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Hazardous Air Pollutant Emissions from the Production of Flexible Polyurethane Foam

Supplementary Information Document for Proposed Standards

NESHAP

HAZARDOUS AIR POLLUTANT EMISSIONS FROM THE PRODUCTION OF FLEXIBLE POLYURETHANE FOAM

Supplementary Information Document for Proposed Standards

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

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ENVIRONMENTAL PROTECTION AGENCY

Hazardous Air Pollutant Emissions from the Production of Flexible Polyurethane Foam - Supplementary Information Document for Proposed Standards

1. The standards regulate hazardous air pollutant emissions from the production of flexible polyurethane foam. Only flexible polyurethane 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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OVERVIEW

This Supplementary Information Document (SID) contains memoranda providing rationale and information used to develop the Flexible Polyurethane Foam 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 section 114 letters 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-95-48).

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

Document No.	Description
II-B-13	Williams, A. and Battye, W., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. June 17, 1996. Memorandum. Flexible Polyurethane Foam Industry Description.
II-B-14	Williams, A., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. November 3, 1995. Memorandum. Flexible Polyurethane Foam Molded Plants: New Count and Nationwide Model Plant Representation.

Document No.	Description
II-B-15	Williams, A. and Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. June 17, 1996. Memorandum. Subcategorization of the Flexible Polyurethane Foam Source Category.
II-B-16	Williams, A., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. June 17, 1996. Memorandum. Flexible Polyurethane Foam Model Plants.
II-B-17	Williams, A. and Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. June 17, 1996. Memorandum. Baseline Emissions for the Flexible Polyurethane Foam Production Industry.
II-B-18	Williams, A. and Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. June 17, 1996. Memorandum. MACT Floors for Flexible Polyurethane Foam Production.
II-B-19	Williams, A. and Norwood, P., EC/R Incoporated, to Svendsgaard, D., U.S. Environmental Protection Agency. June 17, 1996. Memorandum. Regulatory Alternatives for New and Existing Sources in the Flexible Polyurethane Foam Source Category.
II-B-20	Norwood, P. and Williams, A., EC/R Incoporated, to Svendsgaard, D., U.S. Environmental Protection Agency. June 17, 1996. Memorandum. Estimated Regulatory Alternative Impacts for Flexible Polyurethane Foam Production.
II-B-6	Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. September 24, 1996. Development of Equation to Calculate Auxiliary Blowing Agent Formulation Limitation.

MEMORANDUM

Date: June 17, 1996

Subject: Flexible Polyurethane Foam Industry Description

From: Amanda Williams, EC/R Incorporated
William Battye, EC/R Incorporated

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

The purpose of this memorandum is to present a description of the flexible polyurethane foam industry. The information in this memorandum was compiled from several sources including Information Collection Requests (ICRs), trip reports, other project efforts, and from several other sources. This memorandum is arranged in several sections. The first section presents a general description of the industry, including facility location and other general statistics. The next section describes the foam chemistry, foam characteristics, and foam applications. The third section describes the slabstock foam production process, including rebond and fabrication processes, followed by sections that describe where hazardous air pollutant (HAP) emissions occur in the slabstock process, and control technologies for these emissions. The next three sections present the same information for the molded foam process, from production process to emission control.

INDUSTRY DESCRIPTION

The flexible polyurethane foam source category is contained in the initial list of source categories for NESHAP under the amended Clean Air Act of 1990. In the Environmental Protection Agency's (EPA) initial source category listing,[1] the source category is defined as follows:

> "The Flexible Polyurethane Foam Production Source category includes any facility which manufactures foam made from a polymer containing a plurality of carbamate linkages in the chain backbone (polyurethane)."

Three types of polyurethane foam facilities appear to fit in this category description: slabstock flexible polyurethane foam (i.e.,

[1] Documentation for Developing the Initial Source Category List. U.S. Environmental Protection Agency. Research Triangle Park, NC. Publication No. EPA-450-3-91-030. July 1992.

slabstock foam), molded flexible polyurethane foam (i.e., molded foam), and rebond foam. Slabstock foam is produced in large continuous buns that are then cut into the desired size and shape (fabricated). Slabstock foam is used in furniture, bedding, packaging, and carpet cushioning. Molded foam is produced by "shooting" the foam mixture into a mold of the desired shape and size. The major use of molded foam, by weight, is in automobile interiors, but is used in many other applications such as packaging, novelty applications, and medical supplies. Rebond foam is made from scrap foam that is converted into a material primarily used for carpet underlay.

The foam chemistry of the slabstock and molded segments of the industry is analogous; however, the equipment, production processes, emission sources, and control techniques are very different. The rebond foam segment differs from both other segments in these areas, as well as in the chemistry.

Slabstock Foam Facility Distribution and Description

The EPA estimates that there are 78 slabstock foam facilities in the United States. Table 1 shows the distribution of foam facilities by state, and a complete list of slabstock facilities and their location are included as Attachment 1. Data were received from all 78 facilities through the distribution of an Information Collection Request (ICR) by the EPA.[2] The total reported 1992 foam production for these 78 slabstock facilities was approximately 560,000 tons. Three companies were responsible for over half of the production by weight. The annual production rate for individual facilities ranged from under 500 tons, to over 20,000 tons, with an industry average of approximately 7,500 tons.

In terms of corporate ownership and industry concentration, the slabstock foam industry is divided into two main segments. There are 10 companies that own or operate multiple plants. The three largest companies account for over half of the industry's foam production, and the seven largest companies account for 80 percent of the production. At the other end of the spectrum, there are 13 single-plant companies, and two companies operating only two plants each. Together, these small companies account for less that 10 percent of the industry's production.

Since slabstock foam is produced in large "buns," which must be cut into the desired sizes and shapes, fabrication operations are sometimes co-located with slabstock foam production facilities. In the ICR responses, of the 78 plants reporting

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[2] Memorandum. Norwood, P., Williams, A., and Battye, W., EC/R Incorporated to Svendsgaard, D., U.S. Environmental Protection Agency. Summary of Flexible Polyurethane Foam Information Collection Requests. January 24, 1994.

TABLE 1. DISTRIBUTION OF SLABSTOCK FOAM FACILITIES BY STATE

State	Number of Facilities
Arkansas	2
California	8
Delaware	1
Florida	5
Georgia	4
Illinois	3
Indiana	8
Iowa	1
Kansas	1
Kentucky	1
Maryland	1
Massachusetts	1
Michigan	2
Mississippi	8
Minnesota	1
New Jersey	2
New Mexico	1
North Carolina	9
Ohio	2
Oregon	1
Pennsylvania	4
Tennessee	5
Texas	5
Virginia	1
Washington	1
Wisconsin	1
Total	**78**

slabstock production, 69 indicated that they have fabrication operations on-site. The total amount of foam fabricated at the facilities was approximately 233,000 tons in 1992. This indicates that only about 48 percent of the total foam produced is fabricated by on-site fabrication operations.

Also, rebond foam production operations, which use foam scraps as the primary starting material to produce the foam product, are sometimes co-located with slabstock foam production facilities. A total of 21 facilities indicated that they produce rebond foam on-site, with a total production of 182,520 tons per year.[2]

Molded Foam Facility Distribution and Description

The EPA estimates that there are 228 molded foam production facilities in the United States.[3] The EPA used several sources to obtain this estimate. First, ICR responses were received from 46 molded foam facilities. Using the "Polyurethane Industry Directory and Buyer's Guide - 1994",[4] an additional 182 flexible molded foam companies were identified based on company descriptions. Table 2 presents the distribution of these 228 molded foam facilities by state. ICR responses were received from 46 facilities that manufacture molded flexible polyurethane foam. These 46 facilities are owned by 34 companies, and in 1992 they produced just over 99,000 tons of foam. The individual facility production ranged from 1 to 10,000 tons. The majority of this foam, by weight, was manufactured by two companies. Companies producing molded foam tend to be either medium-to-large (over 1500 employees), or much smaller (less than 100 employees). In fact, in 1992, 42 percent of plants produced less than 500 tons per year each.[2]

Rebond Foam Facility Distribution

The EPA estimates that there are 52 rebond foam facilities in the United States.[5] Of these rebond facilities, 21 are located at plant sites that also produce slabstock flexible polyurethane foam. Data were obtained from the ICR responses for these rebond operations.

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[3] Memorandum. Williams, A., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Flexible Polyurethane Foam Molded Plants: New Count and Nationwide Model Plant Representation. November 3, 1995.

[4] The Polyurethane Industry Directory and Buyer's Guide - 1994. Larson Publishing. Saco, Maine.

[5] Telecon. Norwood, P., EC/R Incorporated, with Oler, B., Carpet Cushion Council. May 30, 1996. U.S. Population of Rebond Foam Production Facilities.

TABLE 2. DISTRIBUTION OF MOLDED FOAM FACILITIES BY STATE

State	Number of Facilities	State	Number of Facilities
Alabama	3	Mississippi	1
Arizona	1	Missouri	7
Arkansas	1	Montana	1
California	19	Nebraska	1
Colorado	6	Nevada	2
Connecticut	8	New Hampshire	2
Delaware	2	New Jersey	11
Florida	1	New York	9
Georgia	4	North Carolina	5
Illinois	11	Ohio	23
Indiana	7	Oregon	2
Iowa	5	Pennsylvania	14
Kansas	3	Rhode Island	1
Kentucky	3	South Carolina	2
Maine	1	Tennessee	5
Maryland	5	Virginia	4
Massachusetts	4	Washington	4
Michigan	29	West Virginia	1
Minnesota	7	Wisconsin	8
		TOTAL	228

FOAM CHEMISTRY, CHARACTERISTICS, AND APPLICATIONS

This section describes the chemistry involved in producing flexible polyurethane foam, the foam characteristics used to describe the final foam product by the industry, and some of the many applications for the foam product.

Chemistry of Flexible Polyurethane Foam: Slabstock and Molded

Flexible polyurethane foam is produced by mixing three major ingredients: a polyol polymer, an isocyanate, and water. The polyol is either a polyether or polyester polymer with hydroxyl end groups. Other ingredients are often added to modify the polymer, and catalysts are used to balance the principal foam production reactions. The amount of each ingredient used in a foam formulation varies, depending on the grade of foam desired. Foam formulations are generally denoted in terms of the number of parts (by weight) of diisocyanate and water used, per 100 parts polyol.

A polyol is an organic polymer characterized by more than one terminal hydroxyl ("-ol") group. In flexible foams, the most commonly used polyols are trifunctional, with three terminal hydroxyl groups. Both polyether and polyester polyols are used in the production of flexible foams, but polyether polyols are the most common. These are produced by the polymerization of ethylene oxide and propylene oxide, starting with glycerine. The molecular weight of polyols used in foam production ranges from about 3000 to about 6000.

The second key ingredient in the foam formulation, the diisocyanate, links polyol molecules to produce the foam polymer. The diisocyanates used in flexible foam production are primarily toluene diisocyanate (TDI) and methylene diphenyl diisocyanate (MDI). Typically, TDI used in foam manufacture is a mixture of the 2,4- and 2,6- isomers, with the ratio being 80 percent 2,4- and 20 percent 2,6-. TDI is used primarily in slabstock production and MDI is used primarily in molded foam production. However, neither slabstock producers nor molded foam producers use one isocyanide to the exclusion of the other.

Surfactants and catalysts are also added to the mixture. The surfactants aid in mixing incompatible components of the reaction mixture, and also help control the size of the foam cells by stabilizing the forming gas bubbles. Amine catalysts balance the isocyanate/water and isocyanate/polyol reactions, and assist in driving the polymerization reaction to completion. Tin catalysts control foam gelling by assisting in driving polymerization to completion, which provides an optimal cure in a reasonable period.

Both the polyol and the diisocyanate are liquids at room conditions prior to the foam-producing reaction. These are mixed

with water under carefully controlled conditions. When the polyol, diisocyanate, and water are mixed, two main polymerization reactions occur. Most importantly, isocyanate groups react with hydroxyl groups on the polyol to produce urethane linkages (hence the term polyurethane). This reaction is generally promoted using a catalyst. The rate of polymerization is dependent on the structure of the polyol and the amount of catalyst used. Polyols with primary hydroxyl end-groups are much more reactive than polyols with secondary hydroxyl groups, although the most common polyols have secondary groups.

The other main reaction is that of the isocyanate and water. The initial product of the reaction with water is a substituted carbamic acid, which breaks down into an amine and carbon dioxide. The amine then reacts with another isocyanate to yield a substituted urea linkage. The CO_2 formed in this reaction acts as the "blowing agent." This reaction is extremely exothermic, and causes the temperature of the foam to rise to around 250 - 350°F. The reaction is also much faster than the polyurethane reaction discussed above. Thus, the polyurethane-forming reaction actually uses isocyanate that remains after most of the water is consumed.

The CO_2 generated in the isocyanate/water reaction acts as the "blowing agent" (blowing agents will be discussed in more detail later in this section) and produces bubbles, causing the foam to expand to its full volume within minutes after the ingredients are mixed and poured. The bubbles formed come into close contact and a network of cells is formed separated by thin membranes. Reaction rates must be balanced so that the polymer is strong enough at this point to maintain its shape without collapsing. At full foam rise, the cell membranes are stretched to their limits and rupture, releasing the blowing agent and leaving open cells supported by polymer "struts."

At the time that the cells open the polymer strength is low, with a significant proportion of the isocyanate groups remaining unreacted. The temperature continues to rise after the foam has fully expanded because of the continuing reaction. The maximum temperature is usually reached between 30 minutes and 1 hour after pouring. The temperature of the foam can remain at this temperature for up to 8 hours due to the insulating properties of the foam. After this period, terminal isocyanate groups from the polymer chains continue to react to form cross-links with amine hydrogens in the mid-section of the chains. This reaction can persist for up to 48 hours. These secondary reactions involve the hydrogen atoms of the urethane and urea linkages to form allophanate and biuret linkages, respectively. These cross-link reactions are part of the foam curing process, and affect the strength and elasticity of the foam polymer. Therefore, the amount of isocyanate relative to other ingredients in the

formulation is an important parameter in determining foam properties.

The relative amount of isocyanate is specified by the isocyanate "index." This index is defined as the ratio, expressed in percent, of the number of moles of isocyanate groups to the number of moles of other chemical groups that will react with isocyanate. An index of 105 refers to a 5 percent excess of isocyanate, while an index on 95 refers to a 5 percent shortfall of isocyanate.. An isocyanate index of 100 refers to balanced stoichiometry.

The final polymer is composed of the urethane and urea cross-linkages formed in the isocyanate/polyol and isocyanate/water reactions. The polyol-to-isocyanate urethane linkages provide strength, and the isocyanate-to-isocyanate urea linkages give the foam its firmness.[6]

Auxiliary Blowing Agents

As noted in the previous section, one result of the isocyanate-water reaction is the liberation of CO_2 gas. The blowing action of this CO_2 is termed "water-blowing," because the CO_2 blowing agent is produced from the isocyanate-water reaction. Many grades of foam can be produced using only this CO_2 gas as a blowing agent.

Increasing the amount of water in a formulation generally produces a lower-density foam, because additional CO_2 blowing agent is produced. However, there is a practical limit to the amount of water that can be used. First, an increase in the water level results in an increase in the number of urea linkages in the final polymer. These linkages tend to make the polymer stiffer because they undergo hydrogen bonding. Second, the isocyanate-water reaction is extremely exothermic. An excessive level of water can cause high temperatures that can scorch the foam, or even cause the foam to ignite.

As a result, some grades of foam require the use of an auxiliary blowing agent (ABA). The ABA is mixed with the foam reactants as a liquid when the reactant mixture is first poured. As the exothermic polymerization reactions raise the temperature of the polymer mass, the ABA vaporizes, supplementing the blowing action of CO_2 from the water-isocyanate reaction. The vaporization of the ABA also serves to remove excess heat from the foam, reducing the potential for scorching or auto-ignition.

Auxiliary blowing agents (ABAs) are more widely used in the production of slabstock foams than in the production of molded

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[6] Woods, George. *The ICI Polyurethanes Book*. ICI Polyurethanes and John Wiley & Sons. 1987.

foams. The amount of ABA required depends on the grade of foam being produced and the ABA used. ABAs are most important for low density and soft foams. In these grades, water-blowing alone would cause problems with either overheating or with increased foam stiffness. For low-density foams, ABAs are used in conjunction with water-blowing to avoid overheating. In the case of soft foams, ABAs provide blowing action without increasing the foam's stiffness.

