United States
Environmental Protection
Agency

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

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Air

EPA

Hazardous Air Pollutant Emissions from the Production of Polyether Polyols--

Supplementary Information Document for Proposed Standards

NESHAP

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HAZARDOUS AIR POLLUTANT EMISSIONS FROM THE PRODUCTION OF POLYETHER POLYOLS

Supplementary Information Document for Proposed Standards

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Emission Standards Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

May 1997

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ENVIRONMENTAL PROTECTION AGENCY

Hazardous Air Pollutant Emissions from the Production of Polyether Polyols - Supplementary Information Document for Proposed Standards

1. The standards regulate hazardous air pollutant emissions from the production of polyether polyols. Only polyether polyols production facilities that are part of major sources under Section 112(d) of the Clean Air Act (Act) will be regulated.

2. For additional information contact:

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3. Paper copies of this document may be obtained from:

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OVERVIEW

This Supplementary Information Document (SID) contains memoranda providing rationale and information used to develop the Polyether Polyols proposal package. These memoranda were written by EC/R Incorporated under contract to the U.S. Environmental Protection Agency (EPA). The data and information contained in these memoranda were obtained through literature searches, industry meetings, plant visits, and replies to questionnaires sent to industry.

The memoranda included in this SID are referred to in the Basis and Purpose Document and in the preamble to the proposed rule. These memoranda were compiled into this single document to allow interested parties more convenient access to this information. The memoranda included herein are also available from the docket (Docket A-96-38).

The memoranda included in this SID are listed below with their document numbers.

Document No.	Description
II-B-3	Caldwell, M., Caldwell Environmental, and Seaman, J., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. March 26, 1997. Memorandum. Polyether Polyols Production Industry Description.
II-B-2	Seaman, J., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. February 20, 1997. Memorandum. Maximum Achievable Control Technology Floor Determination and Regulatory Alternative Consideration.

Document No.	Description
II-B-5	Seaman, J., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. April 29, 1997. Memorandum. Summary of Nationwide Baseline Emissions for Polyether Polyols Production Facilities.
II-B-4	Hendricks, D. and Seaman, J., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. April 25, 1997. Memorandum. Estimated Impacts for the Polyols NESHAP.
II-B-7	Seaman, J., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. May 16, 1997. Memorandum. The Definition of an Extended Cookout as a Control Technique for the Polyether Polyols Production Industry.
II-B-17	Chappell, L., U.S. Environmental Protection Agency, to Svendsgaard, D., U.S. Environmental Protection Agency. May 21, 1997. Economic Analysis for the National Emissions Standards for Hazardous Air Pollutants (NESHAP) for the Polyether Polyols Industry.

EC/R Incorporated 1996 EPA Outstanding Small Business Contractor

MEMORANDUM

Date: March 26, 1997

Subject: Polyether Polyols Production Industry Characterization

To: David Svendsgaard, EPA/OAQPS/OCG

From: Mary-Jo Caldwell, Caldwell Environmental, Inc.
Joanne Seaman, EC/R Inc.

The purpose of this memorandum is to describe the polyether polyols manufacturing source category as it is being defined by the U.S. Environmental Protection Agency (EPA) for purposes of developing a national emission standard for hazardous air pollutants (NESHAP). In this memorandum, the source category is described, both existing and projected facilities are discussed, a brief discussion of the end uses of polyether polyols is provided, and the polyether polyol manufacturing process, emissions, and controls are described.

INTRODUCTION

For regulatory development purposes, the EPA has defined the polyether polyol source category as facilities that manufacture polyether polyols, which are defined as follows:

> Polyether polyols are defined as the products formed by the reaction of ethylene oxide (EO), propylene oxide (PO), or other cyclic ethers with compounds having one or more reactive hydrogens (i.e., hydrogen bonded with a nitrogen, sulfur, oxygen, phosphorous atom, etc.). This definition excludes materials regulated as glycols or glycol ethers under the Hazardous Organic NESHAP(HON).[1]

The source category has been divided into two subcategories due to the distinctively different nature of the manufacturing processes. The subcategories are polyether polyols made with epoxides (i.e., EO, PO and butylene oxide (BO)), and polyether polyols made with tetrahydrofuran (THF). The most important distinction between these two subcategories is that the primary monomer for the second reaction (THF) is not an organic HAP, whereas the predominant epoxides, EO and PO, are organic HAP. (Butylene oxide is not an organic HAP, but 1,3-butadiene is emitted from the production of polyether polyols using BO.)[2]

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Additionally, the first group performs the reaction on a batch basis, while the second group reacts on a continuous basis.

MANUFACTURING FACILITY DISTRIBUTION AND DESCRIPTION

The distribution and description of existing polyether polyol manufacturing facilities is discussed in this section. SPI representatives report that no new plants are expected to be built within the next five years, but modifications can make an existing source become a new source.

Existing Facilities

The trade association for polyether polyol manufacturers, the Society of the Plastics Industry (SPI), and the EPA project team worked together to gather information on the polyether polyol manufacturing industry. The SPI supplied to the EPA project team a list of plants that produce polyether polyols in the United States, and this list is provided in Table 1.[3] Two more facilities were added to this list; one facility sent a questionnaire response to the EPA, and the second facility was listed in the Chemical Economics Handbook (CEH). The EPA project team determined that, of the list of 84 plants, there were only two facilities in the list that polymerize THF exclusively, and the remaining 82 produced polyols with epoxides. One of the facilities indicated that although they produce polyols with epoxides, they also have a THF polymerization line. Therefore, the project team tentatively estimated that the source category consists of three facilities that polymerize THF and 82 facilities that polymerize epoxides into polyether polyols.[2]

The types of polyether polyols produced at each of the 84 facilities are also presented in Table 1[3]. In Table 1, polyether polyols are broken down according to application into three main categories: urethane, non-urethane, and surfactants. As shown in Table 1, some facilities produce only one type of polyether polyol and others produce several. Even at those facilities that only produce one type of polyether polyol, multiple polyols within the general classification are often produced. Sixty five percent of the facilities in the database manufacture a surfactant, and 20 percent of the facilities reported urethane production while 35 percent reported non-urethane production.[3]

Projected Facilities

The number of facilities that use epoxides to produce polyether polyols that are expected to be major sources subject to the rule is 76. This number was calculated by first determining the percentage of the facilities in the database that are major sources (92.3 percent). This percentage was multiplied by the total number of facilities in the database that use epoxides in Table 1 (84 facilities), to estimate the number of

facilities using epoxides to produce polyether polyols that are expected to be subject to the rule. The three facilities that use THF to produce polyether polyols are all expected to be major sources subject to the rule. Because one of the facilities that uses THF also produces polyether polyols using epoxides, the total number of facilities expected to be subject to the rule is estimated as 78 (76+2).

POLYETHER POLYOLS PROPERTIES AND END USES

The end use of a polyether polyol is determined by the properties of the polymer. The linear or slightly branched polyether polyols serve in flexible applications, such as in flexible slab and molded foam, reaction injection molding, and in other elastomer, sealant, and coating applications. The branched polyether polyols serve in applications requiring rigidity such as rigid foams, solid or microcellular plastic, and hard, solvent-resistant coatings. As noted in the discussion of Table 1, polyether polyols fall into two main classifications: high-molecular-weight, linear or slightly branched polyether polyols (urethanes), and low-molecular-weight, highly branched polyether polyols (non-urethanes).[4]

Urethanes

Properties. There are three important factors that determine the properties of an polyol product: its functionality, its average molecular weight, and its degree of steric hindrance.

The functionality of the polyether polyol is determined by the functionality of the initiator, and is defined by the number of terminal hydroxyl groups on each polymer molecule. The number of terminal hydroxyl groups influences the degree to which urethanes produced from the polyol will be cross-linked; that is, that larger the number of terminal hydroxyl groups, the more cross-linking. Therefore, the functionality of the polyol is important in determining the properties of the ultimate polyurethanes.[5]

The molecular weight is controlled by the total amount of monomer fed to the reaction, and the amount of initiator used. A high ratio of monomer to initiator results in a comparably high average molecular weight. Higher molecular weights also require longer reaction times. The average molecular weight and functionality of an polyol determine its "hydroxyl number," which is the number of terminal hydroxyl groups per unit weight.[5]

Table 1. U.S. Facilities Producing Polyether Polyols and Products Produced (Ref. 3)

State / City	Company	Urethane	Non-urethane	Alkoxylated Non-ionic Surfactants	Ethoxylated Non-ionic Surfactants	Propoxylated Non-ionic Surfactants
CALIFORNIA						
Santa Fe Springs	Baker		x			
Long Beach	Lonza				x	
Carson	Nalco		x			
Anaheim	Stepan					x
Santa Fe Springs	Witco		x		x	
DELAWARE						
New Castle	ICI				x	
FLORIDA						
Winder	Rhone-Poulenc		x		x	
GEORGIA						
Winder	Stepan					x
ILLINOIS						
Skokie	Calgene		x		x	
Ringwood	Morton				x	
Lyons	Pelron		x			
Gurnee	PPG		x		x	
Elwood	Stepan	x				x

Table 1. U.S. Facilities Producing Polyether Polyols and Products Produced (Ref. 3)

State / City	Company	Urethane	Non-urethane	Alkoxylated Non-ionic Surfactants	Ethoxylated Non-ionic Surfactants	Propoxylated Non-ionic Surfactants
Millsdale	Stepan					x
Chicago	Witco		x		x	
KANSAS						
Kansas City	Harcros				x	
KENTUCKY						
Brandenburg	Olin	x	x			
LOUISIANA						
Geismar	BASF	x				
Geismar	ICI	x				
Geismar	Shell				x	
Reserve	Shell				x	x
Lake Charles	Vista				x	
Harahan	Witco				x	
MARYLAND						
Baltimore	Rhone-Poulenc				x	
MICHIGAN						
Wyandotte	BASF	x				

Table 1. U.S. Facilities Producing Polyether Polyols and Products Produced (Ref. 3)

State / City	Company	Urethane	Non-urethane	Alkoxylated Non-ionic Surfactants	Ethoxylated Non-ionic Surfactants	Propoxylated Non-ionic Surfactants
Midland	Dow		x			
MISSOURI						
St. Louis	Petrolite					
NEW JERSEY						
New Brunswick	Akcros				x	
Edison	Amerchol				x	x
Washington	BASF		x		x	x
Bayonne	CasChem				x	
Elizabeth	Emkay				x	
Hoboken	Henkel				x	
Paterson	Heterene				x	x
Fieldsboro	Stepan					x
Maywood	Stepan					x
NEW YORK						
Bronx	Dexter				x	
Niagara Falls	DuPont	x				
NORTH CAROLINA						
Greensboro	Eastman	x				

Table 1. U.S. Facilities Producing Polyether Polyols and Products Produced (Ref. 3)

State / City	Company	Urethane	Non-urethane	Alkoxylated Non-ionic Surfactants	Ethoxylated Non-ionic Surfactants	Propoxylated Non-ionic Surfactants
Greensboro	Brin-Mont					
Thomasville	Gresco Mfg.				x	
Charlotte	Henkel		x		x	
High Point	High Point				x	
Mount Holly	Hoechst				x	
OKLAHOMA						
Sand Springs	Baker		x			
PENNSYLVANIA						
Mill Hall	Croda				x	x
Philadelphia	Inolex				x	
Williamsport	Lonza				x	
RHODE ISLAND						
Providence	Eastern Color				x	
Providence	Lenox				x	
SOUTH CAROLINA						
Spratansburg	BASF				x	x
Whitestone	BASF		x			
Mauldin	Henkel		x		x	x

Table 1. U.S. Facilities Producing Polyether Polyols and Products Produced (Ref. 3)

State / City	Company	Urethane	Non-urethane	Alkoxylated Non-ionic Surfactants	Ethoxylated Non-ionic Surfactants	Propoxylated Non-ionic Surfactants
Inman	Milliken				x	
Easley	Ortec		x			
Spartanburg	Rhone-Poulenc		x		x	x
Martin	Sandoz				x	
TENNESSEE						
Memphis	QO Chemicals	x				
TEXAS						
Channelview	ARCO	x				
Dayton	Baker		x			
Pasadena	Carpenter	x				
Freeport	Dow	x	x			
Conroe	Eastman	x				
Houston	Exxon		x			
Port Neches	Huntsman				x	
Baytown	Miles	x				
Freeport	Nalco		x			
Freeport	Nalco/				x	
SugarLand	Nalco/				x	

Table 1. U.S. Facilities Producing Polyether Polyols and Products Produced (Ref. 3)

State / City	Company	Urethane	Non-urethane	Alkoxylated Non-ionic Surfactants	Ethoxylated Non-ionic Surfactants	Propoxylated Non-ionic Surfactants
Pasadena	Petrolite		x			
Conroe	Texaco		x			
Port Neches	Texaco		x			
Seedrift	Union Carbide		x	x		
Texas City	Union Carbide				x	
Houston	Witco	x	x	x	x	x
WEST VIRGINIA						
Charleston	ARCO	x				
New Martinsville	Miles	x				
Institute	Union Carbide		x	x	x	
South Charleston	Union Carbide		x			
WISCONSIN						
Janesville	ABITEC				x	
Janesville	Witco				x	

The degree of steric hindrance of an polyol governs its reactivity in the final urethane polymerization reaction. Steric hindrance, or reactivity, is determined by the relative amounts of EO and PO used in the reaction, and by the timing of their use. The steric effect is most important at the end of the polyol chain. When PO is the last monomer added to a chain, the terminal hydroxyl group is termed a "secondary" hydroxyl, because of the presence of the methyl side group. When EO is the last monomer added, the terminal hydroxyl group is "primary". A primary hydroxyl group at the end of an polyol chain reacts more quickly than a secondary group, because the secondary hydroxyl is sterically hindered by the methyl side group. Thus, the resulting polyol is more reactive.[5]

Polyether polyols for polyurethane use must fulfill some strict purity criteria. Traces of catalyst residue or salts can cause problems in the end-use. Catalyst residue concentration must usually be below 15 parts per million (ppm). Other impurities that may have a significant effect at a very low level are dissolved gases, oxidation products, and materials that affect surface tension. Because of the need to control these effects, the polyether polyol manufacturing process has evolved to a high level of complexity to assure product quality and consistency.[4]

The most important nonEO/nonPO polyether polyol is polytetramethylene glycol(PTMEG), derived from tetrahydrofuran.[4] The high-performance elastomers made from PTMEG are superior to castable polyurethane elastomers in their resilience, hydrolytic stability, thermal stability, ultraviolet-light resistance, compression set, and adhesion characteristics; and they are at least comparable to polyurethane elastomers in abrasion resistance. However, they are poorer with respect to ultimate tensile-elongation values, tear strength, and solvent resistance.[6]

<u>End Uses</u>. Most polyether polyols are produced for polyurethane application.[4,7] The largest world market of polyether polyols for urethane applications is in the production of polyurethane foam, primarily flexible foams, and in lesser quantities, for rigid foams. The remainder of the polyether polyols for urethane applications are used in a variety of markets, including microcellular, cast, and thermoplastic elastomers; adhesives and sealants; surface coatings and polyurethane fibers.[7] Polyurethane polyols are also used in some instances to produce reaction injection molding plastics, which are used mainly in automotive applications.[5]

Polytetrahydrofuran can be prepared so that it has reactive end-groups (e.g., hydroxyl or amino), or relatively inert end groups (e.g., alkoxy). The most commercially important polytetrahydrofurans are probably the hydroxy-terminated

polymers, i.e., the PTMEG, which are used in injection molding and extrusions and to prepare nonfiber polyurethanes, spandex, and polyesters.[8,9] Polytetrahydrofuran can also be prepared so that it has a preponderance of primary amino end groups. The resulting elastomers display a high degree of resilience, abrasion resistance, and insensitivity to water.[8]

According to a report by Stanford Research Institute (SRI) International, in the beginning of 1994, the world capacity for polyether polyols for urethanes was approximately 8.5 billion pounds (3.9 million metric tons). The United States accounted for 34 percent of the total capacity. Actual production in Western Europe, the United States, Japan, the Republic of Korea, Canada, Taiwan and Mexico in 1992 was approximately 5.2 billion pounds, representing a 1992 operating rate of about 69 percent in those regions. The projected consumption growth rate for urethane polyether polyols in the United States is 2.7 percent for 1992-1997.[7]

Nonurethanes

Properties. Polyether polyols for nonurethane applications are high-molecular-weight polyols that are nonvolatile and range from viscous fluids to waxy solids at room temperature. Nonurethane polyols are used safely in many personal-care applications because they possess a very low degree of oral toxicity, are relatively nonirritating to the skin, and have low potential for eye injury. Nonurethane polyether polyols can also be thermoplastic.[8]

The pseudo-plastic behavior of nonurethane polyether polyols is used to impart leveling and flowability to waterborne coatings and helps to build a film and reduces spatter and misting in water-based lubricants. Nonurethane polyether polyols are used as a dispersive medium for a variety of applications; they can serve as a wetting agent and a thickening agent, allowing the cleanser or lubricant to cling to the surface. At concentrations higher than normal for friction reduction, they produce a coherent needlelike stream from a normal spray which can be used to cut semisoft solids such as cardboard, leather, and cheese.[8]

End Uses. The major markets for nonurethane polyether polyols are surfactants, functional fluids, lubricants, and personal-care products. Sizeable quantities of nonurethane polyether polyols are also used as chemical intermediates.[9] According to a report by SRI International, in 1994, consumption of nonurethane polyether polyols in the United States was as follows: surface-active agents 38 percent; functional fluids and lubricants 28 percent; other (animal health products, herbicides, rubber chemicals, cosmetics and toiletries, mold release agents, and adhesive formulations) 34 percent.[6] In 1994, nonurethane

polyether polyol production in the United States, Western Europe, and Japan was approximately 1,050 million pounds (475,000 metric tons), according to an SRI International report. In 1994-1997, the United States is expected to exhibit consumption growth of approximately 2.7 percent per year.[6]

PROCESS DESCRIPTION

A description of the manufacturing process and chemistry used to produce polyether polyols from epoxides and from THF are presented in this section.

Polyols from Epoxides

Polyether polyols are produced by the addition polymerization of cyclic ethers. Most polyether polyols are produced by base catalysis. Exceptions are polyether polyols based on amine initiators which are self-catalyzed or require additional catalysts only in the later stages of the process, and polytetrahydrofuran which is produced by acid catalysis.[4]

A generalized block diagram for polyether polyol processing is shown in Figure 1. The polymerization reaction takes place in a reactor made of carbon or stainless steel, and begins with an initiator, which is a starter polyol, amine, glycerin, or other material with one or more reactive hydrogen sites. The starting material used will depend on what functionality is sought in the final product.[4,5]

A catalyst is added to the reactor containing the initiator; potassium hydroxide or sodium hydroxide are typically used, but boron trifluoride (BF_3), and other acids and bases are also used. The catalyst is used to activate the initiator by abstracting the active hydrogen to produce an anion. Then the monomer feed is started. During the formation of the alkoxide ion and the addition of the monomer, oxygen needs to be rigorously excluded because the alkoxide ion is very sensitive to oxidation. The oxygen is purged from the vessel by replacing any air in the vessel with nitrogen.[4,5]

Once the monomer feed is started, the anion reacts with the cyclic ether, cleaving the ether ring. Cleavage of the ether ring leaves an oxygen ion at the end of the new chain, which reacts with another molecule of monomer. This process continues until the desired molecular weight is reached and then the monomer feed is terminated. In some cases, if a higher molecular weight product is required, a facility will start reacting a small amount of epoxide (known as an initiator) in a small reactor. Once a certain molecular weight is achieved, the material is transferred to the main reactor. The initiation and polymerization reactions are illustrated in Figure 2.[5] The

monomers most commonly used to produce polyether polyols are PO and EO (called "epoxides").[4,5]

During the addition of the monomer, the heat of reaction is very high, and heat removal is necessary and is accomplished by external or internal heat exchange. Extensive process control and instrumentation are required to operate safely within a given temperature range in order to produce consistent products. The monomer feed rate may be limited by heat-removal capacity or pressure limitations. The reaction rate depends on catalyst concentration and reaction temperature, as well as the type of monomer feed. The reaction temperature not only affects the reaction rate, but also the composition of the polyether polyol produced.[4]

After the desired molecular weight is reached and the monomer feed stops, the product may have subsequent refining or undergo other reactions to make the final product. In polyol manufacturing, refining usually refers to catalyst removal from the polyol and, if a solvent is used, removal of the solvent from the polyol prior to sale. The degree of catalyst removal from the crude reactor product depends on the application and can range from simple neutralization for polyether polyols used in rigid foams to removal to less than 5 ppm potassium for most other applications, where deleterious effects of salts have been shown. The choice of the catalyst removal process depends on the required purity of the polyether polyol and may involve crystallization and filtration of salts and/or treatment with absorbents. The catalyst can either be neutralized with an acid or stripped with a solvent. If an acid is used, a solid waste results which must be treated. If a solvent is used, solid waste is avoided and the solvent is often recovered and recycled.[4,5] The catalyst separation solvents typically used are the organic HAPs toluene or hexane.

In the final purification step, water and volatile organic compounds are removed by stripping in the reactor or in falling or wiped film evaporators. The polyether polyols are stabilized with proprietary inhibitors (antioxidants), saturated with nitrogen, and stored hot.[4]

Polyether polyol manufacturing industry representatives indicated that organic HAPs other than EO and PO are used for more than just obtaining the purity needed. Reactivity, viscosity (which affects mixing), solubility (in water versus organic solvents), and stability (against oxidative and thermal degradation), are all important factors in manufacturing polyether polyols to realize needed end use properties, and other organic HAPs are necessary in achieving and maintaining the desired levels of each of these characteristics.[10]

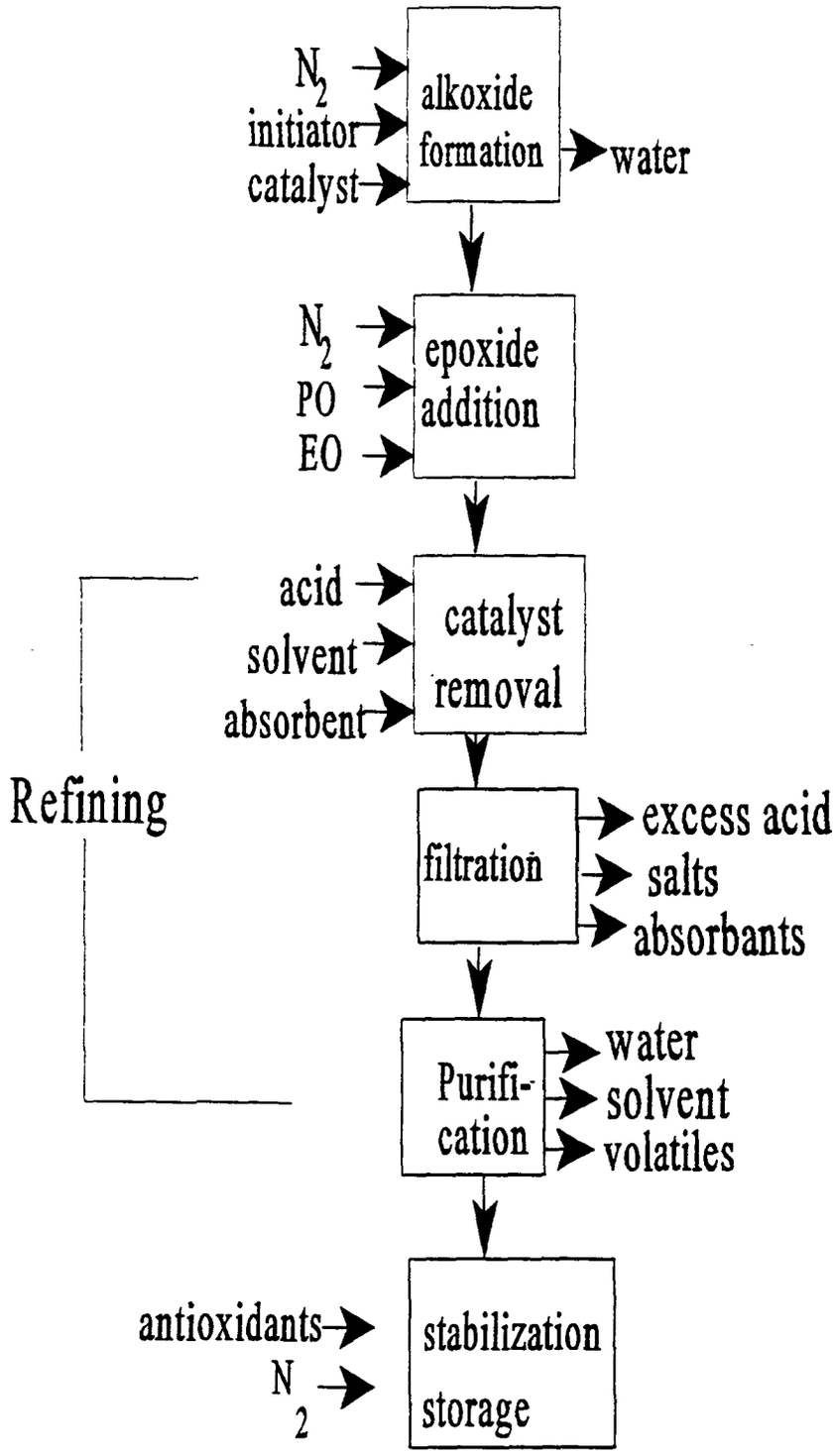
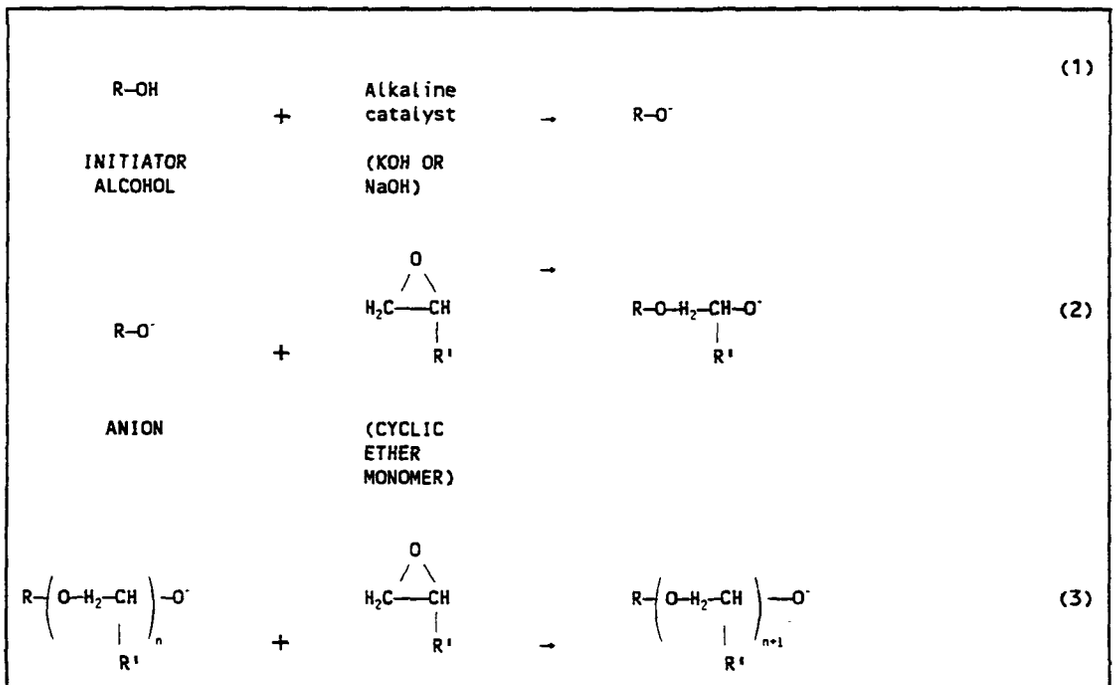


Figure 1. Process Flow Diagram for Polyether Alcohol Manufacturing (Ref. 4)



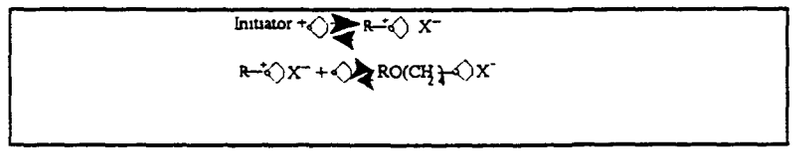
NOTE: R–OH in equation (1) can be replaced with an amine, and the epoxide monomer in equation (2) can be replaced with a larger cyclic ether ring, such as tetrahydrofuran.

FIGURE 2. Reactions in Polyether Polyol Production

Polyols made from Tetrahydrofuran

The polymerization of THF involves cleaving the THF molecule by using an acid catalyst, and then reacting the open THF with unreacted THF to build a longer chain. The basic requirement for polymerization is that a THF molecule must be broken by some mechanism; assuming that a suitable counter-ion is present, polymerization follows. Once initiated, propagation occurs as a result of collisions between the THF monomer and the broken THF's chain end.[8]

The polymerization of THF is represented by the following scheme[8]:



The synthesis of polytetrahydrofuran involves the use of strong acid initiators. Therefore, the polymer is stable against attack by bases, but somewhat acid sensitive. Like all polyether polyols, it is subject to oxidative attack and subsequent breakdown. The addition of common antioxidants (e.g.. amines orpyrocatechol), inhibits these reactions and imparts adequate stability to the polymer for commercial purposes.[8]

Because THF polymerizes only by an ionic mechanism, requirements for successful polymerization include pure, dry reagents, dry apparatus, and either high vacuum or an inert atmosphere (e.g., dry nitrogen). Use of a suitable temperature and a limited amount of solvent, depending on the temperature, are also critical factors, because the polymerization of THF is an equilibrium polymerization.[8]

The most commercially important polytetrahydrofuran is PTMEG. The traditional, as well as the simplest and most direct, method of preparing PTMEG is to initiate the polymerization of THF with protonic acid, which leads to the formation of an -OH head group and termination of the polymerization with water, which also produces an -OH end group.[8] This process is shown by the following:

EMISSION SOURCES AND CONTROL

There are four primary potential sources of organic HAP emissions in the polyether polyol manufacturing process: process vents, storage vessels, equipment leaks, and wastewater. The emissions from these sources, and the types of controls being used, are discussed in the following sections.

Another potential emission source considered in other NESHAPs is unloading operations, and these were investigated for this industry as well. Industry representatives indicated that all organic HAP unloading operations are conducted in a closed vent system due to the explosive nature of EO. Therefore, no emissions are expected to result from this portion of the process.[2]

Emissions and Controls on Production Units that Use Epoxides

Process Vents. The most significant organic HAP loss from the polyether polyol manufacturing process occurs at the end of the batch when the unreacted epoxide is vented. Ethylene oxide reacts quite quickly, so normally the residual EO in the vent is quite low. Propylene oxide reacts an order of magnitude slower at a given catalyst level, temperature, and pressure.

Consequently, the uncontrolled level of PO in the vent is usually substantially higher than EO.[10]

Information on process vent emissions was obtained via a questionnaire. The EPA/SPI questionnaire was written by the EPA project team with input from industry representatives, and was then submitted to SPI members and nonmembers. Additional process vent data, limited to annual emissions and control efficiencies, was received from the SPI. The process vent emissions and control device data for 28 facilities, with the facility names coded, are presented in Table 2.[1] The emissions data in Table 2 indicate that combined EO and PO controlled emissions range for these select facilities from 20 to 80,966 pounds per year (lb/year). As can be seen in Table 2, a variety of controls are used to reduce process vent emissions. The process vent controls used by the 28 facilities, listed in order of frequency of use, are: scrubbers, flares, extended cookout, incinerators, and condensers. Over 40 percent of the facilities that submitted control device data used scrubbers to control process vent emissions, and 25 percent used flares.[1] Some facilities using scrubbers use a condenser upstream of the scrubber to recycle the epoxides back into the batch being processed. The unreacted epoxides not condensed are converted to glycols in the scrubber by using an acid or base medium. This glycol is often sold as a byproduct.[3]

Some facilities use flares or incineration to reduce process vent organic HAP emissions. Because the polyether polyol manufacturing process using epoxides is a batch process, incineration is not always the most economical control alternative, according to industry representatives. The industry representatives reported that the batches can take anywhere from 12 to 36 hours, and this would mean that if a combustion device were used, there is a time period for each batch when the incinerator or combustion device would simply burn natural gas or fuel oil to keep the combustion device in operation.[3] It should be noted that incinerators are used at two of the facilities in the control device database.[1]

Extended cookout (ECO) is also used to reduce process vent organic HAP emissions from polyether polyol production that occur when the reactor is opened. Extended cookout reduces the amount of unreacted EO and/or PO (epoxides) in the reactor by allowing it to react for a longer time period, thereby reducing epoxides emissions that may have otherwise been routed to a control device. Because the epoxides are converted to product, the producer's raw material usage decreases. The point in time where the costs for emissions reduction resulting from a decreased production rate exceed the benefits from improved raw material efficiency is the starting point for an ECO. This point was determined based on average raw material costs and "typical" product profit margins. The starting point for calculating

emission reduction from ECO is when the amount of epoxides in the reactor liquid has decreased to 25 percent of the amount in the vessel after the epoxides addition phase.

