Plant #12.

975-[(511*(1-.94(+(1,328*(1-.97))+(1,073*(1-.99)+(131*(1-.85))]

975 - 101 = 874 lb/yr emission reduction

So, costs for condenser at -10°C on process vents:

Capital: $24,400

Annual: $47,000

Costs for condenser at -10°C on storage are:

Capital: $31,000

Annual: $65,000

Total costs for this facility are:

Capital: $55,500

Annual: $112,000

Plant #15

Currently have scrubber.

$$684-[(471*(1-.94))+(165*(1-.97))+(953*(1-.98))+223]$$

$$684 - 275 = 409 \text{ lb/yr emission reduction}$$

So, costs for the condenser at -10°C on process vents are:

    Capital: $24,400

    Annual: $47,000

Total costs for the facility are:

    Capital: $24,400

    Annual: $47,000

Plant #16

Currently have scrubber.

$$619 - [(611*(1-.85))+(217*(1-.97))+(914*(1-.98))+167]$$

$$619 - 283 = 336 \text{ lb/yr emission reduction}$$

So, costs for a condenser at -10°C on process vents are:

Capital: $24,400

Annual: $47,000

Total costs for the facility are:

Capital: $24,000

Annual: $47,000

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-453/R-94-033a	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Emissions from Epoxy Resins Production and Non-Nylon Polyamides Production - Background Information for Proposed Standards		**5. REPORT DATE** May 1994
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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This document provides information on the control of hazardous air pollutants from the manufacture of basic liquid epoxy resin and wet-strength resins. Information includes emission estimates, environmental and cost impacts of regulatory alternatives and an economic analysis.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Hazardous Air Pollutants Epoxy Resins Wet-Strength Resins	Hazardous Air Pollutants	

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