Previously, the principal ABA used was chlorofluorocarbon 11 (CFC-11). However, since this compound has been shown to deplete the earth's ozone layer, U.S. producers have almost completely phased out its use. Methylene chloride, a listed HAP, has replaced CFC-11 as the principal ABA. Since the role of the methylene chloride is simply to volatilize and expand the foam, it does not directly participate in the polyurethane reaction. Therefore, all of the methylene chloride that is added eventually is emitted.[6]

Foam Grades and Applications

Flexible polyurethane foam is produced in a wide range of grades. Foam grades are almost always identified by two parameters: density, and firmness. Foam densities range from less than 1 pound per cubic foot to more than 3 pounds per cubic foot. Higher density foams are typically more durable than lower density foams, because they contain more mass of polymer per unit volume. However, the higher density foams require more raw materials, and hence have higher production costs.

The firmness of a foam determines its load bearing ability. This parameter is also related to the foam's softness. Softer foams will necessarily have a low degree of firmness. The most common measure of firmness is the "indentation force deflection" (IFD). This is the force required for a 50 square inch disk to cause a certain percentage of indentation in a foam block. IFD is expressed in pounds, and is measured at different percentages of indentation. The most common IFD measurement is at 25 percent indentation. Foam IFD can range from 20 pounds to over 100 pounds (both at 25 percent).

Different grades of foam have different primary applications; however, there is no strict relationship between the grade and the application. For instance, the density of foam used for seat cushioning can range from 1 pound per cubic foot to 3 pounds per cubic foot, depending on quality and other specifications. In general, lower density and softer foams are used for seat backs and arm rests. Low density, stiff foams are well suited for packaging. Foams with moderate density and load bearing capacity are used for seat cushions and bedding. Higher density foams are generally used for carpet packing, and other heavy-duty applications.[6]

In addition to the density and IFD grades, polyurethane foam grades are specified based on additives that are used to achieve specific properties. Some additives are inert materials that become incorporated in the foam polymer matrix. Others are actually incorporated into the polyurethane polymer chains, or increase cross-linking between polymer chains. The most important of these additives are flame retardants. Flame retardants operate by a number of different mechanisms. Some simply provide a heat sink. Others give off incombustible gases when heated, and others actually modify the mechanism of combustion of the foam.

Foam Characteristics and Quality Measurements

A number of other physical properties besides density and IFD are measured as indicators of foam quality. These include hysteresis, dynamic fatigue, air flow, tensile strength, elongation, tear strength, and resilience. Hysteresis is a measure of the foam's durability and is determined by the percentage of the original 25 percent IFD retained after measurement of the 65 percent IFD. Dynamic fatigue is another foam durability measurement. It is measured as the loss in IFD after the sample has been flexed numerous times. Air flow is a measure of the breathability of the foam, and is measured as the rate of pressurized air flow through a foam sample. Tensile strength is a foam's resistance to tearing and shredding, and is measured as the force (pounds) required to break a 0.25 square inch segment of foam. Elongation is defined as a foam's resistance to tearing and shredding, and is measured as the percent extension of a one-inch segment of foam at rupture. Tear strength is another measure of a foam's resistance to tearing and shredding, and is defined as the force required to tear a one-inch length of foam. Resilience is a measure of a foam's surface elasticity or "springiness", and is measured by calculating the percent of the original height a steel ball bounces when dropped on a foam sample. Resilience is also often determined by the compression set performance of the foam, which is the ability of a foam to return to its original shape after being compressed.

SLABSTOCK FOAM PRODUCTION

Process Description

Flexible slabstock foam is produced as a large continuous "bun" that is later cut into sections with the desired dimensions. There are variations in the design of the machines that produce the foam, they may be horizontal or vertical, with the horizontal foam line being the most common. There are several types of horizontal foam machines found in foam facilities. The most common system is called Maxfoam, illustrated in Figure 1, which is described in the next section. Following the description of the Maxfoam line will be a

description of the Vertifoam process, a vertical foam production process (Figure 2). A slabstock foam facility may have more than one foam line, however, for the remaining discussions it will be assumed that there is only one foam line. Rebond and foam fabrication will also be discussed in this section.

Horizontal Maxfoam Production[6,7]

From bulk chemical storage, raw ingredients are moved to smaller feed tanks. The temperature of the feed materials, particularly the TDI, is very important. The chemicals are pumped from the feed tanks to the mixing head of the foam line where they are vigorously mixed. The amount of each chemical sent to the mixing head is carefully controlled by metering pumps. The mixture is discharged through a mixing head into a trough where the reactions begin to occur (i.e., "creaming"). From this trough, the froth flows onto the foam tunnel. The mixture quickly spreads evenly across the width of the tunnel, which is typically around 82 inches.

The bottom of the tunnel consists of a series of five adjustable fall-plates that are covered by paper. The foam reaches its maximum height, or "full rise" about 25 feet from the nozzle. The full rise time is dependent on the grade of foam, with lower density foams rising highest and at the fastest rate. Instead of "rising," the foam actually expands downward along the slope of the fall plates. The slope of the tunnel can be altered to allow for the changing reaction rates of different foam grades. The downward slope helps flatten the top of the bun by cutting down on side-wall drag. Flat-top buns are desirable to eliminate waste foam. The sides of the foam tunnel are vertical conveyors, covered with plastic as they move the foam down the tunnel. The fall plats are stationary, and it is the moving side plastic and the bottom paper that move the foam to the belt conveyor portion.

The belt conveyor carrying the foam block moves at an average speed of 15 to 20 feet per minute. Additional time on the conveyor after full rise is required to allow the polymerization reactions to be completed so the foam will solidify. The side papers are then removed from the bun, and the bun is sawed into the desired lengths. After sawing, the end of the bun is marked with the foam grade, and the bun moves off the belt conveyor onto a roller-type conveyor moving at a higher rate of speed. This conveyor continues through the wall of the pouring area, through the foam storage area, and then into the

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[7] Memorandum. Norwood, P. and Williams, A., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Site Visit Report of Hickory Springs Manufacturing's Conover, NC facility on May 25, 1993. June 18, 1993.

foam curing area. In the curing area, the buns are removed from the conveyor with overhead cranes and placed on the floor.

Typically, buns are cured 12 to 24 hours before being moved from the curing area to foam storage. To move a bun to the storage area, the overhead crane lifts it from the floor and carries it to another conveyor system, which takes it back to the storage area. In the storage area, buns are piled 4 or 5 high. The buns remain in the storage area until ready for fabrication or shipping.

Vertifoam Production Process Description[6,8]

In the Vertifoam process, the foam reaction mixture is introduced at the bottom of a completely enclosed chamber. This chamber is lined with paper or plastic, which is drawn upwards at a controlled rate. The rate is dependent on the pressure in the chamber, the foam formulation, and the rate of production. With a controlled rate of upward pull, the rheology of the foam reaction process, combined with the effect of gravity, ensures a stable foaming front, and prevents the mixing of the still liquid reacting mixture with the partially gelling foam poured a few seconds earlier.

Foam Fabrication Process

As mentioned earlier, slabstock flexible polyurethane foam is produced in large buns which are typically 4 feet tall, 8 feet wide, and 50 to 100 feet long. Prior to being delivered to the furniture manufacturer or other end-user, the large buns are "fabricated" according to the end-use. The simplest type of fabrication is to cut the foam into the desired shape by use of specialized saws, by hand-cutting, or other techniques. However, many customers desire foam products that are more "finished" or complex. To produce such products generally requires the gluing of foam-to-foam, or foam to some other material such as cotton batting. The most commonly used adhesives are methyl chloroform based (a HAP). Since methyl chloroform has also been identified as an ozone depleting substance, fabricators have been searching for alternative adhesives. It appears that the most popular replacement has been $MeCl_2$-based adhesives.

Fabrication operations are sometimes co-located with foam production operations (i.e. on-site). Information from the ICR's revealed that approximately 40 percent of the foam produced is fabricated on-site.[2]

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[8] Memorandum. Williams, A., EC/R Incorporated to Svendsgaard, D., U.S. Environmental Protection Agency. Site Visit Report of Crain Industries' San Leandro, CA facility on August 26, 1993.

Slabstock HAP Emission Sources

This section will discuss the HAP emission points for slabstock foam production and fabrication. The four main sources of HAP emissions are: storage and transfer of raw materials, leaking components in HAP service, the foam tunnel and curing area, and equipment cleaning. In addition, HAP emissions also occur in the fabrication area due to the use of HAP-based adhesives.

Storage and Transfer

Raw HAP chemicals are received at foam facilities by railcar, tank truck, and in drums. Emissions can occur during the unloading of the HAP from the railcar or tank truck. There can also be small amounts of HAP emitted from the storage tank due to diurnal temperature or pressure changes. However, since many foam facilities have storage vessels located in temperature controlled environments, these "breathing loss" emissions are uncommon.

Components in HAP Service

There can be small amounts of HAP releases from leaking components in HAP service. Some examples of components in HAP service that may leak are pumps, valves, flanges, or connectors.

Foam Tunnel and Curing (ABA Usage)

As mentioned earlier, $MeCl_2$ is the principal auxiliary blowing agent used, and its role is simply to volatilize and expand the foam, not directly participate in the polyurethane reaction. Therefore, all of the methylene chloride that is added eventually is emitted. The use of $MeCl_2$ as an ABA was the largest emission source of HAP's reported in the ICRs.[2] Industry representatives state that approximately 40 percent of the methylene chloride emissions occur before the cutoff saw and another 20 percent are released during foam transfer. The remaining 40 percent is emitted in the curing area.[9]

Equipment Cleaning

Methylene chloride is used as a cleaner to rinse and/or soak foam machine parts such as mixheads and foam troughs at the end of a pour. There is hardened foam residues on the trough, fall plates, and other equipment that must be removed.

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[9] Flexible Polyurethane Foam (Slabstock) Assessment of Manufacturing Emission Issues and Control Technology. Polyurethane Foam Association. May 17, 1993.

Fabrication

The HAP emissions in fabrication operations occur due to the use of HAP-based spray adhesives to glue fabric-to-foam, or foam-to-foam. As mentioned earlier, in the slabstock industry, only about 40 percent of the fabrication is done "in-house", and not all fabrication involves gluing. Fabrication covers the broad range of die cut parts, cut parts, as well as glued parts. Normally these adhesives are approximately 20 to 40 percent solids, while the remainder consists of a solvent carrier, such as methyl chloroform or $MeCl_2$.

Control Technologies for Slabstock HAP Emissions

The EPA reviewed information from the ICR responses that were received from flexible polyurethane foam producers, as well as the information contained in other pertinent project files, to identify potential HAP emission reduction and control technologies. This section discusses HAP emission reduction technologies for the slabstock industry. The EPA created a report entitled "Flexible Polyurethane Foam Emission Reduction Technologies Cost Analysis".[10] (This report will hereafter be referred to as the Cost Report.) The intent of this report was to examine some proven emission reduction technologies for this industry, and some of the costs associated with the installation, and use, of these technologies. The reader is referred to this document for information on cost and emission reduction potential, as well as additional process and operational information, for each technology.

Control Technologies for ABA Emissions

There were several alternatives identified to either reduce or eliminate the use of $MeCl_2$ as an ABA in the manufacture of flexible slabstock polyurethane foam. The technologies identified were acetone or liquid CO_2 as an ABA, foaming in a controlled environment, forced cooling, chemical modifications, and carbon adsorption. These alternatives are discussed in the following paragraphs.

Acetone as an ABA.[7] In response to environmental concerns over the use of methylene chloride, Hickory Springs developed and patented a technology to allow the use of acetone as an ABA. Acetone is not a HAP, and has recently been delisted as a volatile organic compound, or VOC (60 FR 31633). One of acetone's biggest advantages is that it only requires 55 percent (by weight) as much acetone as $MeCl_2$ for the same amount of foam. The use of acetone requires certain equipment modifications

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[10] Flexible Polyurethane Foam Emission Reduction Technologies Cost Analysis. EPA-453/R-95-011. U.S. Environmental Protection Agency. September 1996.

because of the high flammability of acetone, but does not require significant changes in the manner in which the process is operated.

Liquid CO_2 as an ABA. Several companies have developed processes for using liquid CO_2 as the ABA in slabstock foam manufacture. One of these systems, called CarDio™, has been developed by the Cannon Group, and is patented worldwide, available under license by Foaming Technologies Cardio B.V. Other companies that have developed liquid CO_2 systems are Hennecke Machinery and the Beamech Group. There are several full scale units reported to be in operation in the United States.

The CarDio™ system operates by adding liquid CO_2 to the polyol stream before the polyol stream is injected into the mixing head. This generates a rapidly expanding froth immediately after the pouring nozzle. Cannon developed a special laydown device to counteract this rapid expansion. This device controls the expansion phase immediately after the mixing head, and allows for the depositing of a homogenous pre-expanding and reacting mixture over the entire section of the fall-plate. The laydown device's special design allows for a progressive release of blowing agent in the reacting mass, avoiding local concentrations of free gas that can cause pinholes or "chimneys" in the foam.[11]

The use of this technology requires additional equipment and modifications to existing equipment, and it cannot be used to produce all grades of foam. Therefore, it is not an acceptable direct replacement for HAP ABA. However, it can provide a significant emission reduction of HAP ABA.

Foaming in a Controlled Environment - Variable Pressure Foaming (VPF) and Controlled Environment Foaming (CEF). Foam expands more under conditions of decreased atmospheric pressure, meaning that many types of foam can be manufactured at higher altitudes with little or no ABA. In other words, when a given foam formulation is processed at less than atmospheric pressure (i.e., under vacuum), a lower density and a softer foam will result when compared to the same foam formulation being processed at atmospheric pressure. This principle can be applied under standard atmospheric conditions through enclosure of the foam line, and subsequent reduction of pressure during foam production. Two systems that control the atmospheric conditions during foam production were identified: variable pressure foaming and controlled environment foaming. Descriptions of these systems follow below.

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[11] Florentine, C., T. Griffiths, M. Taverna, and B. Collins. *Auxiliary Blowing Agent Substitution in Slabstock Foams*.

The VPF system is patented by Foamex Worldwide. The system involves processing foam in an enclosed chamber under a controlled pressure. The pressure in the chamber is fixed before foaming, and remains constant during the foaming operation. After the bun is cut, it is then passed into a second airlock chamber, which is at the same pressure as the foaming chamber. This chamber is then opened to the atmosphere, and the bun is removed and transported to a storage rack. During this time, foam production is continuing in the first chamber. In the United States, Foamex has one VPF facility in full-scale operation, and a few others are being installed.[12,13]

FOAM ONE company has developed and patented a polyurethane foam manufacturing process, which is called CEF.[14] The CEF process is a discrete block production method which uses a containment vessel to control the pressure and temperature during foaming. During production, foam is poured into a mold inside the containment vessel. The foam reaction is allowed to take place under the controlled conditions of the containment vessel.

In addition to the complete elimination of ABA, there are other advantages of the CEF system. Since the blocks are prepared in heated molds, the finished block has a perfectly flat top and a very thin skin, thus maximizing foam yield. The process is under complete computer control, ensuring exact duplication of products. In addition, TDI emissions from the foaming reaction are vented through a carbon bed, thus practically eliminating TDI emissions. While there are low energy requirements and low maintenance expenses, the production rate is considerably slower than a traditional Maxfoam line. Therefore, it would take longer to make the same amount of foam on a CEF machine.

Forced-Cooling: Enviro-Cure®. Two of the primary functions of an ABA are to reduce the density of the foam and to provide cooling effects. Increasing the amount of water in the formulation will reduce the foam density, but increases the exotherm of the reaction, which can lead to bun scorching or even auto-ignition. The cooling of the bun by mechanical means can

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[12] Spellmon, L, Foamex, to Jordan, B., U.S. Environmental Protection Agency. Letter discussing Variable Pressure Foaming (VPF). October 25, 1993.