The use of ECO as an emission control technology has an economic penalty, since ECO must be done in the reactor system, lengthening batch time and reducing the reactor system annual production capacity. This penalty is offset to some extent by the improvement in raw material efficiency due to converting more epoxide to product. Once ECO is complete, the remaining emissions are low.[9]

Storage. The storage vessels used in the polyether polyol manufacturing process are a potential source of organic HAP emissions. Most of the storage vessels used in polyether polyol manufacturing are pressurized, and of this group all of the EO and PO storage vessels are pressurized as a precaution due to the explosive nature of EO.[2]

Equipment Leaks. Emissions of organic HAPs may occur around pumps, valves, and other components, and are referred to as "equipment leaks". In some facilities, pumps may have double mechanical seals, with a fluid such as propylene glycol as a seal barrier fluid. In addition, 69 percent of the facilities have leak detection and repair (LDAR) programs. The LDAR programs allow the facilities to be aware of any leaks immediately so the problem can be fixed, minimizing emissions.[5]

Wastewater. Another potential source of organic HAP emissions in polyether polyol production facilities is the wastewater from the manufacturing process. The majority of wastewater emissions from this industry are a result of the steam ejectors used on these batch reactors to pull a vacuum on the vessel. However, although seventeen percent of the facilities in the database have Group 1 wastewater streams that require controls according to the HON, none of the facilities for which data were received control air emissions from the wastewater streams.[5] A Group 1 wastewater stream is defined by the HON as having a minimum volatile organic HAP (VOHAP) concentration of 10,000 ppm and a minimum stream flowrate of 10 liters per minute.

Emissions and Controls on Production Units that use Tetrahydrofuran

Even though THF is not an organic HAP, there are organic HAP emissions from one of the facilities in the database that polymerize THF. At this facility the catalyst extraction process resulted in organic HAP emissions.[2] An organic HAP solvent is

Table 2. Emissions Estimates and Controls for Selected Facilities (Ref. 1)

FACILITY	BEFORE CONTROL EMISSIONS (LB/YR)				AFTER CONTROL EMISSIONS (LB/YR)				CONTROL EFFICIENCY (PERCENT REDUCTION)				ABATEMENT
	EO	PO	EO&PO	Other-HAP	EO	PO	EO&PO	Other-HAP	EO	PO	EO&PO	Other-HAP	
M	NR	NR	NR	NR	7	35.7	43	NA	99.9	99.9	99.9	NA	Incinerator
D	1,073	15,851	16,924	142,270	11	292	303	142,270	99	99	99	0	Scrubber
J	76,270	260,526	336,796	336,810	1,375	4,950	6,325	33,681	98	98	98	90	CBI
SPI5	NR	NR	NR	NA	20	NA	20	NA	98	NA	98	NA	Scrubber
SPI8	NR	NR	NR	NR	1	48	49	NA	98	98	98	NA	Extended Cookout
SPI16	NR	NR	NR	NR	110	0.4	110	NA	98	98	98	NA	Flare
SPI11	NR	NR	NR	NR	144	NA	144	247	98	NA	98	0	Flare
SPI12	NR	NR	NR	NR	144	NA	144	639	98	NA	98	0	Flare
SPI9	NR	NR	NR	NR	98.7	69.6	168	NA	98	98	98	NA	Flare
SPI10	NR	NR	NR	NR	148	48	196	NA	98	98	98	NA	Extended Cookout
SPI14	NR	NR	NR	NR	164	108	272	NA	98	98	98	NA	Flare
C	4,750	14,250	19,000	NA	95	285	380	NA	98	98	98	NA	Packed Scrubber
I	NR	NR	NR	NR	NA	860	860	2740	NA	98	98	98	Cook out and Flare
SPI7	NR	NR	NR	NR	89	1,240	1,329	1450	98	98	98	0	Extended Cookout, Scrubber
SPI6	NR	NR	NR	NR	1,735	NA	1,735	NA	98	NA	98	NA	Extended Cookout
E	NR	NR	NR	NR	956	1,677	2,633	1751	95	95	95	40	Shell & tube Condenser
K	45,988	345,186	391,174	NA	1,379	23,817	25,196	NA	97	93	94	NA	CBI
SPI13	NR	NR	NR	NR	58	9,800	9,858	20	98	83	91	0	Extended Cookout

FACILITY	BEFORE CONTROL EMISSIONS (LB/YR)				AFTER CONTROL EMISSIONS (LB/YR)				CONTROL EFFICIENCY (PERCENT REDUCTION)				ABATEMENT
SPI4	NR	NR	NR	NR	NR	NR	NR	NR	90	NA	90	NA	Packed column Scrubber
A	NA	556,731	556,731	4	NA	80,966	80,966	4	NA	85	85	0	Caustic Scrubber
SPI15	NR	NR	NR	NR	1675	NA	1,675	NA	85	NA	85	NA	Scrubber
H	NA	NR	NR	NA	NA	169	169	NA	NR	NR	NR	NR	Cook out
G	NR	NR	NR	NA	90	450	540	NA	NR	NR	NR	NR	Incinerator
B	85	2,031	2,116	NA	85	2,031	2,116	NA	NR	NR	NR	NA	Scrubber
SPI3	NR	N/A	NR	NR	170	N/A	170	N/A	99.8	NA	99.8	NA	Packed column Scrubber

NR = Not reported
NA = Not applicable

used for the catalyst extraction, and none of these emissions to the atmosphere are controlled.[2]

Process Vents. The polymerization of THF occurs on a continuous basis. THF is not an organic HAP and organic HAPs are not typically used in the actual synthesis of the polymer.

Storage. Only one of the THF polymerizers stored an organic HAP. The storage vessel was a Group 2 (not requiring controls based on the HON criteria) fixed roof storage vessel.

Equipment Leaks. Potential organic HAP emissions may occur around pumps, valves, and other components in facilities manufacturing polyether polyols from THF. Based on data received from industry, it appears that monitoring of equipment leaks is not generally conducted at such facilities.[2]

Wastewater. Neither facility that polymerized THF generate Group 1 wastewater streams. Therefore, no wastewater controls were reported.[2]

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EC/R Incorporated

1996 EPA Outstanding Small Business Contractor

MEMORANDUM

Date: February 20, 1997

Subject: Maximum Achievable Control Technology Floor Determination and Regulatory Alternative Consideration

From: Joanne C. Seaman, EC/R Incorporated JCS

To: David Svendsgaard, EPA/OAQPS/ESD/OCG

The purpose of this memorandum is to present the approach used to develop maximum achievable control technology (MACT) floors and regulatory alternatives for new and existing sources in the polyether polyols industry. This memorandum is organized in four sections. First, a brief background of the project and regulatory process is provided. Second, a discussion is provided regarding the approach used to determine the MACT floor levels of control. Third, MACT floors calculations are described, followed by a presentation of the results of the analysis. The final section is a discussion of the development of regulatory alternatives more stringent than the MACT floors.

BACKGROUND

Clean Air Act Requirements

Section 112 of the Clean Air Act (CAA), as amended in 1990, defines a minimum level of control, referred to as the "MACT floor," for standards established under Section 112(d). For new sources, emission standards "shall not be less stringent than the emission control that is achieved in practice by the best controlled similar source." For existing sources, the emissions standards must be at least as stringent as either "the average emission limitation achieved by the best performing 12 percent of the existing sources (for which the Administrator has emissions information)... in the category or subcategory for categories or subcategories with 30 or more sources" or "the average emission limitation achieved by the best performing 5 sources" for categories or subcategories with less than 30 sources.

Subcategorization of the Source Category

There are several fundamental decisions that were required to be made before the MACT floor could be determined. These

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decisions are discussed in this section. The EPA decided it was appropriate to subcategorize the source category for purposes of analyzing the MACT floors and regulatory alternatives. The subcategories are polyether polyols made from the polymerization of epoxides and polyether polyols made from the polymerization of tetrahydrofuran (THF). An "epoxide" is a chemical compound consisting of a three-membered cyclic ether. Ethylene oxide (EO) and propylene oxide (PO) are the only epoxides that are listed as HAP, and, therefore regulated by this rule. Subcategorization was necessary due to the distinctively different nature of the epoxide and THF processes and the effect of these differences on the applicability of controls. One noteworthy distinction between the two subcategories is that the first group, polyols made with epoxides, uses HAP as the monomer(s), whereas the second group does not use a HAP monomer. Additionally, the first group performs the reaction primarily on a batch basis, while the second group performs the reaction on a continuous basis. Separate MACT floors were developed for each subcategory and are presented in this memorandum.

Major Source Determination

Of the 26 facilities in the largest portion of the database, the process vent portion, two facilities were reported to be area sources. It was assumed that the remaining 24 facilities are major sources or synthetic minor sources. This determination was made because, while some type of control is in place to reduce emissions at many facilities, there is no evidence that these controls are "federally enforceable." This means that the potential to emit is probably above major source levels if the controls used are not considered when calculating emissions. Further, there are no federal regulations limiting emissions from polyols production at this time.

Database

The joint information gathering effort between the U.S. Environmental Protection Agency (EPA) and the Society of the Plastics Industry (SPI) (EPA/SPI questionnaire) was used in determining MACT floors for the following emission sources at polyether polyols production facilities: storage vessels, equipment leaks, and wastewater. For emissions from process vents, additional information was received from the SPI, in the form of emission and control efficiency data (SPI database).[1] There was a good deal of variation in the level of detail of the process vent information provided by the EPA/SPI questionnaire and the SPI database. Specifically, the responses to the EPA/SPI questionnaire included the following: detailed descriptions of

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[1] Letter and attachment from Maureen Healey of the SPI, to David Svendsgaard, EPA/OAQPS/ESD/OCG. May 2, 1996.

the processes; pre-control and post-control emission rates; and process vent stream characteristics for some streams, including flowrate, duration, and heat content. The SPI data consisted of limited information on 16 facilities, where total process vent post-control emission rates were provided for only 12 facilities; and control efficiencies were provided for all 16 facilities.

The EPA/SPI questionnaire was written by the EPA project team with input from industry representatives. The SPI was then responsible for submitting the questionnaire to SPI members and nonmembers. The SPI representatives indicated that they had sent questionnaires to anyone who voiced an interest in responding, and that they did not select the best performers when soliciting questionnaire responses. Therefore, the EPA project team concludes that the responses received are not skewed towards any control performance range, and are representative of the entire industry.

Number of Sources

The EPA received a list of 82 plants that produce polyether polyols in the United States from the SPI[2]. Two additional facilities were also included on this list: one facility sent a questionnaire response to the EPA, and the second facility was listed in the Chemical Economics Handbook (CEH). The EPA project team determined that, of the list of 84 plants, there were only two facilities in the list that polymerize THF exclusively, and the remaining 82 produced polyols with epoxides. One of the facilities indicated that, although they produce polyols with epoxides, they also have a THF polymerization line. Therefore, the project team estimated that the source category consists of three facilities that polymerize THF and 82 facilities that polymerize epoxides into polyether polyols.

Seventy-six facilities that use epoxides to produce polyether polyols are expected to be major sources subject to the rule. This number was calculated by first determining the percentage of the facilities in the database that are major sources (92.3 percent). This percentage was multiplied by the total number of facilities in the database that use epoxides, to estimate the number of facilities using epoxides to produce polyether polyols. The three facilities that use THF to produce polyether polyols are all expected to be major sources subject to the rule. Because one of the facilities that uses THF also produces polyether polyols using epoxides, the total number of facilities in the entire source category expected to be subject to the rule is estimated as 78 (76+2).

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[2] SPI Enterprise System: May 9, 1996 printout of "Facilities for Polyether Polyols Production" for 1994.

APPROACH TO DETERMINE THE MACT FLOOR LEVELS OF CONTROL

For all emission sources with the exception of process vents, the MACT floor approach was to analyze the level of control in place at the facilities, in order to establish the MACT floor. For process vents, the EPA project team investigated a couple of different MACT floor formats.

Use of the HON in the MACT Floor Determination

The EPA studied methods to simplify the MACT floor analysis, and decided to use the Hazardous Organic NESHAP, or HON (40 CFR part 63; subparts F, G, and H, 59 FR 19402), in the MACT floor analysis. The rationale for this conclusion is provided in this section.

The HON contains emission limitations for five emission source types: process vents, storage vessels, transfer operations, wastewater, and equipment leaks. Because of the similarities between the synthetic organic chemical manufacturing industry (SOCMI) and polyether polyols industries, the EPA concluded that the HON requirements for storage vessels, wastewater, and equipment leaks were appropriate to use in defining the MACT floor for the polyether polyols production industry. Another practical reason for using the HON requirements is that the HON provides "ready-made" alternatives. That is, the HON analysis takes into account equipment type, equipment size, equipment contents, stream characteristics, and other important aspects of the emission source that should be considered in the floor determination.

The intent of this approach is to determine how controls at existing polyols facilities compare to the level of control that would be required by the HON for all emission types except process vent emissions. The HON-based type of analysis does not provide specific numeric values for the MACT floor. Rather, the conclusion of each floor analysis using this HON-based approach is whether the MACT floor is less stringent than, more stringent than, or equal to, the HON-level of control. For each facility in each subcategory, the existing controls were identified for each emission point. The existing level of control was then compared to the level of control that would be required by the HON, and the emission point was characterized as being controlled at a level less stringent than the HON requirements (less than HON), a level equivalent to the HON requirements (equal to HON), or a level more stringent than the HON requirements (greater than HON).

The HON requirements noted above apply to three of the four emission source types and part of the fourth: storage vessels, wastewater, and equipment leaks, as well as process vents from continuous unit operations that use nonepoxide HAP to make or

modify the product. For process vents from batch unit operations that make or modify the product, the "Control of Volatile Organic Compound Emissions from Batch Processes: Alternative Control Techniques Information Document" (EPA-450/R-94-020) (Batch ACT) was used. Finally, for process vent emissions of epoxides and for process vent emissions of nonepoxides from catalyst extraction, an aggregated emission reduction approach was used.

Use of the Batch ACT for Process Vents from Batch Unit Operations

The Batch ACT provides guidance to State and local air pollution regulatory agencies on the development of regulations for air emissions from batch processes, and is intended to apply to all batch operations. Due to the similarities between the processes studied in the Batch ACT, and the general nature of the applicability criteria, the EPA concluded that these criteria were appropriate to use in defining the MACT floor for process vents from batch unit operations in the polyether polyols industry. The determination of the MACT floor using the Batch ACT is also described in the procedures section of this memorandum.

MACT Approach for Process Vents

In the early stages of the presumptive MACT (P-MACT) process, the EPA project team proposed an average emission factor as the format for the MACT floor for process vents. This emission factor was calculated by dividing total process vent emissions by actual production for the year 1993. The EPA project team's intent for this MACT floor format was to allow the facilities to take credit for reacting their product to completion in an extended cookout. The emission factor approach would not require definitions or calculations for these extended cookouts. However, industry representatives criticized this format, saying that the emission factor MACT floor was unrealistically low and that it restricted the facilities from producing certain polyols classes. They added that the EPA project team did not understand the chemistry and diversity of the polyols products, and stated that, in an effort to meet this standard, they would only be able to produce certain polyols classes that were not "capped" with EO. Industry representatives then proposed a control efficiency format, along with a definition of all the controls used at polyols facilities, which included extended cookout.

As a result of the industry recommendations, and due to the lack of data for a MACT floor based on stream characteristics, the project team selected a control efficiency format. Each facility's control efficiency was calculated by subtracting the total controlled process vent emissions from the total uncontrolled process vent emissions. This difference was then divided by the total uncontrolled process vent emissions, and

divided by the total uncontrolled process vent emissions, and multiplied by 100 percent. The MACT floor was calculated as the median of the top twelve percent of the control efficiencies at 28 facilities (or 3.36 facilities).

The MACT floor for existing sources that polymerize THF to produce polyols was determined by averaging the emission information available from the two facilities in the database. Similar to the new source standard for polyols with epoxides, the new source MACT floor for THF polymerization was identified as the level of control at the best performing facility.

MACT FLOOR LEVELS OF CONTROL CALCULATIONS

Two basic procedures were used to determine the MACT floors for the polyether polyols subcategories. The first, the HON-based approach, compared existing levels of control with the level of control that would be required at polyether polyols facilities if the HON requirements were applied. This approach was used for storage vessels, wastewater, and equipment leaks. For process vent emissions of nonepoxides in making or altering the product, the same approach was used, except that the 90 percent control level from the Batch ACT was used for process vents from batch unit operations, and the HON process vent provisions were used for process vents from continuous unit operations. The 90 percent Batch ACT control level was selected, because the estimated cost-effectiveness for this level was comparable to the cost-effectiveness of the HON continuous vent provisions (approximately $3,000 per Megagram). A second approach was used to assess the average emission limitation for process vent emissions of epoxides and for nonepoxide emissions from catalyst extraction. The approach used for these process vent emissions was an aggregated emission reduction percentage for all process vents within the polyether polyols manufacturing process unit (PMPU).

The control level for both existing and new sources was determined by comparing the controls in place at each facility with the existing source requirements in the HON. This section describes the general HON-based approach used for all emission source types (i.e., storage vessels, process vent nonepoxide emissions from making or altering the product, wastewater streams, equipment leaks), followed by specifics of the individual emission source types.

General Approach

After each emission point at each facility was characterized, all emission points of a given emission source type were grouped together and a facility-wide determination was made for each emission source type. For instance, if a storage vessel was controlled at a level less stringent than the HON, and

no other storage vessel was controlled at a level more stringent than the HON, the facility was classified as "less than HON" for storage vessels. If all controls at the facility were equivalent to the HON levels, the facility was classified as "equal to HON." If one or more points was controlled at a level more stringent than the HON, and no point of the same type was controlled at a level less stringent than the HON at that facility, the facility was classified as "greater than HON."

It is important to note, however, that if an emission point was uncontrolled, and the HON would not require control for that point, the level of control was classified as equal to the HON level of control. Therefore, the floor for a subcategory could be the HON, when in fact all emission points of that particular emission source type were uncontrolled.

If a facility reported different levels of control (in comparison to the HON) within one emission source type, an additional analysis was necessary to classify the facility. In these situations, the existing emission level was compared to the emission level that would be required if HON controls were applied. If the existing emissions were less than the HON-level emissions, the facility was classified "greater than HON," but if the HON-level emissions were lower than the existing emissions, the facility was classified "less than HON."

The floor for all emission source types except process vents was defined for both subcategories as less than, equal to, or greater than, the HON level of control. The HON-based approach used for new sources was similar to the existing source approach. This determination was based on the majority of individual facility classifications for the subcategory.

Storage Vessels

The applicability of the existing HON storage tank provisions is based on tank size and vapor pressure of the total organic HAP in the storage tank. Vessels meeting the capacity/vapor pressure criteria must be controlled using one of three control techniques: (1) an internal floating roof, (2) an external floating roof, or (3) a closed vent system to control device (with a 95 percent control efficiency). If the maximum true organic HAP vapor pressure of the vessel contents is high enough, the control options are limited to a closed vent system vented to a control device. Pressure tanks (at a pressure greater than 23 psi) are exempt form the HON requirements.

In order to evaluate the applicability of the HON provisions to polyether polyols storage vessels, the maximum true vapor pressure of the HAP were estimated, and the level of control that would be required determined. For each facility, the existing storage vessel controls were noted and summarized by individual

HAP. The existing level of control was then compared to the HON-level of control for each vessel, and the MACT floors were determined as discussed above in the section entitled "General Approach."

Process Vent Emissions of Nonepoxides from Making or Modifying the Product

The HON process vent provisions apply to continuous process vents emitting streams containing more than 0.005 weight-percent HAP. Control (98 percent emission reduction) is required for each process vent with a flow rate greater than or equal to 0.005 standard cubic meters per minute, an organic HAP concentration greater than or equal to 50 ppmv, and a total resource effectiveness (TRE) index value less than or equal to 1.

The Batch ACT process vent provisions apply to volatile organic compound (VOC) emissions from process vents from batch unit operations. In this analysis, only the organic HAP were considered. The first level of applicability in the Batch ACT is based on annual emissions. If annual HAP emissions, calculated before a control or recovery device, are less than specified levels, control is not required. For the 90 percent control level, these "cutoff" levels are between 7,300 and 11,800 kilograms per year, depending on the volatility of HAP's emitted. If annual emissions were greater than the cutoff level, emission were input into an equation from the ACT to determine a cutoff flow rate. If the actual flow rate of the batch vent stream is less than the cutoff flow rate, 90 percent control is required.

EC/R applied the HON or Batch ACT criteria to each process vent for which the necessary vent stream parameters were provided. In some instances, EC/R was able to estimate the necessary parameters. In situations where a process vent from a continuous unit operation was analyzed, EC/R applied the HON criteria to the stream prior to the control device, to assess whether the stream would have required control based on the HON criteria. Similarly, in situations where a process vent from a batch unit operation was controlled using a control or recovery device, the Batch ACT criteria were applied prior to the device. The existing level of control was then compared to the level of control that would be required by the HON or Batch ACT.

Process Vent Emissions of Epoxides and of Nonepoxides from Catalyst Extraction

For process vent emissions of epoxides and of nonepoxides from catalyst extraction, an average aggregated emission reduction was calculated for each PMPU. To do this the following calculation was used:

where:
R = Emission reduction, percentage;
E_u = Uncontrolled epoxide process vent emissions, pounds per year, (lb/yr); and
E_c = Controlled epoxide process vent emissions, lb/yr.

Wastewater

The HON requires wastewater streams at existing sources that have a total organic HAP concentration of 1,000 ppmw or greater and a flow rate of 10 liters per minute or greater (at the point of determination), or a total organic HAP concentration of 10,000 ppmw or greater at any flow rate, to be managed in controlled equipment and treated to reduce the HAP concentration.

EC/R applied these criteria to uncontrolled wastewater streams at each facility. The stream characteristics were then compared to the HON applicability criteria to assess whether the HON would require control. Each wastewater stream, and in turn each facility, was classified as "less than HON," "equal to HON," or "greater than HON." The floor for wastewater for each subcategory was then determined as discussed above in the section entitled "Use of HON in the MACT Floor Determination."

Equipment Leaks

The HON equipment leak provisions require a combination of leak, detection, and repair (LDAR) procedures and equipment requirements. In order to compare the existing control levels to the HON levels, baseline control levels were assessed for each type of component at each facility. A qualitative assessment was then made for each facility to determine whether the existing level of control was less than, equal to, or greater than the HON level of control.

Maximum Achievable Control Technology Floor Conclusions

Table 1 presents a summary of the MACT floor levels of control for all emission types from both subcategories. Based on existing EPA policy, information from the EPA/SPI questionnaires, and information from the SPI data submittal[3], the EPA is making recommendations for MACT floors for all emission source types identified in the two subcategories. The majority of the data received were based on 1993 information. The sections below present the MACT floors first for polyols made with epoxides, and then for polyols made with THF.

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[3] Letter and attachment from Maureen Healey of the SPI, to David Svendsgaard, EPA/OAQPS/ESD/OCG. May 2, 1996.

MACT Floor Conclusions for Polyether Polyols Made with Epoxides

Unloading

Industry representatives reported that all unloading of HAP was conducted in a closed vent system; therefore, no emissions are expected from this portion of this process.

Storage Vessels

The MACT floor level of control for storage vessels at existing sources that make polyether polyols with oxides was determined to be the HON level of control and applicability. The rationale for this determination follows. The majority of the vessels were pressurized vessels (which are exempt from the HON requirements), with only four facilities reporting vessels that were HON Group 1 storage vessels. It was determined that these four facilities have storage vessels that would require control under the HON. Three of these four facilities with HON Group 1 storage vessels have HON reference control technologies on their HON Group 1 storage vessels; therefore, the MACT floor level of control for storage vessels at existing sources was determined to be equal to the level of control in the HON. No facility had controls more stringent than the HON level of control for their Group 1 vessels; therefore, the MACT floor level of control for storage vessels at new sources is the HON existing source storage vessel level of control.

Equipment Leaks

The database of 13 facilities reporting equipment leak information indicated that nine out of 13 facilities have LDAR programs in place. Of the nine LDAR programs in place, six were reported to be equal to the level of stringency required by the HON (i.e., in terms of monitoring frequency and leak definition). No facility reported an equipment leak emission control program more stringent than the HON existing source level of control. Therefore, the MACT floor level of control for equipment leaks

Table 1. SUMMARY OF EXISTING SOURCE REGULATORY ALTERNATIVES FOR POLYETHER POLYOLS

Subcategory	MACT Floors					
	Storage	Process Vents			Wastewater	Equipment leaks
		Epoxides	Nonepoxides from making or modifying the product	Nonepoxides from catalyst extraction		
Polyols made with epoxides						
Existing Sources	HON	98 percent	0 percent	90 percent	No control	HON
New Sources	HON	99.9 percent	39 percent	98 percent	No control	HON
Polyols made with THF						
Existing Sources	No control	N/A	N/A	0 percent	No control	No control
New Sources	No control	N/A	N/A	0 percent	No control	No control

for new and existing sources was determined to be the level of control required by the HON (40 CFR 63, subpart H).

Process Vents

Three sets of MACT floor levels of control were established for process vent emissions: one for epoxide emissions; a second for nonepoxide HAP emissions from catalyst extraction; and a third for emissions of nonepoxide HAP used to make or modify the product. For the subcategory that uses epoxides, the MACT floor levels were established by determining the average emission control for the best performing 12 percent of the facilities with respect to that emission point, which translated to 3.36 facilities for the database of 28 facilities. The median approach was used where there was a wide range of values within the best performing facilities. For new sources, the MACT floor levels were established by determining the emission control for the best controlled facility for that emission point in the subcategory.

Epoxide Emissions

The MACT floor for epoxide emissions from process vents at existing facilities that produce polyether polyols with epoxides was calculated as the median of the top twelve percent of the database. The MACT floor was calculated to be a 98.1 percent control efficiency, and was rounded to 98 percent since the standard is technology based and it is believed that facilities would not use a different control technology to meet a standard that is a tenth of a percent more stringent.

The MACT floor level of control for epoxide emissions from process vents at new sources was determined to be a control efficiency of 99.9 percent. This new source MACT floor was based on a facility that reported a control efficiency of 99.9 percent.

Nonepoxide HAP Emissions from Catalyst Extraction

For nonepoxide HAP emissions from catalyst extraction, the MACT floor was determined as the median of the data in the database, which was 90 weight percent aggregated emission reduction for existing sources. The MACT floor level of control for new sources was determined to be 98 weight percent aggregated emission reduction.

Nonepoxide HAP From Making or Modifying the Product

For nonepoxide HAP process vent emissions from making or modifying the product at existing sources, the MACT floor level of control was calculated using the median of the top twelve percent. The existing source MACT floor level of control for nonepoxide HAP emissions from making or modifying the product was

determined to be no control. The new source MACT floor level of control for nonepoxide HAP process vent emissions was determined to be 39.0 percent control efficiency.

Wastewater

The MACT floor level of control for wastewater for new and existing sources was identified to be less than the HON level of control. In fact, the level of control is no control. The database indicated that only two facilities in the database reported Group 1 wastewater streams that require controls according to the HON, and neither facility controlled air emissions from these wastewater streams. Further, of the Group 2 wastewater streams that were reported, none had air emission controls.

Maximum Achievable Control Technology Floors for Polyether Polyols Made with Tetrahydrofuran

Only one of the two facilities in the database for the THF subcategory uses and emits organic HAP. Therefore, the MACT floor analysis was based on that one facility. This one source also sets the level of control for the new source MACT floor for THF polymerization.

Storage Vessels

The MACT floor level of control for new and existing sources was identified as the HON level of control. Only one of the THF facilities had a storage vessel for HAP. This storage vessel was a Group 2 vessel that does not require controls and did not have a control.

Process Vents

The facility that uses organic HAP in its process does not control the process vent emissions of the organic HAP. The second facility in the database emits hydrogen fluoride, well below the HON's definition of a halogenated stream, and has minimal controls (approximately 20 percent emission reduction) on these emissions. Therefore, the MACT floor level of control for process vents from polyether polyols produced using THF at existing sources was identified to be no control.

Equipment Leaks

No control of emissions from equipment leaks was reported at the facility that polymerizes THF. Therefore, the MACT floor for equipment leaks at existing and new facilities was determined to be less than the HON level of control. More specifically, the MACT floor level of control is no control.

Wastewater

The MACT floor for wastewater for existing and new facilities that produce polyols by polymerization of THF was determined to be equal to the HON level of control. No Group 1 wastewater streams were reported and no controls were reported for the Group 2 wastewater streams. The MACT floor level of control is equal to the HON level of control (i.e., no control).

DEVELOPMENT OF REGULATORY ALTERNATIVES MORE STRINGENT THAN THE MACT FLOOR

Only one regulatory alternative more stringent than the MACT floor level of control was developed and considered for each subcategory. Table 2 presents the MACT floor and the regulatory alternative for existing sources or each subcategory. The rationale for the level of this alternative is discussed below.

Polyether Polyols Made with Epoxides

The MACT floor level of control for storage vessels and equipment leaks was equal to the HON level of control. Therefore, the regulatory alternative included the HON level of control for these emission types.

The MACT floor level of control was determined to be less stringent than the HON level of control (i.e., no control) for wastewater emissions. The HON level of control was considered for the regulatory alternative for wastewater because it had received extensive evaluation during the development of the HON, at which time the EPA concluded that the cost and other impacts associated with the HON-level of control were reasonable. Therefore, the regulatory alternative included the HON level of control for wastewater.

During the development of the HON, alternatives more stringent than the promulgated levels were considered and rejected by the EPA. Therefore, it was unnecessary to consider controls more stringent than the HON levels, since this industry closely mirrors the SOCMI, and the EPA had previously considered them unacceptable for the HON.

For the process vent regulatory alternatives, an emission reduction format was chosen and applied to the three groups of HAP process vent emissions: epoxide emissions; nonepoxide HAP emissions from the making or modification of the product; and nonepoxide HAP emissions from catalyst extraction. The MACT floor level of control for epoxide process vent emissions was considered to be sufficiently stringent, since it mirrored the highest level of control in the Batch ACT (without performing a

Table 2. SUMMARY OF EXISTING SOURCE REGULATORY ALTERNATIVES FOR POLYETHER POLYOLS

Subcategory	Existing Source Regulatory Alternatives					
	Storage	Process Vents			Wastewater	Equipment leaks
		Epoxides	Nonepoxides from making or modifying the product	Nonepoxides from catalyst extraction		
Polyols made with epoxides						
MACT Floor	HON	98 percent	0 percent	90 percent	No control	HON
Reg Alt I	HON	98 percent	HON or Batch ACT	90 percent	HON	HON
Polyols made with THF						
MACT Floor	No control	N/A	N/A	0 percent	No control	No control
Reg Alt I	HON			HON	HON	HON

cost effectiveness analysis to determine applicability). Therefore, no levels of control more stringent than the floor were evaluated.

The MACT floor level of control for nonepoxide HAP emissions from making or altering the product was determined to be an aggregated control efficiency of 0 percent. The EPA determined that the applicability criteria from either the HON or the Batch ACT could be applied for process vents from continuous or batch unit operations, respectively. The HON Group determination approach was deemed appropriate because in the equation in the HON for determining Group 1/Group 2 applicability, the total resource effectiveness index (TRE) has an inherent cost effectiveness value in it. After determining the Group status, the control requirement from the HON, a 98 percent control efficiency, was used for this regulatory alternative, as well. If the process vent was from a batch unit operation, the Group determination was based on equations first developed in the Batch ACT. The 90-percent control level from the Batch ACT was selected because the facilities that did report controls on these streams reported condensers, and 90 percent was the lowest control efficiency achieved. Further, the estimated cost-effectiveness for this level was comparable to the cost-effectiveness of the HON continuous vent provisions. Based on these analyses, the EPA determined that it was acceptable to consider a single regulatory alternative beyond the MACT floor level.

Polyether Polyols Made with Tetrahydrofuran

The MACT floor level of control for all the emission types in this subcategory was determined to be less stringent than the HON level of control. For these same reasons as presented above for the polyether polyols made with epoxides subcategory, the regulatory alternative included the HON level of control for storage vessels, equipment leaks, and wastewater. For the process vent emissions, similar to the other subcategory, the HON or Batch ACT Group determination was included in the regulatory alternative.

Table 3. SUMMARY OF REGULATORY ALTERNATIVES FOR POLYETHER POLYOLS

Subcategory	New Source Regulatory Alternatives					
	Storage	Process Vents			Wastewater	Equipment leaks
		Epoxides	Nonepoxides from making or modifying the product	Nonepoxides from catalyst extraction		
Polyols made with epoxides						
MACT Floor	HON	99.9 percent	39 percent	98 percent	No control	HON
Reg Alt I	HON	99.9 percent	HON or Batch ACT	98 percent	HON	HON
Polyols made with THF						
MACT Floor	No control	N/A	N/A	0 percent	No control	No control
Reg Alt I	HON			HON	HON	HON

EC/R Incorporated

1996 EPA Outstanding Small Business Contractor

MEMORANDUM

Date: April 29, 1996

Subject: Summary of Nationwide Baseline Emissions for Polyether Polyols Production Facilities

From: Joanne C. Seaman, EC/R Incorporated JCS

To: David Svendsgaard, EPA/OAQPS/ESD/OCG

The purpose of this memorandum is to present the projected nationwide baseline emissions of hazardous air pollutants (HAP) from polyether polyols production facilities. Nationwide baseline emissions were calculated by first calculating the average HAP emissions from the database for each emission source within the polyols production process (i.e., process vents, equipment leaks, storage, and wastewater). Nationwide baseline HAP emissions were estimated by extrapolating average emissions from these emission sources to nationwide emissions based on the number of actual sources in this industry.