[13] Hay, R, Foamex International Inc., to Williams, A., EC/R Incorporated. Letter transmitting comments on the May 1995 preliminary draft of the "Flexible Polyurethane Foam Emission Reduction Technologies Cost Analysis." June 1, 1995.

[14] Carson, S. Controlled Environment Foaming: Manufacturing a New Generation of Polyurethane Foam. Prepared for FOAM ONE.

eliminate this potentially dangerous situation, while allowing the production of low density foams.

The EPA obtained and reviewed information on two different patented types of forced-cooling techniques that are in full-scale operation, Enviro-Cure® by Crain Industries, and Rapid-Cure® by General Foam. The EPA is also aware of other companies experimenting with similar forced cooling processes. Since the Enviro-Cure® technology is fully operational at several facilities acrbss the United States, the following discussion focuses on this system.

Most of the Enviro-Cure® systems in operation in the United States are installed on Vertifoam® lines, which is a type of foam line used only by Crain in the United States at this time. Crain has also retrofit a traditional Maxfoam system with Enviro-Cure®. This type of retrofit is described in the following paragraphs, but the general Enviro-Cure® principle for a Vertifoam® system is the same.

The Maxfoam Enviro-Cure system is an enclosure with an associated conveyor system, which is put in place after the traditional slabstock pouring line. The cut blocks from the Maxfoam machine are transferred to the Enviro-cure unit, where the block is transported through the cooling enclosure. Once the blocks are inside the enclosure, controlled air is passed through the block by means of a vacuum process, which cools the block by convection and conduction. In addition to the elimination/reduction of ABA, forced cooling produces a more uniform bun. That is, the properties are more consistent between the outer portion of the bun and the core.

Chemical Modifications. Chemical modifications are demonstrated methods of reducing ABA usage. The types of chemical modifications included in this analysis can be separated into two groups: chemical additives, and alternative or "soft" polyols. Additives are usually added to the foam formulation at the mixhead. The alternative polyols are substituted for a portion of the traditional polyols in the foam formulations.

Chemical additives and alternative polyols have proven to be successful in the reduction of ABA used for foam softening. There are two basic methods by which these technologies soften the foam. The most common method is by reducing the TDI index, which reduces the number of isocyanate groups available to form urea linkages. One of the additives studied softens foam by changing the reactivity of the isocyanate groups of the TDI isomers so that the resulting polyurea segments of the foam are altered.

These chemical modification technologies can allow the elimination of ABA for foams with densities greater than 1.0 lb/ft^3 and Indentation Force Deflections (IFDs) greater than

20 lbs, although there will likely be a deterioration in foam properties at densities less than 1.5 lbs and IFDs lower than around 25 lbs. However, the use of these chemical alternatives for the lower density/lower IFD foams does allow a reduction in the amount of ABA needed, without sacrificing foam property quality. The actual amount of reduction will vary with the combination of density, IFD, and other desired foam properties, but can be as high as 70 percent.

These technologies have not been as successful in the area of density reduction. Unlike methylene chloride, they do not directly decrease the density by auxiliary "blowing" of the foam. They also do not provide the necessary cooling effects to allow increased water levels. However, as noted above in the section on forced cooling, the combination of forced cooling and chemical modification can allow further reduction in the ABA usage for density reduction.

An advantage of chemical modifications is that their use does not change the production method for slabstock foam. Capital improvements may be necessary, including a new storage tank and associated plumbing, and new pump(s) and a metering system.

Carbon Adsorption. The recovery of HAP ABA is also an option to reduce emissions. However, the traditional layout of a slabstock production line is not conducive to a recovery system, particularly the recovery area. The large volumes of air in the curing area, which is typically a large open warehouse, and the low concentrations, make the design of a recovery device impractical. However, the installation of unconventional curing enclosures to allow higher concentrations and lower flow rate could allow the use of carbon adsorption. One facility in the United States has installed and is successfully operating a carbon adsorption recovery system on a full-scale slab;stock foam production operation.[15]

Control Technologies for Chemical Storage and Handling Emissions

There were two methods identified for reducing HAP emissions from this source, carbon canisters and a vapor balance system. Carbon canisters control emissions by routing the vapors that were displaced from the vapor space of the tank during filling through activated carbon prior to being released to the atmosphere.

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[15] Memorandum. Williams, A. and Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Summary of April 26, 1995 Telephone Conference between Ohio Decorative Products and the EPA. May 31, 1996.

Vapor balancing is the other method identified. When a storage tank is filled, the vapors forced out by the incoming liquid and are routed through piping back to the railcar or tank truck.

Control Technologies for Leaking Components in HAP Service

Two methods for controlling leaks from components in HAP service were identified, canned pumps and a leak detection and repair (LDAR) programs. Canned pumps are a type of sealless pump than can be used to replace traditional pumps except for high pressure metering pumps. LDAR programs have set methods and timetables for monitoring for equipment leaks, and certain procedures for fixing any problems found.

Control Technologies for Equipment Cleaning Emissions

Methylene chloride is used as a cleaner to rinse and/or soak foam machine parts such as mixheads and foam troughs. The two alternatives to eliminate these HAP emissions identified were steam cleaning and non-HAP cleaners.

Non-HAP Cleaners. There were several alternative cleaners identified that were not HAP based. Some solvents they contain are furanone, cyclic amide, ethyl ester, other esters, N-Methylepyrrolidone (NMP), and D-limonene. All cleaners identified are direct replacements for $MeCl_2$, meaning that they typically require no equipment or operational changes.

All the non-HAP solvent-based cleaners identified eliminate HAP emissions, but the solvents in them are still classified as VOCs. All three products have low evaporation rates, and can be reclaimed and reused. There are also savings in disposal costs of the waste material, as none of the spent cleaner from these products is classified as a hazardous waste, unlike $MeCl_2$.

Steam Cleaning. Some flexible polyurethane foam slabstock plants were identified in the ICR database that use steam to flush hoses, mixheads, and other pouring equipment.[2] The reacted foam scrap from the steam cleaning was collected and shredded for use in a rebond operation.

Control Technologies for Fabrication Adhesive Emissions

HAP-based adhesives are used in both slabstock and molded foam facilities. As the reduction alternatives are the same for both subcategories, they will both be discussed below. In slabstock facilities, spray adhesives are used to glue fabric-to-foam, or foam-to-foam. As mentioned earlier, in the slabstock industry, only about 40 percent of the fabrication is done "in-house", and not all fabrication involves gluing. The main use of adhesives in molded foam facilities is for the repair of voids and tears in the molded pieces.

Three alternatives were identified that eliminate HAP emissions from the use of adhesives. These are (1) hot-melt adhesive, (2) water-based adhesives, and (3) Hydrofuse. Each is discussed below.

Hot-Melt Adhesives. Hot-melt adhesives are sold as solids that are melted in a tank system before being sprayed on, like solvent-based adhesives. They have a quick drying, or "tack" time, so it is possible to maintain normal production rates. In some instances, the tack time is too short to allow proper adhesion, so that by the time a cushion as been sprayed, the earliest adhesive applied has cooled to the point that it is no longer sticky. However, the tack time depends on the product used, and some manufacturers produce hot-melts with expanded tack times. Another problem is the possibility of operator injury, as the temperature of the adhesive is maintained above 200° F, which could cause burns.

Hot-melt adhesives do not contain any HAP's; however, small amounts of low molecular weight hydrocarbons may be emitted at application temperatures. There is also a decrease in the amount of adhesive needed to adhere the same amount of foam.

Water-Based Adhesives. The largest advantage to water-based adhesives is that all HAP's have been replaced by water, and there is a complete elimination of organic emissions. The main drawback is the slower drying times of these adhesives. Many fabrication systems require an additional heat source to speed the evaporation of the water. This additional wait increases the space needed, and increases the utilities to operate the lamps. However, there are no other equipment or operational changes necessary to replace HAP-based adhesives with water-based.

Hydrofuse. Another water-based alternative to solvent-based adhesives is a product called Hydrofuse. Hydrofuse is a two-component, water-based adhesive that allows immediate contact bonding without the need for drying. The two-components, a water-based latex adhesive, and a mild citric acid solution, are externally co-sprayed causing the adhesive to immediately coagulate.

This process does require some process and equipment changes. Equipment alterations will include changing to new spray guns, and assuring that all wetted parts are stainless steel or plastic. Process considerations include operator training in the use of a two-component adhesive, and in application rates. Another special requirement for this adhesive is that one of the two surfaces to be adhered must be porous. A significant advantage of this product is that there is little or no penetration of the surface it is applied to, and it dries almost instantly.

MOLDED FOAM PRODUCTION

Process Description[16]

A typical molded foam production line includes multiple molds, with each mold consisting of top and bottom sections, joined by hinges. The molds are mounted on a circular or oval-shaped track. Both the molds and the track can vary broadly in size. Mold sizes range from less than one foot for novelty items, to several feet for mattresses. The track can be a small carousel, with fewer than 10 molds, or a large racetrack, with over 20 molds. The molds travel around the track, and the necessary process operations are performed at fixed stations. The following paragraphs describe a basic molding cycle.

The first step in the molding cycle is the application of mold release agent. This is a substance that is applied to the mold to facilitate removal of the foam product. The mold release agent is typically a wax in a solvent carrier. The carrier may be either a chlorinated solvent or a naphtha petroleum solvent. Mold release agent is typically applied by a spray system. After the mold release agent is applied, any special components to be molded into the foam are placed in the mold. These might include covers, springs, or reinforcing materials.

Raw materials, including polyol, diisocyanate, water, catalyst, and surfactant are all pumped to a common mixhead in predetermined amounts. The mixhead injects a precisely measured "shot" of raw material into each mold. There are two types of mixheads used in the industry, high-pressure and low-pressure. In a high pressure system, mixing is achieved by impingement of the high pressure streams within the mixhead. The low-pressure system relies on a rotating mixer within the mixhead to blend the raw chemicals together. The two types of mixheads have different cleaning requirements, resulting in a dramatic difference in overall emissions from the process, which will be discussed in the HAP emission section that follows.

After the raw materials are charged by the mixhead, the molds may be heated to accelerate foam curing reactions. This can be accomplished by pumping hot water through tubes in the body of the mold, or by passing the mold through a curing oven. The amount of heating required, if any, depends on the specific process.

The mold is then closed, and the polymerization reaction occurs, producing a foam product that fills the mold. Most

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[16] Memorandum. Williams, A. and Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Trip Report - Foamex International, Morristown, TN. EC/R Incorporated. January 18, 1994.

molded foams are produced without any auxiliary blowing agent (ABA), using only the blowing action of carbon dioxide (CO_2) gas from the water-isocyanate reaction. After curing, the molds are opened and the product is removed. The mold is then cleaned and starts the circuit again. The entire cycle takes approximately 10 minutes.

Another important variation of molded foams is the integral skin foam, also known as a self-skinning foam. An integral skin foam is a foam with a dense, tough outer surface. The skin is produced by overpacking the mold and using an ABA, usually Freon-11. Unlike other types of molded foams, integral skin foams require an ABA. The skin production is also driven by the temperature gradient between the center of the foam mass and the relatively cooler surface of the mold. Integral skin foams are used in such products as steering wheels and footwear.

Most grades of molded foam, especially those using more reactive raw materials, have closed cells when they are initially removed from the mold. The cells are opened, by mechanical or physical processes, to prevent shrinkage. The most common method used to open the foam cells is to "crush" the foam by passing it through a set of rollers.

After a foam piece is removed from the mold and its cells are opened, it generally is trimmed and inspected for tears or holes. Any tears and holes are repaired. Repair operations are carried out at glue stations, which may by equipped with local ventilation systems to remove solvent vapors emanating from the glue.

Molded HAP Emission Sources

This section will discuss the HAP emission points for molded foam production. Three main areas of HAP emissions from molded foam are mixhead flush, mold release agents, and repair operations (from adhesive use).

Mixhead Flush

Methylene chloride emissions for flushing of low-pressure mixheads was the largest emission source for flexible molded foam manufacture.[2] With low-pressure mixheads, the chemical streams enter the mixing chamber at approximately 40 to 100 psi, and are blended by rotating mixer blades before being released or "shot" into the mold. Residual materials can remain in the chamber, as well as on the blades. This material needs to be cleaned out, either after every shot, or after several, depending on the conditions. Flushing is necessary because the residual froth can harden and clog the mixhead or can interfere with the necessary precision required of the volume of the foam shot.

Mold Release Agents

Emissions from mold release agents was another source of HAP emissions from molded foam. Mold release agents are sprayed on the mold surface(s) before the foam mixture is poured into the mold to prevent adhesion and create a smooth surface. Traditional mold release agents consist of a resin in a solvent carrier, frequently methylene chloride or 1,1,1-trichloroethylene (methyl chloroform), both HAPs. The carrier evaporates, leaving the resin, which prevents the foam from sticking to the mold.

Molded Foam Repair

Once a foam piece has been removed from the mold, it is inspected for tears or holes. If repair is needed, scrap foam pieces, or the original piece that stuck to the mold, are glued to fill in the void. A HAP-based adhesive may be used for this process, with the carrier solvent being a HAP. The emissions occur when the solvent carrier evaporates after the adhesive is applied.

Control Technologies for Molded HAP Emissions

As was discussed in the HAP control technologies section for slabstock, the EPA identified emission reduction and control techniques for the flexible polyurethane foam industry. Mixhead flush and mold repair emission reduction technologies are discussed below. The emission reduction technologies for repair adhesives are the same as for slabstock fabrication, and were discussed in that section earlier in the memorandum.

Control Technologies for Mixhead Flushing Emissions

As noted above in the discussion of HAP emission sources, methylene chloride emissions for flushing of low-pressure mixheads was the largest emission source for flexible molded foam manufacture. Several technologies were identified to reduce or eliminate this source of HAP emissions for the molded foam producer. They are non-HAP flushes, high-pressure mixheads, self-cleaning mixheads, and solvent recovery units.

High-Pressure (HP) Mixheads. Low-pressure mixheads can be replaced with high pressure (HP) mixheads. HP mixheads dispense the foam at a higher pressure. These mixheads have already replaced low-pressure mixheads in many larger molded foam facilities. With HP mixheads, the raw materials are fed into the mixing chamber through two or more opposing nozzles. The nozzles are sized to produce a sharp pressure drop that causes the liquid streams to be accelerated, so that when they impinge the streams are thoroughly mixed. HP mixheads eliminate the need for $MeCl_2$ as a flushing agent as there is no residual froth left in the mixhead. HP heads may not be applicable for manufacturers of

small parts, as the low throughput rate for these parts may be too low for the HP system to achieve the required mixing.

Replacing low-pressure mixheads with HP heads requires replacing more than just the mixing heads. It usually requires new metering pumps and metering controls to provide the chemicals at the higher pressures. The connecting hoses may also need to be replaced if they are not suitable for handling the chemicals under increased pressure.

Non-HAP Mixhead Flushes. Several non-HAP solvent-based flushes were identified and investigated. The solvents they contain are cyclic amide, ethyl ester, glutarate ester, and other esters;[17,18] and one product's major component is D-limonene, with small amounts of terpene hydrocarbons.[19] The important characteristics of alternative flushes are that they are quick-drying, quick cleaning, and non-reactive with the foam raw ingredients. All flushes identified are direct replacements for methylene chloride, meaning they typically require no equipment or operational changes. The spent flush from these products is not classified as a hazardous waste, unlike $MeCl_2$.

All solvent-based flushes eliminate HAP emissions, but the solvents in them are still classified as VOCs. However, all three products identified have significantly lower evaporation rates, with maximum vapor pressures of 2 mm Hg, as compared to $MeCl_2$ (355 mm Hg vapor pressure.) Another major advantage is that all three products are reclaimable and reusable. According to the vendors, the solids can be filtered out and the solvent reused 2 to 5 times. Further use can be extracted from these products if the solvent is distilled, while $MeCl_2$ can only be reused if it is distilled.

Solvent Recovery Systems. Two molded foam facilities were contacted that had solvent recovery systems in place.[20,21]

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[17] Dynaloy, Inc. *Material Safety Data Sheet.* Transmitted to EC/R Inc. via facsimile on April 26, 1994.

[18] Huron Technologies, Inc. *Material Safety Data Sheet.* Transmitted to EC/R Inc. via facsimile on April 29, 1994. Cover letter from G. Borgeson, president, Huron Technologies, Inc. to A. Williams, EC/R Inc.

[19] Florida Chemical Co., Inc. *Material Safety Data Sheet.* Transmitted via facsimile from Steven Ferdelman, Chem Central, to A. Williams, EC/R Inc., on April 23, 1994.

[20] Telecon: A. Williams, EC/R Inc., to D. Peck, Renosol Corp. June 7, 1994.

Both systems had a capture system where the HAP flush is captured in a 55-gallon drum at each line. The drums are then taken to a reclamation room, and the flush is pumped into a 2000 to 2500 pound tote. This tote is placed in a solvent reclamation unit, which is heated to between 210 and 240° F. The solvent vapors are flashed off and go to a condenser. The solids from the still are collected for disposal. Both systems had a recovery rate of about 70 to 80 percent.

One of the systems had an additional step to reduce emissions at the capture area. They have equipped the three molded lines that use solvent flush with a "closed-loop system" for capturing the methylene chloride vapors from the area around the 55-gallon drum used to capture the flush. This system consists of a fan that draws the air from that area through a carbon filter, which captures the solvent vapors before they are released to the atmosphere.

Control Technologies for Mold Release Agent Emissions

Alternatives being used, or being investigated, by the industry to eliminate the use of HAP-based mold release agents include water- or naphtha-based agents, and reduced-VOC solvent agents. The following paragraphs discuss these three options.

Reduced-VOC Mold Release Agents. The reduced-VOC mold release agents are high-solids, solvent-based formulations. The advantage of these agents over traditional HAP-based agents is a reduction in VOC emissions of up to 80 percent. It was unclear if any of the solvents used are HAP's, although the EPA believes that they are not. One vendor stated that most users have seen a reduction in mold release consumption of 20 to 50 percent after switching to the reduced-VOC release agents.[22] No equipment changes are necessary in switching to this type of release agent, and no significant operator training or mold temperature changes are necessary.

Naphtha-based Release Agents. Naphtha-based release agents are composed of resins in a hydrocarbon naphtha carrier solvent. Naphtha typically composes at least 90 percent of the mold release agent.[23] Naphtha is not considered a HAP, however, it is listed as a VOC, so the emission reduction is in HAP emissions only. Foam manufacturers contacted indicated that they have

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[21] Telecon: A. Williams, EC/R Inc., to S. Smoller, E-A-R Specialty Corporation. June 10, 1994.

[22] Telecon: A. Williams, EC/R Inc., to J. Robinson, Air Products. July 11, 1994.

[23] Telecon: A. Williams, EC/R Inc., to M. Gromnicki, Swenson Corp. July 14, 1994.

found less naphtha-based release agents are required than HAP-based, however, the EPA was unable to quantify this reduction. There were no necessary process or equipment changes identified.

Water-based release agents. The use of water-based mold release agents is more complicated than for naphtha or reduced-VOC solvent based agents.[22,24] However, unlike the other two alternatives, water-based mold release agents totally eliminate organic emissions.

All water-based mold release agent manufacturers spoken to emphasized that selecting a water-based release agent is very customer-specific, and that the correct selection can require considerable time and many trials before the correct product is found. The developmental procedures can be costly in time, as well as in scrap foam, during the transitional period.

There are also a few production changes that need to be made when converting from a solvent-based to a water-based agent. Water-based release agents are more application-sensitive than the solvent-based agents, so some spray re-training may be necessary. Mold temperature is another common change necessary when switching to water-based agents, due to the higher evaporation temperature of water. There are no equipment changes necessary, except that some manufacturers recommend High Volume Low Pressure (HVLP) sprayers for use with the water-based agents, due to the need for increased application sensitivity.

The major disadvantages of water-based agents are the increased drying time and a development period which may be extensive. Also, foams produced using water-based mold release agents have a less porous surface than those poured with conventional release agents, which can be a disadvantage when adhering fabrics to the foam.

REBOND FOAM PRODUCTION

Process Description[25]

Another flexible foam product that is produced on-site at slabstock foam facilities is rebond. Rebond foam is also produced at stand-alone, or off-site facilities. Rebonding is a process where scrap foam is converted into a material that is used for carpet underlay and several other end-uses such as

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[24] Telecon: A. Williams, EC/R Inc., to C. Asuncion, Air Products. April 20, 1994.

[25] Norwood, P. and Williams, A., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Site Visit Report of Foamex L.P.'s Morristown, TN facility on May 26, 1993. January 18, 1994.

school bus seats. A typical rebond production process is described below.

The scrap foam may have been generated at the facility from its slabstock operations, or may have been shipped or bought from other foam facilities. There is such a high demand for this product that foam scrap is imported from overseas. The scraps are received in "bales." The baled foam is loaded by conveyor into the bale-breaker, which "chews" the foam into smaller pieces. The scrap bales are sent to the bale-breaker as received, and often contain plastic and other non-foam materials. Magnets at the exit of the bale-breaker remove any metal pieces that could damage the grinders. The foam pieces from the bale-breaker fall through screens into the grinder where the scrap is converted into 3/4 to 3/8 inch pieces.

These small pieces are loaded into a blender, where a mixture of polyol and TDI (or MDI) is added. The foam and binder mixture, and occasionally a dye, is poured into a cylindrical mold, that is below floor level. This mold has a central core so that there is a hole that runs the length of the cylinder. Pressure and steam are applied to the mixture in the mold, and then the roll is taken out of the mold and allowed to cool or "set" for about 24 hours.

To manufacture carpet padding, the roll is carried to the sawing area after it has set, using a forklift. In this area, the roll is peeled in a continuous operation, comparable to peeling a potato. The end of the sliced material is fed into a series of conveyors. As it is being peeled, the end of a roll is glued to the beginning of the next roll to keep a continuous sheet of rebond moving to the cutting and packaging area. The amount and grade of the foam added, as well as the particle size, determine the density of the final product. A density of 6 lb/ft^3 is considered to be quality rebond carpet backing.

Rebond HAP Emission Sources

There were three emission sources identified in the production of rebond foam. First, there is the opportunity for emissions of TDI or MDI in the mold area. However, the emissions from this area are minimal. The other two emission sources identified were from the use of HAP cleaners and HAP-based mold release agents.

Control Technologies for Rebond HAP Emissions

No control technologies were identified for the TDI or MDI emissions from the molding area. For equipment cleaning and mold release agents, there are numerous options available that do not result in HAP emissions. These options were not investigated by the EPA.

MEMORANDUM

Date: November 3, 1995

Subject: Flexible Polyurethane Foam Molded Plants: New Count and Nationwide Model Plant Representation

From: Amanda Williams, EC/R Incorporated

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

Since the early phases of the polyurethane foam maximum achievable control technology (MACT) project there has been a difficulty in determining the number of flexible molded facilities in the U.S. The number has been difficult to estimate for several reasons, one being that this segment of the flexible foam industry has no real representation by any trade organization. The Society for Plastics Institute (SPI), and the Polyurethane Foam Trade Association (PFA) both had some knowledge of this industry, but neither had listings of facilities. Other reasons the molded plant population has been hard to estimate is that many of these facilities are small, and may be combined with other industrial operations. Only 46 molded foam facilities were identified when the information collection requests (ICRs) were distributed in the fall of 1992. The information from these 46 facilities was used to create model plants. However, the EPA and industry representatives both believe that there could be as many as several hundred facilities nationwide.

The purpose of this memorandum is to describe an attempt to provide a better nationwide estimate, predominantly for the purpose of the economic impact analysis. In this effort to establish a better estimate of the molded facilities nationwide, the "Polyurethane Industry Director and Buyer's Guide - 1994"[1] was used. This resource contains company names and addresses, as well as some information as to what the company does.

The directory contains several indexes, one of which is by finished goods. This index identified facilities producing flexible polyurethane foam, fabricated or raw bun stock, or molded pieces. Another index used was for integral skin manufacturers (a type of molded flexible polyurethane foam). The companies identified on this list were then looked up in the main

[1] The Polyurethane Industry Directory and Buyer's Guide - 1994. Larson Publishing. Saco, Maine.

body of the directory where more detailed company descriptions are provided, and a judgement was made as to whether they produced molded flexible foam. These indices are included as Attachment 1, with the selected companies starred. Every effort was made to only include facilities that produced molded foam from raw materials, and not fabricators that press manufactured foam into molds. Based on the company descriptions, an additional 182 flexible molded foam companies were identified, bringing the total nationwide estimate up to 228. The directory used did not indicate whether the companies had multiple facilities, therefore it was assumed that each company had one facility unless otherwise indicated.

The first assumption that was made regarding the characterization of the newly identified facilities was that all the facilities had low pressure (LP) mixheads. This assumption was made based on the fact that all known facilities using high pressure (HP) mixheads are large facilities, and that is believed that all large facilities have all been identified.

There was no information on the size of these facilities, therefore it was determined that it would be necessary to assume the same distribution across the model plants as the facilities for which information was obtained through the ICRs.

ATTACHMENT 1

PLAXTONS PLC - *UK*
PLUIMERS ISOLATIE - *NETHERLANDS*
POLIFLEKS SENTETIK MADDELER - *TURKEY*
PONISCH REISEN GMBH - *GERMANY*
RADIUM FOAM BV - *NETHERLANDS*
RADOMSKIE ZAKLADY - *POLAND*
RAMICO BOILEVIN - *FRANCE*
RAOUL LABORD, SA - *FRANCE*
RCB - *FRANCE*
RECORD RIGA FOOTWEAR - *LATVIA*
REIN SPA - *ITALY*
RENAULT - *FRANCE*
RK FOOTWEAR MNFTS (PVT) - *ZIMBABWE*
ROMIKA - *GERMANY*
ROSSETTI SPA - *ITALY*
ROTH FRERES, SA - *FRANCE*
ROVER - *UK*
SAAB SCANIA - *SWEDEN*
SABA DINXPERLO - *NETHERLANDS*
SAITEC - *FRANCE*
SALOMON, SA - *FRANCE*
SAMSONITE NV - *BELGIUM*
SANDELLA FABRIKKEN - *NORWAY*
SARRAIZIENNE, SA - *FRANCE*
SCAN-AQUA LTD. - *FINLAND*
SCHAFER WERKE GMBH - *GERMANY*
SCHMITZ-ANHANGER - *GERMANY*
SCHOLL, SA - *FRANCE*
SCHOMBERG & GRAF GMBH - *GERMANY*
SECURITE 24 - *FRANCE*
SHELLER CLIFFORD LTD. - *UK*
SHORT BROS PLC - *UK*
SIEVIN STALLMAN - *SWEDEN*
SILAC - *FRANCE*
SILENTNIGHT KENYA LTD. - *KENYA*
SISA SPA - *ITALY*
SITAB SPA - *ITALY*
SOLEMAKERS (OLEMARK) - *FINLAND*
SOLMARK SOLECKIE ZAK - *POLAND*
STEELCASE STRAFOR - *FRANCE*
STOWE WOODWARD FINLAND OY - *FINLAND*
TEBBUTT AND HALL BROS LTD. - *UK*
TELEWIG GMBH - *GERMANY*
THREE STAR SHOE CO. - *IRAN*
TILMAR BV - *NETHERLANDS*
TOBESCO HANDELS GMBH - *AUSTRIA*
TOCOVER - *FRANCE*
TORTORA EFCT G - *FRANCE*
TOYOTA MOTOR CORP - *BELGIUM*
TREVES - *FRANCE*
TUFTON BV - *NETHERLANDS*
UHL GMBH - *GERMANY*
UNITED FOAM UK LTD. - *UK*
UTA CLIFFORD LTD. - *UK*
VARIOFORM GMBH - *GERMANY*
VEB SACHSANRING AUTOMOBILWK - *GERMANY*
VEENENDAAL & CO. BV - *NETHERLANDS*
VEENENDAAL SCHAUMSTOFFWERK - *GERMANY*
VILJANMAA OY - *FINLAND*
VITA ACHTER LTD. - *UK*
VREDESTEIN ICOPRO BV - *NETHERLANDS*
WEBAC CHEMIE GMBH - *GERMANY*
WILHELM KARMANN GMBH - *GERMANY*
WOLLASTON VULCANIZING CO. - *UK*
YMOS AG - *GERMANY*

FLEXIBLE FOAM

South/Central/North America

A.M.E. CORP. - *USA*
AASR, INC. - *USA*
ABBOT INDUSTRIES, INC. - *USA*
ACCESSIBLE PRODUCTS - *USA*
ACCURATE FOAM CO. - *USA*
ACME MACHELL CO., INC. - *USA*
ADAPT PLASTICS, INC. - *USA*
ADFOAM - *USA*
ADVANCE LATEX PRODUCTS, INC. - *USA*
ADVANCE FOAM PLASTICS, INC. - *USA*
ADVANCED FOAM AND PLASTIC CO. - *USA*
AERO SPECIALTIES CORP. - *USA*
AGC, INC. - *USA*
AIR-O-PLASTIK - *USA*
AIRTEX INDUSTRIES, INC. - *USA*
AKRON PORCELAIN & PLASTICS CO. - *USA*
ALACRA SYSTEMS - *USA*
ALADDIN INDUSTRIES, INC. - *USA*
ALFA III CORP. - *USA*
ALL AMERICAN ENTERPRISES - *USA*
ALL-STATE BELTING CO. - *USA*
ALLEN FOAM CORP. - *USA*
ALLIED-BALTIC RUBBER, INC. - *USA*
ALMAC PLASTICS, INC. - *USA*
AME CORP. - *USA*
AMERICAN EXCELSIOR COMPANY - *USA*
AMERICAN FIBRIT, INC. - *USA*
AMERICAN FOAM PRODUCTS, INC. - *USA*
AMERICAN POLY-FOAM CO., INC. - *USA*
AMERICAN POLY-THERM CO. - *USA*
AMERICAN PRECISION PRODUCTS - *USA*
AMERICAN RUBBER PRODUCTS CORP. - *USA*
AMES RUBBER CORP. - *USA*
APPLIED PRODUCTS, INC. - *USA*
ARMALY FOAM - *USA*
ASHTABULA RUBBER CO. - *USA*
ASSOCIATED RUBBER, INC. - *USA*
ASTEC CO. - *USA*
ASTROFOAM, INC. - *USA*

ATLANTIC POLYMERS & PRODUCTS - *USA*
ATLANTIC THERMOPLASTICS CO., INC. - *USA*
AUSTIN URETHANE, INC. - *USA*
AUTOMA INTERIOR SYSTEMS - *USA*
B. W. FREEMAN, INC. - *USA*
BANKS BROS. - *USA*
BARNHARDT MANUFACTURING - *USA*
BASF CORPORATION - *USA*
BENDIES FORMS, INC. - *CANADA*
BEST FOAM FABRICATORS - *USA*
BONDED PRODUCTS, INC. - *USA*
BOYD CORPORATION - *USA*
BRUNSWICK SEAT CO. - *USA*
BRYN HILL INDUSTRIES - *USA*
BUCKEYE RUBBER & PACKING CO. - *USA*
BURKART FOAM, INC. - *USA*
C.J. PRODUCTS INCORPORATED - *USA*
CALIFORNIA URETHANE - *USA*
CARPENTER INSULATION & COATINGS, INC. - *USA*
CARTEX CORP. - *USA*
CASTLE RUBBER CO. - *USA*
CHARLES ENGINEERING & SERVICES INCORPORATED - *USA*
CHESTNUT RIDGE FOAM, INC. - *USA*
CHIVAS PRODUCTS LIMITED HEADQUARTERS - *USA*
COLEMAN CO. - *USA*
COMPONENT FINISHING CORP. - *USA*
CONE MILLS CORP. - *USA*
CONITRON - *USA*
CONVERTERS, INC. - *USA*
CONWAY INDUSTRIES, INC. - *USA*
CORCORAN MANUFACTURING CO., INC. - *USA*
COWART FOAM CO., INC. - *USA*
CRAIN INDUSTRIES - *USA*
CREATIVE FOAM CORP. - *USA*
CREATIVE URETHANES, INC. - *USA*
CREST FOAM INDUSTRIES, INC. - *USA*
CUSTOM COATING, INC. - *USA*
CUSTOM PACK, INC. - *USA*
CUSTOM RUBBER CORP. - *USA*
DAVIDSON INTERIOR TRIM TEXTRON - *USA*
DAYTON POLYMERIC PRODUCTS, INC. - *USA*
DELAWARE SEAT CO. - *USA*
DELCO PRODUCTS - *USA*
DIPOL, SA DE C.V. - *MEXICO*
DIVERSIFIED FOAM, INC. - *USA*
DOMFOAM INTERNATIONAL, INC. - *CANADA*
DOUGLAS AND LOMASON CO. - *USA*
DOUGLASS INDUSTRIES - *USA*
DOVE PRODUCTS, INC. - *USA*
DURAFOAM SEATING - *USA*
DYNAMIC FOAM PRODUCTS, INC. - *USA*
DYNAMIC PACKAGING, INC. - *USA*
E-A-R SPECIALTY COMPOSITES - *USA*
E-K MANUFACTURING - *USA*
E. R. CARPENTER CO. - *USA*