This approach was used instead of developing "model plants" and then scaling up emissions from each possible model plant to nationwide emissions. The rationale behind this decision was that there would have been an extremely large number of possible model plants, considering the different combinations of scenarios from the various emission sources in the polyols production process.

SOURCE CATEGORY DEFINITION

Polyether polyols are defined as the products formed by the reaction of ethylene oxide (EO), propylene oxide (PO), or other cyclic ethers with compounds having one or more reactive hydrogens (i.e., a compound having a hydrogen terminally bounded with a nitrogen, sulfur, oxygen, phosphorous atom, etc.). This definition excludes materials regulated as glycols or glycol ethers under the Hazardous Organic National Emission Standard for Hazardous Air Pollutants (HON). A major source is 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 of any HAP or 25 tons per year of any combination of HAP. The source category has been divided into two subcategories: polyether polyols made with epoxides, which is the majority of the source category; and polyols made from the

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polymerization of tetrahydrofuran (THF). The source category was subcategorized due to the inherently different nature of the two types of processes. Epoxide means a chemical compound consisting of a three-membered cyclic ether. For the purposes of this rule, epoxides include EO and PO.

The Society of the Plastics Industry (SPI) supplied to the EPA project team a list of 82 plants that produce polyether polyols in the United States. Two more facilities were added to this list: one facility sent a questionnaire response to the EPA, and the second facility was listed in the Chemical Economics Handbook (CEH). The EPA project team determined that, of the list of 84 plants, there were only two facilities in the list that polymerize THF exclusively, and the remaining 82 produced polyols with epoxides. One of the facilities indicated that, although they produce polyols with epoxides, they also have a THF polymerization line. Therefore, the project team estimated that the source category consists of three facilities that polymerize THF and 82 facilities that polymerize epoxides into polyether polyols.[2]

The number of facilities that use epoxides to produce polyether polyols that are expected to be major sources subject to the rule is 76. This number was calculated by first determining the percentage of the facilities in the database that are major sources (92.3 percent). This percentage was multiplied by the total number of facilities in the database that use epoxides, to estimate the number of facilities using epoxides to produce polyether polyols that are expected to be subject to the rule. The three facilities that use THF to produce polyether polyols are all expected to be major sources subject to the rule. Because one of the facilities that uses THF also produces polyether polyols using epoxides, the total number of facilities in the entire source category expected to be subject to the rule is estimated as 78 (76+2).

A description of the calculation approach and data used, along with the resulting nationwide emissions for each emission source type, is presented in the appropriate sections below.

NATIONWIDE BASELINE EMISSIONS

The polyether polyols process vent database was developed based on two main sources: (1) responses to a questionnaire that was a joint information gathering effort between the U.S. Environmental Protection Agency (EPA) and the SPI (EPA/SPI questionnaire); and (2) emission and control efficiency data provided by the SPI (SPI database).[1] For equipment leaks,

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[1] Letter and attachment from Maureen Healey of the SPI, to David Svendsgaard, EPA/OAQPS/ESD/OCG. May 2, 1996.

wastewater and storage vessels, baseline emissions were calculated from the EPA/SPI questionnaire responses. For process vent baseline emissions, the EPA/SPI questionnaire data was supplemented by the SPI database.

Process Vents

Polyols Made with Epoxides

The responses to the EPA/SPI questionnaire included the following: detailed descriptions of the processes; pre-control and post-control emission rates; and process vent stream characteristics, such as flowrate, duration and heat content. The SPI data consisted of limited information on 16 facilities, where total process vent post-control emission rates were provided for only 12 facilities, and control efficiencies were provided for all 16 facilities. Both the SPI database and the EPA/SPI questionnaire database were used to estimate baseline emissions. The SPI database reported total epoxide and other-HAP emissions and did not distinguish where in the process these emissions occurred. Therefore, due to the lack of detailed information, it was assumed that all epoxide emissions from the SPI database were from the reactor step of the process, and all other-HAP emissions were from the finishing step of the process. In performing these calculations, it was assumed that the information in the SPI database and the EPA/SPI questionnaire database are representative of the entire industry.

Process Emissions from Reactors

The process of producing polyols is performed in two basic steps: the reaction step, where the polyol is polymerized; and the finishing step, where the crude polyol from the reactor is further treated. Table 1 presents the summary of emissions from both databases for the reactor step of the process. The EO and PO emissions from the reactors ranged from 20 pounds per year (lb/yr) to 80,966 lb/yr. The EO and PO emission rates were separated into two emissions scenarios: a low epoxide emissions scenario and a high epoxide emissions scenario. In the low epoxide emissions scenario, emissions were less than or equal to one ton per year (tpy), with an average emission rate of 474 lb/yr. This scenario represents 74 percent of the facilities in the database. In the high epoxide emissions scenario, emissions were greater than 1 tpy and the average epoxide emission rate was 21,200 lb/yr. This scenario represents 26 percent of the facilities in the database.

Five of the polyols producers using epoxides in the EPA/SPI questionnaire database reported emissions of HAP other than EO and PO (other-HAP) from their reactors. Similar to the EO and PO data, emissions of other HAP were separated into two scenarios: low other-HAP emitters, with emissions less than 36 lb/yr for

Table 1. Summary of Baseline HAP Emissions from the Reactor Step of the Polyols Production with Epoxides Process

FACILITY	REPORTED EPOXIDE EMISSIONS (pounds per year)	Epoxide	REPORTED OTHER-HAP EMISSIONS (pounds per year)	POLLUTANT
1	20	EO		
2	49	EO&PO		
3	110	EO&PO		
4	125	EO&PO		
5	144	EO		
6	144	EO		
7	160	EO&PO		
8	169	PO		
9	196	EO&PO		
10	224	EO&PO	36	1,3-Butadiene
11	272	EO&PO		
12	303	EO&PO	25,732	Toluene & Toluene Diamine
13	540	EO&PO	27	Diethylene Glycol & Ethylene Glycol
14	860	EO&PO		
15	1329	EO&PO		
16	1675	EO		
17	1735	EO		
18	2,116	EO&PO		
19	2,633	EO&PO	1,751	Methanol & Ethylene Glycol
20	6,325	EO&PO		
21	9,858	EO&PO		
22	15,602	EO&PO		
23	80,966	EO&PO	4	Toluene
TOTAL	135,000	EO&PO	27,500	Other-HAP
Low Emitters' Average	474	EO&PO	22	Other-HAP
High Emitters' Average	21,200	EO&PO	13,700	Other-HAP

other-HAP; and high other-HAP emitters, with emissions greater than 1,751 lb/yr. Of the facilities in the database, 13 percent were low other-HAP emitters from the reactor step, with an average emission rate of 23 lb/yr. Eight percent of the facilities were calculated to be high other-HAP emitters from the reactor step, with an average emission rate of 13,700 lb/yr.

Process Emissions from Finishing

The EPA/SPI questionnaire responses indicated that there were three basic finishing options: (1) neutralization of the catalyst only, with the resulting salt remaining in the polyol; (2) catalyst neutralization followed by mechanical removal (such as filtration or centrifugation) of the salt formed during the neutralization step; and (3) catalyst neutralization followed by solvent removal of the salt that forms from the neutralization step. The first two finishing procedures described do not result in HAP emissions. It is only in the third finishing procedure, when solvents are used to remove the salt, that HAP emissions occur from the solvent use. Table 2 summarizes the emissions reported from the finishing steps in the process. Other-HAP emissions ranged from 20 lb/yr to 116,812 lb/yr. Due to the wide range of emissions, finishing step emissions were also separated into two emissions scenarios: low other-HAP emitters; and high other-HAP emitters. The low other-HAP emission scenario is characterized by emissions less than or equal to 2,740 lb/yr, with an average emission rate of 1,020 lb/yr. This scenario represents 22 percent of the facilities in the database. The high other-HAP emitting scenario, consisted of facilities with emissions greater than 2,740 lb/yr, with an average emission rate of 53,400 lb/yr. This scenario represents thirteen percent of the facilities in the database. Although one facility reported EO and PO emissions from the finishing step of the process, the data indicated that this is not typical at any other polyols production facilities, so these emissions were not included in the calculation of national baseline emissions from process vent finishing operations.

Scale-up to Nationwide Emissions

Nationwide process vent baseline emissions of HAP from the reactor and finishing steps of the process were calculated by multiplying the average emission rate of the HAP from that emission scenario by the percent occurrence of the scenario in the database, and by the nationwide estimate of polyols producers with epoxides, 82. For example:

$$E_{LO},\ lb/yr = E_{AVG} * O_d * 82 = 474 * 0.74 * 82 = 28,800$$

Where:

E_{LO} = Emissions from the low epoxide emissions scenario, (lb/yr);

E_{AVG} = Average epoxide emissions (lb/yr*facility);

O_d = Occurrence of facilities in the database that were characterized by this scenario, 0.74; and

82 = Number of facilities in the nation.

Table 3 summarizes the nationwide baseline emissions from the reactor and finishing steps of the process.

Table 2. Summary of Baseline HAP Emissions from the Finishing Step of the Polyols Production with Epoxides Process

FACILITY	REPORTED OTHER-HAP EMISSIONS (pounds per year)	OTHER-HAP POLLUTANT	REPORTED EPOXIDE EMISSIONS (pounds per year)	EPOXIDE
1	20	Other (unspecified)		
2	247	Other (unspecified)		
3	639	Other (unspecified)		
4	1,450	Other (unspecified)		
5	2,740	Hexane		
6	9,596	Other (unspecified)		
7	33,681	Hexane & Toluene		
8	116,812	Toluene		
9			140,768	EO&PO
TOTAL	165,185	Other-HAP	140,768	EO&PO
Low Emitters' Average	1,020			
High Emitters' Average	53,400	Other-HAP	140,768	EO&PO

After the nationwide baseline emissions were calculated for each emissions scenario, they were totaled. This total is the nationwide process vent emissions of HAP from polyols facilities with epoxides. Therefore,

$$E_{PVTOT} = (28,800 + 452,000 + 235 + 89,900 + 18,400 + 569,000)\ \text{lb/yr}$$
$$= 579\ \text{tons/yr}$$

Table 3. Summary of Baseline Nationwide Process Vent HAP Emissions from Polyether Polyols Made with Epoxides

REACTOR EMISSIONS					
EMISSION SCENARIO	PERCENT OF FACILITIES IN DATABASE	AVERAGE EO&PO EMISSIONS (pounds per year)	NATIONWIDE EO&PO EMISSIONS (pounds per year)	AVERAGE OTHER-HAP EMISSIONS (pounds per year)	NATIONWIDE OTHER-HAP EMISSIONS (pounds per year)
Low Epoxide Emitters	74%	474	28,800	NA	NA
High Epoxide Emitters	26%	21,200	452,000	NA	NA
Low Other-HAP Emitters	13%	NA	NA	22	235
High Other-HAP Emitters	8%	NA	NA	13,700	89,900
	TOTAL		480,800		90,100
FINISHING EMISSIONS					
EMISSION SCENARIO	PERCENT OF FACILITIES IN DATABASE	AVERAGE EO&PO EMISSIONS (pounds per year)	NATIONWIDE EO&PO EMISSIONS (pounds per year)	AVERAGE OTHER-HAP EMISSIONS (pounds per year)	NATIONWIDE OTHER-HAP EMISSIONS (pounds per year
Low Other-HAP Emitters	22%	NA	NA	1,020	18,400
High Other-HAP Emitters	13%	NA	NA	53,400	569,000
TOTAL					587,000

Polyols Made by Polymerizing Tetrahydrofuran

As stated above, there are only three facilities in the nation that presently polymerize THF in order to make polyether polyols. One of the facilities does not emit HAP; therefore, nationwide process vent emissions are the total of the process vent emissions reported in the EPA/SPI questionnaire from the other two facilities. These emissions are presented in Table 4.

Table 4. Summary of Baseline Nationwide Process Vent HAP Emissions from Polyether Polyols Producers that Polymerize Tetrahydrofuran

FACILITY	REPORTED EMISSIONS (lb/yr)	POLLUTANT
1	3,533	Hydrogen fluoride
2	43,497	Toluene
TOTAL	47,030	Total HAP

Equipment Leaks

Polyols Made with Epoxides

The nationwide baseline emissions for equipment leaks were estimated by first calculating the emissions for each component per each control option (component/control) for each facility in the EPA/SPI questionnaire database. Control options for equipment leaks were reported as any of the following: LDAR with the frequency and leak definition specified; or the percent of components with any of the three control options presented in the EPA/SPI questionnaire. Table 5 summarizes the control options that were presented in the EPA/SPI questionnaire.

The equipment leak emissions for each component at each control level reported were calculated in the following manner:

$$E_{ELC/C}\ (lb/yr) = N_{C/C} * EF * (100 - CE) * C_{HAP} * UC$$

Where:

$E_{ELC/C}$ (lb/yr) = Emissions from each equipment component/ control option combination, lb/yr;

$N_{C/C}$ = Number or equipment components with the specific control option;

EF = Emission factor, for SOCMI uncontrolled equipment components, kg/(source*hr)

CE = Control efficiency assigned to the control option, from the EPA's Protocol Document for Estimating Equipment Leaks [2], percent;

C_{HAP} = Concentration of the HAP in the line; and

UC = Unit conversion, 8760 hr/yr * 2.204 lb/kg.

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[2] Hausle, K.J. (Radian Corporation). Protocol For Equipment Leak Emission Estimate. Prepared for U. S. Environmental Protection Agency. Research Triangle Park, NC. Publication No. EPA-453/R-93-026. June 1993.

Table 5. Summary of the Control Options for Equipment Leaks Presented in the EPA/SPI Questionnaire

Control Option	Equipment	Controls
A	All	Closed vent system
B	Valves	Sealless
	Pumps	Dual mechanical seal with barrier fluid
	Compressors	Mechanical seals with barrier fluid
	Open-ended lines	Capped, plugged, blind-flagged
	Sampling connections	In-situ sampling
	Pressure Relief Valves	Rupture disk
C	Pumps	Sealless
	Sampling connections	Closed loop sampling

This calculation was completed for each component/control type at each facility. These calculations are not presented in this document. The equipment leaks database was then sorted by each component/control, and the average emission rate of each component/control per facility was calculated. Also, the percent occurrence of each component/control in the database was calculated.

Finally, emissions were scaled to nationwide emissions by multiplying the average emissions per component/control by the percent occurrence of each component/control, and by the number of facilities in the country, then dividing by the number of facilities in the database, 11. That is:

$$E_{NAT,\ C/C},\ lb/yr = E_{AVG,\ C/C} * 82/11$$

Where:

$E_{NAT,\ C/C}$ = Nationwide emissions from each equipment component with each control option, lb/yr;

$E_{AVG,\ C/C}$ = Average emissions, from the database, of each equipment component with each control option, lb/yr;

82 = Number of facilities in the nation, and;

11 = Number of total facilities in the database.

Table 6 presents the nationwide baseline emission for each component/control.

Table 6. Estimate of Baseline Nationwide HAP Emissions from Equipment Components on Polyether Polyols Production Lines that Use Epoxides

EQUIPMENT COMPONENT	CONTROL	CONTROL EFFICIENCY (percent)	AVERAGE CONTROLLED EMISSIONS PER FACILITY (lb/yr)	NATIONWIDE EMISSIONS (lb/yr)
Valves - vapor	HON LDAR	92	790	5,900
Valves - vapor	Quarterly LDAR	67	30,000	220,000
Valves - vapor	No controls	0	5,900	44,000
Valves - light liquid	HON LDAR	88	910	6,800
Valves - light liquid	Quarterly LDAR	61	89,000	670,000
Valves - light liquid	No controls	0	47,000	350,000
Valves - heavy liquid	LDAR, no specified frequency or leak definition	?	290	2,100
Valves - heavy liquid	No controls	0	1,200	8,800
Connectors	HON LDAR	93	4,600	35,000
Connectors	Weekly LDAR with 10,000 leak definition	Emission factor from PES memorandum[3]	7,500	56,000

[3] Memorandum, from Meardon, K., Pacific Environmental Services, Inc., to Group IV Resins Docket No. A-95-45. March 24, 1995. Determination of MACT Floors for Equipment Leaks.

Table 6. Estimate of Baseline Nationwide HAP Emissions from Equipment Components on Polyether Polyols Production Lines that Use Epoxides

EQUIPMENT COMPONENT	CONTROL	CONTROL EFFICIENCY (percent)	AVERAGE CONTROLLED EMISSIONS PER FACILITY (lb/yr)	NATIONWIDE EMISSIONS (lb/yr)
Connectors	Quarterly LDAR with 10,000 leak definition	Emission factor from PES memorandum[3]	7,300	54,000
Connectors	No controls	0	30,000	220,000
Pumps - light liquid	100 percent with control option B	100	0	0
Pumps - light liquid	HON LDAR	75	53	394
Pumps - light liquid	Monthly monitoring at 10,000 ppm	69	2,300	17,000
Pumps - light liquid	Quarterly LDAR at varying leak definitions	45	10,000	78,000
Pumps - light liquid	No controls	0	1,900	14,000
Pumps - heavy liquid	No controls	0	100	750
Pressure Relief Valves	100 percent with control option B	100	0	0
Pressure Relief Valves	Quarterly LDAR with 500 ppm leak	Emission Factor from PES memorandum[3]	16,000	120,000
Pressure Relief Valves	63 percent with control option B	63	3,000	22,000
Pressure Relief Valves	Quarterly LDAR with 10,000 leak	Emission Factor from PES memorandum[3]	41,000	304,000

Table 6. Estimate of Baseline Nationwide HAP Emissions from Equipment Components on Polyether Polyols Production Lines that Use Epoxides

EQUIPMENT COMPONENT	CONTROL	CONTROL EFFICIENCY (percent)	AVERAGE CONTROLLED EMISSIONS PER FACILITY (lb/yr)	NATIONWIDE EMISSIONS (lb/yr)
Pressure Relief Valves	Varying percentages with control option B	15-22	180,000	1,300,000
Compressors	Quarterly LDAR w/ 500 ppm	Emission factor from PES memorandum[3]	4,000	30,000
Sample Connectors	100 percent with control option B or C	100	0	0
Sample Connectors	38 percent with control option C	38	500	3,700
Sample Connectors	No controls	0	2,200	16,000
Open Ended Lines	100 percent with control option B	100	0	0
Open Ended Lines	86 percent with control option B	86	180	1,400
Open Ended Lines	No controls	0	86	640
TOTAL EMISSIONS (tons per year)				1,800 tons/yr

Polyols Made by Polymerizing Tetrahydrofuran

There are three facilities in the nation that use THF to make polyether polyols, but only one of these three use organic HAP in the process. Therefore, nationwide equipment leak emissions for polyols made by the polymerization of THF are the emissions from the one facility in this subcategory that uses organic HAP. Further, it should be noted that the facility that

reported emissions did not report any controls for equipment leak emissions. Equipment leak emissions from polyols made by the polymerization of THF are summarized in Table 7.

Table 7. Estimate of Baseline Nationwide HAP Emissions from Equipment Components at Polyether Polyols Facilities that Polymerize Tetrahydrofuran

EQUIPMENT COMPONENT	NATIONWIDE ESTIMATE OF EMISSIONS (pounds per year)
Valves - vapor	23,000
Connectors	212,000
Pumps - heavy liquid	4,660
Pressure Relief Valves	28,100
Sample Connectors	2,900
Open Ended Lines	656
TOTAL (tons per year)	**136**

Storage Vessels

Polyols Made with Epoxides

Polyols production facilities store epoxides and other-HAP onsite. The nationwide baseline emissions estimate of HAP emissions from the storage of these substances was made on a per pollutant per control option basis (pollutant/control). Nationwide baseline emissions were estimated by first calculating the average emissions from each pollutant/control for each storage vessel at each facility in the EPA/SPI database. To yield a nationwide emissions estimate, the following calculation was made for each pollutant/control:

$$E_{EO,P}\ (lb/yr) = N_{V,EO,P} * E_{AVG,EO,P} * 82$$
$$= 1.4 * 1.7 * 82$$
$$= 195$$

Where:
$E_{EO,P}$ = Nationwide, baseline emissions from EO stored in pressurized vessels, lb/yr;
$N_{V,EO,P}$= Average number of EO, pressurized vessels per facility;
$E_{AVG,EO,P}$ = Average emissions per vessel from EO pressurized vessels, lb/yr; and
82 = Number of facilities in this subcategory in the nation.

Table 8 summarizes the inputs into the calculation for nationwide emissions and the resulting emissions estimates from storage vessels for each HAP stored per each control option for polyether polyols facilities.

Table 8. Baseline Nationwide HAP Emissions Estimate from Storage Vessels at Facilities that Produce Polyether Polyols with Epoxides

POLLUTANT	AIR POLLUTION CONTROL	AVERAGE NUMBER OF VESSELS PER FACILITY	AVERAGE EMISSIONS PER VESSEL (pounds per year)	NATIONWIDE EMISSIONS (pounds per year)
EO	Pressurized	1.4	1.7	200
PO	Pressurized	1.6	1.5	200
PO	Internal Floating Roof	0.10	1510	12,000
PO	Fixed Roof venting to Incinerator	0.20	0	0
Toluene	Pressurized	0.10	74	600
Toluene	Fixed Roof	0.10	0 (seems low)	0
Ethylene Glycol	Fixed Roof	0.10	0.055	0.41
Formaldehyde	Fixed Roof	0.10	89	740
Hexane	Pressurized vessel to vent condenser	0.10	320 (seems high)	2,600
Methanol	Fixed Roof	0.10	6.4	53
Acrylonitrile	Pressurized	0.10	0	0
Diethanolamine	Fixed Roof	0.20	10	160
TOTAL (lb/yr)				17,000

Polyols Made by Polymerizing Tetrahydrofuran

Nationwide baseline storage emissions from facilities that polymerize THF equals the emissions from the one facility that uses and stores organic HAP. Emissions were reported to be 349 lb/yr from one fixed-roof toluene storage vessel.

Wastewater

Polyols Made with Epoxides

Organic-containing wastewater streams result from (1) the direct contact of water with organic compounds during chemical processing and (2) contamination of "indirect-contact" water. There were five wastewater sources in the database, which were (1) scrubber effluent; (2) equipment washing; (3) direct contact with organics from "other process equipment" (the "other process equipment" category consisted of decanters, solvent recovery, condensers, and cooling tower blowdown) (4) vacuum system effluent; and (5) filter washing. The average flowrate and organic HAP concentration of the wastewater streams in the EPA/SPI database were calculated for each wastewater source listed above. Also calculated from the database were the average number of each model wastewater stream per facility. These average flow rates and organic HAP concentrations for each wastewater source make up the model wastewater streams for this industry.

Emissions were calculated from each of the five wastewater model streams in the following manner:

$$E_{WW/MODEL}\ (lb/yr) = F_{AVG/MODEL} * C_{HAP/MODEL} * Fe * T_{MODEL} * UC$$

$$E_{SCRUBBER} = 29 * 490 * 0.5 * 32,640 * 1/453,600$$
$$= 511\ lb/yr$$

Where:

$E_{WW/MODEL}$ = Emissions from each model wastewater stream, lb/yr;

$F_{AVG/MODEL}$ = Average flowrate of each wastewater model stream, liters per minute;

$C_{HAP/MODEL}$ = Average organic HAP concentration of each wastewater model stream, milligram per liter;

Fe = Fraction emitted, from the HON;

T_{MODEL} = Duration of time the model wastewater stream flows per year, minutes per year; and

UC = Unit conversion, 1 mg/453,600 lb.

The duration of each wastewater model stream flow was estimated from information provided in the process vent section of the EPA/SPI questionnaire responses. Specifically, the average number and average duration of vent stream occurrences reported for process vents from the reactors and vacuum systems were calculated. The average number of reaction runs per line was calculated to be 544 events per year, with the average reaction duration calculated to be 103 minutes. Similarly, the

average number of evacuation events per year was calculated to be 375 with an average duration of 137 minutes.

Also, in order to estimate the duration of the wastewater flows per year, the following assumptions were made:

1) Scrubber effluent flowed for one hour after the completion of each reaction;
2) Equipment is washed down once each day, with wastewater flow lasting one hour;
3) Other process equipment wastewater events (decanters, condensers, and cooling tower blowdown) occur once per reaction and last 30 minutes each;
4) The wastewater from vacuum systems flows for the same amount of time that the vents from the vacuum systems release to the atmosphere;
5) Filter washing occurs once each day, with wastewater flow lasting one hour.

The durations of the wastewater streams from each wastewater source are listed in Table 9.

Table 9. Baseline Nationwide HAP Emissions from Wastewater at Facilities that Produce Polyether Polyols with Epoxides

WASTEWATER MODEL STREAM	NUMBER OF STREAMS PER FACILITY	AVERAGE FLOWRATE (liters/min)	AVERAGE ORGANIC HAP CONCENTRATION (parts per million)	DURATION (min/yr)	PREDOMINANT HAP	NATIONWIDE EMISSIONS (lb/yr)
Scrubber Effluent	1.33	29	490	32,640	EO	32,000
Equipment Washing	4.00	21	500	21,900	PO	58,000
Other Process Equipment	2.50	200	1,300	16,320	Toluene	890,000
Vacuum System	1.83	5.6	70,000	51,375	PO	2,300,000
Filter Washing	0.83	17	850	21,900	Toluene	22,000
TOTAL (TONS/YR)						1,700

Scale-up to Nationwide Emissions

The emissions from each wastewater model stream were scaled up to nationwide emissions by multiplying the organic HAP emission rate from each wastewater model stream by the percent of facilities that reported data for their wastewater streams (that

is, 7 facilities reporting wastewater information/12 facilities in the database = 58 percent). The percentage of facilities with wastewater data in the database was needed in the calculation because, unlike the other emission sources, the questionnaire instructed facilities not to respond to this portion of the questionnaire if their wastewater streams were dilute enough or had a small enough flow to have "insignificant" emissions. Nationwide wastewater organic HAP emissions from scrubber effluent streams ($E_{N,WW/SCRUBBER}$) were calculated in the following manner:

$$E_{N,WW/SCRUBBER}\ (lb/yr) = E_{WW/MODEL} * 0.583 * 82 * 1.33$$
$$= 511.5\ lb/yr * 0.583 * 82 * 1.33$$
$$= 32{,}525\ lb/yr$$

where:

$E_{WW/MODEL}$ = Nationwide emissions from the scrubber model wastewater stream, lb/yr;

0.583 = Portion of facilities in the total EPA/SPI database with significant wastewater emissions;

82 = Nationwide estimate of polyol facilities; and

1.33 = Number of scrubber streams per facility, from the database.

The nationwide baseline emissions of wastewater emissions from polyols facilities that use epoxides were then totaled for the five wastewater model streams. These emissions are presented in Table 9.

Polyols Made by Polymerizing Tetrahydrofuran

Nationwide baseline emissions from wastewater at polyols facilities that polymerize THF are the total emissions from the one facility that uses an organic HAP in the process. The calculation approach and duration assumptions used to calculate organic HAP emissions from the model wastewater streams were also used to calculate the organic HAP emissions from this facility's wastewater streams. Wastewater organic HAP emissions for the facility that polymerizes THF were 213 lb/yr from two streams with a total flowrate of 115 liters per minute and an organic HAP concentration of 302 ppm.

SUMMARY

Total nationwide baseline HAP emissions from polyols production with epoxides is 4,100 tons per year. The majority of the emissions, 44 percent and 42 percent, are from equipment leaks and wastewater, respectively. The nationwide baseline emissions from polyols production with THF are 160 tons per year, which is four percent of the total nationwide emissions from the source category; however, THF polymerizers are only 2.4 percent

of the number of total facilities in the source category. Further, the majority (85 percent) of emissions from the THF polymerizers come from equipment leaks.

The summary of nationwide baseline emissions from all emission sources in the polyols production process are presented in Table 10, for polyols that use epoxides, and in Table 11 for polyols made from the polymerization of THF.

Table 10. Summary of Nationwide Baseline HAP Emissions from Polyols Made with Epoxides

SOURCE	NATIONWIDE BASELINE EMISSIONS (Total HAP tons /year)
Process Vents	580
Equipment Leaks	1,800
Storage Vessels	8.5
Wastewater	1,700
TOTAL	4,100

Table 11. Summary of Nationwide Baseline HAP Emissions from Polyols Made by Polymerizing Tetrahydrofuran

SOURCE	NATIONWIDE BASELINE EMISSIONS (Total HAP tons /year)
Process Vents	24
Equipment Leaks	136
Storage Vessels	0.18
Wastewater	0.11
TOTAL	160

EC/R Incorporated

1996 EPA Outstanding Small Business Contractor

MEMORANDUM

Date: April 25, 1997

Subject: Estimated Impacts for the Polyether Polyols NESHAP

From: David Hendricks, EC/R Incorporated
Joanne Seaman, EC/R Incorporated

To: David Svendsgaard, EPA/OAQPS/ESD/OCG

The purpose of this memorandum is to present the estimated impacts of the hazardous air pollutant (HAP) control options for existing sources under the proposed polyether polyols manufacturing standards. This memorandum is divided into six sections, beginning with a description of regulated emission sources and the regulatory requirements for each source. The second section presents the methodology used to develop the model plants for which the impacts were estimated. The remaining sections present the primary environmental impacts, secondary environmental impacts (air pollution, water pollution, and solid and hazardous waste impacts), energy impacts, and costs.

DESCRIPTION OF EMISSION SOURCES AND REGULATORY REQUIREMENTS

There are four primary potential sources of organic HAP emissions in the polyether polyols manufacturing process: process vents, storage vessels, equipment leaks, and wastewater. The emissions from these sources, and the types of controls being used, are discussed in the following sections.

Another potential emission source considered in other NESHAPs is unloading operations, and these were investigated for this industry as well. Industry representatives indicated that all organic HAP unloading operations are conducted in a closed vent system due to the explosive nature of ethylene oxide (EO). Therefore, no emissions are expected to result from this portion of the process.

Emissions and Controls on Production Units that Use Epoxides

Process Vents. The most significant organic HAP loss from the polyether polyols manufacturing process occurs at the end of the batch when the unreacted epoxide is vented. Ethylene oxide reacts quite quickly, so normally the residual EO in the vent is quite low. Propylene oxide (PO) reacts an order of magnitude slower at a given catalyst level, temperature, and pressure.

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manufacturing polyether polyols from THF. Based on data received from industry, it appears that monitoring of equipment leaks is not generally conducted at such facilities.

Wastewater. Neither facility that polymerized THF generate Group 1 wastewater streams. Therefore, no wastewater controls were reported.

Regulatory Requirements

The proposed regulation for polyether polyols production will address HAP emissions from five emission source types: (1) process vents (epoxide emissions), (2) process vents (nonepoxide HAP emissions), (3) storage tanks, (4) equipment leaks, and (5) wastewater treatment. The regulatory requirements for existing and new sources are summarized in Tables 1 and 2, respectively.

DEVELOPMENT OF MODEL PLANTS

The estimation of primary impacts, secondary impacts, and costs required the development of model plants that divided the industry into "typical" groups based on similar characteristics. Three such model plants were developed. The small model plant category defines the segment of the industry that uses an epoxide (i.e., EO and PO) and has a production capacity of 50 million pounds per year (MMlb/yr). This category also includes one additional facility to account for the polyether polyols made from the polymerization of THF subcategory. The large model plant category also uses an epoxide-based process, but has a production capacity of 200 MMlb/yr. The final model plant category uses a HAP solvent in the catalyst extraction step. This category is referred to as the catalyst extraction model plant and has a production capacity of 100 MMlb/yr.

The model plant production capacities were established using the production capacities listed in the Chemical Economics Handbook[1] (CEH) for each facility in the EPA database. Other characteristics used to define the model plants were process vent exhaust stream characteristics, storage tank capacity and throughput, total number of each type of equipment covered in the HON equipment leaks regulations (40 CFR 63, subpart H) and existing level of control, and wastewater characteristics. The model plant parameters are summarized in Table 3, and the development of each parameter is discussed in the following sections.

Process Vents

The primary process vent exhaust stream characteristics needed to size control devices were flow rate, temperature, pressure, and pollutant concentration. Information on each of

reactor system's annual production capacity. This penalty is offset to some extent by the improvement in raw material efficiency due to converting more epoxide to product. Once ECO is complete, the remaining emissions are low.

Storage. The storage vessels used in the polyether polyols manufacturing process are a potential source of organic HAP emissions. Most of the storage vessels used are pressurized, and all of the reported EO and PO storage vessels are pressurized as a precaution due to the explosive nature of EO.

Equipment Leaks. Emissions of organic HAPs may occur around pumps, valves, and other components, and are referred to as "equipment leaks." Sixty-nine percent of the facilities in the database have leak detection and repair (LDAR) programs. The LDAR program alerts the facility of any leaking components so the problem can be fixed, thereby minimizing emissions.

Wastewater. Another potential source of organic HAP emissions is the processing of wastewater from the manufacturing process. The majority of wastewater emissions from this industry are a result of the steam ejectors used on the batch reactors to pull a vacuum on the vessel. Although 17 percent of the facilities in the database have Group 1 wastewater streams that require controls according to the HON, none of the facilities for which data were received control air emissions from the wastewater streams. A Group 1 wastewater stream is defined by the HON as having a minimum organic HAP concentration of 10,000 parts per million (ppm) and a minimum stream flowrate of 10 liters per minute.

Emissions and Controls on Production Units that use Tetrahydrofuran

Even though tetrahydrofuran (THF) is not an organic HAP, there are organic HAP emissions from one of the facilities in the database that polymerizes THF. At this facility, the catalyst extraction process resulted in organic HAP emissions. An organic HAP solvent is used for the catalyst extraction, and none of these emissions to the atmosphere are controlled.

Process Vents. The polymerization of THF occurs on a continuous basis. THF is not an organic HAP and organic HAPs are not typically used in the actual synthesis of the polymer.

Storage. Only one of the THF polymerizers stored an organic HAP. The storage vessel was a Group 2 (not requiring controls based on the HON criteria) fixed-roof storage vessel.

Equipment Leaks. Potential organic HAP emissions may occur around pumps, valves, and other components in facilities

manufacturing polyether polyols from THF. Based on data received from industry, it appears that monitoring of equipment leaks is not generally conducted at such facilities.

Wastewater. Neither facility that polymerized THF generate Group 1 wastewater streams. Therefore, no wastewater controls were reported.

Regulatory Requirements

The proposed regulation for polyether polyols production will address HAP emissions from five emission source types: (1) process vents (epoxide emissions), (2) process vents (nonepoxide HAP emissions), (3) storage tanks, (4) equipment leaks, and (5) wastewater treatment. The regulatory requirements for existing and new sources are summarized in Tables 1 and 2, respectively.

DEVELOPMENT OF MODEL PLANTS

The estimation of primary impacts, secondary impacts, and costs required the development of model plants that divided the industry into "typical" groups based on similar characteristics. Three such model plants were developed. The small model plant category defines the segment of the industry that uses an epoxide (i.e., EO and PO) and has a production capacity of 50 million pounds per year (MMlb/yr). This category also includes one additional facility to account for the polyether polyols made from the polymerization of THF subcategory. The large model plant category also uses an epoxide-based process, but has a production capacity of 200 MMlb/yr. The final model plant category uses a HAP solvent in the catalyst extraction step. This category is referred to as the catalyst extraction model plant and has a production capacity of 100 MMlb/yr.

The model plant production capacities were established using the production capacities listed in the Chemical Economics Handbook[1] (CEH) for each facility in the EPA database. Other characteristics used to define the model plants were process vent exhaust stream characteristics, storage tank capacity and throughput, total number of each type of equipment covered in the HON equipment leaks regulations (40 CFR 63, subpart H) and existing level of control, and wastewater characteristics. The model plant parameters are summarized in Table 3, and the development of each parameter is discussed in the following sections.

Process Vents

The primary process vent exhaust stream characteristics needed to size control devices were flow rate, temperature, pressure, and pollutant concentration. Information on each of

TABLE 1. SUMMARY OF LEVEL OF PROPOSED STANDARDS FOR EXISTING SOURCES

Source Category Subcategory	Emission Sources					
	Storage	Process Vents			Waste water	Equip. Leaks
		Epoxides	Nonepoxide HAP in making or altering product	Nonepoxide HAP in catalyst extraction		
Polyether Polyols made with Epoxides	HON	98 percent aggregate emission reduction	For batch vents, the Group 1/Group 2 criteria are from the P&R I NESHAP, except that the criteria are applied to the combination of all batch vents associated with the use of an organic HAP to make or alter the product. If the collection of vents is Group 1, the requirement is a 90 percent aggregate emission reduction. For continuous vents, the Group 1/Group 2 criteria are from the HON, except that the criteria are applied to the combination of all continuous vents associated with the use of an organic HAP to make or alter the product. If the collection of vents is Group 1, the requirement is a 98 percent aggregate emission reduction.	90 percent aggregate emission reduction	HON	HON
Polyether Polyols made with THF	HON	NA	NA	The Group 1/Group 2 criteria are from the HON TRE equations. The control requirement is 98% emission reduction.	HON	HON

TABLE 2. SUMMARY OF LEVEL OF PROPOSED STANDARDS FOR NEW SOURCES

Source Category Subcategory	Emission Sources					
	Storage	Process Vents			Waste water	Equip. Leaks
		Epoxides	Nonepoxide HAP in making or altering product	Nonepoxide HAP in catalyst extraction		
Polyether Polyols made with Epoxides	Existing Source HON	99.9 percent aggregate emission reduction	For batch vents, the Group 1/Group 2 criteria are from the P&R I NESHAP, except that the criteria are applied to the combination of all batch vents associated with the use of an organic HAP to make or alter the product. If the collection of vents is Group 1, the requirement is a 90 percent aggregate emission reduction. For continuous vents, the Group 1/Group 2 criteria are from the HON, except that the criteria are applied to the combination of all continuous vents associated with the use of an organic HAP to make or alter the product. If the collection of vents is Group 1, the requirement is a 98 percent aggregate emission reduction.	98 percent aggregate emission reduction	HON	HON
Polyether Polyols made with THF	Existing Source HON	NA	NA	The Group 1/Group 2 criteria are from the HON TRE equations. The control requirement is 98% emission reduction.	HON	HON

TABLE 3. MODEL PLANT PARAMETERS

Parameter	Model Plant		
	Small	Large	Solvent Extraction
Production Capacity (MMlb/yr)	50	200	100
Process Vent Exhaust Stream Characteristics			
Flow (acfm)	250	250	250
Heat Content (Btu/scf)	8	8	8
Temperature (°F)	150	150	150
Pressure (atm)	1	1	1
Pollutant Concentration (lb/scf)	0.02	0.02	0.02
Fixed-roof Storage Tanks			
Number Per Facility	1	1	1
Capacity (gal)	38,667	38,667	38,667
Throughput (gal/yr)	134,500	134,500	134,500
Equipment Leaks - Number of Uncontrolled Components			
Compressors	1	1	0
Open-ended Lines	0	7	58
Sampling Connections	12	2	6
Pressure Relief Devices	8	11	34
Valves in Gas Service	125	3	57
Valves in Light Liquid Service	166	392	218
Pumps in Light Liquid Service	2	13	5
Connectors	409	385	219
Wastewater Group I Wastewater Stream?	No	Yes	No

these parameters was obtained from the EPA database for facilities that generally matched the specifications (process type and production rate) of each model plant. An analysis of this data showed that there was no apparent trend in the exhaust stream characteristics from one model plant to another. For example, the reported flow rate for facilities corresponding to the large model plant category was not significantly larger than that for the small model plant category. Consequently, the process vent exhaust stream data for all three model plant categories were used to develop a single "model" process vent exhaust stream. This one exhaust stream was used to size all control devices for all model plants.

Storage Vessels

Information in the EPA database was used to determine the capacity and throughput of non-pressurized tanks that would be applicable to the HON storage requirements. As there was no general trend in the capacity or throughput of the tanks with the size of the facilities, an average capacity and throughput was calculated for all applicable tanks in the database. This "model" tank was used for all three model plant categories. The database also showed no more than one tank per facility that would require control; therefore, it was assumed that each model plant would have only one such tank.

Equipment Leaks

Extensive LDAR program information was provided in the questionnaire responses used to develop the EPA database. This information was analyzed to determine the average number of each equipment type (i.e, compressors, open-ended lines, sampling connectors, pressure relief devices, valves in gas service, valves in light liquid service, pumps in light liquid service, and connectors) for each model plant category. The questionnaires showed that most facilities currently have some type of LDAR program in place. While some of these LDAR programs met the HON requirements, others did not. For those programs that did not meet the HON requirements, the model plants must address (for the purpose of estimating impacts) this intermediate level of control.

The total number of each equipment type was first estimated. This was done by selecting facilities from the database that closely corresponded to the model plant categories in terms of production capacity and manufacturing type (with or without catalyst extraction). Next, using the entire database of facilities, the fraction of each component type controlled at a level equal to or more stringent than the HON was determined.

For those components controlled at a level less than the HON, a control efficiency was assigned to each type of control based on the control strategy reported, and the fraction of each component type at each of these levels of control was determined. These two numbers were then multiplied together, and the resulting number was used as the portion of components with a control efficiency calculated to be equivalent to the HON level of control. Finally, the percentage of components at the HON level of control and HON equivalent level of control were subtracted from the total number of components. The resulting number of uncontrolled components was used to estimate the cost impacts (see Attachment 7).

In two instances (open-ended lines for small model plants and compressors for catalyst extraction model plants), there were no components reported for the facilities selected from the database. Based on the database as a whole and knowledge of the industry, there is no indication that this should be the case. For example, catalyst extraction model plants have valves in vapor service, so it is expected that there should be at least one compressor. Further analysis of the database, however, did not provide adequate information to accurately estimate the number of these components per model plant. As a result, the data was used as is with the understanding that impacts may be slightly underestimated.

Wastewater

Wastewater streams reported in the EPA/SPI questionnaire were compared to the HON Group 1 wastewater characteristics. Only two facilities reported wastewater streams that met the Group 1 requirements, and both of these facilities fell into the large model plant category. No wastewater emission controls were reported for either facility. For the purposes of the impacts analysis, it was assumed that small and catalyst extraction model plants have no Group 1 wastewater streams.

PRIMARY ENVIRONMENTAL IMPACTS

This section presents the nationwide primary air pollution impacts (reduction of HAP emissions) resulting from the implementation of the proposed standards. The primary impacts were calculated by applying sufficient controls to each emission source at each model plant type to bring them into compliance with the standards. The control technologies and efficiencies used in these calculations are shown in Table 4. The model plant emission reductions were then scaled up to nationwide levels based on the number of model plants and the existing level of control. For example, it was estimated that there are 38 facilities nationwide that would be characterized by the large model plant, but only 11 of these facilities would require

TABLE 4. SUMMARY OF CONTROL TECHNOLOGIES SELECTED TO COMPLY WITH THE PROPOSED STANDARDS AND NUMBER OF MODEL PLANTS REQUIRING CONTROL

Model Plant	Nationwide Number of Model Plants	Emission Source	Control Technology	Emission Reduction (%)	Number of Model Plants Requiring Control
Small	20[a]	Process Vents	Scrubber	98	6
		Storage Tanks	Internal Floating Roof[b]	95	5
		Equipment Leaks	HON Subpart H	c	20
		Wastewater	N/A	N/A	N/A
Large	38	Process Vents	Flare	98	11
		Storage Tanks	Internal Floating Roof[b]	95	10
		Equipment Leaks	HON Subpart H	c	38
		Wastewater	Steam Stripper	98	6
Catalyst Extraction	19	Process Vents - Oxides	Flare	98	6
		Process Vents - Nonepoxide HAPs	Flare	98	15
		Storage Tanks	Internal Floating Roof[b]	95	5
		Equipment Leaks	HON Subpart H	c	19
		Wastewater	N/A	N/A	N/A

[a] The 20 small model plants are comprised of 19 plants representing the polyether polyols made with epoxides subcategory and one plant representing the polyether polyols made from the polymerization of THF.

[b] The internal floating roof includes liquid-mounted primary seal, controlled fittings, and rim-mounted secondary seal.

[c] Varies according to component type.

control of epoxide emissions from process vents (see Attachment 1 for further details of the number of model plants requiring control). This information is also presented in Table 4.

Table 5 presents the emission reductions by emission source for each model plant. Table 6 summarizes this information by emission source for all model plant types, along with the nationwide baseline emissions[2] and percent reduction from baseline. As shown in Table 6, the proposed standards are expected to reduce HAP emissions by 1,810 Mg/yr, or 42.5% from baseline. The vast majority of emission reductions are achieved through the control of process vents and equipment leaks. These two source types account for approximately 85 percent (1,550 Mg/yr) of total emission reductions. The methodologies used to calculate the emission reductions is presented in Attachment 1.

SECONDARY ENVIRONMENTAL IMPACTS

The intent of the proposed standards is to reduce HAP emissions; however, the application of control technologies can lead to other secondary environmental impacts. These secondary impacts can have a positive environmental impact, such as the improvement of wastewater quality through the implementation of wastewater controls, or a negative impact. Negative impacts may result, for example, from air pollutants emitted as a result of combustion sources (e.g., flares) or the generation of a solid or liquid waste stream. The secondary impacts on air pollution, water pollution, solid waste, and hazardous waste are discussed in this section for each emission source.

Air Pollution

The secondary air pollution impacts associated with the proposed standards are the increased criteria and toxic pollutant emissions resulting from the on-site combustion of organic HAPs and fuels. The combustion of organic HAPs and natural gas in a flare generates emissions of nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOC). The combustion of fuel oil generates these same criteria pollutant emissions, as well as particulate matter (PM) and sulfur oxides (SO_x). In addition, fuel oil combustion generates emissions of the following HAPs: arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), lead (Pb), manganese (Mn), mercury (Hg), and nickel (Ni).

Criteria pollutant emissions will also occur as a result of the combustion of coal, oil, or natural gas used to generate the additional energy needed by the control equipment. These off-site air impacts were not included in this analysis, although an estimation of the additional energy requirements is presented later in this section.

TABLE 5. EMISSION REDUCTION BY MODEL PLANT

Model Plant	Emission Reduction (Mg/yr)				
	Process Vents	Storage Tanks	Equipment Leaks	Wastewater	Total
Small	32.2[a]	3.1	104[a]	0	139
Large	350	6.2	794	249	1400
Catalyst Extraction	64.2	3.1	199	0	266

[a] Includes emission reduction from the THF facility.

TABLE 6. EMISSION REDUCTION FROM BASELINE BY EMISSION SOURCE

Emission Source	Total Emission Reduction (Mg/yr)	Baseline Emissions (Mg/yr)	Reduction From Baseline (%)
Process Vents	447	604	74.0
Storage Tanks	12.4	22.2	55.9
Equipment Leaks	1100	1940	56.7
Wastewater	249	1700	14.6
Total	1810	4260	42.5

There is no on-site combustion associated with the required control technologies for storage tanks or equipment leaks. Therefore, no secondary air impacts are expected from these technologies.

Table 7 presents the estimated criteria air pollutant impacts for process vent and wastewater control technologies. The total criteria air pollutant emission increases are estimated to be 79.3 Mg/yr. Table 8 presents the toxic emissions resulting from the fuel oil combustion. Total toxic pollutant emissions are estimated to be 25.7 kg/yr. The following sections briefly describe the methodologies used to calculate the emissions shown in Tables 7 and 8. More detailed information is presented in Attachment 2.

Process vents. Secondary air impacts from process vent controls are a result of the combustion of organic HAPs and supplemental fuel in flares, as well as the combustion of fuels to generate steam. Emission factors for flares were obtained from Section 13.5 of AP-42.[3] The emission factors (lb/MMBtu) were multiplied by the heat content of the exhaust stream to obtain the emission rate.

In order to conservatively estimate secondary air emissions resulting from the process vent control requirements, it was assumed that the steam used by the flares is generated on site. Emissions were calculated for a small industrial boiler with a thermal efficiency of 80 percent burning No. 2 fuel oil (0.5 percent sulfur by weight).

The steam requirements of the flares were determined by the OAQPS Control Cost Manual (OCCM)[4] spreadsheet. The steam requirements were converted to gallons of fuel oil by dividing by 140,000 Btu/gal, then dividing by 0.80 to account for the boiler efficiency. The fuel oil usage was used to estimate emissions from steam generation.

Criteria and toxic air pollutant emissions from the combustion of fuel oil were estimated using emission factors from Section 1.3 of AP-42. Fuel oil usage was multiplied by the AP-42 emission factors to obtain emissions per model plant.

The EPA database was used to determine the percentage of facilities that are not controlled at the level of the proposed standard (98 percent control). Analysis of the database showed that approximately 30 percent of the facilities are either uncontrolled or controlled at less than 98 percent. This percentage was then multiplied by the total number of each model plant type to obtain the number of uncontrolled facilities per model plant type. The emissions per model plant were multiplied by the number of uncontrolled facilities in each model plant type, then added together to obtain nationwide emissions.

TABLE 7. SECONDARY AIR IMPACTS FOR COMBUSTION SOURCES

CRITERIA POLLUTANTS

Control Device/ Model Plant	Fuel Type	Number of Model Plants	Fuel Usage (MM Btu/yr for flares) (1000 gal/yr for fuel oil)	Emission Factors (AP-42) (lb/MM Btu for flares) (lb/1000 gal for fuel oil)					Total Emissions (Mg/yr)				
				NOx	SOx	CO	PM	TOC	NOx	SOx	CO	PM	TOC
Flare													
Large	Natural Gas	11	1548.5	0.068	---	0.37	---	0.14	5.3E-01	---	2.9E+00	---	1.1E+00
Catalyst Extraction													
-Oxides and Other-HAP	Natural Gas	6	2484.2	0.068	---	0.37	---	0.14	4.6E-01	---	2.5E+00	---	9.5E-01
-Other HAP Only	Natural Gas	9	1548.5	0.068	---	0.37	---	0.14	4.3E-01	---	2.3E+00	---	8.9E-01
Flare (steam generation)													
Large	Fuel Oil No. 2	11	42.1	20	72	5	2	0.556	4.2E+00	1.5E+01	1.1E+00	4.2E-01	1.2E-01
Catalyst Extraction													
-Oxides and Other-HAP	Fuel Oil No. 2	6	77.2	20	72	5	2	0.556	4.2E+00	1.5E+01	1.1E+00	4.2E-01	1.2E-01
-Other HAP Only	Fuel Oil No. 2	9	42.1	20	72	5	2	0.556	3.4E+00	1.2E+01	8.6E-01	3.4E-01	9.6E-02
Steam Stripper													
Large	Fuel Oil No. 2	6	30.4	20	72	5	2	0.556	1.7E+00	6.0E+00	4.2E-01	1.7E-01	4.6E-02
TOTAL									1.5E+01	4.9E+01	1.1E+01	1.4E+00	3.3E+00

Emission factors for flares from AP-42, Table 13.5-1. PM emissions assumed to be zero because of exhaust stream characteristics and flare design.
Emission factors for fuel oil from AP-42, Tables 1.3-2 and 1.3-4.
Sulfur content of No. 2 fuel oil assumed to be 0.5%.

TABLE 8. SECONDARY AIR IMPACTS FOR COMBUSTION SOURCES BURNING NO. 2 FUEL OIL (0.5% SULFUR)

TOXIC POLLUTANTS

Control Device/ Model Plant	Number of Model Plants	Fuel Usage per Model Plant (gal/yr)	Emission Factors (AP-42) (lb/1E12 Btu)								Emissions per Model Plant (Mg/yr)							
			As	Be	Cd	Cr	Pb	Mn	Hg	Ni	As	Be	Cd	Cr	Pb	Mn	Hg	Ni
Flare																		
Large	11	42066	4.2	2.5	11	57.5	8.9	14	3	170	1.2E-04	7.4E-05	3.2E-04	1.7E-03	2.6E-04	4.1E-04	8.8E-05	5.0E-03
CE-Other-HAP	9	42066	4.2	2.5	11	57.5	8.9	14	3	170	1.0E-04	6.0E-05	2.7E-04	1.4E-03	2.1E-04	3.4E-04	7.2E-05	4.1E-03
CE-Oxides and Other-HAP	6	77151	4.2	2.5	11	57.5	8.9	14	3	170	1.2E-04	7.4E-05	3.2E-04	1.7E-03	2.6E-04	4.1E-04	8.8E-05	5.0E-03
Steam Stripper																		
Large	6	30446	4.2	2.5	11	57.5	8.9	14	3	170	4.9E-05	2.9E-05	1.3E-04	6.7E-04	1.0E-04	1.6E-04	3.5E-05	2.0E-03
TOTAL											4.0E-04	2.4E-04	1.0E-03	5.4E-03	8.4E-04	1.3E-03	2.8E-04	1.6E-02

Emission factors from AP-42, Table 1.3-11

Wastewater. Steam stripping was the control technology that was analyzed for control of air emissions from wastewater. Secondary air impacts associated with steam stripper operation can occur from combustion of fuels for steam generation and the handling or combustion of the recovered organic compounds. For the purpose of this evaluation, it was assumed that recovered organic compounds are handled properly and that no significant emissions occur from the handling process.

As with process vents, it was assumed that additional steam must be generated on site by a small industrial boiler. The boiler emission calculations and methodology for scaling to nationwide emissions were completed in a manner similar to that described above for process vents.

Water Pollution

Potential water pollution impacts may result from each of the control technologies evaluated, with the exception of flares. Positive effects will result from wastewater and equipment leak controls, while negative effects will be seen from process vent and storage tank controls.

Steam strippers remove organic compounds from wastewater, thereby improving the quality of the wastewater being discharged to the wastewater treatment plant, or discharged from the facility. As this wastewater will have a reduced level of organics, water quality impacts will be positive.

Control of equipment leaks will reduce the amount of organic material that may eventually be contained in a wastewater stream. For example, the leaking material may enter a wastewater stream through equipment washdowns or from stormwater runoff. However, the nature of these organic materials is such that the majority of the material will evaporate before or soon after entering the wastewater stream, so that the final effects will be minimal.

The potential for water pollution is also present with storage tank improvements. Before an internal floating roof can be installed or upgraded, the tank must be emptied and cleaned. A small amount of wastewater will be generated during tank cleaning, but it is not expected that this source of water pollution will be large enough to have a measurable impact on water quality.

The most significant impact on water quality is associated with process vent control. Control of organic HAP emissions using combustion does not result in any water quality impacts, as no water effluents are generated through the use of a flare. However, the use of a scrubber for organic HAP control results in increased water consumption and an effluent wastewater stream.

In a scrubber control system, water is used to remove water-soluble pollutants contained in the exhaust air stream. The amount of wastewater generated is equal to the amount of water needed by the scrubber to absorb the pollutants (assuming there is no recycle of scrubbing water). The scrubber water flow rate used in the scrubber cost analysis was 17 gallons per 1000 ft^3 of exhaust gas flow, which is the basic design assumption used in the OCCM. The exhaust flow rate to the scrubber was 220 ft^3, and the scrubber was assumed to operate 8,000 hours per year. This equates to an annual wastewater generation of approximately 1.8 million gallons.

Nationwide water quality impacts were then calculated by multiplying the annual scrubber water usage rate by the number of facilities that will install such a system. Based on an analysis of the EPA database, it was assumed that only small facilities will install a scrubber (large and catalyst extraction facilities are expected to install flares). The 6 small facilities which will require process vent control (see discussion in the model plants section) are estimated to produce a total of 10.8 million gallons of wastewater annually.

Solid and Hazardous Waste

In general, there are few solid or hazardous waste impacts associated with the implementation of the proposed standards. There are no significant solid or hazardous wastes generated as a result of storage tank control by tank improvements, or as a result of process vent control using a flare or scrubber.

Solid waste from equipment replacement includes seals, packing, rupture disks, and other used equipment components, such as pumps and valves. Metal solid wastes such as mechanical seals, rupture disks, and valve parts could be sold to metal recyclers. Although additional monitoring of equipment may result in a greater rate of replacement of faulty equipment, it may also reduce equipment failure. These solid waste impacts are considered not to be significant.

Solid and hazardous waste could be generated from the use of steam strippers to control wastewater emissions. The possible sources include organic compounds recovered in the steam stripper overheads condenser, solids removed during feed pretreatment, and wastes generated in the control of system vent emissions. System vent emissions, if not sent to a combustion control device, may be collected on a sorbent medium that requires either disposal or regeneration. If the sorbent is disposed, it creates additional solid waste.

Although waste generation can increase for any nonrecyclable organics that cannot be used as supplemental fuel, these organic waste would most likely have been removed otherwise from the

wastewater via the air (volatile organics only) or via an oil/water separator. Similarly, solids removed from the wastewater in cases where pretreatment is necessary would have likely been removed in a clarifier or activated sludge unit.

ENERGY IMPACTS

The energy demands associated with the control technologies for the proposed regulation include the need for additional electricity, natural gas, and fuel oil. The storage tank and equipment leak controls are not expected to require any additional energy consumption. The total nationwide energy demands that would result from implementing the process vent and wastewater controls are presented in Table 9. Overall, the controls will require approximately 2.2×10^{11} Btu annually. Attachment 3 provides more detailed information on the calculation of the energy impacts.

The electricity requirements for the pumps and blowers in the scrubber systems were calculated using the procedure detailed in the OCCM. This procedure takes into account the pressure drop throughout the system, and the pump requirements to recirculate the water. The steam stripper electricity requirements were based on the horsepower requirements of the pumps used in the system.

The use of a flare generally results in an increased natural gas usage for device start-up, supporting combustion of the vent stream, or to promote flame stability if the heat content of the vent stream is too low. The fuel impacts are equal to the design fuel requirements. The fuel requirements are dependent on the exhaust flow rate and heat content.

Wastewater steam strippers require additional energy to generate the steam. As discussed in the secondary air pollution impacts section, it was assumed that this energy was obtained from the combustion of No. 2 fuel oil in a boiler. The fuel usages are based on the steam stripper design, and the boiler characteristics that were discussed previously.

COST IMPACTS

The costs to the affected industry due to the application of the requirements of the proposed standards include the costs of any control equipment that must be purchased, along with the costs of the installation of that control equipment. There are also costs for the operation of control equipment. There may also be costs associated with certain work practices and other programs that reduce HAP emissions. Finally, there are costs associated with the required reporting, recordkeeping, and monitoring. This section presents the methodologies used to

TABLE 9. CALCULATION OF ENERGY REQUIREMENTS

ENERGY REQUIREMENTS FOR SCRUBBERS
ELECTRICITY

Control Device/ Model Plant	Electricity Cost ($/yr)	Electricity Unit Cost ($/kW-hr)	Conversion Factor (Btu/kW-hr)	Number of Model Plants	Total Energy Requirement (Btu/yr)
Scrubber					
Small	77.04	0.059	3,415	6	2.68E+07

ENERGY REQUIREMENTS FOR WASTEWATER TREATMENT
ELECTRICITY

Control Device/ Model Plant	Electricity Requirement (kW-hr/yr)	Conversion Factor (Btu/kW-hr)	Number of Model Plants	Total Energy Requirement (Btu/yr)
Steam Stripper				
Large	15,462	3415	6	3.17E+08

ENERGY REQUIREMENTS FOR WASTEWATER TREATMENT
STEAM

Control Device/ Model Plant	Energy Requirement (Btu/yr)	Boiler Efficiency	Number of Model Plants	Total Energy Requirement (Btu/yr)
Steam Stripper				
Large	3.41E+09	0.80	6	2.56E+10

ENERGY REQUIREMENTS FOR FLARES
NATURAL GAS

Control Device/ Model Plant	Natural Gas Cost ($/yr)	Natural Gas Unit Cost ($/Mscf)	Natural Gas Heat Content (Btu/ft3)	Number of Model Plants	Total Energy Requirement (Btu/yr)
Flare					
Large	1,889	3.03	1,000	11	6.86E+09
CE-Oxides	1,889	3.03	1,000	9	5.61E+09
CE-Oxides and Other-HAP	1,921	3.03	1,000	6	3.80E+09

ENERGY REQUIREMENTS FOR FLARES
STEAM

Control Device/ Model Plant	Steam Cost ($/yr)	Steam Unit Cost ($/1000 lb)	Steam Heat Content (Btu/lb)	Boiler Efficiency	Number of Model Plants	Total Energy Requirement (Btu/yr)
Flare						
Large	18,166	4.65	1,206	0.80	11	6.48E+10
CE-Oxides	18,166	4.65	1,206	0.80	9	5.30E+10
CE-Oxides and Other-HAP	33,317	4.65	1,206	0.80	6	6.48E+10

estimate the cost impacts, as well as a summary of the estimated costs.

In general, the methodologies used to estimate the capital and annual control costs are the same as the methodologies used to estimate the costs of the HON. These methodologies are described in detail in Volume 1B of the HON Background Information Document[5] (BID) and are not reproduced here. The OCCM was also used extensively in the cost estimates. Parameters used in the costing analysis for process vents, storage tanks, equipment leaks, and wastewater treatment are shown in Tables 10, 11, 12, and 13, respectively. Model plant costs are presented in Tables 14, 15, and 16 for small, large, and catalyst extraction model plants, respectively. Nationwide costs are summarized in Table 17.

Process Vents

Cost estimates were developed for two different control devices, depending on the size of the model plant. A scrubber was used as the basis for the cost estimate for small model plants, and a flare was used for large and catalyst extraction model plants. As described in the secondary air pollution impacts section, a single "model" exhaust stream was developed for costing the control devices. A detailed presentation of the scrubber cost analysis is presented in Attachment 4, and the flare cost analysis is presented in Attachment 5.

While the HAP emissions from small and large model plants are assumed to be contained in a single exhaust stream (the "model" exhaust stream discussed above), the catalyst extraction model plants have two exhaust streams. The first is from the reactor vents and is identical to the small and large model plants. The second is the exhaust from the catalyst extraction process. This second exhaust stream is considered to be identical to the "model" exhaust stream; therefore, there are two "model" exhaust streams to be controlled at the catalyst extraction model plants.

As discussed in the secondary air pollution impacts section, it was estimated that there are six catalyst extraction model plants that will require process vent control. This same analysis showed that 15 catalyst extraction model plants will require control of the catalyst extraction process (referred to as nonepoxide HAP emissions). For the six facilities that will require process vent control, it was assumed that they will combine the process vent and nonepoxide HAP emission streams into a single stream for control purposes. Consequently, a larger flare was costed for these six facilities (i.e., the flare was sized to handle twice the flow rate as the other flares). The remaining nine model plants that require only nonepoxide HAP

TABLE 10. PARAMETERS USED IN THE POLYETHER POLYOLS COST ANALYSIS FOR PROCESS VENTS

Parameter	Value
Base Year	
Scrubber	July 1989
Flare	July 1995
Reporting Year	August 1996
Chemical Engineering Plant Cost Index	
July 1989	356.0
July 1995	381.4
August 1996	382.1
Electricity Cost (scrubber)	$0.059/kW-hr
Water Cost (scrubber)	$0.22/1000 gal
Steam Cost (flare)	$4.65/1000 lb
Natural Gas Cost (flare)	$3.03/1000 ft
Operating Labor Rate	
Scrubber	$13.20/hr
Flare	$16.00/hr
Maintenance Labor Rate	
Scrubber	$14.50/hr
Flare	$17.20/hr
Interest Rate	7%
Raw Chemical Cost Used for Recovery Credit	N/A
Equipment Life	
Scrubber	10 years
Flare	15 years

TABLE 11. PARAMETERS USED IN THE POLYETHER POLYOLS COST ANALYSIS FOR STORAGE TANKS

Parameter	Value
Base Year	July 1989
Reporting Year	August 1996
Chemical Engineering Plant Cost Index	
July 1989	356.0
August 1996	382.1
Electricity Cost	N/A
Water Cost	N/A
Steam Cost	N/A
Natural Gas Cost	N/A
Operating Labor Rate	N/A
Maintenance Labor Rate	N/A
Interest Rate	7%
Raw Chemical Cost Used for Recovery Credit (hexane)	$0.40/kg
Equipment Life	10 years

TABLE 12. PARAMETERS USED IN THE POLYETER POLYOLS COST ANALYSIS FOR EQUIPMENT LEAKS

Parameter	Value
Base Year	July 1989
Reporting Year	August 1996
Chemical Engineering Plant Cost Index	
July 1989	356.0
August 1996	382.1
Electricity Cost	N/A
Water Cost	N/A
Steam Cost	N/A
Natural Gas Cost	N/A
Operating Labor Rate	N/A
Maintenance Labor Rate	$22.50
Interest Rate	7%
Raw Chemical Cost Used for Recovery Credit (propylene oxide)	$1.41/kg
Equipment Life	
Pump Seals	2 years
Rupture Disk	2 years
Monitoring Instrument	6 years
All Other Equipment	10 years

TABLE 13. PARAMETERS USED IN THE POLYETER POLYOLS COST ANALYSIS FOR WASTEWATER

Parameter	Value
Base Year	July 1989
Reporting Year	August 1996
Chemical Engineering Plant Cost Index	
July 1989	356.0
August 1996	382.1
Electricity Cost	$0.059/kW-hr
Water Cost	$0.0580/1000 liters
Steam Cost	$7.68/Mg
Natural Gas Cost	N/A
Operating Labor Rate	$13.20/hr
Maintenance Labor Rate	$14.50/hr
Interest Rate	7%
Raw Chemical Cost Used for Recovery Credit	N/A
Equipment Life	15 years

TABLE 14. ESTIMATED TOTAL CAPITAL INVESTMENT AND ANNUAL COSTS FOR SMALL MODEL PLANTS POLYETHER POLYOLS NESHAP[a]

Emission Point	Unit Cost ($/MMlb)	Cost per Model Plant (thousand $)					Nationwide Number of Facilities Requiring Control	Emission Reduction (Mg/yr)	Total Costs for Small Model Plants (thousand $)	
		Total Capital Investment	Annual Costs						Total Capital Investment	Annual Costs
			Direct Cost	Indirect Cost	Monitoring, Recordkeeping and Reporting[b]	Total				
Process Vents										
Scrubber	1.2	38.0	24.2	21.1	13.6	58.9	6	32.2	228	353
Fixed-roof Storage Tanks	0.1	16.0	(0.25)	3.6	1.0	4.4	5	3.1	80.0	22.0
Equipment Leaks	0.5	52.7	3.0	17.1	6.0	26.1	20	104	1,050	522
Wastewater Treatment[c]										

[a] August 1996 dollars.
[b] 30 percent of annual costs.
[c] No Group 1 wastewater streams at small model plants.