EAGLE PICHER AUTOMOTIVE GROUP - *USA*
EASTERN CONTAINERS - *USA*
EASTERN FOAM CORP. - *USA*
EG GASKET & SUPPLY, INC. - *USA*
ENGINEERED POLYMERS CORP. - *USA*
ENGINEERED SYSTEMS - *USA*
ENGINEERING POLYMERS CORP. - *USA*
EVERGREEN MOLDING - *USA*
EXPANDED RUBBER & PLASTICS - *USA*
F. H. MALONEY CO. - *USA*
F. P. WOLL & CO. - *USA*
FLEXAN CORP. - *USA*
FLEXIBLE FOAM PRODUCTS - *USA*
FLEXIBLE INDUSTRIES - *USA*
FLEXIBLE PRODUCTS MFG CO., INC. - *USA*
FLEXSTEEL INDUSTRIES - *USA*
FLEXTRON INDUSTRIES - *USA*
FLORIDA FOAM CO. - *USA*
FLORIFOAM - *USA*
FOAM MOLDERS & SPECIALTIES - *USA*
FOAM PACKAGING LTD. - *USA*
FOAM PRODUCTS CORP. - *USA*
FOAM PRODUCTS CORPORATION - *USA*
FOAM PRODUCTS, INC. - *USA*
FOAM RUBBER FABRICATORS, INC. - *USA*
FOAM RUBBER PRODUCTS - *USA*
FOAM SPECIALITIES - *USA*
FOAM CONVERTERS T/A COMPLETE PKG. - *USA*
FOAM DESIGN, INC. - *USA*
FOAM FABRICATORS, INC. - *USA*
FOAM FACTORY, INC. - *USA*
FOAM FAIR INDUSTRIES - *USA*
FOAM TEK INCORPORATED - *USA*
FOAM TO SIZE - *USA*
FOAM-FORM, INC. - *USA*
FOAMADE INDUSTRIES - *USA*
FOAMCRAFT INCORPORATED - *USA*
FOAMCRAFT, INC. - *USA*
FOAMCRAFTERS - *USA*
FOAMEDGE PRODUCTS - *USA*
FOAMEX L. P. - *USA*
FOAMFAB, INC. - *USA*
FORD MOTOR, CO. UTICA TRIM OPERATIONS - *USA*
FRANK LOWE RUBBER & GASKET CO, INC. - *USA*
FRANKLIN FIBRE-LAMITEX CORPORATION - *USA*
FREUDENBERG-NOK - *USA*
FUROM CO. - *USA*
FUTURA COATINGS, INC. - *USA*
FUTURE FOAM, INC. - *USA*
G-FORCE AERODYNAMICS - *USA*
G. T. SALES & MANUFACTURING, INC. - *USA*
GASKA TAPE, INC. - *USA*
GASKET & MOLDED PRODUCTS - *USA*
GENERAL FOAM - *USA*
GENERAL FOAM - *USA*

GENERAL FOAM OF MINNESOTA - *USA*
GENERAL PLASTICS MFG. CO. - *USA*
GENERAL RUBBER & PLASTICS CO., INC. - *USA*
GEORGIA BONDED FIBERS, INC. - *USA*
GOODYEAR TIRE & RUBBER CO. - *USA*
GOULD MID-WEST CORP. - *USA*
GOULD SOUTHERN, INC. - *USA*
GREAT WESTERN FOAM PRODUCTS CO. - *USA*
GREEN MOUNTAIN FOAM PRODUCTS - *USA*
GUARDIAN PACKAGING, INC. - *USA*
HEDSTROM CO. - *USA*
HELLER CO. - *USA*
HERMAN A. GELMAN CO. - *USA*
HERMAN MILLER - *USA*
HIBCO PLASTICS, INC. - *USA*
HICKORY SPRINGS MANUFACTURING CO. - *USA*
HOUSTON FOAM PLASTICS, INC. - *USA*
HOY SHOE CO. - *USA*
HUDSON INDUSTRIES, INC. - *USA*
HYDRA-MATIC PACKING CO. - *USA*
ILLBRUCK, INC. - *USA*
ILLIG INDUSTRIES, INC. - *USA*
ILLINOIS INSTITUTE OF TECHNOLOGY - *USA*
INDUSTRIAL & MILITARY TECHNOLOGY CORP. - *USA*
INDUSTRIAL CUSTOM PRODUCTS - *USA*
INDUSTRIAL POLYMERS, INC. - *USA*
INDUSTRIAL RUBBER & PLASTICS CO., INC. - *USA*
INDUSTRIAL RUBBER & SUPPLY, INC. - *USA*
INDUSTRIAL RUBBER WORKS, INC. - *USA*
INOAC U.S.A., INC. - *USA*
INSTA-FOAM PRODUCTS, INC. - *USA*
INTEGRAM ST. LOUIS FOAM OPERATIONS - *USA*
INTEK WEATHERSEAL PRODUCTS, INC. - *USA*
J. L. SCHROTH CO. - *USA*
JEFFCO UPHOLSTERY & FOAM PRODUCTS - *USA*
JOHNSON BROTHERS RUBBER CO. - *USA*
JOHNSON CONTROLS, INC. - *USA*
KEENE CORP. - *USA*
KEMCO PLASTICS - *USA*
KENT MFG CO. - *USA*
KERN FOAM PRODUCTS CORP. - *USA*
KEYSTONE URETHANE PRODUCTS - *USA*
KIRSCH CHEMICAL COMPANY, INC. - *USA*
KRYPTONICS, INC. - *USA*
KURTH INTERNATIONAL - *USA*
KUSTOM FOAM MFG., INC. - *USA*
LAMATEK, INC. - *USA*
LARSTAN, INC. - *USA*
LEGGETT & PLATT, INC. - *USA*
LEWIS INDUSTRIES - *USA*
LIBERTY FOAM & PACKAGING - *USA*
LOYALTY FOAM CO. - *USA*
LUDWIG, INC. - *USA*
LUNDELL MFG CORP. - *USA*
M & C SPECIALTIES CO. - *USA*
M & R FLEXIBLE PACKAGING, INC. - *USA*
M&H INDUSTRIES - *USA*
MAC SPECIALITIES LTD. - *USA*
MADISON POLYMERIC ENG - *USA*
MANCHESTER PLASTICS - *USA*
MARCHEM CORPORATION - *USA*
MARCHEM DUBLON, INC. - *USA*
MARIAN RUBBER PRODUCTS CO., INC. - *USA*
MARKO FOAM PRODUCTS, INC. - *USA*
MARTEC PLASTICS - *USA*
MARVLEE - *USA*
MAYPAK, INC. - *USA*
MEARTHANE PRODUCTS - *USA*
MECHANICAL RUBBER PRODUCTS CORP. - *USA*
MERRYWEATHER FOAM, INC. - *USA*
MICROFOAM, INC. - *USA*
MIDCO PACKAGING INDUSTRIES - *USA*
MIDWEST CORTLAND, INC. - *USA*
MIDWEST URETHANE - *USA*
MILCUT, INC. - *USA*
MILFOAM CORPORATION - *USA*
MILSCO MANUFACTURING CO. - *USA*
MINNESOTA RUBBER - *USA*
MOLDED MATERIALS, INC. - *USA*
MONO-THANE - *USA*
MOULDED CHEMICAL PRODUCTS. CO., INC. - *USA*
MUTH ASSOCIATES, INC. - *USA*
NASHVILLE RUBBER & GASKET - *USA*
NATION/RUSKIN, INC. - *USA*
NATIONAL FOAM MFG. CO. - *USA*
NEW ENGLAND FOAM PRODUCTS - *USA*
NO SAG PRODUCTS CORP./ LEAR SIGLER - *USA*
NORTH AMERICAN FOAM & PACKAGING, INC. - *USA*
NORTH CAROLINA FOAM INDUSTRIES, INC. - *USA*
NORTON PERFORMANCE PLASTICS CORPORATION - *USA*
NORWOOD INDUSTRIES - *USA*
NTD AMERICAN, INC. - *USA*
OHIO FOAM CORPORATION - *USA*
OLEA INTERNATIONAL - *USA*
OLYMPIC PRODUCTS CO. - *USA*
OMEGA RUBBER PRODUCTS - *USA*
OMNI PLASTICS, INC. - *USA*
PAC FOAM PRODUCTS CORP. - *USA*
PACIFIC STATES FELT AND MANUFACTURING - *USA*
PACKAGING FOAM FABRICATORS, INC. - *USA*
PACKAGING TECHNOLOGY, INC. - *USA*
PACKATEERS, INC. - *USA*
PAGE BELTING CO. - *USA*
PAR-FOAM PRODUCTS - *USA*
PENN FOAM CORP. - *USA*
PERMA-FOAM INC. - *USA*
PERRY CHEMICAL & MANUFACTURING CO. - *USA*
PHOENIX FOAM & FIBERGLASS, INC. - *USA*
PIPELINE PIGGING PRODUCTS - *USA*
PLASTOMER CORPORATION - *USA*

PLEIGER PLASTICS COMPANY - *USA*
PLYFOAM PRODUCTS - *USA*
POLLY PIG BY KNAPP, INC. - *USA*
POLLY PRODUCTS - *USA*
POLY FOAM, INC. - *USA*
POLY-FOAM, INC. - *USA*
POLYFOAM PACKERS CORPORATION - *USA*
PONTIAC PLASTICS & SUPPLY - *USA*
POW-R-TOW, INC - *USA*
PRESTO TECHNOLOGIES, INC. - *CANADA*
PRINCE MASTERCRAFT, INC. - *USA*
PRODUCTS RESEARCH & CHEMICAL CORP. - *USA*
PROTECT MANUFACTURING, INC. - *USA*
PURETHANE, INC. - *USA*
R.B.L. INDUSTRIES - *USA*
RADVA CORP. - *USA*
RANDALL TEXTRON - *USA*
REDCO - *USA*
REILLY FOAM CORP. - *USA*
REISS INDUSTRIES, INC. - *USA*
RELIABLE PLASTICS, INC. - *USA*
RELIANCE PATTERN WORKS CO. - *USA*
RELIANCE UPHOLSTERY SUPPLY CO. - *USA*
REMPAC FOAM CORP. - *USA*
RENOSOL CORPORATION - *USA*
REPUBLIC PACKAGING CORP. - *USA*
RICHARDS, PARENTS & MURRAY, INC. - *USA*
RIVERSIDE SEAT CO. - *USA*
ROCKMONT INDUSTRIES - *USA*
RODAC RUBBER CO. - *USA*
RODMAR MFG & RESEARCH, INC. - *USA*
ROGERS CORP. WILLIMANTIC DIVISION - *USA*
ROGERS CORPORATION - *USA*
ROGERS CORPORATION - *USA*
ROGERS FOAM CORP. - *USA*
ROMEO RIM, INC. - *USA*
ROSS & ROBERTS, INC. - *USA*
ROYAL PRODUCTS CO. - *USA*
RS RUBBER CORP. - *USA*
RUBBER & SILICONE PRODUCTS CO., INC. - *USA*
RUBBER DEVELOPMENT, INC. - *USA*
RYNEL LTD. - *USA*
S&S PLASTICS - *USA*
SACKNER PRODUCTS - *USA*
SAN ANTONIO FOAM FABRICATORS - *USA*
SANIGLASTIC MFG. CO. - *USA*
SAVON FOAM CORP. - *USA*
SCCI CORP - *USA*
SCHNADIG CORP. - *USA*
SCOTT PORT-A-FOLD, INC. - *USA*
SCOTTDEL INC. - *USA*
SEARS MANUFACTURING CO. - *USA*
SFT, INC. - *USA*
SHELLER-GLOBE CORP - *USA*
SNOW CRAFT CO., INC. - *USA*
SOLAR COMPOUNDS CORP. - *USA*
SORBOTHANE, INC. - *USA*
SOUNDCOAT CO., INC. - *USA*
SOUTH ATLANTIC FOAM - *USA*
SOUTHEASTERN FOAM RUBBER CO. - *USA*
SPAN-AMERICA - *USA*
SPECIAL DESIGN PRODUCTS - *USA*
SPECIALTY FOAM PRODUCTS - *USA*
SSF MOLDERS, INC. - *USA*
STALLMAN CO. M.H. - *USA*
STEPHEN GOULD CORP. - *USA*
STEPHENSON & LAWYER, INC. - *USA*
STERLING MANUFACTURING - *USA*
STONEHURST INDUSTRIES - *USA*
STRUCKMEYER CORP. - *USA*
STRUCTURAL FOAM PLASTICS - *USA*
STYRO-MOLDERS CORP. - *USA*
SUPERIOR PRODUCTS CO - *USA*
SWISS-TEX, INC. - *USA*
SYNAIR CORPORATION - *USA*
T & S DIE CUTTING - *USA*
T.O. PLASTICS - *USA*
TECHNICON - *USA*
TECNIFOAM - *USA*
TELEDYNE MONO-THANE - *USA*
TEMPRESS, INC. - *USA*
TEXSTAR, INC. - *USA*
TEXTILE RUBBER & CHEMICAL CO. - *USA*
TEXTILE RUBBER CO. - *USA*
THARCO - *USA*
THOMBERT, INC. - *USA*
THORODIN, INC. - *USA*
TILTON ENGINEERED COMPONENTS - *USA*
TRINITY FOAM OF CAROLINA, INC. - *USA*
TRULY MAGIC PRODUCTS, INC. - *USA*
TRUSTY-COOK, INC. - *USA*
TUSCARORA PLASTICS, INC. - *USA*
UNICAST, INC. - *USA*
UNIQUE FABRICATING, INC. - *USA*
UNIQUE URETHANES, INC. - *USA*
UNITED FOAM PLASTICS CORPORATION - *USA*
UNIVERSAL AIR FILTER - *USA*
UNIVERSAL PRODUCTS, INC. - *USA*
UNIVERSAL URETHANES - *USA*
URETHANE ENGINEERING CORP. - *USA*
URETHANE PRODUCTS CO., INC. - *USA*
VANGUARD FOAM & PACKAGING CO. - *USA*
VISCOR, INC. - *USA*
VITAFOAM INCORPORATED - *USA*
W.H. PORTER, INC. - *USA*
WEAVER INDUSTRIES, INC. - *USA*
WEINBRENNER SHOE COMPANY, INC. - *USA*
WEST COAST LAMINATING - *USA*
WESTERN TEXTILE PRODUCTS - *USA*
WILLIAM T. BURNETT & COMPANY - *USA*

WILSHIRE ADVANCED MATERIAL - *USA*
WILSHIRE FOAM PRODUCTS, INC. - *USA*
WISCONSIN FOAM PRODUCTS, INC. - *USA*
WM. T. BURNETT & CO., INC. - *USA*
WOODBRIDGE FOAM CORPORATION - *CANADA*
WOODBRIDGE FOAM FABRICATING, INC. - *USA*
WOODBRIDGE GROUP, THE - *USA*
ZERILLO PRODUCTS, INC. - *USA*