TABLE 15. ESTIMATED TOTAL CAPITAL INVESTMENT AND ANNUAL COSTS FOR LARGE MODEL PLANTS POLYETHER POLYOLS NESHAP[a]

Emission Point	Unit Cost ($/MMlb)	Cost per Model Plant (thousand $)					Nationwide Number of Facilities Requiring Control	Emission Reduction (Mg/yr)	Total Costs for Large Model Plants (thousand $)	
		Total Capital Investment	Annual Costs						Total Capital Investment	Annual Costs
			Direct Cost	Indirect Cost	Monitoring, Recordkeeping and Reporting[b]	Total				
Process Vents										
Flare	0.5	22.4	50.3	21.5	21.5	93.3	11	350	246	1,030
Fixed-roof Storage Tanks	0.02	16.0	(0.25)	3.6	1.0	4.4	10	6.2	160	44.0
Equipment Leaks	0.3	61.7	17.2	21.6	11.6	50.4	38	794	2,340	1,920
Wastewater Treatment	0.7	416	34.8	76.3	33.3	144	6	249	2,490	866

[a] August 1996 dollars.
[b] 30 percent of annual costs.

TABLE 16. ESTIMATED TOTAL CAPITAL INVESTMENT AND ANNUAL COSTS FOR CATALYST EXTRACTION MODEL PLANTS
POLYETHER POLYOLS NESHAP[a]

Emission Point	Unit Cost ($/MMlb)	Cost per Model Plant (thousand $)					Nationwide Number of Facilities Requiring Control	Emission Reduction (Mg/yr)	Tota Costs for Catalyst Extraction Model Plants (thousand $)	
		Total Capital Investment	Annual Costs						Total Capital Investment	Annual Costs
			Direct Cost	Indirect Cost	Monitoring, Recordkeeping and Reporting[b]	Total				
Process Vents (EO/PO and nonepoxide HAP) Flare	1.1	25.2	65.5	21.9	26.2	113	6	41.1	151	682
Process Vents (nonepoxide HAP only) Flare	1.0	22.4	50.3	21.5	21.5	93.3	9	23.1	202	840
Fixed-roof Storage Tanks	0.04	16.0	(0.25)	3.6	1.0	4.4	5	3.1	80.0	22.0
Equipment Leaks	0.6	159	24.3	31.4	16.7	72.4	19	199	3,030	1,380
Wastewater Treatment[c]										

[a] August 1996 dollars.
[b] 30 percent of annual costs.
[c] No Group 1 wastewater streams at catalyst extraction model plants.

TABLE 17. NATIONWIDE COST OF CONTROL TO MEET THE POLYETHER POLYOLS NESHAP TOTAL NATIONWIDE COSTS[a]

Emission Point	Nationwide Costs By Model Plant (thousand $)						Emission Reduction (Mg/yr)	Total Costs (thousand $)	
	Small		Large		Catalyst Extraction				
	Capital	Annual	Capital	Annual	Capital	Annual		Capital	Annual
Process Vents	228	353	246	1,030	353	1,520	447	827	2,900
Fixed-roof Storage Tanks	80.0	22.0	160	44.0	80.0	22.0	12.4	320	88.0
Equipment Leaks	1,050	522	2,340	1,920	3,030	1,380	1,100	6,420	3,820
Wastewater Treatment			2,490	866			249	2,490	866
Total	1,360	897	5,240	3,860	3,460	2,920	1810	10,060	7,670

[a] August 1996 dollars.

control will use a smaller flare sized for a single exhaust stream.

The THF facility is characterized by the small model plant category. Therefore, process vent control costs for the THF facility are estimated to be equal to that for a single small model plant. From Table 14, the total capital investment for the THF facility is $38,000, and the total annual costs (including direct; indirect; and monitoring, recordkeeping, and reporting costs) are $58,900.

Storage Tanks

The storage tank cost estimates directly followed the methodology presented in the HON BID. The primary input parameters for this methodology were tank dimensions (height and diameter) and product recovery due to implementation of controls. Tank dimensions were calculated based on the capacity and assuming that the diameter is twice the height. The product recovery is equal to the emission reduction, which was calculated using the EPA's TANKS3 program. A detailed analysis of the storage tank cost analysis is presented in Appendix 6.

Equipment Leaks

The equipment leaks cost estimates were calculated using a spreadsheet developed by EC/R. The spreadsheet was based on the HON methodologies and incorporates credit for recovery of product. The procedure used to determine the number of uncontrolled components to be monitored is discussed in the model plants section. Attachment 7 presents the cost calculation methodology in more detail.

The equipment leak control costs associated with the THF facility is represented by the costs estimated for a small model plant. From Table 14, the total capital investment for the THF facility is $52,700, and the total annual costs (including direct; indirect; and monitoring, recordkeeping, and reporting costs) are $26,100.

Wastewater

Steam stripper cost were calculated using the HON wastewater spreadsheet, which is presented in Attachment 8.

Monitoring, Recordkeeping, and Reporting

In addition to the control costs, the facilities will incur monitoring, recordkeeping, and reporting (MRR) costs. Due to the similarity of the MRR requirements in the proposed standards with those for elastomer production facilities, the same methodology

used in the Polymers and Resins I NESHAP will be used to estimate the MRR costs for these standards as well.

The Polymers and Resins I NESHAP methodology used information from the HON SF-83 analysis to develop a ratio of annual MRR costs to the total annual control costs (sum of the direct and indirect control costs). This analysis[6] showed that the MRR costs are approximately 30 percent of the total annual control costs.

To estimate the MRR cost on a model plant basis, the total annual costs were multiplied by 0.30. For example, the process vent annual control cost for a small model plant was estimated to be $45,300. The MRR costs would then be $13,600, and the total annual cost would be $58,900. On a model plant basis, this analysis probably overstates the MRR costs for those facilities where control is already required, and understates the MMR costs for facilities that are essentially uncontrolled. However, this analysis does provide a reasonable nationwide estimate for the entire Polyether Polyols project.

Estimated Cost of Compliance

As previously noted, Table 17 summarizes the total capital investment and total annual costs by model plant and nationwide totals.

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6. Memorandum from Norwood, P., EC/R Inc., to Evans, L., United States Environmental Protection Agency. Estimated Monitoring, Reporting, and Recordkeeping Costs for Polymer and Resins I. August 9, 1994.

ATTACHMENT 1

CALCULATION OF EMISSION REDUCTIONS

Calculation Methodology Description

Emission Reduction

Process Vents

The EPA database was used to determine the number of facilities already achieving the level of control specified in the proposed regulation (98 percent control). Of the 28 facilities in the database, 19 facilities (approximately 70 percent) were achieving 98 percent control or greater. It was assumed that the percentage of controlled facilities would be the same for all model plant categories.

The number of uncontrolled facilities for each model plant type was then calculated. For large and solvent extraction model plants, the total estimated number of major source facilities (76) was multiplied by the fraction represented by each model plant category to calculate the number of model plants. This number was then multiplied by the percent of facilities controlled at a level below the standard (30 percent). The following example is presented for solvent extraction model plants:

(76 major facilities)x(0.25 fraction sol. ext.)x(1-0.70 fraction controlled below standard)

= 6 facilities

Similar calculations were performed to determine the number of large model plants (11) controlled at a level below the proposed standard.

For small model plants, the total estimated number of major source facilities was increased by one (for a total of 77) to account for the HAP-emitting facility that produces polyether polyols by polymerizing tetrahydrofuran (THF). The same calculation as shown above was then used to determine the number of small model plants (6) controlled at a level below the proposed standard.

Next, the existing level of control was evaluated for those facilities in the database at less than 98 percent control. Four categories were developed based on the existing level of control: 95-98 percent control, 90-95 percent control, 80-90 percent control, and no control. Of those facilities at less than 98 percent control, 12.5 percent were in the 95-98 percent control category, 37.5 percent in the 90-95 percent capacity, 25.0 percent in the 80-90 percent category, and 25.0 percent in the no control category.

Based on data reported in the Section 114 questionnaires, uncontrolled process vent emission rates were estimated for each model plant category. These emission rates were 24.3 Mg/yr for small model plants, 97.3 Mg/yr for large model plants, and 48.6 Mg/yr for catalyst extraction model plants. These uncontrolled emission rates, along with the number of facilities at less than

98 percent control were used to estimate the emission reductions. For the four categories of existing level of control listed above, 95 percent, 92 percent, 85 percent, and 0 percent control were used in the emission reduction calculations. The following example is presented for small model plants:

(24.3 Mg/yr)x(0.98-0.95 percent additional control)x(1 facility)
+ (24.3 Mg/yr)x(0.98-0.92 percent additional control)x (3 facilities)
+ (24.3 Mg/yr)x(0.98-0.85 percent additional control)x(1 facility)
+ (24.3 Mg/yr)x(0.98-0 percent additional control)x(1 facility)
= 32.2 Mg/yr

Similar calculations were performed to determine the emission reductions for large and catalyst extraction model plants (350.2 Mg/yr and 64.2 Mg/yr, respectively).

For the THF facility represented in the small model plant category, the emission reduction is estimated to be the average emission reduction per small model plant:

(32.2 Mg/yr)/(6 model plants) = 5.4 Mg/yr

Storage Tanks

As described in the model plant section of the memorandum, an analysis of the EPA database showed that there was typically one uncontrolled fixed-roof storage tank at each model plant. It was also determined that the average capacity of the uncontrolled tanks was 38,667 gallons and the average annual throughput was 134,500 gallons.

The EPA's TANKS3 program was used to calculate annual emissions for the tank first without any control, then with an internal floating roof. Hexane was used as the stored liquid. The difference between these two annual emission rates (0.62 Mg/yr) was used as the estimated emission reduction per tank.

The number of model plants with tanks requiring control was determined using the EPA database. An analysis showed that 3 out of 12 facilities (25 percent) have uncontrolled fixed-roof tanks. This percentage was multiplied by the total number of each type model plant to determine the number with tanks requiring control.

The emission reduction per tank was then multiplied by the number of facilities with tanks requiring control to obtain the total emission reduction. The following example is presented for small model plants:

(20 model plants)x(0.25 fraction uncontrolled)x(0.62 Mg/yr-model plant) = 3.1 Mg/yr

Similar calculations were performed to determine the emission reductions for large and catalyst extraction model plants (6.2 Mg/yr and 3.1 Mg/yr, respectively).

Wastewater

Two facilities in the EPA database reported Group 1 wastewater streams. Uncontrolled emissions for each facility were calculated by multiplying the average VOC concentration in the wastewater stream by the annual flowrate. The fraction removed (F_r) for each HAP (HON, Table 9) was applied to the uncontrolled emission rates to determine the emission reduction for each facility. These two values were averaged, and a value of 41.5 Mg/yr was used as the emission reduction per facility.

Both of the facilities reporting Group 1 wastewater streams are large facilities; therefore, it was assumed that only large model plants have Group 1 wastewater streams. To determine the number of large model plants with wastewater streams requiring control, the two facilities with Group 1 wastewater streams were divided by 12, the total number of large facilities in the EPA database. Consequently, 17 percent of the large model plants, or 6 facilities, were estimated to have Group 1 wastewater streams requiring control.

The total emission reduction was calculated by multiplying the emission reduction by the number of facilities:

$$(41.5 \text{ Mg/yr}) \times (6 \text{ facilities}) = 249.0 \text{ Mg/yr}$$

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$$(41.5 \text{ Mg/yr}) \times (6 \text{ facilities}) = 249.0 \text{ Mg/yr}$$

TANKS PROGRAM 3.0
EMISSIONS REPORT - DETAIL FORMAT
TANK IDENTIFICATION AND PHYSICAL CHARACTERISTICS

Identification

Identification No.:	HEXANEFIX
City:	Houston
State:	TX
Company:	EPA
Type of Tank:	Vertical Fixed Roof

Tank Dimensions

Shell Height (ft):	11.8
Diameter (ft):	23.6
Liquid Height (ft):	10.8
Avg. Liquid Height (ft):	5.9
Volume (gallons):	38667
Turnovers:	3.5
Net Throughput (gal/yr):	134500

Paint Characteristics

Shell Color/Shade:	White/White
Shell Condition:	Good
Roof Color/Shade:	White/White
Roof Condition.	Good

Roof Characteristics

Type.	Cone
Height (ft).	0.74
Radius (ft) (Dome Roof):	0.00
Slope (ft/ft) (Cone Roof):	0.0625

Breather Vent Settings

Vacuum Setting (psig):	-0.03
Pressure Setting (psig):	0.03

Meteorological Data Used in Emission Calculations: Houston, Texas (Avg Atmospheric Pressure = 14.7 psia)

Mixture/Component	Month	Daily Liquid Surf. Temperatures (deg F) Avg.	Min.	Max.	Liquid Bulk Temp. (deg F)	Vapor Pressures (psia) Avg.	Min.	Max.	Vapor Mol. Weight	Liquid Mass Fract.	Vapor Mass Fract.	Mol. Weight	Basis for Vapor Pressure Calculations
Hexane (-n)	All	70.13	64.62	75.64	68.32	2.4754	2.1551	2.8337	86.170			86.17	Option 2: A=6.8760, B=1171.170, C=224.410

Annual Emission Calculations

Standing Losses (lb):	1879.7492
Vapor Space Volume (cu ft):	2688.40
Vapor Density (lb/cu ft):	0.0375
Vapor Space Expansion Factor:	0.092226
Vented Vapor Saturation Factor:	0.553613
Tank Vapor Space Volume	
Vapor Space Volume (cu ft):	2688.40
Tank Diameter (ft):	23.6
Vapor Space Outage (ft):	6.15
Tank Shell Height (ft):	11.8
Average Liquid Height (ft):	5.9
Roof Outage (ft):	0.25
Roof Outage (Cone Roof)	
Roof Outage (ft):	0.25
Roof Height (ft):	0.738
Roof Slope (ft/ft):	0.06250
Shell Radius (ft):	11.8
Vapor Density	
Vapor Density (lb/cu ft):	0.0375
Vapor Molecular Weight (lb/lb-mole):	86.170000
Vapor Pressure at Daily Average Liquid Surface Temperature (psia):	2.475418
Daily Avg. Liquid Surface Temp.(deg. R):	529.80
Daily Average Ambient Temp. (deg. R):	527.97
Ideal Gas Constant R (psia cuft /(lb-mole-deg R)):	10.731
Liquid Bulk Temperature (deg. R):	527.99
Tank Paint Solar Absorptance (Shell):	0.17
Tank Paint Solar Absorptance (Roof):	0.17
Daily Total Solar Insolation Factor (Btu/sqftday):	1351.00
Vapor Space Expansion Factor	
Vapor Space Expansion Factor:	0.092226
Daily Vapor Temperature Range (deg.R):	22.05
Daily Vapor Pressure Range (psia):	0.678644
Breather Vent Press. Setting Range(psia):	0.06
Vapor Pressure at Daily Average Liquid Surface Temperature (psia):	2.475418
Vapor Pressure at Daily Minimum Liquid Surface Temperature (psia):	2.155064
Vapor Pressure at Daily Maximum Liquid Surface Temperature (psia):	2.833708
Daily Avg Liquid Surface Temp. (deg R):	529.80
Daily Min. Liquid Surface Temp. (deg R):	524.29
Daily Max. Liquid Surface Temp. (deg R):	535.31
Daily Ambient Temp. Range (deg.R):	21.70

Annual Emission Calculations
Vented Vapor Saturation Factor

Vented Vapor Saturation Factor:	0.553613
Vapor Pressure at Daily Average Liquid Surface Temperature (psia):	2.475418
Vapor Space Outage (ft):	6.15
Working Losses (lb):	683.0896
Vapor Molecular Weight (lb/lb-mole):	86.170000
Vapor Pressure at Daily Average Liquid Surface Temperature (psia):	2.475418
Annual Net Throughput (gal/yr):	134500
Turnover Factor:	1.0000
Maximum Liquid Volume (cuft):	4724
Maximum Liquid Height (ft):	10.8
Tank Diameter (ft):	23.6
Working Loss Product Factor:	1.00
Total Losses (lb):	2562.84

Annual Emissions Report

Liquid Contents	Losses (lbs.): Standing	Working	Total
Hexane (-n)	1879.75	683.09	2562.84
Total.	1879.75	683.09	2562.84

TANKS PROGRAM 3.0
EMISSIONS REPORT - DETAIL FORMAT
TANK IDENTIFICATION AND PHYSICAL CHARACTERISTICS

Identification

Identification No.:	HEXANEFLOA
City:	HOUSTON
State:	TX
Company:	EPA
Type of Tank:	Internal Floating Roof

Tank Dimensions

Diameter (ft):	23.6
Volume(gallons):	38667
Turnovers:	3.4

Paint Characteristics

Shell Condition:	Light Rust
Shell Color/Shade:	White/White
Shell Paint Condition:	Good
Roof Color/Shade:	White/White
Roof Condition:	Good

Rim-Seal System

Primary Seal:	Liquid-mounted
Secondary Seal:	N
Deck Type:	Welded

Deck Characteristics

Deck Fitting Category:	Typical

Deck Fitting/Status	Quantity
Access Hatch (24-in. Diam.)/Unbolted Cover, Ungasketed	1
Automatic Gauge Float Well/Unbolted Cover, Ungasketed	1
Column Well (24-in. Diam.)/Built-Up Col.-Sliding Cover, Ungask.	1
Ladder Well (36-in Diam.)/Sliding Cover, Ungasketed	1
Roof Leg or Hanger Well/Adjustable	9
Sample Pipe or Well (24-in. Diam.)/Slit Fabric Seal 10% Open	1
Vacuum Breaker (10-in. Diam.)/Weighted Mech. Actuation, Gask.	1

Meteorological Data Used in Emission Calculations: Houston, Texas (Avg Atmospheric Pressure = 14.7 psia)

Annual Emission Calculations

Rim Seal Losses (lb):	149.8920
Seal Factor A (lb-mole/ft-yr):	1.6000
Seal Factor B (lb-mole/ft yr (mph)^n):	0.3000
Value of Vapor Pressure Function:	0.0461
Vapor Pressure at Daily Average Liquid Surface Temperature (psia):	2.475418
Tank Diameter (ft):	23.6
Vapor Molecular Weight (lb/lb-mole):	86.170000
Product Factor:	1.0000
Withdrawal Losses (lb):	1.0809
Number of Columns:	1.0000
Effective Column Diameter (ft):	1.0000
Annual Net Throughput (gal/yr):	131468
Shell Clingage Factor:	0.0015
Average Organic Liquid Density (lb/gal):	5.5270
Tank Diameter (ft):	23.6
Deck Fitting Losses (lb):	1041.2253
Value of Vapor Pressure Function:	0.0461
Vapor Molecular Weight (lb/lb-mole):	86.170000
Product Factor:	1.0000
Tot. Deck Fitting Loss Fact. (lb-mole/yr):	262.3000
Deck Seam Losses (lb):	0.0000
Deck Seam Length (ft):	0
Deck Seam Loss per Unit Length Factor (lb-mole/ft-yr):	0.0000
Deck Seam Length Factor (ft/sqft):	0.0000
Tank Diameter (ft):	23.6
Vapor Molecular Weight (lb/lb-mole):	86.170000
Product Factor:	1.0000

Deck Fitting/Status	Quantity	Deck Fitting Loss Factors KFa (lb-mole/yr)	KFb (lb-mole/(yr mph^n))	m	Losses (lb.)
Access Hatch (24-in. Diam.)/Unbolted Cover, Ungasketed	1	36.00	0.00	0.00	143.0077
Automatic Gauge Float Well/Unbolted Cover, Ungasketed	1	14.00	0.00	0.00	55.6141
Column Well (24-in. Diam.)/Built-Up Col.-Sliding Cover, Ungask.	1	47.00	0.00	0.00	186.7045
Ladder Well (36-in Diam.)/Sliding Cover, Ungasketed	1	76.00	0.00	0.00	301.9052
Roof Leg or Hanger Well/Adjustable	9	7.90	0.00	0.00	282.4403
Sample Pipe or Well (24-in. Diam.)/Slit Fabric Seal 10% Open	1	12.00	0.00	0.00	47.6692
Vacuum Breaker (10-in. Diam.)/Weighted Mech. Actuation, Gask.	1	6.20	0.00	0.00	24.6291

Total Losses (lb): 1192.20

Annual Emission Calculations

Rim Seal Losses (lb):	149.8920
Seal Factor A (lb-mole/ft-yr):	1.6000
Seal Factor B (lb-mole/ft yr (mph)^n):	0.3000
Value of Vapor Pressure Function:	0.0461
Vapor Pressure at Daily Average Liquid Surface Temperature (psia):	2.475418
Tank Diameter (ft):	23.6
Vapor Molecular Weight (lb/lb-mole):	86.170000
Product Factor:	1.0000
Withdrawal Losses (lb):	1.0809
Number of Columns:	1.0000
Effective Column Diameter (ft):	1.0000
Annual Net Throughput (gal/yr):	131468
Shell Clingage Factor:	0.0015
Average Organic Liquid Density (lb/gal):	5.5270
Tank Diameter (ft):	23.6
Deck Fitting Losses (lb):	1041.2253
Value of Vapor Pressure Function:	0.0461
Vapor Molecular Weight (lb/lb-mole):	86.170000
Product Factor:	1.0000
Tot. Deck Fitting Loss Fact (lb-mole/yr):	262.3000
Deck Seam Losses (lb):	0.0000
Deck Seam Length (ft):	0
Deck Seam Loss per Unit Length Factor (lb-mole/ft-yr):	0.0000
Deck Seam Length Factor (ft/sqft):	0.0000
Tank Diameter (ft):	23.6
Vapor Molecular Weight (lb/lb-mole):	86.170000
Product Factor:	1 0000

Deck Fitting/Status	Quantity	Deck Fitting Loss Factors KFa (lb-mole/yr)	KFb (lb-mole/(yr mph^n))	m	Losses (lb)
Access Hatch (24-in. Diam.)/Unbolted Cover, Ungasketed	1	36.00	0.00	0.00	143.0077
Automatic Gauge Float Well/Unbolted Cover, Ungasketed	1	14 00	0.00	0.00	55.6141
Column Well (24-in. Diam.)/Built-Up Col.-Sliding Cover, Ungask.	1	47.00	0.00	0.00	186.7045
Ladder Well (36-in Diam.)/Sliding Cover, Ungasketed	1	76.00	0.00	0.00	301.9052
Roof Leg or Hanger Well/Adjustable	9	7 90	0.00	0.00	282.4403
Sample Pipe or Well (24-in. Diam.)/Slit Fabric Seal 10% Open	1	12.00	0.00	0.00	47.6692
Vacuum Breaker (10-in. Diam.)/Weighted Mech. Actuation, Gask.	1	6.20	0.00	0.00	24.6291

Total Losses (lb): 1192.20

Annual Emissions Report

Liquid Contents	Losses (lbs.): Total Withdrawal	Rim-Seal	Deck-Fitting	Deck Seam	Total Standing	Total
Hexane (-n)	1.08	149.89	1041.23	0.00	1191.12	1192.20
Total:	1.08	149.89	1041.23	0.00	1191.12	1192.20

ATTACHMENT 2

CALCULATION OF SECONDARY AIR IMPACTS FOR PROCESS VENT AND WASTEWATER CONTROL

Calculation Methodology Description

Secondary Air Impacts

Methodologies and example calculations are presented below for secondary air pollution emissions from the use of control devices on process vent exhaust streams and wastewater streams. Calculations for all model plants are presented in Tables 5 and 6 of the memorandum.

Process Vents

No secondary air pollutant emissions are expected from the use of scrubbers on process vent exhaust streams. Flares, however, will generate secondary air emissions from two sources: combustion of organics and supplemental fuel in the flare itself, and combustion of fuel to generate the steam used by the flare.

To obtain the total Btu content of the stream burned by the flare, the Btu content of the process vent exhaust stream was added to the Btu content of the supplemental fuel. This total Btu content was then multiplied by the emission factors for flares in Section 13.5 of AP-42 to obtain criteria pollutant emissions.

The Btu content of the supplemental fuel was calculated by first dividing the annual fuel costs (calculated by the OCCM spreadsheet) by the unit cost of the fuel. The resultant fuel usage was multiplied by the Btu content per cubic foot of natural gas to obtain the Btu content of the supplemental fuel.

The following example is presented for NO_x emissions from a large model plant:

Btu content of the process vent exhaust:
$(8\ Btu/ft^3)x(220\ ft^3/min)x(60\ min/hr)x(8760\ hr/yr) = 925\ MMBtu/yr$

Btu content of the supplemental fuel:
$(\$1889/yr)/(\$3.03/Mft^3)x(1000\ Btu/ft^3) = 623\ MMBtu/yr$

Total Btu content of the exhaust stream:
$925\ MMBtu/yr + 623\ MMBtu/yr = 1,548\ MMBtu/yr$

NO_x emissions:
$(1548\ MMBtu/yr)x(0.068\ lb/MMBtu)x(1\ Mg/2200\ lb) = 0.048\ Mg/yr$

It was assumed that the steam required by the flare was generated by a small industrial boiler with an efficiency of 80 percent burning No. 2 fuel oil. The fuel oil requirements were calculated by taking the steam costs from the OCCM spreadsheet, dividing by the unit cost of the steam, then multiplying by the Btu content per pound of steam (saturated steam at 400 psig). The resultant Btu/yr was divided by the Btu content of No. 2 fuel

oil (140,000 Btu/gal) to obtain the fuel oil usage. Emission factors from Section 1.3 of AP-42 were then used to calculate criteria and toxic pollutant emissions. The following example is presented for NO_x emissions from a large model plant:

Energy required to produce the steam:

$$(\$18,166/yr)/(\$4.65/Mlb)x(1206\ Btu/lb)/0.80 = 5.9x10^9\ Btu/yr$$

Fuel oil requirement:

$$(5.9x10^9\ Btu/yr)/(140,000\ Btu/gal) = 42,066\ gal/yr$$

NO_x emissions:

$$(42.1\ Mgal/yr)x(20\ lb/Mgal)x(1\ Mg/2200\ lb) = 0.38\ Mg/yr$$

Wastewater

As with flares, it was assumed that the required steam is generated on-site through the use of a small industrial boiler burning No. 2 fuel oil. Starting with the steam costs calculated by the HON wastewater spreadsheet, fuel oil usage and secondary emissions were calculated as described above for process vents.

ATTACHMENT 3

CALCULATION OF ENERGY IMPACTS

Calculation Methodology Description

Energy Impacts

Methodologies and example calculations are presented below for energy requirements from electricity, natural gas, and steam requirements. Calculations for all model plants are presented in Table 7 of the memorandum.

Electricity

Annual electricity costs for the scrubber were calculated by the OCCM spreadsheet. The annual electricity requirements (kW-hr/yr) for the steam stripper were calculated by the HON wastewater spreadsheet. Unit cost used by both spreadsheets is \$0.059/kW-hr. An energy conversion factor of 3,415 Btu/kW-hr was used to convert electricity requirements to Btu/yr. The following example is presented for a small model plant using a scrubber:

$$(\$77.04/yr)/(\$0.059/kW\text{-}hr)x(3415\ Btu/kW\text{-}hr) = 4.46x10^6\ Btu/yr$$

Natural Gas

Annual natural gas costs for the flares were calculated by the OCCM spreadsheet. Unit cost used by the spreadsheet is \$3.03/1000 ft^3. Natural gas usage was converted to Btu/yr using the factor 1,000 Btu/ft^3. The following example is presented for a large model plant:

$$(\$1889/yr)/(\$3.03/1000\ ft^3)x(1000\ Btu/ft^3) = 6.23x10^8\ Btu/yr$$

Steam

Annual steam costs for the flares were calculated by the OCCM spreadsheet, and annual steam costs for the steam strippers were calculated by the HON wastewater spreadsheet. Unit cost used by the OCCM spreadsheet is \$4.65/1000 lb steam, and \$3.49/1000 lb steam by the HON wastewater spreadsheet. Steam usage was converted to Btu/yr using the factor 1,206 Btu/lb steam. This conversion factor was taken from the HON wastewater spreadsheet and assumes that the steam is saturated at 400 psig. It was assumed that the steam would be produced by a small industrial boiler with an efficiency of 80 percent. The following example is presented for a flare at a large model plant:

$$(\$18,166/yr)/(\$4.65/1000\ lb)x(1206\ Btu/lb)/0.80 = 5.89x10^6\ Btu/yr$$

ATTACHMENT 4

CALCULATION OF SCRUBBER COSTS

Calculation Methodology Description

Scrubber Costs

The following procedure was taken from Volume 1B of the HON BID, and most of the same assumptions concerning vapor-liquid equilibrium were followed here. The process vent exhaust stream characteristics (e.g., flow rate and pollutant concentration) were determined from the Section 114 questionnaire responses, and is discussed further in the model plant section of the memorandum.

The average flow rate of the process vent exhaust streams reported in the Section 114 questionnaire responses was 250 actual cubic feet per minute (acfm); however, the input to the HON costing procedure requires the flow to be measured at standard conditions. The flow was corrected to standard conditions (77°F was used as standard temperature in order to be consistent with other physical property values used in various equations of the costing procedure), and 220 standard cubic feet per minute (scfm) was used to size the scrubber. The majority of other input parameters were consistent with the that used in the HON BID, although three require further discussion. The calculation of the absorption factor requires the slope of the vapor-liquid equilibrium line. The HON analysis assumed a value of 0.1 for the slope, which is valid if the solute is highly soluble in the solvent. As propylene oxide is very soluble in water, this assumption is valid here. The vapor Schmidt number was assumed to be equal to 1, which is generally valid for very dilute streams. The liquid Schmidt number was assumed to be 350, as diffusivity data for propylene oxide and water was not available. However, the liquid Schmidt number has very little effect on the overall design of the column. Using a liquid Schmidt number as high as 1000 changes the column height from 11.2 feet to only 11.4 feet.

Scrubber Capital Investment

The scrubber design and capital investment is based on a packed bed, countercurrent scrubber tower. The scrubber capital investment includes the cost of the scrubber, packing, platform, stack, and any associated ducts and fans. The capital investment is directly related to the size of the scrubber and the pressure drop across the scrubber, which is dependent on the liquid and vapor flow rates through the column. The absorbing liquid is water, and the vapor consists mainly of air. The design and costing procedures closely follow the procedure presented in Chapter 9 of the OCCM (Gas Absorbers), and the Handbook on Control Technologies for Hazardous Air Pollutants (HAP Manual)[1].

1. Calculate the flow rate of gas to the scrubber.

The amount of vapor flowing to the scrubber is equal to the average exhaust flow rate from the reactor vents reported in the questionnaires. The vapor stream is predominantly air.

$$\text{Mols Vapor}\left(\frac{\text{lb-mol}}{\text{hr}}\right) = (220.0\ \text{scfm}) * \left(60\ \frac{\text{min}}{\text{hr}}\right) * \left(\frac{1\ \text{lb-mol}}{392\ \text{scf (at T = 77°F)}}\right)$$

$$= 33.67\ \frac{\text{lb-mol}}{\text{hr}}$$

2. Calculate the liquid flow rate through the scrubber.

It is assumed that the liquid and vapor flow rates through the column are essentially constant. Therefore, the liquid to vapor flow rate ratio throughout the column is also constant and, as used in the HON analysis, equal to 17 gpm/1000 scfm. By converting both quantities to lb-moles per hour and multiplying the ratio by the vapor flow rate, the liquid flow rate is found.

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[1] Handbook - Control Technologies for Hazardous Air Pollutants. Publication Number EPA-625/6-86-014. United States Environmental Protection Agency, Air and Energy Engineering Research Laboratory, Research Triangle Park, North Carolina. September 1986.

$$\frac{17\ \text{gpm}}{1000\ \text{scfm}} = \frac{\left(17\ \frac{\text{gal}}{\text{min}}\right) * \left(60\ \frac{\text{min}}{\text{hr}}\right) * \left(8.34\ \frac{\text{lb}}{\text{gal}}\right) * \left(\frac{\text{lb-mol}}{18\ \text{lb}}\right)}{\left(1000\ \frac{\text{ft}^3}{\text{min}}\right) * \left(\frac{1\ \text{lb-mol}}{392\ \text{scf}}\right) * \left(60\ \frac{\text{min}}{\text{hr}}\right)}$$

$$= \frac{472.6\ \frac{\text{lb-mol}}{\text{hr}}\ \text{water}}{153.06\ \frac{\text{lb-mol}}{\text{hr}}\ \text{vapor}}$$

$$\begin{array}{c}\text{Liquid}\\ \text{Flow Rate}\\ \text{Through}\\ \text{Scrubber}\\ (\text{lb-mol/hr})\end{array} = \left(\frac{472.6\ \frac{\text{lb-mol}}{\text{hr}}\ \text{water}}{153.06\ \frac{\text{lb-mol}}{\text{hr}}\ \text{vapor}}\right) * 33.67\ \frac{\text{lb-mol Vapor}}{\text{hr}} = 103.96\ \frac{\text{lb-mol}}{\text{hr}}$$

3. Calculate the diameter of the tower.

As explained in Section 3.1.2.1.5 of Volume 1B of the HON BID, a correlation for randomly packed towers based on flooding considerations is used to determine the tower diameter. The vapor flow rate per cross-sectional area of the column is first determined by the correlation. By knowing the vapor flow rate, the cross-sectional area of the column can then be found.

$$\text{ABSCISSA} = \frac{\text{Liquid Flowrate}\left(\frac{\text{lb}}{\text{hr}}\right)}{\text{Vapor Flowrate}\left(\frac{\text{lb}}{\text{hr}}\right)} * \left(\frac{\text{Density of Vapor}\ (\rho_V)}{\text{Density of Liquid}\ (\rho_L)}\right)^{.5}$$

$$= \frac{\left(103.96\frac{\text{lb-mol}}{\text{hr}}\right) * \left(\frac{18\ \text{lb}}{\text{lb-mol}}\right)}{\left(33.67\ \frac{\text{lb-mol}}{\text{hr}}\right) * \left(29\ \frac{\text{lb}}{\text{lb-mol}}\right)} * \left(\frac{0.0739\ \frac{\text{lb}}{\text{ft}^3}}{62.2\ \frac{\text{lb}}{\text{ft}^3}}\right)^{.5}$$

$$= 0.0661$$

$$\text{ORDINATE} = -0.9809237 * (\text{ABSCISSA})^{(-0.0065226 * \ln(\text{ABSCISSA}))} + (\text{ABSCISSA})^{(-0.021897)}$$

$$= 0.126$$

The vapor flow rate per cross-sectional area is calculated by the following equation. The column is assumed to operate at 60 percent of flooding.

$$\text{Vapor Flowrate Per Cross-Sectional Area}\left(\frac{\text{lb}}{\text{sec}\cdot\text{ft}^2}\right) = \left[\frac{\text{ORDINATE} * \rho v * \rho L * gc}{\left(\frac{a}{\epsilon^3}\right) * \left(\frac{\mu L}{2.42}\right)^{.2}}\right]^{1/2} * f$$

where:

ρv	=	density of the vapor = 0.0739 lb/ft^3
ρ_L	=	density of water = 62.2 lb/ft^3
g_c	=	gravitational constant = 32.2 $ft \cdot lbm/lbf \cdot sec^2$
$\mu L/2.42$	=	viscosity of solvent = 0.85 cp
a/ϵ^3	=	the void space of packing per surface area to volume ratio of packing[2] = 69.1 ft
f	=	flooding factor = 0.6

$$\text{Vapor Flowrate per Cross-Sectional Area}\left(\frac{\text{lb}}{\text{sec}\cdot\text{ft}^2}\right) = \left(0.126 * 0.0739 * 62.2 * \frac{32.2}{69.1} * \frac{1}{(0.85)^{0.2}}\right)^{1/2} * 0.6$$

$$\text{Vapor Flowrate per Cross-Sectional Area} = 0.3168\ \frac{\text{lb}}{\text{sec}\cdot\text{ft}^2}$$

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[2] Treybal, R.E. Mass-Transfer Operations, Third Edition. New York, McGraw-Hill Book Company. 1980. p.196.

$$\text{Area of Tower } (ft^2) = \frac{\left(\text{Vapor Flowrate } \frac{lb}{sec}\right)}{\text{Vapor Flowrate per Cross-Sectional Area}}$$

$$\text{Area of Tower } (ft^2) = \frac{\left(33.67 \frac{lb\ mol}{hr}\right) * \left(29 \frac{lb}{lbmol}\right) * \left(\frac{1hr}{3600\ sec}\right)}{0.3168 \frac{lb}{sec \cdot ft^2}}$$

$$= 0.856\ ft^2$$

$$A = \pi * (radius)^2 = \pi * \left(\frac{Diameter}{2}\right)2$$

$$\text{Diameter } (ft) = \left(\frac{4}{\pi} * A\right)\frac{1}{2}$$

$$\text{Diameter} = \left(\frac{4}{\pi} * 0.856\right)\frac{1}{2} = 1.044\ ft$$

4. Determine the number of transfer units.

The number of transfer units represent the number of theoretical equilibrium stages required to absorb the vapor pollutant. This number is determined from a quantity called the absorption factor which is calculated by dividing the liquid to vapor ratio by the slope of the equilibrium line. The slope of the equilibrium line is represented by the difference in the vapor mole fractions divided by the difference in the liquid mole fractions from the top to the bottom of the column. As used in the HON analysis, the slope is equal to 0.1.

$$\text{Absorption Factor} = \left(\frac{472.6\ lb\text{-}mol/hr\ water * \frac{18\ lb}{lb\text{-}mol}}{153.06\ lb\text{-}mol/hr\ vapor * \frac{29\ lb}{lb\text{-}mol}}\right) * \left(\frac{1}{0.1}\right)$$

$$= 19.16$$

$$\text{Number of Transfer Units (NOG)} = \ln\left[\left(\frac{\text{Hal—Conc}}{0.02 * \text{Hal—Conc}}\right) * (1 - 1/AF) + (1/AF)\right] * \left(\frac{1}{1 - 1/AF}\right)$$

$$NOG = 4.072$$

5. Determine the height of a transfer unit.

The height of a transfer unit is the height of one theoretical equilibrium stage. This number is determined from the vapor and liquid flow rates per cross-sectional area of the tower and from the Schmidt numbers of the vapor and the liquid.

$$\text{Vapor Flowrate per Cross-Sectional Area}\left(\frac{lb}{ft^2 \cdot hr}\right) = \left(0.3168\ \frac{lb}{ft^2 \cdot sec}\right) * \left(\frac{3600\ sec}{hr}\right)$$

$$= 1140.48\ \frac{lb}{ft^2 \cdot hr}$$

$$\text{Liquid Flowrate per Cross-Sectional Area}\left(\frac{lb}{ft^2 \cdot hr}\right) = \frac{\left(103.96\ \frac{lb\text{-}mol}{hr}\right) * \left(18\ \frac{lb}{lbmol}\right)}{0.856\ ft^2}$$

$$= 2186.1\ \frac{lb}{ft^2 \cdot hr}$$

$$\text{Height of a Transfer Unit} = HG + \left(\frac{1}{AF}\right) * HL$$

where:

$$HG = b * \frac{(\text{Vapor Flowrate per Area})^c}{(\text{Liquid Flowrate per Area})^d} * \left(\text{Vapor Schmidt Number}\right)^{0.5}$$

$$HL = Y * \left(\frac{\text{Liquid Flowrate per Area}}{\text{Viscosity of the Liquid}} \right)^{s} * \left(\begin{matrix} \text{Liquid} \\ \text{Schmidt} \\ \text{Number} \end{matrix} \right)^{0.5}$$

The values b, c, d, Y, and s and the Schmidt numbers are all constants which are dependent on the packing and the liquid and vapor flow rates through the tower. The vapor Schmidt number is assumed to be equal to 1, which is valid for very dilute gas streams at atmospheric pressure, and the liquid Schmidt number is assumed to be 350. The height (HOG) of a transfer unit is calculated below.

$$HG = \frac{3.82 * \left(1140.48 \ \frac{lb}{ft^2 \cdot hr} \right)^{0.41} * (1)^{0.5}}{\left(2186.1 \ \frac{lb}{ft^2 \cdot hr} \right)^{0.45}} = 2.15$$

$$HOG = 2.15 + \left[\left(\frac{1}{19.16} \right) * 1.08 \right] = 2.206 \text{ ft}$$

6. Determine the height of the column.

The height of the column is determined from the number of transfer units and the height of a transfer unit.

$$\text{Height (ft)} = (HOG * NOG) + 2 + (0.25 * \text{Diameter})$$

$$\text{Height (ft)} = (2.206 * 4.072) + 2 + (0.25 * 1.044)$$

$$= 11.24 \text{ ft}$$

7. Determine the pressure drop across the tower.

The pressure drop is related to the height of the tower, the liquid and vapor flow rates per cross-sectional area, and the liquid and vapor densities.

$$\text{Pressure Drop} = \frac{NOG * HOG * g * (10^{-8})}{5.2}$$

$$* (10)^{(r * L''/\rho L)} * \left(\frac{(G'')^2}{\rho_V}\right)$$

Where:

NOG	=	Number of Transfer Units
HOG	=	Height of a Transfer Unit (ft)
ρL	=	Density of the liquid (lb/ft^3)
ρV	=	Density of the vapor (lb/ft^3)
L"	=	Liquid Flow rate per Area ($lb/ft^2 \cdot hr$))
G"	=	Vapor Flow rate per Area ($lb/ft^2 \cdot hr$))
5.2	=	Conversion between lb/ft^2 and inches of H_2O

The values of g (11.13) and r (0.00295) are constants dependent on the tower design parameters.

$$\text{Pressure Drop} = \left(\frac{2.206 * 4.072}{5.2}\right) * 11.13 * (10^{-8}) *$$

$$(10)^{\left(\frac{0.00295 * 2186.1}{62.2}\right)} *$$

$$\left(\frac{(1140.48)^2}{0.0739}\right) = 4.30 \text{ inches } H_2O$$

8. Calculate the weight of the tower.

As explained in Section 3.1.2.2 of Volume 1B of the HON BID, the weight of the tower is dependent on the height and diameter of the tower.

$$\text{Weight} = (48 * \text{Diameter (ft)} * \text{Height (ft)}) + 39 * (\text{Diameter})^2$$

$$\text{Weight} = (48 * 1.044 * 11.24) + 39 * (1.044)^2 = 605.8 \text{ lb}$$

9. Calculate the capital cost of the scrubber.

The capital cost of the tower and associated equipment is calculated from the design parameters. All costs are reported in July 1989 dollars, except for total capital costs, total annual direct costs, total annual indirect costs, and total annual costs, which are also reported in August 1996 dollars.

$$\text{Tower Cost} = \left(1.900604 * \left(\frac{\text{wt (lb)}}{1000 \text{ lb}}\right)^{0.93839}\right) * \$1000 * \frac{\text{Cost Index}}{\$298.2}$$

$$\text{Tower Cost} = \left(1.900604 * \left(\frac{605.8 \text{ lb}}{1000 \text{ lb}}\right)^{0.93839}\right) * \$1000 * \frac{\$355.9}{\$298.2}$$

$$= \$1417.27$$

The volume of packing is needed to determine packing costs.

$$\text{Volume } (\text{ft}^3) = \pi * (\text{Radius (ft)})^2 * \text{HOG (ft)} * \text{NOG}$$

$$= \pi * \left(\frac{\text{Diameter (ft)}}{2}\right)^2 * \text{HOG (ft)} * \text{NOG}$$

$$= \pi * \left(\frac{1.044 \text{ (ft)}}{2}\right)^2 * (2.206) \text{ ft} * (4.072)$$

$$= 7.690 \text{ ft}^3$$

$$\text{Packing Cost} = \frac{\$9.7}{\text{ft}^3} * \frac{\$392.8}{\$324.4} * \text{Volume} = \$11.75 * 7.690 = \$90.36$$

The cost of the ducting and fans are based on 100 feet of 24-inch diameter ducting that is 1/8 inch thick carbon steel and has two elbows per 100 feet.

$$\text{Duct Cost} = [(210 * (24)^{0.839}) + (2 * 4.52 * (24)^{1.43})] * \left(\frac{\$355.9}{\$352.4}\right)$$

$$\text{Duct Cost} = \$3910.80$$

$$\text{Fan Cost} = 79.1239 * (24)^{0.5612} * \left(\frac{\$355.9}{\$342.5}\right) = \$489.27$$

The platform cost is dependent on the diameter of the column.

$$\text{Platform Cost} = [(10)^{(0.7884 * \ln (\text{diameter}) + 3.325)}] * \left(\frac{\$355.9}{\$298.2}\right)$$

$$= [(10)^{(0.7884 * \ln (1.044) + 3.325)}] * \left(\frac{\$355.9}{\$298.2}\right)$$

$$= \$2727.52$$

For consistency with the HON BID, the stack cost was assumed to be $5000.00. The basic equipment cost (BEC) is the sum of the tower, packing, duct, fan, platform, and stack cost.

$$\text{BEC} = \$1417.27 + \$90.36 + \$3910.80 + \$489.27 + \$2727.52 + \$5000.00 = \$13,635.22$$

The purchased equipment cost includes the BEC and instrumentation, freight, and sales tax.

$$\text{Instrumentation} = 0.1 * \text{BEC}$$

$$\text{Freight} = 0.05 * \text{BEC}$$

$$\text{Sales Tax} = 0.03 * \text{BEC}$$

$$\text{PEC} = 1.18 * \text{BEC} = 1.18 * \$13{,}635.22 = \$16{,}089.56$$

The total capital cost of the scrubber system incorporates an installation factor of 2.2.

$$\text{TCI} = 2.2 * \text{PEC} = 2.2 * \$16{,}089.56 = \$35{,}397.03$$

$$= \$37{,}992.15 \quad \text{(August 1996\$)}$$

<u>Scrubber Annual Cost</u>

1. Calculate the direct annual cost.

The direct annual cost associated with the scrubber includes the operating and supervisory labor costs, the maintenance material and labor costs, and the utility costs. It is assumed that the scrubber operates for 8,000 hours per year. Labor rates are reported in July 1989 dollars, except where noted otherwise.

1a. Calculate the operating and supervisory labor.

It is assumed that the supervisory labor cost is 15 percent of the operating labor cost.

$$\begin{matrix}\text{Operating/}\\ \text{Supervising}\\ \text{Labor}\end{matrix} = (1.15) * \left(\frac{0.5 \text{ hrs}}{8 \text{ hr shift}}\right) * \begin{matrix}\text{Operating}\\ \text{Hours}\\ \text{(hr/yr)}\end{matrix} * \begin{matrix}\text{Labor}\\ \text{Wage}\end{matrix}\left(\frac{\$}{\text{hr}}\right)$$

$$= 1.15 * \frac{0.5 \text{ hrs}}{8 \text{ hr}} * 8000 \frac{\text{hr}}{\text{yr}} * \frac{\$13.20}{\text{hr}}$$

$$= \$7590.00/\text{yr}$$

1b. Calculate the maintenance material and maintenance labor cost.

It is assumed that maintenance material is equal to maintenance labor.

$$\text{Maintenance} = \left(\frac{0.5\ \text{hr}}{8\ \text{hr shift}}\right) * \left(\begin{matrix}\text{Operating}\\ \text{Hours}\end{matrix}\ \frac{\text{hr}}{\text{yr}}\right) * \left(\begin{matrix}\text{Labor}\\ \text{Wage}\end{matrix}\ \frac{\$}{\text{yr}}\right)$$

$$= \left(\frac{0.5\ \text{hr}}{8\ \text{hr}}\right) * \left(8000\ \frac{\text{hr}}{\text{yr}}\right) * \left(\frac{\$14.50}{\text{hr}}\right)$$

Maintenance Labor	=	$7250.00/yr
Maintenance Material	=	$7250.00/yr

1c. Calculate utility costs.

The scrubber utility costs include water and electricity costs. The electricity costs depend on the vapor flow and pressure drop through the column.

$$\begin{matrix}\text{Water}\\ \text{Cost}\end{matrix} = \frac{\text{water (lb/hr)}}{8.34\ \text{(lb/gal)}} * \frac{\$0.22}{1000\ \text{gal}} * 8000\ \frac{\text{hr}}{\text{yr}}$$

$$= \frac{\left(103.96\ \frac{\text{lbmol}}{\text{hr}} * 18\ \frac{\text{lb}}{\text{lbmol}}\right)}{8.34\ \frac{\text{lb}}{\text{gal}}} * \frac{\$0.22}{1000\ \text{gal}} * 8000\ \frac{\text{hr}}{\text{yr}}$$

$$= \$394.90/\text{yr}$$

$$\begin{matrix}\text{Electricity}\\ \text{Cost}\end{matrix} = 0.0002 * \begin{matrix}\text{Vapor}\\ \text{Flow}\\ \text{Through}\\ \text{Scrubber}\\ \text{(SCFM)}\end{matrix} * \begin{matrix}\text{Pressure}\\ \text{Drop}\end{matrix}\ \text{(inches } H_2O) *$$

$$\begin{matrix}\text{Operating}\\ \text{Hours}\end{matrix}\left(\frac{\text{hr}}{\text{yr}}\right) * \frac{\$0.0509}{\text{KW} \cdot \text{hr}}$$

$$= 0.0002 * 220.0\ \text{SCFM} * 4.30\ \text{inches} *$$

$$8000\ \frac{\text{hr}}{\text{yr}} * \frac{\$0.0509}{\text{KW} \cdot \text{hr}}$$

$$= \$77.04/\text{yr}$$

The direct annual cost of the scrubber is the sum of the costs presented above.

Scrubber Direct Annual Cost = Operating Supv.Labor + Maintenance Labor and Materials + Utilities

= $7590.00 + $7250.00 + $7250.00 + $394.90 + $77.04

= $22,561.94/yr

= $24,216.06/yr (August 1996$)

2. Calculate the scrubber indirect annual cost.
The scrubber indirect annual costs include the overhead, taxes, insurance, administrative costs, and capital recovery.

2a. Calculate the overhead cost.
The overhead cost is a function of the operating and supervisory labor costs, and the maintenance labor and materials costs.

Overhead = (Operating/Supv. Labor + Maintenance Labor and Materials) * 0.6

= $7590.00 + $7250.00 + $7250.00) * 0.6

= $13,254.00/yr

2b. Calculate the taxes, insurance, and administrative costs, and the capital recovery costs. These costs are dependent on the total capital cost of the scrubber. Capital recovery isbased on equipment life of 10 years and an interest rate of 7 percent.

$$\text{Taxes} = 0.01 * \text{TCI}$$

$$\text{Insurance} = 0.01 * \text{TCI}$$

$$\text{Administration} = 0.02 * \text{TCI}$$

$$\text{Capital Recovery Cost} = 0.14245 * \text{TCI}$$

$$\text{Total Cost} = 0.18245 * \text{TCI} = 0.18245 * \$35{,}397.03$$

$$= \$6458.19/\text{yr}$$

The indirect annual cost is the sum of the above costs.

$$\text{Scrubber Annual Indirect Cost} = \text{Overhead} + \text{Taxes} + \text{Insurance} + \text{Administration} + \text{Capital Recovery}$$

$$= \$13{,}254.00 + \$6458.19 = \$19{,}712.19/\text{yr}$$

$$= \$21{,}157.38/\text{yr} \quad \text{(August 1996\$)}$$

The total annual cost of the scrubber is equal to the sum of the direct annual cost and the indirect annual cost.

$$\text{Scrubber Total Annual Cost} = \$22{,}561.94 + \$19{,}712.19 = \$42{,}274.13/\text{yr}$$

$$= \$45{,}373.44/\text{yr} \quad \text{(August 1996\$)}$$

nonepoxide HAP exhaust steams into a single 500 acfm stream for control purposes. The remaining 9 catalyst extraction model plants would control a single 250 acfm exhaust stream for nonepoxide HAP emissions from the finishing process.

ATTACHMENT 5

CALCULATION OF FLARE COSTS

Calculation Methodology Description

Flare Costs

The OCCM spreadsheet was used to calculate the flare costs for process vents at large model plants (oxide emissions only) and catalyst extraction model plants (oxide and nonepoxide HAP emissions). The process vent exhaust stream characteristics (e.g., flow rate and pollutant concentration) were determined from the Section 114 questionnaire responses and is discussed further in the model plant section of the memorandum.

The average flow rate of the process vent exhaust streams reported in the Section 114 questionnaire responses was 250 actual cubic feet per minute (acfm). However, the flow rate entered into the spreadsheet must be the flow at the flare tip. As suggested in the OCCM, the exhaust pressure at the collection point (1 atmosphere, gauge)is assumed to drop to 1 psig at the flare tip. Accounting for this pressure drop reduces the flow from 250 acfm to 17.0 acfm, which is the value entered into the spreadsheet. All other spreadsheet input parameters were based on physical property data or were taken from tables in the OCCM.

It was assumed that all process vent exhaust streams are collected into a single stream for control purposes (this stream is represented by the 250 acfm exhaust stream discussed above). Catalyst extraction model plants, however, have oxide emissions from process vents and nonepoxide HAP emissions from the finishing steps. For cost purposes, it was assumed that the nonepoxide HAP emissions constitute another 250 acfm exhaust stream.

The EPA database was used to determine the number of facilities already achieving the level of control specified in the regulation for nonepoxide HAP emissions (90 percent control) (see Attachment 1 for a discussion of oxide emissions from process vents). Of the 9 facilities reporting nonepoxide HAP emissions, 2 facilities (22 percent) were achieving 90 percent control or greater.

The number of uncontrolled catalyst extraction model plants was then calculated. The total number of catalyst extraction model plants (19) was multiplied by the fraction of facilities control at a level below the standard (78 percent):

(19 facilities)x(0.78) = 15 model plants with uncontrolled nonepoxide HAP emissions

In Attachment 1, it was shown that there are 6 catalyst extraction model plants which will require controls for oxide emissions from process vents. The flare costing procedure assumed that these 6 facilities combined the oxide and

TOTAL ANNUAL COST SPREADSHEET PROGRAM--FLARES [1]

SMALL FACILITY WITH A PRODUCTION RATE OF 50 MM lbs/yr

COST BASE DATE: March 1990 [2]

VAPCCI (Third Quarter 1995): [3]

INPUT PARAMETERS

– Vent flowrate (acfm):	17.0
(lb/hr):	1114.9
– Vent heat content (BTU/scf):	8.0
– Fuel heat content (BTU/scf):	1000
– Inlet gas temperature (oF):	150
– Vent stream density (lb/scf):	0.08446
– System pressure (psig):	14.70
– Liquid density (lb/ft3):	51.74

DESIGN PARAMETERS

– Gas velocity, max. (ft/sec):	60.00
– Auxil. fuel requirement (scfm):	7.09
– Total gas flowrate (scfm):	24.1
– Flare tip diameter (in):	1.24
– Heat release rate (BTU/hr):	105603
– Flare height (ft):	1.8
– KO drum max. velocity (ft/sec):	4.95
– KO drum min. diameter (in):	3.2
– KO drum height (in):	9.7
– KO drum thickness (in):	0.25
– No. of pilot burners:	1

CAPITAL COSTS

Equipment Costs ($):

– Flare/self-supported:	8,220
– Flare/guy-supported:	0
– Flare/derrick-supported:	0
Minimum flare cost:	8,220
Knockout drum cost:	78
– Total equipment (base):	8,298
' ' (escalated):	9,880
Purchased Equipment Cost ($):	11,658
Total Capital Investment ($):	22,383

ANNUAL COST INPUTS

Operating factor (hr/yr):	8760
Operating labor rate ($/hr):	16
Maintenance labor rate ($/hr):	17.20
Operating labor factor (hr/yr):	630
Maintenance labor factor (hr/sh):	0.5
Steam price ($/1000 lb):	4.65
Natural gas price ($/mscf):	3.03
Annual interest rate (fraction):	0.07
Control system life (years):	15
Capital recovery factor:	0.1098
Taxes, insurance, admin. factor:	0.04

ANNUAL COSTS

Item	Cost ($/yr)	Wt. Factor	W.F.(cond.)
Operating labor	9,853	0.137	—
Supervisory labor	1,478	0.021	—
Maintenance labor	9,419	0.131	—
Maintenance materials	9,419	0.131	—
Natural gas	1,889	0.026	—
Steam	18,166	0.253	—
Overhead	18,102	0.253	0.673
Taxes, insurance, administrative	895	0.012	—
Capital recovery	2,458	0.034	0.047
Total Annual Cost (July 1995$)	71,679	1.000	1.000

Costs Revised to August 1996 Dollars:

Total Capital Investment:	$22,425
Total Annual Direct Costs:	$50,317
Total Annual Indirect Costs:	$21,494
Total Annual Costs:	$71,811

[1] Data used to develop this spreadsheet were taken from Chapter 7 of the 'OAQPS Control Cost Manual' (4th edition).

[2] Base equipment costs reflect this date.

[3] VAPCCI = Vatavuk Air Pollution Control Cost Index (for flares) corresponding to year and quarter shown. Base equipment cost, purchased equipment cost, and total capital investment have been escalated to this date via the VAPCCI and control equipment vendor data.

TOTAL ANNUAL COST SPREADSHEET PROGRAM--FLARES [1]

SMALL FACILITY WITH A PRODUCTION RATE OF 50 MM lbs/yr

COST BASE DATE: March 1990 [2]

VAPCCI (Third Quarter 1995): [3]

INPUT PARAMETERS

– Vent flowrate (acfm):	34.0
(lb/hr):	2044.8
– Vent heat content (BTU/scf):	8.0
– Fuel heat content (BTU/scf):	1000
– Inlet gas temperature (oF):	150
– Vent stream density (lb/scf):	0.08446
– System pressure (psig):	14.70
– Liquid density (lb/ft3):	51.74

DESIGN PARAMETERS

– Gas velocity, max. (ft/sec):	60.00
– Auxil. fuel requirement (scfm):	14.18
– Total gas flowrate (scfm):	48.2
– Flare tip diameter (in):	1.75
– Heat release rate (BTU/hr):	193682
– Flare height (ft):	2.5
– KO drum max. velocity (ft/sec):	4.95
– KO drum min. diameter (in):	4.6
– KO drum height (in):	13.7
– KO drum thickness (in):	0.25
– No. of pilot burners:	1

CAPITAL COSTS

Equipment Costs ($):

– Flare/self-supported:	9,184
– Flare/guy-supported:	0
– Flare/derrick-supported:	0
Minimum flare cost:	9,184
Knockout drum cost:	129
– Total equipment (base):	9,313
" " (escalated):	11,088
Purchased Equipment Cost ($):	13,084
Total Capital Investment ($):	25,121

ANNUAL COST INPUTS

Operating factor (hr/yr):	8760
Operating labor rate ($/hr):	16
Maintenance labor rate ($/hr):	17.20
Operating labor factor (hr/yr):	630
Maintenance labor factor (hr/sh):	0.5
Steam price ($/1000 lb):	4.65
Natural gas price ($/mscf):	3.03
Annual interest rate (fraction):	0.07
Control system life (years):	15
Capital recovery factor:	0.1098
Taxes, insurance, admin. factor:	0.04

ANNUAL COSTS

Item	Cost ($/yr)	Wt. Factor	W.F.(cond.)
Operating labor	9,853	0.113	—
Supervisory labor	1,478	0.017	—
Maintenance labor	9,419	0.108	—
Maintenance materials	9,419	0.108	—
Natural gas	1,921	0.022	—
Steam	33,317	0.382	—
Overhead	18,102	0.207	0.553
Taxes, insurance, administrative	1,005	0.012	—
Capital recovery	2,758	0.032	0.043
Total Annual Cost (July 1995$)	87,272	1.000	1.000

Costs Revised to August 1996 Dollars:

Total Capital Investment:	$25,167
Total Annual Direct Costs:	$65,528
Total Annual Indirect Costs:	$21,905
Total Annual Costs:	$87,433

[1] Data used to develop this spreadsheet were taken from Chapter 7 of the 'OAQPS Control Cost Manual' (4th edition).

[2] Base equipment costs reflect this date.

[3] VAPCCI = Vatavuk Air Pollution Control Cost Index (for flares) corresponding to year and quarter shown. Base equipment cost, purchased equipment cost, and total capital investment have been escalated to this date via the VAPCCI and control equipment vendor data.

ATTACHMENT 6

CALCULATION OF STORAGE TANK CONTROL COSTS

Calculation Methodology Description

Storage Tank Control Costs

The responses to the EPA/SPI questionnaires were used to determine the following parameters for the uncontrolled fixed-roof tanks: size, throughput, number per facility, and chemical stored. In addition, the EPA's TANKS3 program (see Attachment 1) was used to determine the emission reduction.

Of the 12 facilities that reported information on storage tanks, 3 had uncontrolled fixed-roof tanks large enough to be covered by proposed regulation. An analysis of the information supplied by these 3 facilities showed that there was no general trend that related the size and throughput of the tanks with the size of the facility. Therefore, a single "model tank" for use with all three model plants was developed.

The average tank volume was 38,667 gallons, with a throughput of 134,500 gallons. As none of the facilities reported more than one uncontrolled fixed-roof tank, it was assumed that there was only one such tank per model plant. Hexane was used as the chemical stored in the model tank.

The following procedure for calculating the cost of adding an internal floating roof to a fixed-roof tank was taken from Volume 1B of the HON BID.

COSTS FOR THE INSTALLATION OF AN INTERNAL FLOATING ROOF IN A FIXED-ROOF TANK

The following calculations are used to estimate the total annual cost for the installation and operation of an internal floating roof in an existing fixed-roof tank.

The model tank stores toluene and has a capacity of 38,667 gallons. Additional design parameters for the example tank are presented in Table 1. The internal floating roof, installed in this model tank, will have a liquid-mounted primary seal and controlled deck fittings.