Europe/Middle East/Africa

AARSLEV POLYMERE IND, AS - *DENMARK*
AB B AKESSON & COMPANY - *SWEDEN*
ASTRALI ACCESSORIES - *UK*
AVALON CHEMICAL CO. LTD - *UK*
CALIGEN FOAM LIMITED - *UK*
DC-SYSTEM INSULATION, AS - *DENMARK*
DRAKA INTERFOAM B.V. - *NETHERLANDS*
DUNLOP LTD. - *UK*
EUROPLASTIC GMBH & COMPANY - *GERMANY*
F. S. FEHRER GMBH & CO. KG - *GERMANY*
HAIRLOK LTD. - *UK*
JARRI PLASTIC INDUSTRIES LTD. - *ISRAEL*
JOHNSON CONTROLS LTD. - *UK*
KAYFOAM WOOLFSON LTD. - *IRELAND*
KOEPP AKTIENGESELLSCHAFT - *GERMANY*
LOXI-PUR, AB - *SWEDEN*
NORDFLEX, AB - *SWEDEN*
RECTICEL DEUTSCHLAND GMBH - *GERMANY*
RECTICEL INTERNATIONAL - *BELGIUM*
SPUMOTIM, SA - *ROMANIA*
SUNTAS FOAM & MATTRESS CORP. - *TURKEY*
TANEX, PLASTY AS - *CZECHOSLOVAKIA*
TECNODENT SPA - *ITALY*
TRAMICO, SA - *FRANCE*
VERTIFOAM INTERNATIONAL LTD. - *UK*
VITA CORTEX HOLDINGS LTD. - *IRELAND*
VITAFOAM LTD. - *UK*
WOODBRIDGE FOAM GMBH - *GERMANY*
ZACO (PTI) BV - *NETHERLANDS*
ZDA PARTIZANSKE - *CZECHOSLOVAKIA*

Asia/Pacific Rim

ADVANCE FOAM - *MALAYSIA*
AEROFOAM - *MALAYSIA*
AGMAN - *MALAYSIA*
AMIT POLYSEATS (P) LTD. - *INDIA*
AMRAPALI PROPERTIES LTD. - *INDIA*
ART RISE - *MALAYSIA*
BAN MORE FOAM PVT. LTD. - *INDIA*
BANGKOK FOAM CO. LTD. - *THAILAND*
BRIDGESTONE (M) SDN. BHD. - *MALAYSIA*
CAMATIC-AUSTRALIA PTY. LTD. - *AUSTRALIA*
CAMEL - *MALAYSIA*
CHANGSU PU CUSHION MATERIAL FACTORY - *PRC*
CHEMI-NOVA INDUSTRIES PTE. LTD. - *INDIA*
CHIAN CHEN COMPANY PTE. LTD. - *SINGAPORE*
CHIAO FU ENTERPRISE CO. LTD. - *TAIWAN ROC*
CHIAO FU ENTERPRISES CO. - *AUSTRALIA*
CHINA SHENYANG PU FACTORY - *PRC*
CHONGQINY CHAOYANG CHEMICAL PLANT - *PRC*
CONCORDE (M) SDN. BHD. - *MALAYSIA*
CRECIMIENTO INDUSTRIES CO. LTD. (CRMTO) - *TAIWAN RO*
CRYSTAL FOAM - *MALAYSIA*
DA-FUNG FOAM CO. LTD. - *TAIWAN ROC*
DAE WON SEATS INDUSTRIAL CO. LTD. - *KOREA*
DEWFOAM CORP. - *PHILIPPINES*
DP FOAM PRIVATE LTD. - *INDIA*
DREAMLAND - *MALAYSIA*
DUNIA CHEMICAL INDUSTRIES - *INDONESIA*
DURAFOAM INDUSTRIES PVT. LTD. - *INDIA*
ERLANGGA FOAM INDUSTRY - *INDONESIA*
FAR EAST - *MALAYSIA*
FLEXO FOAM INDUSTRIES - *INDIA*
FOAM CENTRE - *SINGAPORE*
FUZHOU NO.6 PLASTICS FACTORY - *PRC*
GANGES URETHANE PVT. LTD. - *INDIA*
GANSU POLYURETHANE IND. CORP. - *PRC*
GAO FENG PU PRODUCTS CO. LTD. (JV) - *PRC*
GLOBAL PKO - *MALAYSIA*
GOA FOAM PVT. LTD. - *INDIA*
GOODNITE BEDDING - *MALAYSIA*
GUANGZHOU XINSHI SOFT FOAM FACTORY - *PRC*
HANBEE INDUSTRIES INC. - *KOREA*
HENDERSON'S PLASTICS PTY. LTD. - *AUSTRALIA*
HOLY FOAM ENTERPRISE CO. - *TAIWAN ROC*
HYUNDAI MOTOR CO. - *KOREA*
INOAC CORPORATION - *JAPAN*
INOAC CORPORATION - *JAPAN*
J.J. FOAM PVT. LTD. - *INDIA*
JAYA CHEMICAL INDUSTRIES (M) SDN. BHD. - *MALAYSIA*
JEMICA INDUSTRIES, INC. - *PHILIPPINES*
JOONG LIM CHEMICAL CO. LTD. - *KOREA*
JOYCE AUSTRALIA - *AUSTRALIA*
JOYCE CORPORATION LIMITED - *AUSTRALIA*
JUTA FOAM SDN. BHD. - *MALAYSIA*
KAILY PACKAGING PTE. LTD. - *SINGAPORE*
KARN YANG YEEN YONG INDUSTRY LTD. PART. - *THAILAND*
KAYFOAM LTD. - *INDIA*
KING KOIL BEDDING INDUSTRIES (M) SDN. BHD. - *MALAYSIA*
KOREA POLYOL CO. LTD. - *KOREA*
KUN CHING INDUSTRIAL CO. LTD. - *TAIWAN ROC*
LIGA FOAM - *INDONESIA*
LONG LAST MERCHANDISING CENTRE - *PHILIPPINES*
LOW AH CHONG & CO. - *SINGAPORE*
LUCKY GROUP - *THAILAND*
MADRAS POLYMOULDS - *INDIA*
MANDAUE FOAM INDUSTRIES - *PHILIPPINES*
MAYO FOAM MANUFACTURING PTE. LTD. - *SINGAPORE*
MOW WING COTTON MANUFACTURING CO. - *SINGAPORE*
MUSTIKA - INDUSTRI BUSA URETHANE - *INDONESIA*
NANTA FOAM (M) SDN. BHD. - *MALAYSIA*

NATSON FOAM MANUFACTURING PVT. LTD. - *INDIA*
NECHECO - FOAM PLASTICS - *INDONESIA*
NEW RAHARDJA FOAM - *INDONESIA*
NGAI LIM INDUSTRIES PTE. LTD. - *SINGAPORE*
NIPPON MEKTRON LTD. - *JAPAN*
NITE BEAUTY (M) SDN. BHD. - *MALAYSIA*
NUFOAM INDUSTRIES - *INDIA*
NYLON FOAM INDUSTRIAL CORP. - *PHILIPPINES*
OCEAN FOAM - *INDONESIA*
PACIFIC DUNLOP PTY. LTD. - *AUSTRALIA*
PANAMA POLY PRODUCTS PVT. LTD. - *INDIA*
PEACE & HAPPINESS COMPANY - *PRC*
PEXAFOAM SDH. BHD. - *MALAYSIA*
PHOENIX BASE SDN. BHD. - *MALAYSIA*
POLYFOAM-RGC INTERNATIONAL CORP. - *PHILIPPINES*
PON TON ENTERPRISE CO. LTD. - *TAIWAN ROC*
PT MAJU FOAM - *INDONESIA*
PT SURYA AGUNG - PU FOAM INDUSTRY - *INDONESIA*
PT. CITRA SARANA MAKMUR - *INDONESIA*
PT. DASA WINDU AGUNG - *INDONESIA*
PT. INDUSTRI URETHAN - *INDONESIA*
PT. MEIWA INDONESIA - *INDONESIA*
PT. POSITIVE FOAM INDUSTRY - *INDONESIA*
PT. REMAJA JAYA FOAM - *INDONESIA*
PT. SUPER POLY FOAM INDUSTRY - *INDONESIA*
PT. VITAFOAM - INDONESIA (INOAC) - *INDONESIA*
QING YANG PLASTIC FOAM FACTORY - *PRC*
QUANGZHOU FOAM PLASTICS FACTORY - *PRC*
RECOS FOAM (M) SDN. BHD. - *MALAYSIA*
SAM KWANG URETHANE CO., LTD. - *KOREA*
SAM YANG CHEMICAL CO. LTD. - *KOREA*
SAM YOUNG CHEMICAL CO. LTD. - *KOREA*
SAMMIT AUTOSEATS & PARTS CO. LTD. - *THAILAND*
SEDA CHEMICAL PRODUCTS CO. LTD. - *TAIWAN ROC*
SERIM CO. LTD. - *KOREA*
SHANDONG PENGLAI PU PRODUCTS FACTORY - *PRC*
SHANGHAI NO.6 PLASTICS FACTORY/CHIAO FU ENTERPRISE CO. - *PRC*
SHANGHAI YAN FENG MACHINE MOULD FACTORY - *PRC*
SHARIKAT PERNIAGAAN COSMO - *MALAYSIA*
SHEELA FOAM PVT. LTD. - *INDIA*
SHIH FENG CHEMICAL PRODUCTS CO. LTD. - *TAIWAN ROC*
SHROFF FOAM INDUSTRIES PVT. LTD. - *INDIA*
SIONG BEE INDUSTRIES PTE. LTD. - *SINGAPORE*
STAR LIGHT CHEMICAL INDUSTRY - *INDONESIA*
SWASTIK FOAM PVT. LTD. - *INDIA*
SYARIKAT PERINDUSTRIAN MADAH - *MALAYSIA*
SYARIKAT POLYKIM SDN. BHD. - *MALAYSIA*
SYARIKAT UNITED CHEMICAL INDUSTRIES - *MALAYSIA*
SYRENE HOLDINGS (M) SDN. BHD. - *MALAYSIA*
TAH U THONG FOAM INDUSTRY - *SINGAPORE*
TAKEDA CHEMICAL INDUSTRIES LTD. - *JAPAN*
TEKCO TRADING CO. - *MALAYSIA*
TONG HEUNG ELECTRIC CO. LTD. - *KOREA*
TOSOH CORPORATION - *JAPAN*
TSUANG HINE CORP. LTD. - *TAIWAN ROC*
U-FOAM - *INDIA*
URATEX PHILIPPINES - *PHILIPPINES*
VINYLEX (M) SDN. BHD. - *MALAYSIA*

HIGH DENSITY

South/Central/North America

DAVIDSON EXTERIOR TRIM TEXTRON - *USA*
FYPON, INC. - *USA*
MARLOCK, INC. - *USA*

INTEGRAL SKIN

South/Central/North America

A.M.E. CORP. - *USA*
ABBA RUBBER CO., INC. - *USA*
ADAPT PLASTICS, INC. - *USA*
ADVANCED FOAM AND PLASTIC CO. - *USA*
ATLANTIC THERMOPLASTICS CO., INC. - *USA*
BASF CORPORATION - *USA*
BONDED PRODUCTS, INC. - *USA*
BOYD CORPORATION - *USA*
CALIFORNIA URETHANE - *USA*
CHIVAS PRODUCTS LIMITED HEADQUARTERS - *USA*
COMCAST URETHANE COMPANY - *USA*
CONITRON - *USA*
CREATIVE URETHANES, INC. - *USA*
DAYTON POLYMERIC PRODUCTS, INC. - *USA*
DOVE PRODUCTS, INC. - *USA*
E. R. CARPENTER CO. - *USA*
EVERGREEN MOLDING - *USA*
FLEXAN CORP. - *USA*
FLEXIBLE INDUSTRIES - *USA*
FRANK LOWE RUBBER & GASKET CO, INC. - *USA*
FREUDENBERG-NOK - *USA*
G-FORCE AERODYNAMICS - *USA*
G. T. SALES & MANUFACTURING, INC. - *USA*
GPI CORP. - *USA*
GRIFFITH POLYMERS, INC. - *USA*
HEDSTROM CO. - *USA*
HERMAN MILLER - *USA*
ILLINOIS INSTITUTE OF TECHNOLOGY - *USA*
INJECTEC LTD. - *USA*
KALAMAZOO PLASTICS CO. - *USA*
KEMCO PLASTICS - *USA*
KERN FOAM PRODUCTS CORP. - *USA*
KRYPTONICS, INC. - *USA*
KURTH INTERNATIONAL - *USA*
KUSTOM FOAM MFG., INC. - *USA*
LUDWIG, INC. - *USA*

MANCHESTER PLASTICS - *USA*
MANDRELS INCORPORATED - *USA*
MARCHEM CORPORATION - *USA*
MARCHEM DUBLON, INC. - *USA*
MATERIALS TECHNOLOGY ASSOCIATES - *USA*
MERAMEC GROUP, INC. - *USA*
MILFOAM CORPORATION - *USA*
MILSCO MANUFACTURING CO. - *USA*
MINNESOTA RUBBER - *USA*
MODERN TOOLS - *USA*
NORTH CAROLINA FOAM INDUSTRIES, INC. - *USA*
PAGE BELTING CO. - *USA*
POW-R-TOW, INC - *USA*
PRINCE MASTERCRAFT, INC. - *USA*
PURETHANE, INC. - *USA*
REISS INDUSTRIES, INC. - *USA*
RENOSOL CORPORATION - *USA*
ROGERS CORPORATION - *USA*
ROMEO RIM, INC. - *USA*
SCCI CORP - *USA*
SCOTT PORT-A-FOLD, INC. - *USA*
SEARS MANUFACTURING CO. - *USA*
SSF MOLDERS, INC. - *USA*
STEPHENSON & LAWYER, INC. - *USA*
TANDEM PRODUCTS INCORPORATED - *USA*
TECNIFOAM - *USA*
TEMPRESS, INC. - *USA*
UNIQUE URETHANES, INC. - *USA*
URETHANE ENGINEERING CORP. - *USA*
WEAVER INDUSTRIES, INC. - *USA*
WEINBRENNER SHOE COMPANY, INC. - *USA*

Europe/Middle East/Africa

AARSLEV POLYMERE IND, AS - *DENMARK*
ASTRALI ACCESSORIES - *UK*
BRINSEA PRODUCTS LTD. - *UK*
FIBRE FOAM LTD. - *UK*
HAIRLOK LTD. - *UK*
JARRI PLASTIC INDUSTRIES LTD. - *ISRAEL*
LAITOSJALKINE OY - *FINLAND*
MIDLAND INDUSTRIAL PLASTICS LTD. - *UK*
RECTICEL INTERNATIONAL - *BELGIUM*
SPUMOTIM, SA - *ROMANIA*
TANEX, PLASTY AS - *CZECHOSLOVAKIA*
TECNODENT SPA - *ITALY*

Asia/Pacific Rim

AMIT POLYSEATS (P) LTD. - *INDIA*
CAMATIC-AUSTRALIA PTY. LTD. - *AUSTRALIA*
HENDERSON'S PLASTICS PTY. LTD. - *AUSTRALIA*
HYUNDAI MOTOR CO. - *KOREA*
INOAC CORPORATION - *JAPAN*
INOAC CORPORATION - *JAPAN*
POLYFOAM-RGC INTERNATIONAL CORP. - *PHILIPPINES*
PT. DASA WINDU AGUNG - *INDONESIA*
RIMCO PTY. LTD. - *AUSTRALIA*
SEDA CHEMICAL PRODUCTS CO. LTD. - *TAIWAN ROC*
SHANGHAI YAN FENG MACHINE MOULD FACTORY - *PRC*
TAKEDA CHEMICAL INDUSTRIES LTD. - *JAPAN*
TOSOH CORPORATION - *JAPAN*
U-FOAM - *INDIA*
URATEX PHILIPPINES - *PHILIPPINES*

MICROCELLULAR

South/Central/North America

ATLANTIC POLYMERS & PRODUCTS - *USA*
BOTTOMS U.S.A., INC. - *USA*
CALCODOS SAMELLO, SA - *BRAZIL*
CALVO Y CIA, SA - *CHILE*
COMCAST URETHANE COMPANY - *USA*
CUSTOM MATERIALS, INC. - *USA*
ENDICOTT JOHNSON - *USA*
FALCON SHOE MFG COMPANY - *USA*
JAMES H. RHODES & COMPANY - *USA*
JONES & VINING - *USA*
KINGSLEY MFG COMPANY - *USA*
KNAPP SHOE - *USA*
LACKS INDUSTRIES - *USA*
PARKWAY PRODUCTS, INC. - *USA*
POLY FLEX, INC. - *USA*
ROGERS CORP. WILLIMANTIC DIVISION - *USA*
U.S.A. DRIVES, INC. - *USA*
WINFIELD INDUSTRIES, INC. - *USA*

Europe/Middle East/Africa

CABER ITALIA SPA - *ITALY*
LA GEAR - *UK*
NIKE (UK) LTD. - *UK*

MILLABLE GUMS

South/Central/North America

AK RUBBER PRODUCTS CO., INC. - *USA*
ALEXANDER RUBBER PRODUCTS - *USA*
APEX MOLDED PRODUCTS CO. - *USA*
COATED FABRICS GROUP, INC. - *USA*
CONNECTICUT RUBBER MOLDING CORPORATION - *USA*
FOULKE RUBBER PRODUCTS, INC. - *USA*
NATIONAL O-RING - *USA*
RHEIN-CHEMIE CORPORATION - *USA*
SCULLY RUBBER MANUFACTURING INC. - *USA*

MEMORANDUM

Date: June 17, 1996

Subject: Subcategorization of the Flexible Polyurethane Foam Source Category

From: Amanda Williams, EC/R Incorporated
Phil Norwood, EC/R Incorporated

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

The purpose of this memorandum is to present information related to the subcategorization of the flexible polyurethane foam production source category. The first section identifies criteria for subcategorizing a source category, the second section presents brief descriptions of the flexible polyurethane foam operations, and the third section presents discusses the application of these criteria to the source category.

SUBCATEGORIZATION CRITERIA

Subcategories, or subsets of similar emission sources within a source category, may be defined if technical differences in emissions characteristics, processes, control device applicability, or opportunities for pollution prevention exist within the source category.[1] Specific examples of these differences include the types of products, process equipment differences, the type and level of emission control, emission sources, and any other factors that would impact a maximum achievable control technology (MACT) standard.

Four types of flexible polyurethane foam processes were identified. These are slabstock foam production, molded foam production, slabstock foam fabrication, and rebond foam production. Each process will be discussed briefly below. More

[1] Federal Register. Vol. 57, No. 137. Initial List of Categories of Sources Under Section 112(c)(1) of the Clean Air Act Amendments of 1990.

complete descriptions of these processes are in the industry description memo.[2]

PROCESS AND HAP EMISSION DESCRIPTIONS

This section briefly describes the molded, slabstock, fabrication, and rebond processes, including the main hazardous air pollutant (HAP) emission points, as well as a brief discussion of flexible polyurethane foam chemistry.

Polyurethane Foam Chemistry

Flexible polyurethane foam is produced by mixing three major ingredients: a polyol polymer, an isocyanate, and water. The polyol is either a polyether or polyester polymer with hydroxyl end groups. The second key ingredient in the foam formulation, the diisocyanate, links polyol molecules to produce the foam polymer. The diisocyanates used in flexible foam production are primarily toluene diisocyanate (TDI) and methylene diphenyl diisocyanate (MDI). Typically, TDI used in foam manufacture is a mixture of the 2,4- and 2,6- isomers, with the ratio being 80 percent 2,4- and 20 percent 2,6-. TDI is used primarily in slabstock production and MDI is used primarily in molded foam production. However, neither slabstock producers nor molded foam producers use one isocyanide to the exclusion of the other. Surfactants and catalysts are also added to the mixture. The surfactants aid in mixing incompatible components of the reaction mixture, and also help control the size of the foam cells by stabilizing the forming gas bubbles.

When the polyol, diisocyanate, and water are mixed, two main polymerization reactions occur. Most importantly, isocyanate groups react with hydroxyl groups on the polyol to produce urethane linkages (hence the term polyurethane). The other main reaction is that of the isocyanate and water. The initial product of the reaction with water is a substituted carbamic acid, which breaks down into an amine and carbon dioxide. The amine then reacts with another isocyanate to yield a substituted urea linkage. The CO_2 formed in this reaction acts as the "blowing agent" and produces bubbles, causing the foam to expand to its full volume within minutes after the ingredients are mixed and poured. The final polymer is composed of the urethane and urea cross-linkages formed in the isocyanate/polyol and isocyanate/water reactions.

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[2] Memorandum. Williams, A. and Battye, W., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Flexible Polyurethane Foam Industry Description. June 19, 1996.

Slabstock Polyurethane Foam Production

Flexible slabstock foam is produced as a large continuous "bun" that is cut into sections with the desirable dimensions. The raw ingredients are pumped to a mixing head and discharged through the nozzle onto the front of a conveyor belt, called the foam line. The conveyor first passes through an enclosed, ventilated "tunnel," where the ingredients react quickly to form the foam bun. From the point of its maximum expansion, the foam begins to release blowing agents and unreacted chemicals. These chemicals are exhausted from the enclosed section. As the bun leaves the conveyor, it is sawed into smaller sections and transported to a curing area, where the remainder of the blowing agents leave the bun.

The major HAP emission source at slabstock facilities is from the use of methylene chloride ($MeCl_2$) as an ABA. Methylene chloride's role is simply to volatilize and expand the foam, not directly participate in the polyurethane reaction. Therefore, all of the methylene chloride that is added eventually is emitted. Approximately 40 percent of the methylene chloride emissions occur before the cutoff saw and another 20 percent are released during foam transfer. The remaining 40 percent is emitted in the curing area.

HAP's are also emitted through the use of HAP cleaning solvents. Methylene chloride is used as a cleaner to rinse and/or soak foam machine parts such as mixheads and foam troughs at the end of a pour. There is hardened foam residues on the trough, fall plates, and other equipment that must be removed after each production run.

Molded Polyurethane Foam Production

Molded foam production uses somewhat different chemical formulations from those used for slabstock production, although the basic polyurethane foam reaction is the same. These foams have higher densities than the slabstock flexible foams, and therefore, seldom use an ABA. In contrast to the slabstock process, the molding method is an intermittent batch process where the raw ingredients are placed in a mold and allowed to react.
The molded production line includes multiple molds, with each mold consisting of top and bottom sections, joined by hinges. The molds are mounted on a circular or oval-shaped track, with the molds and tracks varying broadly in size from facility to facility. The molds travel around the track, and the necessary process operations are performed at fixed stations. The following paragraph describes a basic molding cycle.

The first step in the molding cycle is the application of mold release agent. This is a substance that is applied to the mold to facilitate removal of the foam product. After the mold release agent is applied, any special components to be molded

into the foam, such as springs or reinforcing materials are placed in the mold. The foam mixture is then injected into the mold through a mix head, which injects a precisely measured "shot" of raw material into each mold. There are two types of mix heads used in the industry, high-pressure and low-pressure. The two types of mix heads have different cleaning requirements, resulting in a dramatic difference in overall emissions from the process, which will be discussed briefly in the next paragraph. The mold is then closed, and the polymerization reaction occurs, producing a foam product that fills the mold. After curing for a predetermined time, the molds are opened and the product is removed. The mold is then cleaned and starts the circuit again. After a foam piece is removed from the mold, it generally is trimmed and inspected for tears or holes, and any tears and/or holes are repaired. Repair operations are carried out at glue stations, which may by equipped with local ventilation systems to remove solvent vapors emanating from the glue.

Methylene chloride emissions for flushing of low-pressure mixheads is the largest emission source for flexible molded foam manufacture. With low-pressure mixheads, flushing is necessary because the residual froth can harden and clog the mixhead or can interfere with the necessary precision required of the volume of the foam shot. Emissions from mold release agents is another source of HAP emissions from molded foam. Traditional mold release agents consist of a resin in a solvent carrier, frequently methylene chloride or 1,1,1-trichloroethylene (methyl chloroform), both HAPs. The carrier evaporates, leaving the resin, which prevents the foam from sticking to the mold. If repair of the molded piece is needed, scrap foam, or the original piece that stuck to the mold, are glued to fill in the void. A HAP-based adhesive may be used for this process, with the carrier solvent being a HAP. The emissions occur when the solvent carrier evaporates after the adhesive is applied.

Slabstock Foam Fabrication

As mentioned earlier, slabstock flexible polyurethane foam is produced in large buns which are typically 4 feet tall, 8 feet wide, and 50 to 100 feet long. Prior to being delivered to the furniture manufacturer or other end-user, the large buns are "fabricated" according to the end-use. The simplest type of fabrication is to cut the foam into the desired shape by use of specialized saws, by hand-cutting, or other techniques. However, many customers desire foam products that are more "finished" or complex. To produce such products generally requires the gluing of foam-to-foam, or foam to some other material such as cotton batting. The most commonly used adhesives are either methyl chloroform based, or $MeCl_2$-based.

Rebond Foam Production

Another flexible foam product that is sometimes produced on-site at slabstock foam facilities is rebond. Rebonding is a

process where scrap foam is converted into a material that is used for carpet underlay and several other end-uses such as school bus seats. The scrap foam may have been generated at the facility from its slabstock operations, or may have been shipped or bought from other foam facilities. The baled foam is "chewed" into smaller pieces in a bale-breaker. The foam pieces then through screens into a grinder where the scrap is converted into 3/4 to 3/8 inch pieces. These small pieces are loaded into a blender, where a mixture of polyol and TDI is added. The foam and binder mixture, and occasionally a dye, is poured into a cylindrical mold, that is below floor level. This mold has a central core so that there is a hole that runs the length of the cylinder. Pressure and steam are applied to the mixture in the mold, and then the roll is taken out of the mold and allowed to cool or "set" for about 24 hours.

CONCLUSIONS

As is evident from the information presented in the paragraphs above, the only characteristic that the flexible polyurethane foam processes share is a similar chemistry between the molded and foam production processes. While the foam chemistry is analogous, the equipment, emission sources, and control techniques are very different. Molded foam is manufactured in a batch-type process, while slabstock is made in a continuous method. The major emission source for slabstock foam is from the use of an ABA, and there is no analogous emission point for molded foam. The only significant HAP emission point that the two segments share is equipment cleaning (mixhead cleaning for molded), and the reasons for these emissions, and the control technologies that could be used, are very different.

MEMORANDUM

Date: June 17, 1996

Subject: Flexible Polyurethane Foam Model Plants

From: Amanda Williams, EC/R Incorporated

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

This memorandum presents model plants for the flexible polyurethane foam production industry. A model plant does not represent any single actual facility, but rather it represents a range of facilities with similar characteristics that may be impacted by a standard. Each model plant is characterized in terms of facility type, size, and other parameters that affect estimates of emissions, control costs, and secondary impacts. The model plants developed here will be used further in the development of the Maximum Achievable Control Technology (MACT) standard for the flexible polyurethane foam production source category to analyze cost and environmental impacts, control options, and the final regulation.

The molded and slabstock segments of the foam industry were treated separately in the development of the model plants. In both cases, model plants were developed based on available information including data in company responses to the Information Collection Requests (ICR's), observations made during site visits, and information received from Polyurethane Foam Association (PFA) representatives, vendors, manufacturers, and foam producers. Information was also used from the Environmental Protection Agency's (EPA's) report, "Flexible Polyurethane Foam Emission Reduction Technologies Cost Analysis."[1] This report is hereafter referred to as the "Cost Report."

All 21 rebond facilities located at major source plant sites reported emission controls that would be in compliance with the proposed standards. It is estimated the remaining 31 rebond foam facilities are area sources, and would not be subject to the regulation. Therefore, since it is estimated that no rebond facilities will be subject to the standard, no rebond model plants were developed.

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[1] Flexible Polyurethane Foam Emission Reduction Cost Analysis. EPA-453/R-95-011. U.S. Environmental Protection Agency. September 1996.

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The first section of this memorandum provides a brief background on emission points at slabstock and molded foam production facilities. This is followed by tables presenting the slabstock and molded model plants, and brief discussions of the development of the model parameters.

POLYURETHANE FOAM PRODUCTION HAP EMISSION SOURCES

Flexible slabstock foam is produced as a large continuous "bun" that is cut into sections with the desirable dimensions. The raw ingredients are pumped to a mixing head and discharged through the nozzle onto the front of a conveyor belt, called the foam line. The conveyor first passes through an enclosed, ventilated "tunnel," where the ingredients react quickly to form the foam bun. From the point of its maximum expansion, the foam begins to release blowing agents and unreacted chemicals. These chemicals are exhausted from the enclosed section. As the bun leaves the conveyor, it is sawed into sections and transported to a curing area, where the remainder of the blowing agents leave the bun. The major HAP emission source at slabstock facilities is from the use of methylene chloride ($MeCl_2$) as an ABA. HAP's are also emitted through the use of HAP cleaning solvents.

Molded foam production uses somewhat different chemical formulations from those used for slabstock production, although the basic polyurethane foam reaction is the same. These foams have higher densities than the slabstock flexible foams, and therefore, seldom use an ABA. In contrast to the slabstock process, the molding method is an intermittent batch process where the raw ingredients are placed in a mold and allowed to react. The major HAP emission source at molded facilities is from the use of HAP solvents to clean, or "flush," the dispensing mixhead. HAP's are also used in smaller quantities for many other purposes at molding facilities such as the use of HAP-based adhesives, and HAP-based mold release agents.

MODEL PLANT DESCRIPTIONS

Model plants for the flexible polyurethane foam industry, and the rationale for their development, are presented below. The discussion is separated into the slabstock and molded segments of the industry.

Slabstock Model Plants

Operating and Emission Parameters

Five basic model plants were developed for the slabstock segment of the industry, which are presented in Table 1. They differ in the amount of foam produced and the amount of $MeCl_2$ used (and emitted). The range of foam produced in each of these models was determined by creating a frequency distribution of the amount of foam produced by slabstock manufacturers. Within each

TABLE 1. SLABSTOCK FOAM PRODUCTION MODEL PLANT PARAMETERS

	Model Plant 1		Model Plant 2		Model Plant 3		Model Plant 4		Model Plant 5	
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
OPERATING PARAMETERS										
Foam Production Range (thousand tons/yr)	0-3.9	0-3.9	4.0-7.9	4.0-7.9	8.0-11.9	8.0-11.9	12.0-15.9	12.0-15.9	≥16.0	≥16.0
Average Foam Production (thousand tons/yr)	2.0	2.0	6.0	6.0	10.0	10.0	13.75	13.75	19.0	19.0
Storage Tanks[a] - (10,000 gal)	1 1	1 1	1 2	1 2	1 3	1 3	1 3	1 3 4	1 3	1 3
Number of Components In HAP Service[b]										
$MeCl_2$	1	1	1	1	1	1	1	1	1	1
Transfer pumps	1	1	1	1	1	1	1	1	1	1
Metering pumps	16	16	16	16	16	16	16	16	16	16
Valves	20	20	20	20	20	20	20	20	20	20
Flanges/connectors	2	2	2	2	2	2	2	2	2	2
Pressure relief valves	6	6	6	6	6	6	6	6	6	6
Open-ended lines	1	1	2	2	3	3	3	3	3	3
TDI	1	1	1	1	1	1	1	1	1	1
Transfer pumps	16	16	24	24	32	32	32	32	32	32
Metering pumps	20	20	30	30	40	40	40	40	40	40
Valves	0	0	0	0	0	0	0	0	0	0
Flanges/connectors	6	6	9	9	12	12	12	12	12	12
Pressure relief valves										
Open-ended lines										
Number of Production Lines	1	1	1	1	1	1	1	1	1	1
Speed of Line (ft/min)	15	15	15	15	15	15	15	15	15	15
Line Electricity Use (kw)	120	120	120	120	120	120	120	120	120	120
HAP ABA Used (1000 gallons $MeCl_2$)	9.9	9.9	29.8	29.8	59.6	59.6	60.5	60.5	68.6	68.6
HAP Used as Cleaner (gallons $MeCl_2$)	994	0	994	0	994	0	994	0	994	0
Number of Plants Represented Nationwide	6	13	9	19	5	9	4	7	2	4

TABLE 1. SLABSTOCK FOAM PRODUCTION MODEL PLANT PARAMETERS (continued)