1. Before an internal floating roof can be installed in the example tank, the tank must be cleaned and degassed. The cost for cleaning and degassing a tank (cstdegas) is based on its capacity.

$$\text{Cstdegas} = 7.61\ (\$/\text{gal}) * [\text{tank_size, gal}]^{0.5132}$$
$$\text{Cstdegas} = 7.61 * [38{,}667\ \text{gal}]^{0.5132}$$
$$\text{Cstdegas} = \$1{,}720 \text{ per tank}$$

2. Determine the installed capital cost for a new internal floating roof (cstroof) having a primary liquid-mounted seal and controlled deck fittings.

$$\text{Cstroof} = [509\ (\$/\text{ft}) * \text{tank_dia(ft)}] + 1160\ (\$)$$
$$\text{Cstroof} = [509\ (\$/\text{ft}) * 23.6\ (\text{ft})] + 1160\ (\$)$$
$$\text{Cstroof} = \$13{,}172$$

3. The total capital investment (TCI) for the installation of an internal floating roof in the model tank is the sum of the tank preparation costs and the installed capital cost for the roof.

$$\text{Total capital investment (TCI)} = \text{Tank cleaning and degassing cost} + \text{Installed capital cost for floating roof}$$

$$\text{TCI (July 1989\$)} = \$1{,}720 + \$13{,}172$$

$$\text{TCI (July 1989\$)} = \$14{,}892$$

$$\text{TCI (August 1996\$)} = \$15{,}984$$

4. Indirect annual costs (ann_fix) are estimated as a percentage of the total capital investment (TCI) and include capital recovery; maintenance charges (5 percent); inspection charges (1 percent); and taxes, insurance, and administrative charges (4 percent). The capital recovery factor (0.14245) is based on 7 percent interest over 10 years.

$$\text{ann_fix (July 1989\$)} = \$14{,}892 * [0.14245 + 0.05 + 0.01 + 0.04]$$

$$\text{Indirect Annual Cost (July 1989\$)} = \$3{,}611/\text{yr}$$

$$\text{Indirect Annual Cost (August 1996\$)} = \$3{,}876/\text{yr}$$

5. The direct annual cost (ann_var) is a cost savings equal to the value of the recovered product. This product recovery credit is based on the HAP emission reduction achieved by the internal floating roof and the market value of the HAP.

$$\begin{matrix}\text{Direct Annual} \\ \text{Cost} \\ \text{(August 1996 \$)}\end{matrix} = \begin{matrix}\text{HAP emissions} \\ \text{reduction} \\ \text{(Mg/yr)}\end{matrix} * \begin{bmatrix}\text{-Average market} \\ \text{value of HAP} \\ \text{(\$/Mg)}\end{bmatrix}$$

$$\text{ann_var} = 0.62\ (\text{Mg/yr}) * [-0.40\ (\$/\text{kg})] * 1{,}000\ (\text{kg/Mg})$$

$$\text{Direct Annual Cost (August 1996\$)} = -\$248/\text{yr}$$

6. The total annual cost (TAC) for the installation and operation of an internal floating roof is the sum of the indirect annual cost and direct annual cost.

$$\text{Total annual cost} = \text{Indirect annual cost} + \text{Direct annual cost}$$

$$\text{Total annual cost (August 1996\$)} = \$3{,}876 + [-\$248]$$

$$\text{Total annual cost (August 1996\$)} = \$3{,}628/\text{yr}$$

TABLE 1. MODEL TANK DESIGN PARAMETERS

Parameter Description	Units	Value
Tank capacity (tank_size)	gal	38,667
Annual tank throughput	gal/yr	134,500
Tank orientation and type	---	vertical fixed roof
Tank diameter (tank_dia)	feet	23.6
Tank height	feet	11.8
Average tank vapor space height	feet	5.9
Adjustment factor for small diameter tanks	dimensionless	1.0
Tank paint factor - white roof and aluminum color shell	dimensionless	1.3
Average ambient diurnal temperature change	^{o}F	20
Product factor - organic liquid other than crude oil	dimensionless	1.0
Stored product - HAP	---	hexane
Product molecular weight	lb/lb mol	86.17
Product specific gravity	---	0.659
Product vapor pressure at 25 ^{o}C	mmHg psia	151.3 2.92
Product Antoine coefficients		
A	dimensionless	6.87776
B	dimensionless	1171.530
C	dimensionless	224.366
Product average market price	August 1996$/kg	0.40

ATTACHMENT 7

CALCULATION OF EQUIPMENT LEAK COSTS

SMALL MODEL PLANT
UNCONTROLLED COMPONENTS FOR LDAR PROGRAM

Equipment Type	Total Number	Total with HON Level of Control	Total with HON Equivalent Control	Total Number Uncontrolled	Average Number Uncontrolled
Compressors	1	0	0	1	1
Open-ended Lines	0	0	0	0	0
Sampling Connections	25	0	2	24	12
Pressure Relief Devices	25	0	10	15	8
Valves in Vapor Service	695	56	389	250	125
Valves in Light Liquid Service	690	14	345	331	166
Pumps in Light Liquid Service	8	1	3	4	2
Connectors	3716	1152	1747	818	409

SMALL MODEL PLANT
UNCONTROLLED COMPONENTS FOR LDAR PROGRAM

Equipment Type	Total Number	Total with HON Level of Control	Total with HON Equivalent Control	Total Number Uncontrolled	Average Number Uncontrolled
Compressors	1	0	0	1	1
Open-ended Lines	0	0	0	0	0
Sampling Connections	25	0	2	24	12
Pressure Relief Devices	25	0	10	15	8
Valves in Vapor Service	695	56	389	250	125
Valves in Light Liquid Service	690	14	345	331	166
Pumps in Light Liquid Service	8	1	3	4	2
Connectors	3716	1152	1747	818	409

SMALL MODEL PLANT
INPUT TABLE FOR LDAR PROGRAM COSTS

Equipment Type	Total Uncontrolled
Compressors	1
Open-ended Lines	0
Sampling Connections	12
Pressure Relief Devices	8
Valves in Gas/Vapor Service	125
Valves in Light Liquid Service	166
Pump Seals in Light Liquid Service	2
Connectors	409
Total Components	723

Control Equipment	Base Cost (July 1989$)
Monitoring Instrument	6,500
Replacement Pump Seal	180
Compressor	6,240
Pressure Relief Device	
Rupture Disk	78
Holders, Valves, Installation, etc.	3,852
Open-ended Lines	102
Sample Connections	408

Initial Leak Detection and Repair Program	Value
Monitoring Fee ($/component)	2.5
Initial Leak Frequency (fraction)	
Valves in Gas/Vapor Service	0.114
Valves in Light Liquid Service	0.065
Pump Seals in Light Liquid Service	0.2
Connectors	0.021
Leaks Requiring Further Repair	
Valves	0.25
Connectors	0.25
Pumps	0.75
Hours for Repairs	
Valves	4
Pumps	16
Connectors	2

SMALL MODEL PLANT
INPUT TABLE FOR LDAR PROGRAM COSTS

Annual Leak Detection and Repair Program	Value
Monitoring Fee ($/component)	2
Additional Pump Monitoring Time (hr)	0.0083
Initial Leak Frequency (fraction)	
Valves in Gas/Vapor Service	0.02
Valves in Light Liquid Service	0.02
Pump Seals in Light Liquid Service	0.1
Connectors	0.005
Leaks Requiring Further Repair	
Valves	0.25
Connectors	0.25
Pumps	0.75

Maintenance Program	Value
Calibration/Maintenance for Monitoring Instrument (July 1989$)	$4,280.00
Annual Maintenance Charge for Compressors, Pressure Relief Devices, Open-ended Lines, and Sampling Connections (percent of capital costs)	5
Replacement Pump Seal Cost (July 1989$)	$180.00
Miscellaneous Charges for Compressors, Pressure Relief Devices, Open-ended Lines, and Sampling Connections (percent of capital costs)	4
Miscellaneous Charges for Pump Seals (percent of capital costs)	80

Economic Data	Value
Interest Rate	0.07
Economic Life (years)	
Pump Seals	2
Rupture Disks	2
Monitoring Instrument	6
All Other Equipment	10
CRF Values	
2 Years	0.5531
6 Years	0.2099
10 Years	0.1425
Chemical Engineering Plant Cost Index	
July 1989	356.0
August 1996	382.1
Recovery Credit	
Average Emission Reduction (Mg/yr)	5.2
Raw Material Cost (July 1989$/Mg)	$1,164
Labor Rate ($/hour)	$22.50

SMALL MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

Initial Repair, Leaks Found

Gas/Vapor Valves							
125 gas/vapor valves	x	0.114 leaks/valve		=	14.3 leaks		
Light Liquid Valves							
166 light liquid valve	x	0.065 leaks/valve		=	10.8 leaks		
Light Liquid Pumps							
2 light liquid pumps	x	0.200 leaks/pump		=	0.4 leaks		
Connectors							
409 connectors	x	0.021 leaks/connector		=	8.6 leaks		
Leaks Requiring Repair							
Gas/Vapor Valves							
14.25 gas/vapor valves	x	0.25		=	3.6 leaks		
Light Liquid Valves							
10.79 light liquid valve	x	0.25		=	2.7 leaks		
Light Liquid Pumps							
0.4 light liquid pumps	x	0.75		=	0.3 leaks		
Connectors							
8.589 connectors	x	0.25		=	2.1 leaks		
Repair Costs							
Gas/Vapor Valves							
3.563 leaks	x	4 hours/leak	x	$22.50 /hour		=	$320.63
Light Liquid Valves							
2.698 leaks		4 hours/leak	x	$22.50 /hour		=	$242.78
Light Liquid Pumps							
0.3 leaks		16 hours/leak	x	$22.50 /hour		=	$108.00
Connectors							
2.147 leaks		2 hours/leak	x	$22.50 /hour		=	$96.63
TOTAL REPAIR COSTS							$768.03
TOTAL INITIAL LDAR COSTS (MONITORING + REPAIR)							$2,523.03

SMALL MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

Initial Repair, Leaks Found

Gas/Vapor Valves							
125 gas/vapor valves	x	0.114 leaks/valve		=	14.3 leaks		
Light Liquid Valves							
166 light liquid valve	x	0.065 leaks/valve		=	10.8 leaks		
Light Liquid Pumps							
2 light liquid pumps	x	0.200 leaks/pump		=	0.4 leaks		
Connectors							
409 connectors	x	0.021 leaks/connector		=	8.6 leaks		
Leaks Requiring Repair							
Gas/Vapor Valves							
14.25 gas/vapor valves	x	0.25		=	3.6 leaks		
Light Liquid Valves							
10.79 light liquid valve	x	0.25		=	2.7 leaks		
Light Liquid Pumps							
0.4 light liquid pumps	x	0.75		=	0.3 leaks		
Connectors							
8.589 connectors	x	0.25		=	2.1 leaks		
Repair Costs							
Gas/Vapor Valves							
3.563 leaks	x	4 hours/leak	x	$22.50 /hour		=	$320.63
Light Liquid Valves							
2.698 leaks		4 hours/leak	x	$22.50 /hour		=	$242.78
Light Liquid Pumps							
0.3 leaks		16 hours/leak	x	$22.50 /hour		=	$108.00
Connectors							
2.147 leaks		2 hours/leak	x	$22.50 /hour		=	$96.63
TOTAL REPAIR COSTS							$768.03
TOTAL INITIAL LDAR COSTS (MONITORING + REPAIR)							$2,523.03

SMALL MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

ANNUAL LEAK DETECTION AND REPAIR

Monitoring Costs

Gas/Vapor Valves							
125 gas/vapor valves	x	12 times/year	x	$2.00 /time/valve	=	$3,000.00	
Light Liquid Valves							
166 light liquid valves	x	12 times/year	x	$2.00 /time/valve	=	$3,984.00	
Light Liquid Pumps							
2 light liquid pumps	x	12 times/year	x	$2.00 /time/valve	=	$48.00	
Connectors							
409 connectors	x	12 times/year	x	$2.00 /time/valve	=	$9,816.00	
Pressure Relief Valves							
8 pressure relief valves	x	1 time/year	x	$2.00 /time/valve	=	$16.00	
Pumps (visual)							
2 pumps	x	52 times/year	x	0.0083 hour/time			
	x	$22.50 /hour			=	$19.42	
TOTAL MONITORING COSTS						$16,883.42	

Annual Leaks Found

Gas/Vapor Valves							
125 gas/vapor valves	x	12 times/year	x	0.02 leaks/valve	=	30.0	leaks
Light Liquid Valves							
166 light liquid valves	x	12 times/year	x	0.02 leaks/valve	=	39.8	leaks
Light Liquid Pumps							
2 light liquid pumps	x	12 times/year	x	0.10 leaks/pump	=	2.4	leaks
Connectors							
409 connectors	x	12 times/year	x	0.005 leaks/conn.	=	24.5	leaks

SMALL MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

Leaks Requiring Repair

Gas/Vapor Valves						
30 gas/vapor valves	x	0.25	=	7.5 leaks		
Light Liquid Valves						
39.84 light liquid valves	x	0.25	=	10.0 leaks		
Light Liquid Pumps						
2.4 light liquid pumps	x	0.75	=	1.8 leaks		
Connectors						
24.54 connectors	x	0.25	=	6.1 leaks		

Cost of Repairs

Gas/Vapor Valves						
7.5 leaks	x	4 hours/leak	x	$22.50 /hour	=	$675.00
Light Liquid Valves						
9.96 leaks	x	4 hours/leak	x	$22.50 /hour	=	$896.40
Light Liquid Pumps						
1.8 leaks	x	16 hours/leak	x	$22.50 /hour	=	$648.00
Connectors						
6.135 leaks	x	2 hours/leak	x	$22.50 /hour	=	$276.08
TOTAL REPAIR COSTS						$2,495.48
TOTAL ANNUAL LDAR COSTS (MONITORING + REPAIR)						$19,378.90

SMALL MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

Sample Connections					
	$4,896.00	x	0.05	=	$244.80
Replacement Pump Seals					
	$180.00	x	1.8	=	$324.00
TOTAL ANNUAL MAINTENANCE COSTS					$6,732.80

MISCELLANEOUS ANNUAL CHARGES

Monitoring Instrument					
	$6,500.00	x	0.04	=	$260.00
Compressors					
	$6,240.00	x	0.04	=	$249.60
Rupture Disks					
	$624.00	x	0.04	=	$24.96
Holders, Valves, Etc.					
	$30,816.00	x	0.04	=	$1,232.64
Sample Connections					
	$4,896.00	x	0.04	=	$195.84
Replacement Pump Seals					
	$324.00	x	0.80	=	$259.20
TOTAL MISCELLANEOUS ANNUAL CHARGES					$2,222.24

LABOR CHARGES

Monitoring Cost				=	$16,883.42
Repair Costs				=	$2,495.48
Administration and Support					
	$19,378.90	x	0.40	=	$7,751.56
TOTAL LABOR CHARGES					$27,130.46

SMALL MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

Sample Connections					
	$4,896.00	x	0.05	=	$244.80
Replacement Pump Seals					
	$180.00	x	1.8	=	$324.00
TOTAL ANNUAL MAINTENANCE COSTS					$6,732.80

MISCELLANEOUS ANNUAL CHARGES

Monitoring Instrument					
	$6,500.00	x	0.04	=	$260.00
Compressors					
	$6,240.00	x	0.04	=	$249.60
Rupture Disks					
	$624.00	x	0.04	=	$24.96
Holders, Valves, Etc.					
	$30,816.00	x	0.04	=	$1,232.64
Sample Connections					
	$4,896.00	x	0.04	=	$195.84
Replacement Pump Seals					
	$324.00	x	0.80	=	$259.20
TOTAL MISCELLANEOUS ANNUAL CHARGES					$2,222.24

LABOR CHARGES

Monitoring Cost				=	$16,883.42
Repair Costs				=	$2,495.48
Administration and Support					
	$19,378.90	x	0.40	=	$7,751.56
TOTAL LABOR CHARGES					$27,130.46

SMALL MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

ANNUAL COSTS

Annualized Capital Charges	=	$8,220.86
Annual Operating Costs (Maintenance + Miscellaneous Charges)	=	$8,955.04
Annual Labor Costs	=	$27,130.46
ANNUAL COSTS (July 1989$)		$44,306.35
ANNUAL COSTS (August 1996$)		$47,554.65

CREDIT DUE TO EMISSION REDUCTION

5.2 Mg/yr x $1,164.00 /Mg = $27,133.60

TOTAL ANNUAL COSTS

TOTAL ANNUAL COSTS = ANNUAL COSTS - EMISSION REDUCTION CREDIT

TOTAL ANNUAL COSTS (August 1996$) = $20,421.05

Annual Cost per MMlb Capacity (based on a capacity of 50 MMlb/yr) $408.42 /MMlb

LARGE MODEL PLANT
UNCONTROLLED COMPONENTS FOR LDAR PROGRAM

Equipment Type	Total Number	Total with HON Level of Control	Total with HON Equivalent Control	Total Number Uncontrolled	Average Number Uncontrolled
Compressors	3	0	0	3	1
Open-ended Lines	85	0	58	27	7
Sampling Connections	10	0	1	9	2
Pressure Relief Devices	71	0	28	43	11
Valves in Vapor Service	36	3	20	13	3
Valves in Light Liquid Service	3270	65	1635	1570	392
Pumps in Light Liquid Service	72	13	9	50	13
Connectors	7005	2172	3292	1541	385

LARGE MODEL PLANT
INPUT TABLE FOR LDAR PROGRAM COSTS

Equipment Type	Total Uncontrolled
Compressors	1
Open-ended Lines	7
Sampling Connections	2
Pressure Relief Devices	11
Valves in Gas/Vapor Service	3
Valves in Light Liquid Service	392
Pump Seals in Light Liquid Service	13
Connectors	385
Total Components	814

Control Equipment	Base Cost (July 1989$)
Monitoring Instrument	6,500
Replacement Pump Seal	180
Compressor	6,240
Pressure Relief Device	
Rupture Disk	78
Holders, Valves, Installation, etc.	3,852
Open-ended Lines	102
Sample Connections	408

Initial Leak Detection and Repair Program	Value
Monitoring Fee ($/component)	2.5
Initial Leak Frequency (fraction)	
Valves in Gas/Vapor Service	0.114
Valves in Light Liquid Service	0.065
Pump Seals in Light Liquid Service	0.2
Connectors	0.021
Leaks Requiring Further Repair	
Valves	0.25
Connectors	0.25
Pumps	0.75
Hours for Repairs	
Valves	4
Pumps	16
Connectors	2

LARGE MODEL PLANT
INPUT TABLE FOR LDAR PROGRAM COSTS

Annual Leak Detection and Repair Program	Value
Monitoring Fee ($/component)	2
Additional Pump Monitoring Time (hr)	0.0083
Initial Leak Frequency (fraction)	
Valves in Gas/Vapor Service	0.02
Valves in Light Liquid Service	0.02
Pump Seals in Light Liquid Service	0.1
Connectors	0.005
Leaks Requiring Further Repair	
Valves	0.25
Connectors	0.25
Pumps	0.75

Maintenance Program	Value
Calibration/Maintenance for Monitoring Instrument (July 1989$)	$4,280.00
Annual Maintenance Charge for Compressors, Pressure Relief Devices, Open-ended Lines, and Sampling Connections (percent of capital costs)	5
Replacement Pump Seal Cost (July 1989$)	$180.00
Miscellaneous Charges for Compressors, Pressure Relief Devices, Open-ended Lines, and Sampling Connections (percent of capital costs)	4
Miscellaneous Charges for Pump Seals (percent of capital costs)	80

Economic Data	Value
Interest Rate	0.07
Economic Life (years)	
Pump Seals	2
Rupture Disks	2
Monitoring Instrument	6
All Other Equipment	10
CRF Values	
2 Years	0.5531
6 Years	0.2099
10 Years	0.1425
Chemical Engineering Plant Cost Index	
July 1989	356.0
August 1996	382.1
Recovery Credit	
Average Emission Reduction (Mg/yr)	20.9
Raw Material Cost (July 1989$/Mg)	$1,164
Labor Rate ($/hour)	$22.50

LARGE MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

CAPITAL COSTS

Monitoring Instrument					$6,500.00
Compressors					
1 compressors	x	$6,240.00	/compressor	=	$6,240.00
Pressure Relief Devices					
11 rupture disks	x	$78.00	/rupture disk	=	$858.00
11 holders, valves, etc	x	$3,852.00	/holder, valve, etc	=	$42,372.00
Sample Connections					
2 sample connections	x	$408.00	/sample connection	=	$816.00
Open-ended Lines					
7 open-ended lines	x	$102.00	/open-ended line	=	$714.00
TOTAL CAPITAL COSTS					$57,500.00

INITIAL MONITORING AND LEAK REPAIR

Monitoring

Gas/Vapor Valves					
3 gas/vapor valves	x	$2.50	/component	=	$7.50
Light Liquid Valves					
392 light liquid valve	x	$2.50	/component	=	$980.00
Light Liquid Pumps					
13 light liquid pumps	x	$2.50	/component	=	$32.50
Connectors					
385 connectors	x	$2.50	/component	=	$962.50
TOTAL MONITORING COSTS					$1,982.50

LARGE MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

Initial Repair, Leaks Found

Gas/Vapor Valves					
3 gas/vapor valves	x	0.114 leaks/valve	=	0.3 leaks	
Light Liquid Valves					
392 light liquid valve	x	0.065 leaks/valve	=	25.5 leaks	
Light Liquid Pumps					
13 light liquid pumps	x	0.200 leaks/pump	=	2.6 leaks	
Connectors					
385 connectors	x	0.021 leaks/connector	=	8.1 leaks	
Leaks Requiring Repair					
Gas/Vapor Valves					
0.342 gas/vapor valves	x	0.25	=	0.1 leaks	
Light Liquid Valves					
25.48 light liquid valve	x	0.25	=	6.4 leaks	
Light Liquid Pumps					
2.6 light liquid pumps	x	0.75	=	2.0 leaks	
Connectors					
8.085 connectors	x	0.25	=	2.0 leaks	
Repair Costs					
Gas/Vapor Valves					
0.086 leaks	x	4 hours/leak	x	$22.50 /hour	= $7.70
Light Liquid Valves					
6.37 leaks		4 hours/leak	x	$22.50 /hour	= $573.30
Light Liquid Pumps					
1.95 leaks		16 hours/leak	x	$22.50 /hour	= $702.00
Connectors					
2.021 leaks		2 hours/leak	x	$22.50 /hour	= $90.96
TOTAL REPAIR COSTS					$1,373.95
TOTAL INITIAL LDAR COSTS (MONITORING + REPAIR)					$3,356.45

LARGE MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

ANNUAL LEAK DETECTION AND REPAIR

Monitoring Costs

Gas/Vapor Valves								
3 gas/vapor valves	x	12	times/year	x	$2.00	/time/valve	=	$72.00
Light Liquid Valves								
392 light liquid valves	x	12	times/year	x	$2.00	/time/valve	=	$9,408.00
Light Liquid Pumps								
13 light liquid pumps	x	12	times/year	x	$2.00	/time/valve	=	$312.00
Connectors								
385 connectors	x	12	times/year	x	$2.00	/time/valve	=	$9,240.00
Pressure Relief Valves								
11 pressure relief valves	x	1	time/year	x	$2.00	/time/valve	=	$22.00
Pumps (visual)								
13 pumps	x	52	times/year	x	0.0083	hour/time		
	x	$22.50	/hour				=	$126.24
TOTAL MONITORING COSTS								$19,180.24

Annual Leaks Found

Gas/Vapor Valves								
3 gas/vapor valves	x	12	times/year	x	0.02	leaks/valve	=	0.7 leaks
Light Liquid Valves								
392 light liquid valves	x	12	times/year	x	0.02	leaks/valve	=	94.1 leaks
Light Liquid Pumps								
13 light liquid pumps	x	12	times/year	x	0.10	leaks/pump	=	15.6 leaks
Connectors								
385 connectors	x	12	times/year	x	0.005	leaks/conn.	=	23.1 leaks

LARGE MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

Leaks Requiring Repair

Gas/Vapor Valves					
0.72 gas/vapor valves	x	0.25	=	0.2 leaks	
Light Liquid Valves					
94.08 light liquid valves	x	0.25	=	23.5 leaks	
Light Liquid Pumps					
15.6 light liquid pumps	x	0.75	=	11.7 leaks	
Connectors					
23.1 connectors	x	0.25	=	5.8 leaks	

Cost of Repairs

Gas/Vapor Valves						
0.18 leaks	x	4 hours/leak	x	$22.50 /hour	=	$16.20
Light Liquid Valves						
23.52 leaks	x	4 hours/leak	x	$22.50 /hour	=	$2,116.80
Light Liquid Pumps						
11.7 leaks	x	16 hours/leak	x	$22.50 /hour	=	$4,212.00
Connectors						
5.775 leaks	x	2 hours/leak	x	$22.50 /hour	=	$259.88

TOTAL REPAIR COSTS $6,604.88

TOTAL ANNUAL LDAR COSTS (MONITORING + REPAIR) $25,785.12

LARGE MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

Replacement Pump Seals				
	$180.00 x	11.7	=	$2,106.00
TOTAL ANNUAL MAINTENANCE COSTS				$8,936.00

MISCELLANEOUS ANNUAL CHARGES

Monitoring Instrument				
	$6,500.00 x	0.04	=	$260.00
Compressors				
	$6,240.00 x	0.04	=	$249.60
Rupture Disks				
	$858.00 x	0.04	=	$34.32
Holders, Valves, Etc.				
	$42,372.00 x	0.04	=	$1,694.88
Sample Connections				
	$816.00 x	0.04	=	$32.64
Replacement Pump Seals				
	$2,106.00 x	0.80	=	$1,684.80
TOTAL MISCELLANEOUS ANNUAL CHARGES				$3,956.24

LABOR CHARGES

Monitoring Cost			=	$19,180.24
Repair Costs			=	$6,604.88
Administration and Support				
	$25,785.12 x	0.40	=	$10,314.05
TOTAL LABOR CHARGES				$36,099.17

LARGE MODEL PLANT
LEAK DETECTION AND REPAIR ANNUAL COSTS

Replacement Pump Seals				
	$180.00 x	11.7	=	$2,106.00
TOTAL ANNUAL MAINTENANCE COSTS				$8,936.00

MISCELLANEOUS ANNUAL CHARGES

Monitoring Instrument				
	$6,500.00 x	0.04	=	$260.00
Compressors				
	$6,240.00 x	0.04	=	$249.60
Rupture Disks				
	$858.00 x	0.04	=	$34.32
Holders, Valves, Etc.				
	$42,372.00 x	0.04	=	$1,694.88
Sample Connections				
	$816.00 x	0.04	=	$32.64
Replacement Pump Seals				
	$2,106.00 x	0.80	=	$1,684.80
TOTAL MISCELLANEOUS ANNUAL CHARGES				$3,956.24

LABOR CHARGES

Monitoring Cost			=	$19,180.24
Repair Costs			=	$6,604.88
Administration and Support				
	$25,785.12 x	0.40	=	$10,314.05
TOTAL LABOR CHARGES				$36,099.17

MODEL PLANT WITH CATALYST EXTRACTION
UNCONTROLLED COMPONENTS FOR LDAR PROGRAM

Equipment Type	Total Number	Total with HON Level of Control	Total with HON Equivalent Control	Total Number Uncontrolled	Average Number Uncontrolled
Compressors	0	0	0	0	0
Open-ended Lines	263	0	147	116	58
Sampling Connections	13	0	1	12	6
Pressure Relief Devices	110	0	43	67	34
Valves in Vapor Service	315	25	176	113	57
Valves in Light Liquid Service	906	18	453	435	218
Pumps in Light Liquid Service	24	4	9	11	5
Connectors	1988	616.28	934	437	219

MODEL PLANT WITH CATALYST EXTRACTION
UNCONTROLLED COMPONENTS FOR LDAR PROGRAM

Equipment Type	Total Number	Total with HON Level of Control	Total with HON Equivalent Control	Total Number Uncontrolled	Average Number Uncontrolled
Compressors	0	0	0	0	0
Open-ended Lines	263	0	147	116	58
Sampling Connections	13	0	1	12	6
Pressure Relief Devices	110	0	43	67	34
Valves in Vapor Service	315	25	176	113	57
Valves in Light Liquid Service	906	18	453	435	218
Pumps in Light Liquid Service	24	4	9	11	5
Connectors	1988	616.28	934	437	219

MODEL PLANT WITH CATALYST EXTRACTION
INPUT TABLE FOR LDAR PROGRAM COSTS

Equipment Type	Total Uncontrolled
Compressors	0
Open-ended Lines	58
Sampling Connections	6
Pressure Relief Devices	34
Valves in Gas/Vapor Service	57
Valves in Light Liquid Service	218
Pump Seals in Light Liquid Service	5
Connectors	219
Total Components	597

Control Equipment	Base Cost (July 1989$)
Monitoring Instrument	6,500
Replacement Pump Seal	180
Compressor	6,240
Pressure Relief Device	
Rupture Disk	78
Holders, Valves, Installation, etc.	3,852
Open-ended Lines	102
Sample Connections	408

Initial Leak Detection and Repair Program	Value
Monitoring Fee ($/component)	2.5
Initial Leak Frequency (fraction)	
Valves in Gas/Vapor Service	0.114
Valves in Light Liquid Service	0.065
Pump Seals in Light Liquid Service	0.2
Connectors	0.021
Leaks Requiring Further Repair	
Valves	0.25
Connectors	0.25
Pumps	0.75
Hours for Repairs	
Valves	4
Pumps	16
Connectors	2

MODEL PLANT WITH CATALYST EXTRACTION
INPUT TABLE FOR LDAR PROGRAM COSTS

Annual Leak Detection and Repair Program	Value
Monitoring Fee ($/component)	2
Additional Pump Monitoring Time (hr)	0.0083
Initial Leak Frequency (fraction)	
Valves in Gas/Vapor Service	0.02
Valves in Light Liquid Service	0.02
Pump Seals in Light Liquid Service	0.1
Connectors	0.005
Leaks Requiring Further Repair	
Valves	0.25
Connectors	0.25
Pumps	0.75

Maintenance Program	Value
Calibration/Maintenance for Monitoring Instrument (July 1989$)	$4,280.00
Annual Maintenance Charge for Compressors, Pressure Relief Devices, Open-ended Lines, and Sampling Connections (percent of capital costs)	5
Replacement Pump Seal Cost (July 1989$)	$180.00
Miscellaneous Charges for Compressors, Pressure Relief Devices, Open-ended Lines, and Sampling Connections (percent of capital costs)	4
Miscellaneous Charges for Pump Seals (percent of capital costs)	80

Economic Data	Value
Interest Rate	0.07
Economic Life (years)	
Pump Seals	2
Rupture Disks	2
Monitoring Instrument	6
All Other Equipment	10
CRF Values	
2 Years	0.5531
6 Years	0.2099
10 Years	0.1425
Chemical Engineering Plant Cost Index	
July 1989	356.0
August 1996	382.1
Recovery Credit	
Average Emission Reduction (Mg/yr)	10.4
Raw Material Cost (July 1989$/Mg)	$1,164
Labor Rate ($/hour)	$22.50

MODEL PLANT WITH CATALYST EXTRACTION
LEAK DETECTION AND REPAIR ANNUAL COSTS

CAPITAL COSTS

Monitoring Instrument					$6,500.00
Compressors					
0 compressors	x	$6,240.00	/compressor	=	$0.00
Pressure Relief Devices					
34 rupture disks	x	$78.00	/rupture disk	=	$2,652.00
34 holders, valves, etc	x	$3,852.00	/holder, valve, etc	=	$130,968.00
Sample Connections					
6 sample connections	x	$408.00	/sample connection	=	$2,448.00
Open-ended Lines					
58 open-ended lines	x	$102.00	/open-ended line	=	$5,916.00
TOTAL CAPITAL COSTS					$148,484.00

INITIAL MONITORING AND LEAK REPAIR

Monitoring

Gas/Vapor Valves					
57 gas/vapor valves	x	$2.50	/component	=	$142.50
Light Liquid Valves					
218 light liquid valve	x	$2.50	/component	=	$545.00
Light Liquid Pumps					
5 light liquid pumps	x	$2.50	/component	=	$12.50
Connectors					
219 connectors	x	$2.50	/component	=	$547.50
TOTAL MONITORING COSTS					$1,247.50

MODEL PLANT WITH CATALYST EXTRACTION
LEAK DETECTION AND REPAIR ANNUAL COSTS

Initial Repair, Leaks Found

Gas/Vapor Valves							
57 gas/vapor valves	x	0.114 leaks/valve		=	6.5 leaks		
Light Liquid Valves							
218 light liquid valve	x	0.065 leaks/valve		=	14.2 leaks		
Light Liquid Pumps							
5 light liquid pumps	x	0.200 leaks/pump		=	1.0 leaks		
Connectors							
219 connectors	x	0.021 leaks/connector		=	4.6 leaks		
Leaks Requiring Repair							
Gas/Vapor Valves							
6.498 gas/vapor valves	x	0.25		=	1.6 leaks		
Light Liquid Valves							
14.17 light liquid valve	x	0.25		=	3.5 leaks		
Light Liquid Pumps							
1 light liquid pumps	x	0.75		=	0.8 leaks		
Connectors							
4.599 connectors	x	0.25		=	1.1 leaks		
Repair Costs							
Gas/Vapor Valves							
1.625 leaks	x	4 hours/leak	x	$22.50 /hour		=	$146.21
Light Liquid Valves							
3.543 leaks		4 hours/leak	x	$22.50 /hour		=	$318.83
Light Liquid Pumps							
0.75 leaks		16 hours/leak	x	$22.50 /hour		=	$270.00
Connectors							
1.15 leaks		2 hours/leak	x	$22.50 /hour		=	$51.74
TOTAL REPAIR COSTS							$786.77
TOTAL INITIAL LDAR COSTS (MONITORING + REPAIR)							$2,034.27

MODEL PLANT WITH CATALYST EXTRACTION
LEAK DETECTION AND REPAIR ANNUAL COSTS

Leaks Requiring Repair

Gas/Vapor Valves							
13.68 gas/vapor valves	x	0.25		=	3.4 leaks		
Light Liquid Valves							
52.32 light liquid valves	x	0.25		=	13.1 leaks		
Light Liquid Pumps							
6 light liquid pumps	x	0.75		=	4.5 leaks		
Connectors							
13.14 connectors	x	0.25		=	3.3 leaks		

Cost of Repairs

Gas/Vapor Valves							
3.42 leaks	x	4 hours/leak	x	$22.50 /hour	=	$307.80
Light Liquid Valves							
13.08 leaks	x	4 hours/leak	x	$22.50 /hour	=	$1,177.20
Light Liquid Pumps							
4.5 leaks	x	16 hours/leak	x	$22.50 /hour	=	$1,620.00
Connectors							
3.285 leaks	x	2 hours/leak	x	$22.50 /hour	=	$147.83
TOTAL REPAIR COSTS						$3,252.83
TOTAL ANNUAL LDAR COSTS (MONITORING + REPAIR)						$15,345.38

MODEL PLANT WITH CATALYST EXTRACTION
LEAK DETECTION AND REPAIR ANNUAL COSTS

Leaks Requiring Repair							
Gas/Vapor Valves							
13.68 gas/vapor valves	x	0.25		=	3.4 leaks		
Light Liquid Valves							
52.32 light liquid valves	x	0.25		=	13.1 leaks		
Light Liquid Pumps							
6 light liquid pumps	x	0.75		=	4.5 leaks		
Connectors							
13.14 connectors	x	0.25		=	3.3 leaks		
Cost of Repairs							
Gas/Vapor Valves							
3.42 leaks	x	4 hours/leak	x	$22.50 /hour		=	$307.80
Light Liquid Valves							
13.08 leaks	x	4 hours/leak	x	$22.50 /hour		=	$1,177.20
Light Liquid Pumps							
4.5 leaks	x	16 hours/leak	x	$22.50 /hour		=	$1,620.00
Connectors							
3.285 leaks	x	2 hours/leak	x	$22.50 /hour		=	$147.83
TOTAL REPAIR COSTS							$3,252.83
TOTAL ANNUAL LDAR COSTS (MONITORING + REPAIR)							$15,345.38

MODEL PLANT WITH CATALYST EXTRACTION
LEAK DETECTION AND REPAIR ANNUAL COSTS

ANNUAL MAINTENANCE COSTS

Monitoring Instrument				=	$4,280.00
Compressors					
	$0.00	x	0.05	=	$0.00
Rupture Disks					
	$2,652.00	x	0.05	=	$132.60
Holders, Valves, Etc.					
	$130,968.00	x	0.05	=	$6,548.40
Open-ended Lines					
	$5,916.00	x	0.05	=	$295.80
Sample Connections					
	$2,448.00	x	0.05	=	$122.40
Replacement Pump Seals					
	$180.00	x	4.5	=	$810.00
TOTAL ANNUAL MAINTENANCE COSTS					$12,189.20

MISCELLANEOUS ANNUAL CHARGES

Monitoring Instrument					
	$6,500.00	x	0.04	=	$260.00
Compressors					
	$0.00	x	0.04	=	$0.00
Rupture Disks					
	$2,652.00	x	0.04	=	$106.08
Holders, Valves, Etc.					
	$130,968.00	x	0.04	=	$5,238.72
Sample Connections					
	$2,448.00	x	0.04	=	$97.92
Replacement Pump Seals					
	$810.00	x	0.80	=	$648.00
TOTAL MISCELLANEOUS ANNUAL CHARGES					$6,350.72

MODEL PLANT WITH CATALYST EXTRACTION
LEAK DETECTION AND REPAIR ANNUAL COSTS

ANNUAL MAINTENANCE COSTS

Monitoring Instrument				=	$4,280.00
Compressors					
	$0.00	x	0.05	=	$0.00
Rupture Disks					
	$2,652.00	x	0.05	=	$132.60
Holders, Valves, Etc.					
	$130,968.00	x	0.05	=	$6,548.40
Open-ended Lines					
	$5,916.00	x	0.05	=	$295.80
Sample Connections					
	$2,448.00	x	0.05	=	$122.40
Replacement Pump Seals					
	$180.00	x	4.5	=	$810.00
TOTAL ANNUAL MAINTENANCE COSTS					$12,189.20

MISCELLANEOUS ANNUAL CHARGES

Monitoring Instrument					
	$6,500.00	x	0.04	=	$260.00
Compressors					
	$0.00	x	0.04	=	$0.00
Rupture Disks					
	$2,652.00	x	0.04	=	$106.08
Holders, Valves, Etc.					
	$130,968.00	x	0.04	=	$5,238.72
Sample Connections					
	$2,448.00	x	0.04	=	$97.92
Replacement Pump Seals					
	$810.00	x	0.80	=	$648.00
TOTAL MISCELLANEOUS ANNUAL CHARGES					$6,350.72

MODEL PLANT WITH CATALYST EXTRACTION
LEAK DETECTION AND REPAIR ANNUAL COSTS

CREDIT DUE TO EMISSION REDUCTION

10.4 Mg/yr	x	$1,164.00 /Mg	=	$12,105.60

TOTAL ANNUAL COSTS

TOTAL ANNUAL COSTS = ANNUAL COSTS - EMISSION REDUCTION CREDIT

TOTAL ANNUAL COSTS = $55,717.08
(August 1996$)

Annual Cost per MMlb Capacity $557.17 /MMlb
(based on a capacity of 100 MMlb/yr)

MODEL PLANT WITH CATALYST EXTRACTION
LEAK DETECTION AND REPAIR ANNUAL COSTS

CREDIT DUE TO EMISSION REDUCTION

10.4 Mg/yr	x	$1,164.00 /Mg	=	$12,105.60

TOTAL ANNUAL COSTS

TOTAL ANNUAL COSTS = ANNUAL COSTS - EMISSION REDUCTION CREDIT

TOTAL ANNUAL COSTS = $55,717.08
(August 1996$)

Annual Cost per MMlb Capacity $557.17 /MMlb
(based on a capacity of 100 MMlb/yr)

ATTACHMENT 8

CALCULATION OF STEAM STRIPPER COSTS

Calculation Methodology Description

Steam Stripper Costs

From the EPA/SPI questionnaires responses, it was determined that only two facilities have Group 1 wastewater streams. As both of these facilities would fall under the classification of a large model plant, it was assumed that small and catalyst extraction model plants do not have Group 1 wastewater streams. Consequently, the average of the wastewater flow rates reported by the two large facilities was used to estimate steam stripper costs for large model plants.

The HON wastewater spreadsheet was used to calculate the cost of the steam stripper.

BASIC EQUIPMENT COST SUMMARY 16 774977545305648 GPM

Equipment Component	Price Year	Price Index	July 1989 CE Index	Correction Factor	Estimated Price	July 1989 Price	Percent of PEC
Feed Tanks	1st qtr 79	230 9	356	1.5418	$24,192	$37,299	19.7
Feed Preheater (Shell and Tube)	July 1989	356	356	1.0000	$14,374	$14,374	7 6
Steam Stripping Tray Column	1st qtr 79	230.9	356	1.5418	$46,699	$72,000	38.1
Primary Condenser (Water Cooled, Shell & Tube)	July 1988	343	356	1.0379	$3,938	$4,087	2 2
Overhead Collection Decanter	Jan 1979	225.9	356	1.5759	$2,727	$4,298	2.3
Flame Arrestor	Sep 1986	319	356	1.1160	$100	$112	0.059
Pumps (4)	Nov 1988	347.8	356	1.0236	$26,218	$26,836	14 2

A. CAPITAL COSTS

1) Steam Stripper Column

Di = inside diameter, ft = 1.3

Lt, Tl = tangent-to-tang length, ft= 29.0

Ts = est. wall thickness, ft = 0.0521

rho(ss304), lb/ft^3 = 501

Weight of the column:

Ws = pi*Di(Tl + 0.8116*Di)Ts*rho

Ws, lb = 3,286

BE SURE WEIGHT, DIAMETER, AND TOWER HEIGHT ARE WITHIN THE LIMITS FOR ALL EQUATIONS

The weight equation for calculating steam stripper column cost is the same for carbon and stainless steel, but the densities of the two metals are different.

- density of carbon steel = 490 lb/ft^3
- density of stainless steel = 501 lb/ft^3

::

a. Chemical Engineering Magazine, December 28, 1981, pg. 180.

COST INDEX = 230.9

-Shell, skirts, nozzles, and manholes

Cbs = exp[6.823 + 0.14178 (ln Ws) + 0.02468 (ln Ws)^2]

9020 lb < Ws < 2,470,000 lb

WEIGHT TOO SMALL

Cbs, $ = 14,608

Cbs(304ss), $ = Cbs*Xcol = 43971

Xcol,304ss = 3.01 (Based on Vendor data)

-Platforms and Ladders

Cbp = 151.81*Di^0.63316*Lt^0.80161

3 ft < Di < 24 ft : 57.5 ft < Lt < 170 ft

DIAMETER TOO SMALL

LENGTH TOO SHORT

Cbp, $ = 2707

-Cost of Trays - 304 stainless sieve trays

Cbt = (Number of trays)*278.38*exp[0.1739*D]

2 ft < D < 16 ft

DIAMETER TOO SMALL

Cbt, $ = 3,509

Total column Cost:

Column Cost (304 ss) = Cbs(304ss) + Cbp + Ftm*Ftt*Cbt

COLUMN COST, $ = 50,453

where

Ftt(Sieve Trays) - Table V = 0.85

Ftm(304Stainless)= (1.189 +0.0577*D) = 1.27

::

b. Peters and Timmerhaus Che Plant Design pg 768 - 773.

COST INDEX = 225.9

-Shell Fig 15-24

Shell cost = 133.46*Ws^0.6347

1000 lb < Ws < 70,000 lb

WEIGHT OKAY

Shell cost, $ = 22,773

-Manholes Fig 15-25 (SUGGEST USING 10 MANHOLES - ONE FOR EACH TRAY)

Mannole cost = (no. of manholes)*(internal diameter, in)*

STEAM STRIPPER COSTING PROCEDURE: BASED
ON ASPEN PRINTOUT - 300LPM (80GPM) CASE

STEAM/FEED RATIO, KG STEAM/KG WW:			0.040	0.333818375		
WASTEWATER FEED RATE, GPM:			16.7750			
	TAC:		$111,150		TDAC	$34,830
FLOW RATES	TCI:		$415,586		TIAC	$76,320
FEED FLOW, KG/HR:	3802.33	GPM:		16.8		DENSITY H2O = 8.33lb/gal
BOTTOMS FLOW, KG/HR:	3766.19215	GPM:		16.6		DENSITY Steam = 8.00lb/gal
STEAM FLOW, KG/HR:	152.182596	KJ/hr:		426415.6		kilogram, kg = 2.205 lb
OVERHEAD FLOW,KG/HR:	188.318694	GPM:		0.8		
PRI COND H2O, KG/S:	3.82909831	GPM:		60.8		
						WATT=9.486E-04 BTU/S
EQUIPMENT						1,750 based on telecon with Rob Goldman of Edwards Eng.
PREHEATER AREA, M^2:	50.7502412	FT^2:		546.0		
PRI COND AREA, M^2:	4.58713858	FT^2:		49.4		
COLUMN DIAMETER, M:	0.34893212	FT:		1.3		0.13 ft^2 area based on telecon with Rob Goldman of Edwards Engineering.
NTU:	16.25					
NO. OF COLUMN TRAYS:	10					
ACTIVE HEIGHT, FT:	15					
TOTAL HEIGHT, FT:	29					

(53.83 + 40.71*(tower wall thickness,in))
0.375 inches < Ts < 2 inches
THICKNESS OKAY

no. of manholes = 10
int. diam, in = 18 (THIS IS INHERENT IN THE CURVE)

Manhole cost, $ = 14,269

-Nozzles Fig 15-25 (SUGGEST USING: ONE,6 inch(overheads); ONE,4 inch(feed); TWO,4 inch(steam); and ONE,4 inch(bottoms)

Nozzles cost = SUM[(no. of nozzles)*(inches of nozzle)]*
(24.57 + 35.94*(tower wall thickness, in))
0.375 inches < Ts < 2 inches
THICKNESS OKAY

sum[(no. noz)(in noz.)] = [(4*4")+(1*6")] = 22

Nozzles cost, $ = 1,035

-Trays Fig 15-26 304 stainless only

Trays cost = (no. of trays)*214.54*exp(0.2075*Di)
2 ft < Di < 12,5 ft
DIAMETER TOO SMALL

Trays cost, $ = 2,828

-Ladders Table 9
$.43/lb of ladder, 30lb/ft of ladder
Ladder height = column height = 29
Ladder cost, $ = 374.1

-Platforms and Handrails Table 9
$.43/lb (d=4ft, 1700lb)
Assume a linear relationship - 425 lb/ft of diameter
P and H cost, $ = 243.22

-Insulation Fig 15-27
Use foamglass (ave)
Assume 3" thick (ave)
$10/ft2
A (ft^2)= 142.28125

Insulation cost, $ = 1422.8125

Total column cost, $ = 42,944

TOTAL COLUMN COST, $ = 46,699

2) Feed Tanks - Chemical Engineering Magazine January 25, 1982. PG 144-46.

COST INDEX = 230.9 (sum CE index (Jan-Apr/4))

Cb = exp[2.331 + 1.3673 (ln V) - 0.063088 (ln V)^2]
1,300 gal < V < 21,000 gal

or

Cb = exp[11.362 - 0.6104 (ln V) + 0.045355 (ln V^2)]
21,000 gal < V < 11,000,000
VOLUME OKAY

V, gal = 53,680 (VOLUME BASED ON 48 HOURS RETENTION)

Cb, $ = 24,192

-Information obtained from vendors on the cost of feed tanks was compared to the cost of the feed tanks from Chemical Engineering Magazine in July, 1989 dollars to verify that scaling costs from 1982 to 1989 is accurate. It is assumed that the tank is not completely filled with water and is only filled to 90% of its capacity.

---

3) Decanters - Peters and Timmerhaus Che Plant Design pg 572, Fig 13-58

COST INDEX = 225.9

Assumptions:
1) 304 Stainless Steel
2) 95% VOC removal design
3) Retention time of ONE hour
4) Operation at 50% capacity

Decant Cap, gal = 100

Decanter cost = 216.8*(capacity, gal)^0.5502

Decanter cost, $ = 2,727

---

4) Feed preheaters - Telecon. Scott, K.A., Radian Corporation with Ambassador Heat Transfer Company. May 12, 1993. Cost of Heat Exchangers.

Cost in July 1989 Dollars
Assume carbon steel with copper tubes
Assume 100 psi and 300 F
Built to ASME codes

Cost of Preheater = [4213.357 * (Flow Rate (gpm))^.5]
- 2882.31

Preheat cost, $ = 14,374

---

5) Primary condensers - Chemical Engineering Magazine November 21, 1988. pg. 66 - 75. Figs. 1 & 2. cost index = 343

Assume fixed-tube, single shell, single pass exchangers and 12 foot length tubes.

Pri Cond cost = 2228.8*exp(0.00411*A,ft^2)
150 ft^2 < A < 240 ft^2
or Pri Cond cost = 5328.8*exp(0.0008762*A,ft^2)
240 ft^2 < A < 1500 ft^2
AREA TOO SMALL
Xcond(304ss) = .8193 + .15984(lnA) = 1.442507
(Xcond is called Fm in the Chem. Eng article.)
Pri Cond cost, $ = 3,938

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6) Pumps - Chemical engineering Magazine Nov. 21, 1988. pg 66 - 75. Fig 17. ALL PUMPS ARE 316 STAINLESS STEEL.
COST INDEX = 347.8
Group A pumps - 10 to 150 gpm; Group B - 30 to 900 gpm.
Group A pumps - 0.5 to 10 hp; Group B - 3 to 20 hp.
Pump Cost = 8740.7*(hp)^0.4207 GROUP A
Pump Cost = 13783.4*(hp)^0.2890 GROUP B

Assume a pump is needed for the feed to and from the feed tank, the bottoms,and the overheads.
An engineering estimate of 122 feet of water is assumed for the head. Total pump efficiency is assumed to be 64%.
Pump head,ft H2O = 122

a. Feed Tank HP = {feed flow (gpm)*(122 ft H2O)*(8.33 lb/gal)*(min/60 s)* (lbf/lb)/[0.64]*[(0.001341 hp)/(0.7376 ft lbf/s)]

Feed Tank hp = 0.8
GROUP A FLOW OKAY GROUP A: HP OKAY
GROUP B: HP TOO SMALL

FEED TANK PUMPS (2), 15,975

b. Bottoms HP = {feed flow (gpm)*(122 ft H2O)*(8.33 lb/gal)*(min/60 s)* (lbf/lb)/[0.64]*[(0.001341 hp)/(0.7376 ft lbf/s)]

Bottoms hp = 0.8
GROUP A FLOW OKAY GROUP A: HP OKAY
GROUP B: HP TOO SMALL

BOTTOMS PUMP, $ = 7,987

c. overhead HP = {overhead flow(gpm)*(122 ft H2O)*(8.33 lb/gal)* (min/60 s)*(lbf/lb)/[0.64]*[(0.001341 hp)/(0.7376 ft lbf/s)]

Overhead hp = 0.0
GROUP A FLOW TOO SMALL GROUP A: HP TOO SMALL
GROUP B: HP TOO SMALL

OVERHEAD PUMP, $ = 2,256

Total Cost of Pumps = sum of (feed,bottoms,overhead)

TOT PUMP COST, $ = 26,218

Conversion from hp to kw-hr/yr is (W)/(0.001341hp)*(KW/1000W)* (8424 hr/yr)

---

7) Flame arrestors - Costs given by Penny Lassiter from a telecon by A. Gitelman (RTI). Each arrestor is estimated at $100. Cost is in September 1986 dollars. COST INDEX = 319
From an RTI report from Paul Peterson to Susan Thornloe, EPA/CPB, dated January 18, 1988: It is assumed that vent lines from the storage tanks, condensers, and decanters each had flame arrestors in place. The current approach assumes that these vent lines are routed back to the feed storage tank for the steam stripper and a that there is a single flame arrestor on the vent line from the storage tank to the control device.

Cost of 1 arrester, $ = 100

B. ANNUAL COSTS - Utility costs BASIS: 8424 hr/yr operation

Utility costs consist of electricity, steam, and water costs

1) Electricity - Electricity is needed for pumps and for refrigeration.

a. Pumps - electricity use is calculated under the capital costs

Pump Electricity use = (Total pump use in hp)*0.7457KW(mech.)/hp*(8424 hr/yr)

Tot Pump Use, HP = 2.46

PUMP ELECT USE, KW-H/yr = 15,462

TOTAL ELECT USE, KW-H/YR = 15,462

2) Steam - Steam is needed for stripping the organics.
Steam cost is estimated at $9.26/Mg ($4.20/lbm).
This cost is presented in July 1989 dollars. There is no cost index.
The steam is 400 psig sat'd steam with a heat content of 2802 KJ/kg (1206 BTU/lbm).
The heat loss through the column is 5% of the heat input.
Telecon, Kristine Scott, Radian with Rob Stepian, APV Crepaco.

steam use = (steam flow,kg/hr)*(Mg/10^3 kg)*(1.05)*(8424hr/yr)

Steam use, Mg/yr = 1,346

3) Water - Cooling water is used in the primary condenser.

Water use = (Pri cond H2O flow,gpm)*(60 min/hr)*(3.785liters/gal)* (8424hr/yr)*(fraction lost to cooling tower evaporation and blowdown = 0.04)
WATER USE, L/YR = 4,653,791

EC/R Incorporated

1996 EPA Outstanding Small Business Contractor

MEMORANDUM

DATE: May 16, 1997

SUBJECT: The Definition of an Extended Cookout as a Control Technique for the Polyether Alcohol Production Industry

FROM: Joanne C. Seaman, EC/R Incorporated

TO: David Svendsgaard, EPA/OAQPS/ESD/OCG

This memorandum defines an extended cookout (ECO) as a control option for ethylene oxide (EO) and propylene oxide (PO) (epoxide) emissions from the production of polyether alcohols made with epoxides. Also included in this memorandum is the description of the default onset point for the ECO which can be used by facilities that prefer to accept this value in lieu of calculating their own onset point for the ECO.

BACKGROUND

Polyether alcohols made with epoxides are predominately produced in a batch process. Epoxide emissions from the batch reactor vent result, in part, from the release of unreacted epoxide when the reactor is opened during any stage of the batch reaction cycle. Typically, during a batch where an extended cookout (ECO) is not practiced, the operator finishes adding the epoxide to the reactor, and the reaction is stopped by either cooling the reactor or neutralizing the catalyst. The reactor is then opened in order to vent excess gas pressure, and transfer the reacted product to other equipment for additional handling (such as catalyst removal or product purification) or transfer the reacted product directly to product storage if further processing is not required. Facilities maximizing production from a reactor would typically empty the reactor as quickly as possible to start a new batch cycle. The reactor is emptied despite raw material economics that indicate that it would be advantageous to keep the product in the reactor, and the reactor emissions are typically vented to a control device.

Facilities that practice ECO use this as an alternative to, or in addition to add-on control devices to control epoxide emissions from process vents. Extended cookout reduces the amount of unreacted epoxide in the reactor by allowing it to react for a longer time period, thereby reducing epoxide emissions. For an ECO, the product continues to react in the

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reactor for longer than is calculated to be economically advantageous. This additional reaction period (or ECO) reduces the emissions of epoxide that otherwise would vent to a control device or may make an add-on control device unnecessary to achieve the required epoxide emission reduction. Since the epoxide that would have been vented is converted to product, the producer's raw material usage decreases.

A facility using ECO, however, assumes the disadvantage of decreased annual throughput, because the reactor is used for emission reduction cookout rather than to react another batch immediately. Additionally, there is the potential for decreased product quality, due to the possibility of secondary reactions occurring during the ECO. When a producer uses ECO, it is going beyond the economic balance of raw material savings versus production capacity. The ECO is being used to reduce emissions and the lost capacity is not compensated by the recovered raw material.

CALCULATION FOR THE ONSET OF AN EXTENDED COOKOUT

The calculation for the onset of an ECO assumes that a producer will operate a cookout as long as it is economically viable; that is, as long as the value of the epoxide recovered as product exceeds the value of the production lost due to the ECO batch time. Beyond this point, the producer has no economic incentive to continue to cookout the remaining epoxide. At this economic breakpoint the cookout becomes an emission control. Therefore, that economic breakpoint is considered the onset of ECO for the purpose of evaluating the emission reduction.

For the purpose of determining a "default" ECO onset, representatives from Union Carbide Corporation performed a calculation for four product classes. This calculation required the following confidential information: the batch size; the epoxide concentration at the end of the epoxide feed step; the batch time without the extended cookout, the amount of time the reactor runs on line per year; the cost of the epoxide; and, the product variable margin (profit of the product, dollar per pound ($/lb).

The calculation takes into account only the liquid phase epoxide. Some epoxide in the vapor phase is also recovered and reacted into useful product during cookout, but this is normally small and may be ignored without affecting the break point. Also, this analysis does not take into account the capital charges for the reactor itself; it only takes into account the annual lost production due to longer batches. A capital utilization charge per hour of reactor batch time could be included in the calculation; this would reduce the time required to reach the economic breakpoint. This was not done in this calculation for the sake of simplicity.

Equations

Union Carbide has data to show that a first order reaction rate fits the base-catalyzed alcohol alkoxylations its facilities conduct using either a monol or polyol starter. Based on this knowledge, the rate constant was calculated for each product used in the evaluation of ECO. The rate constant was determined by solving the rate equation for K, and then inserting the epoxide concentration at the end of the epoxide addition (C_o) and at any given time (C_t), as indicated in Equation 1.

$$C_{Epox,t} = C_{Epox,o} * e^{(-K*t)}$$

Equation 1.

where:

$C_{Epox,t}$ = the concentration of the epoxide in the reactor liquid at a given time, weight percent (wt percent);
$C_{Epox,o}$ = the concentration of the epoxide in the reactor liquid after the usual end of the reaction phase, wt percent;
K = reaction rate constant, 1/hours;
t = time, hours.

Next, the amount of epoxide converted to product (pounds per batch) as a result of an ECO was calculated as presented in Equation 2.

$$E_{con} = E_{to} - E_{tf}$$

Equation 2.

where:

E_{con} = the amount of epoxide converted to product as a result of the cookout, pounds per batch (lb/batch);
E_{to} = the amount of epoxide in the reactor at the end of the usual batch time, lb/batch. Calculated by multiplying the concentration from Equation 1 ($C_{Epox,o}$) with the batch size;
E_{tf} = the amount of epoxide in the reactor at the end of the cookout interval, lb/batch. Calculated by multiplying the concentration from Equation 1 ($C_{Epox,t}$) with the batch size.

Next, the value of the epoxide converted into additional product was calculated. This savings was calculated with Equation 3.

$$Val_{Epox,CO} = E_{con} * B/yr * Cost_{Epox}$$

Equation 3.

where:

$Val_{Epox,CO}$ = Value of the epoxide converted to product, dollars per year ($/yr);
E_{con} = the amount of epoxide converted to product as a result of the cookout, pounds per batch (lb/batch), from Equation 2;
B/yr = number of batches per year at the extended cookout rate,
$Cost_{Epox}$ = cost of the epoxide, dollars per pound.

Then, the amount of production lost, in dollars lost per year, as a result of the reactor being used longer for an ECO was calculated by multiplying the difference in the number of batches made without an ECO and the number made with an ECO, at that given cookout time, by the product variable margin ($/lb). Equation 4 illustrates this calculation.

$$PL = (B\ w/o\ CO/yr - B\ w/CO/yr) * BS * Prof$$

Equation 4.

where:
PL = production lost due to the cookout, $/yr;
B w/o CO/yr = number of batches that would have occurred without the cookout, batches/yr;
B w/CO/yr = number of batches at the cookout rate, batches/yr;
BS = batch size, lb/batch, and;
Prof = the profit made on the product, $/lb.

Finally, the incremental economic analysis was calculated by first determining the cost analysis at time 2. The cost analysis was calculated as the difference between the value of epoxide converted minus the lost production, as presented in Equation 5.

$$CA_t = Val_{Epox,co,t} - LP_t$$

Equation 5.

where:
CA = cost analysis at a given cookout time;
$Val_{Epox,CO}$ = value of the epoxide converted to product for that given time, $/yr, from Equation 3, and;
LP = lost production for that given time, $/yr from Equation 4.

To be conducted incrementally, the cost analysis conducted at time 2 is subtracted from the cost analysis done at time 1.

Extended Cookout Onset Determination

These calculations were made on a spreadsheet at one tenth of an hour intervals, and the incremental cookout economics calculated. The break-even point, or the "onset" of an ECO, was identified as the point in time when the incremental cookout economics changed from a positive to a negative value.

The break-even point was identified for four different classes of products made by Union Carbide. For all four classes of products, it was determined that the break-even point occurred prior to the point in time when the combined unreacted epoxide concentration in the reactor liquid is equal to 25 percent of the concentration of the epoxide at the end of the epoxide feed step. The variables used in these calculations are considered confidential business information, and therefore cannot be reproduced for this memorandum. However, the individual facility can recreate this calculation for the products made at that facility and document a different ECO point of onset. The rule will be written to reflect flexibility in setting a point of onset for an ECO.

MEMORANDUM

TO: David Svendsgaard

FROM: Linda Chappell

SUBJECT: Economic Analysis for the National Emissions Standards for Hazardous Air Pollutants (NESHAP) for the Polyether Polyols Industry

DATE: May 21, 1997

A brief discussion of the economic analysis and regulatory flexibility analysis conducted for the Polyether Polyols NESHAP follows.

I. ECONOMIC IMPACTS

The goal of the economic impact analysis is to estimate the market response of the polyether polyols industry to the emission standards and to determine any adverse effects that may result from the regulation. Polyether polyols are classified as a thermoset resin and typically produced as an intermediate product or as an input into other products. The majority of polyether polyols are used for the manufacture of urethanes, surface-active agents, functional fluids, and synthetic lubricants. Approximately 79 facilities owned by 36 different companies produce polyether polyols domestically, and 72 of these facilities may potentially be affected by the regulation. The polyether polyol facilities are dispersed throughout the country in 22 different states with the largest concentration of 18 facilities in Texas. Of the 36 companies producing polyether polyols, seven are classified as small businesses.

Since the nationwide annualized cost of this regulation of $7.7 million represents approximately 0.06 percent of the estimated 1996 sales revenues for domestically produced polyether polyols, the EPA determined that the regulation is not likely to have a significant impact on this industry as a whole. For this reason, a streamlined economic analysis is performed. The goal of this streamlined analysis is to determine whether individual facilities producing polyether polyols and companies owning those facilities are likely to be adversely impacted by the regulation. Facility-specific impacts are examined to assess the likelihood of facility closures and employment impacts.

A. Analytical Approach and Control Cost Estimates

Three different model plants (small, large, and catalyst extraction model plants) are developed to estimate facility and nationwide annualized and capital control costs for the regulation. The capital and annualized costs for each of the model plants, as well as estimates of the nationwide costs are shown on Table 1. The capital costs for the regulation are estimated to

be $10.1 million and the annualized costs $7.7 million. (All values are shown in 1996 dollars.)

Table 1
Model Plant and Nationwide Control Cost Estimates - Polyether Polyols NESHAP
(Thousands of 1996 dollars)

Model Plant/ Nationwide	Capital Costs	Annualized Costs
Small[1]	$106.7	$89.4
Large[1]	516.1	292.1
Catalyst Extraction[1]	222.6	283.1
Nationwide Totals	$10,060.0	$7,670.0

[1] Capital and annualized model plant control cost estimates represent the maximum costs of compliance that any model plant will incur as a result of the regulation, and this estimate may overstate costs for some affected facilities.

Compliance costs are assigned to each facility assuming that each facility must control all emission points. For example, the small model plant category includes control cost estimates for three emission points that consist of process vent scrubbers, fixed-roof storage tanks, and equipment leaks. Specific facilities may not require controls for all emissions points. However, the analysis assumes that each facility incurs the maximum costs of compliance for plants within a model plant category. This assumption results from insufficient facility-specific data and is necessary to ensure that the costs incurred by any affected facility are not understated. The Agency recognizes that, by using this assumption, it is overstating the costs incurred by many affected facilities.

Capital costs are annualized at a seven percent discount rate to compute the annual costs of capital. Then, the annualized capital costs are combined with annual operating and maintenance costs, recordkeeping, monitoring, and reporting costs, and other annual costs to compute the total annualized costs to comply with the proposed rule.

Model plant annualized control costs are compared to facility-specific revenues for each of the 72 facilities that will be impacted by the regulation. A cost-to-sales ratio is developed to estimate the impact each facility is likely to experience as a result of the regulation. Since polyether polyols are frequently produced at multi-product facilities and in some cases by firms owning multiple facilities, revenue data specific to the polyether polyols production of each facility are not readily available. For this reason, revenues are estimated using the production and/or capacity data available for facilities in this industry and an estimate of the market price per pound paid for polyether polyols during 1996 of $1.05. Actual production data are available for only 12 companies that responded to an Information Collection Request administered through the Society of Plastics Institute for the EPA. Based upon the production and capacity data for the 12 surveyed facilities and capacity information obtained from other data sources, an estimate of annual production for each of the 72 facilities is obtained. Facility-specific revenues are calculated by multiplying the price per pound of polyether polyols of $1.05 by the estimated

production for each facility.

The cost-to-sales ratios are computed for each facility in the three model plant categories by dividing model plant costs by the estimated facility-specific revenues. A cost-to-sales ratio exceeding one percent is determined to be an initial screening criteria for a significant facility-specific impact.

Facility-Specific Impacts

Descriptive statistics including the estimated minimum, maximum, mean, and median cost-to-sales ratios for the 72 facilities are shown for each model plant category on Table 2. While the mean cost-to-sales ratios for each model plant category are well below one percent and as such determined not to be significant, the maximum cost-to-sales ratio in the catalyst extraction model plant category exceeds one percent. To examine the impacts more closely, a frequency distribution of cost-to-sales ratios is developed. This distribution is shown on Table 3.

Table 2
Facility Impacts of the Proposed Polyether Polyols NESHAP

Model Plant Size/ Statistic	Total Annual Cost / Estimated Sales Revenue (%)[1]
Small Model Plant:	
Minimum	0.028
Maximum	0.881
Mean	0.280
Median	0.192
Catalyst Extraction Model Plant:	
Minimum	0.169
Maximum	1.542
Mean	0.448
Median	0.373
Large Model Plant:	
Minimum	0.139
Maximum	0.232
Mean	0.145
Median	0.139

[1] Assumes that the mean sales for facility with data available are the sales levels for facilities for which data are unavailable.

Only one facility out of the 72 facilities impacted is expected to experience a cost-to-sales ratio exceeding one percent. The facility for which costs exceed one percent of sales is estimated to produce about 23 million pounds of polyether polyols per year. Total annualized compliance costs are estimated to be about 1.5 percent of annual sales for this facility, which is classified in

the catalyst extraction model plant category. This facility is owned by a large, financially strong company. Company sales were more than $2 billion in 1996, with net income more than $200 million. The compliance costs are an insignificant share of those resources, so it is probable that the company will choose to comply with the regulation, rather than shutting down their polyether polyol production.

Based on the foregoing, the EPA concludes that the proposed NESHAP for polyether polyols will impose costs that are negligible on the majority of facilities. For only one facility out of 72 in the industry do costs exceed one percent of sales. Based on an analysis of the costs of compliance compared to facility and company financial data, the Agency finds it unlikely that the company owning this facility will choose to close it, because the company is financially robust and the costs are a small share of the company sales and net income. The generally small scale of the impacts suggests that there will be no significant impacts on markets for the products made using polyether polyols, such as polyurethanes.

Costs do not exceed one percent of company sales for any of the companies owning facilities producing polyether polyols. Thus, the Agency concludes that no company will be made likely to incur bankruptcy as a result of this regulation.

REGULATORY FLEXIBILITY ANALYSIS

The Regulatory Flexibility Act (RFA) provides that, whenever an agency promulgates a final rule under 5 U.S.C. (MARK) 553, after being required to publish a general notice of proposed rulemaking, an agency must prepare a final regulatory flexibility analysis unless the head of the agency certifies that the final rule will not have a significant economic impact on a substantial number of small entities. Pursuant to section 605(b) of the Regulatory Flexibility Act, 5 U.S.C. 605 (b), it is certified that this rule will not have a significant impact on a substantial number of small entities.

The EPA analyzed the potential impact of the rule on small entities and determined that only seven of the 36 polyether polyol producing firms are small entities -- not substantial number of entities. Of these seven, no small companies will experience an increase in costs as a result of the promulgation of this rule that is greater than one percent of revenues. Therefore, the Agency did not prepare an initial regulatory flexibility analysis.

Although the statute does not require the EPA to prepare an RFA because the Administrator has certified that the rule will not have a significant economic impact on a substantial number of small entities, the EPA did undertake a limited assessment, to the extent it could, of possible outcomes and the economic effect of these on small polyether polyol producing entities as previously discussed.

Table 3
Frequency Distribution: Total Annual Compliance Cost/Facility Sales by Model Plant Category

Model Plant/ Frequency Distribution	Total Number of Facilities
Small Model Plant Cost-to-Sales Ratio[1]:	
0 to 0.2 percent	16
0.2 to 0.5 percent	3
0.5 to 1 percent	3
1 to 5 percent	0
over 5 percent	0
Total Small	22
Catalyst Extraction Model Plant Cost-to-Sales Ratio[1]:	
0 to 0.2 percent	1
0.2 to 0.5 percent	12
0.5 to 1 percent	1
1 to 5 percent	1
over 5 percent	0
Total Catalyst Extraction Model Plant	15
Large Model Plant Cost-to-Sales Ratio[1]:	
0 to 0.2 percent	29
0.2 to 0.5 percent	4
0.5 to 1 percent	2
1 to 5 percent	0
over 5 percent	0
Total Large Model Plant	35

[1] Assumes that the mean sales for facility with data available are the sales levels for facilities for which data are unavailable.

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