	Model Plant 1		Model Plant 2		Model Plant 3		Model Plant 4		Model Plant 5	
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
OPERATING PARAMETERS										
EMISSIONS (tons/yr)										
TDI										
Storage	0	0	0	0	0	0	0	0	0	0
Equipment Leaks	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
TDI Total	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
$MeCl_2$										
Storage	0.09	0.09	0.26	0.26	0.52	0.52	0.03	0.03	0.03	0.03
ABA	55	55	165	165	330	330	335	335	380	380
Equipment Cleaning	5	0	5	0	5	0	5	0	5	0
Equipment Leaks	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
$MeCl_2$ Total	64	59	174	169	339	334	343	338	388	383
TOTAL HAP EMISSIONS	64	59	174	169	339	334	343	338	388	383
COST PARAMETERS										
Cost of ABA (thousand$/yr)	44.0	44.0	132.0	132.0	264.0	264.0	268.0	268.0	304.0	304.0
Cost of HAP Cleaner (thousand$/yr)	4.4	0	4.4	0	4.4	0	4.4	0	4.4	0
Total Chemical Cost (thousand$/yr)	2,726	2,722	8,583	8,579	14,360	14,356	19,645	19,641	26,974	26,970
ABA-blown Chemical Cost (thousand$/yr)	2,172	2,172	6,517	6,517	11,057	11,057	14,541	14,541	17,568	17,568
Total Facility Operating Costs (thousand$/yr)	3,408	3,403	10,729	10,724	17,950	17,945	24,557	24,551	33,718	33,713
Disposal Cost of waste $MeCl_2$ ($/yr)	1,450	0	1,450	0	1,450	0	1,450	0	1,450	0

[a] Model plants 1 and 2 have no control for storage or unloading of either HAP, model plant 3 has VB control (95%) for TDI; and model plants 4 and 5 have Vapor Balance control (VB) for both HAP.
[b] It was assumed that there is one transfer pump per storage vessel at each model plant, and one metering pump per HAP. Canned pumps are only available for transfer pumps, and only Model Plant 5 uses canned pumps for $MeCl_2$ transfer. Model plants 2, 3, 4, and 5 have canned pumps for TDI transfer.

production range, the average amount of foam produced was calculated by averaging the production amounts for the "real" plants represented by each model plant. For example, 19 slabstock facilities reported annual foam production less than 4,000 tons per year. This was the production range selected to characterize model plant 1. The total foam produced by these 19 facilities was around 40,500 tons per year, yielding an average facility production of just over 2,000 tons per year. This average production value was selected to represent the annual production of Model Plant 1.

Although approximately 25 percent of the foam plants in the industry reported having more than one line, there was no correlation identified between the amount of foam produced and the number of lines at the facility. Therefore, each model plant has only one production line. The speed of the line and the electricity used represent operating parameters for a typical Maxfoam line.

While the size of HAP storage vessels at slabstock facilities varies, the model plant storage tank sizes were assumed to be consistent for all model plants. The tank capacities represent typical tank sizes for the industry. The number of tanks was based on actual numbers reported in the ICR's from actual plants in each size category. Only 16 facilities reported using vapor balance (VB) to control $MeCl_2$ storage and unloading emissions, and 27 reported using VB to control TDI emissions. Therefore, model plants 1 and 2 have no controls for storage or unloading, model plant 3 has emission controls for TDI only, and 4 and 5 have controls for both TDI and $MeCl_2$.

The number of HAP pumps was calculated assuming one transfer pump per storage vessel, and one metering pump per chemical. The other types of components were estimated using the following component to pump ratios: 8:1 for valves, 10:1 for flanges connectors, and 3:1 for open-ended lines. The number of $MeCl_2$ pressure relief valves was calculated assuming one valve per pump. It was assumed that all TDI systems were closed with no pressure-relief valves. Some slabstock facilities reported using canned pumps, a type of sealless pumps to eliminate leaks. For the model plants it was assumed that for model plant 2, 3, and 4, have canned pumps for all TDI transfer pumps, and model plant 5 has canned pumps for $MeCl_2$ and TDI transfer. According to industry representatives, canned pumps can not be used for metering due to the high pressure requirements.

As mentioned earlier, the use of a HAP (usually $MeCl_2$) as an ABA is the primary source of HAP emissions at a slabstock foam facility. However, the amount of ABA needed varies considerably depending on the "grade" of the foam being produced. During the development of the Cost Report, the EPA worked with a group of PFA representatives to develop foam grades and formulations for a "representative" slabstock facility. Each slabstock model plant

presented in this memorandum incorporates the same grades and formulations as the representative plant from the Cost Report. The grades produced by the model plants represent the most commonly produced grades in the industry, and the formulations are based on ICR responses and input from PFA representatives. The grade-specific information for each major model plant is presented in Table 2.

For each of the five model plants, the average facility HAP ABA usage was determined using information from the real facilities represented by the model plant. The amount of each grade of foam produced by the model plant was adjusted so that the total annual HAP ABA usage for the model plant equaled the average of the real plants. All HAP ABA used was assumed to be emitted. Storage emissions were calculated using AP-42 emission factors for chemical storage tanks.[2] Emissions from components in HAP service (e.g. pumps, valves, flanges, etc.) were calculated using SOCMI average emissions factors.[3]

Thirty-three percent of the slabstock facilities reported the use of $MeCl_2$ as a general equipment cleaner, including facilities represented by all five model plants. However, no correlation was found between the use of a HAP cleaner (or the amount of HAP used as a cleaner) and the amount of foam produced. Therefore, each of the five model plants were separated into two smaller model plants (i.e., 1A and 1B), with one using $MeCl_2$ as a cleaner, and the other employing cleaning methods that did not use a HAP. One-third of the nationwide facilities represented by each of the five model plants were assigned to the smaller model plant that uses a HAP cleaner. An average $MeCl_2$ usage rate was determined for those facilities reporting its use as a cleaner, and this average rate was applied to each model plant that used a HAP cleaner, regardless of size.

For those model plants using a HAP cleaner, it was assumed that 90 percent of the $MeCl_2$ used as a cleaner is eventually emitted. The 10 percent was assumed to be contained in the solid/liquid waste from the cleaning process that is collected and discarded as hazardous waste.

Cost Parameters

Because many of the emission reduction technologies that will be studied for the slabstock industry will involve process changes or other pollution prevention techniques, it is necessary

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[2] Compilation of Air Pollutant Emission Factors. AP-42. U.S. Environmental Protection Agency.

[3] Protocol for Equipment Leak Emission Estimates. EPA-453/R-93-026. U.S. Environmental Protection Agency. June 1993. Table 2-10.

Table 2. Slabstock Foam Production Model Plant Formulation Information

Grade	Density (pcf)	IFD (25%)	$MeCl_2$ in formulation (pph polyol)	Foam Produced (tons/yr)					Baseline $MeCl_2$ used as ABA and emitted (tons/yr)				
				MP1	MP2	MP3	MP4	MP5	MP1	MP2	MP3	MP4	MP5
0930	0.9	30	10	80	240	600	550	570	5.3	16.0	40.0	36.7	38.0
1010	1.0	10	22	40	120	300	140	190	5.9	17.6	44.0	20.5	27.9
1015	1.0	15	19	40	120	300	140	190	4.9	14.8	37.0	17.3	23.4
1020	1.0	20	14	40	120	200	140	190	3.7	11.2	18.7	13.1	17.7
1030	1.0	30	8	80	240	500	550	570	4.0	12.0	25.0	27.5	28.5
1120	1.1	20	14	40	120	200	280	190	3.6	10.8	18.0	25.2	17.1
1130	1.1	30	7	60	180	300	410	570	2.6	7.8	13.0	17.8	24.7
1230	1.2	30	5	100	300	500	690	950	3.3	10.0	16.7	23.0	31.7
1330	1.3	30	6	60	180	300	410	570	2.2	6.6	11.0	15.0	20.9
1340	1.3	40	2	60	180	200	550	570	0.8	2.4	2.7	7.3	7.6
1440	1.4	40	2	60	180	300	410	570	0.8	2.4	4.0	5.5	7.6
1520	1.5	20	13	40	120	300	280	190	3.3	10.0	25.0	23.3	15.8
1530	1.5	30	6	40	120	200	410	380	1.6	4.8	8.0	16.4	15.2
1540	1.5	40	2	120	360	500	690	950	1.6	4.8	6.7	9.2	12.7
1640	1.6	40	1	120	360	400	830	950	0.8	2.4	2.7	5.5	6.3
1740	1.7	40	1	120	360	400	830	950	0.8	2.4	2.7	5.5	6.3
1820	1.8	20	10	60	180	400	410	380	4.0	12.0	26.7	27.3	25.3
1830	1.8	30	6	60	180	300	410	570	2.2	6.6	11.0	15.0	20.9
1840	1.8	40	0	120	360	600	830	1,240	0.0	0.0	0.0	0.0	0.0
1930	1.9	30	7	60	180	300	410	570	2.8	8.4	14.0	19.1	26.6
1940	1.9	40	1	100	300	500	690	860	0.7	2.0	3.3	4.6	5.7
>2020	2.5	25	0	500	1,500	2,400	3,710	6,840	0.0	0.0	0.0	0.0	0.0
								Total	55	165	330	335	380

to include baseline operational costs for the model plants. The costs developed include the total annual chemical costs, the total annual chemical costs for ABA-blown foam, and the total annual operating costs. In addition, baseline costs associated with the use of methylene chloride as a cleaner were needed.

In the development of the Cost Report, the PFA chemical alternative workgroup provided standard chemical costs for the foam grades included in the representative facility. The costs used include the cost of polyol, toluene diisocyanate (TDI), and additives. These costs assumed the following raw chemical costs: $0.50 per pound for polyol, $1.00 per pound for TDI, and $0.40/lb for $MeCl_2$.

The model plant chemical costs were determined by multiplying the amount of each grade of foam produced by the grade-specific chemical cost. The ABA-blown foam chemical cost includes only those grades that use ABA. The total facility operating costs were calculated using the common industry assumption that the chemical costs make up 80 percent of a facility's total annual operating costs.

The cost of $MeCl_2$ for cleaning was determined using the $0.40 per pound cost cited above. The disposal cost of $MeCl_2$-contaminated waste was calculated assuming an industry estimate of $800 per 55-gallon drum.

Molded Foam Facilities

While the basic processes are similar at all molded foam facilities, there are two different types of equipment used to pour the foam that create large differences in their HAP emission potential. The two types of equipment are low pressure (LP) and high pressure (HP) mixheads. LP mixheads require a solvent flush between foam shots to remove residual foam, while HP mixheads do not. Consequently, HAP emissions from LP facilities are usually significantly higher than emissions from HP facilities. All of the molded foam major sources were LP facilities, and all of the HP facilities were area sources.

Four molded foam model plants were developed, one with a HP mixhead, and three with LP mixheads. They are presented in Table 3. Only one model plant was created for HP mixhead facilities since the other parameters and HAP emissions were not found to be linked to production. The LP model plants differ mainly in the amount of foam produced, and the amount of HAP used to flush. The foam production range was determined in the same way as described above in the slabstock section, as was the average annual foam production.

The number of lines or carrousels was not found to be linked in any representative or replicatable way to the amount of foam produced. Therefore, the average number of carrousels for HP and

TABLE 3. MOLDED FOAM MODEL PLANT PARAMETERS

	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
Operating Parameters				
Foam production range (tons/yr)	0-15,000	0-99	100-499	≥500
Average foam production (tons/yr)	3,331	26	308	2718
Number of carrousels	2	5	5	5
Operating schedule	16 hrs/day 250 days/yr	8 hrs/day 250 days/yr	16 hrs/day 250 days/yr	16 hrs/day 250 days/yr
Type of mixheads	HP	LP	LP	LP
HAP flush amount (55-gal drums)	0	19	72	177
Waste $MeCl_2$ from flush (55-gal drums)	0	2	8	18
HAP mold release agent amount (gal/year)	0	41	32	831
HAP repair adhesive amount (gal)	581	0	0	66
HAP content of adhesive	70%	0	0	70%
Number of facilities represented nationwide	27	109	54	44
Emissions (tons/yr)				
Emissions from HAP mixhead flush/plant	0	5.14	19.69	21.31
Emissions from HAP mold release/plant	0	0.15	0.12	6.0
Emissions from HAP adhesive/plant	2.093	0	0	1.35
Cost Parameters				
Disposal cost of waste $MeCl_2$	0	$1,600	$6,400	$14,400
Cost of HAP-based mold release agent	0	$198	$154	$4,005
Cost of HAP-based adhesive	$4,939	0	0	$561

LP facilities was calculated and applied to each plant respectively. The operating schedule of actual facilities represented by the model plants was examined, and a typical schedule was determined for each type.

As mentioned above, LP mixheads require flushing to remove residual foam from the mixhead. The HAP flush amount for each model plant was calculated from the average emissions from HAP flush for facilities represented by each model plant, multiplied by 1.1, and the weight per gallon of $MeCl_2$. The emissions were multiplied by 1.1 because the emissions reported represent only 90 percent of the amount of $MeCl_2$ actually used. The remaining 10 percent is unrecoverable from the solid/liquid mixture collected at the bottom of the containers that capture the flush.

The amount of HAP mold release agent used was calculated using the average emissions from HAP-based mold release agents for facilities represented by each model plant, and the HAP weight per gallon of the model mold release agent. The mold release agent chosen was indicated by vendors to have a representative HAP content (75 percent by weight) and density of those used by many foam facilities. No facilities using HP mixheads reported any HAP emissions from mold release agents, therefore the HAP model plant uses none. The amount of HAP-based repair adhesives was calculated in the same manner, using the 70 percent by weight HAP content.

Emission and cost parameters

The emissions from HAP mixhead flush, mold release agent, and adhesives, were all calculated in the same manner. The total emissions from the real facilities in each model plant category were divided by the number of facilities reporting emissions from each of the sources.

The cost parameters were all provided by vendors or industry personnel, as being representative of costs by the industry. The disposal cost of waste $MeCl_2$ was based on a cost of $800 per 55-gallon drum. The HAP-based mold release agent, and HAP-based adhesive were based on costs of $4.82 and $8.50 per gallon, respectively.

Table 2. Slabstock Foam Production Model Plant Formulation Information

Grade	Density (pcf)	IFD (25%)	$MeCl_2$ in formulation (pph polyol)	Foam Produced (tons/yr)					Baseline $MeCl_2$ used as ABA and emitted (tons/yr)				
				MP1	MP2	MP3	MP4	MP5	MP1	MP2	MP3	MP4	MP5
0930	0.9	30	10	80	240	600	550	570	5.3	16.0	40.0	36.7	38.0
1010	1.0	10	22	40	120	300	140	190	5.9	17.6	44.0	20.5	27.9
1015	1.0	15	19	40	120	300	140	190	4.9	14.8	37.0	17.3	23.4
1020	1.0	20	14	40	120	200	140	190	3.7	11.2	18.7	13.1	17.7
1030	1.0	30	8	80	240	500	550	570	4.0	12.0	25.0	27.5	28.5
1120	1.1	20	14	40	120	200	280	190	3.6	10.8	18.0	25.2	17.1
1130	1.1	30	7	60	180	300	410	570	2.6	7.8	13.0	17.8	24.7
1230	1.2	30	5	100	300	500	690	950	3.3	10.0	16.7	23.0	31.7
1330	1.3	30	6	60	180	300	410	570	2.2	6.6	11.0	15.0	20.9
1340	1.3	40	2	60	180	200	550	570	0.8	2.4	2.7	7.3	7.6
1440	1.4	40	2	60	180	300	410	570	0.8	2.4	4.0	5.5	7.6
1520	1.5	20	13	40	120	300	280	190	3.3	10.0	25.0	23.3	15.8
1530	1.5	30	6	40	120	200	410	380	1.6	4.8	8.0	16.4	15.2
1540	1.5	40	2	120	360	500	690	950	1.6	4.8	6.7	9.2	12.7
1640	1.6	40	1	120	360	400	830	950	0.8	2.4	2.7	5.5	6.3
1740	1.7	40	1	120	360	400	830	950	0.8	2.4	2.7	5.5	6.3
1820	1.8	20	10	60	180	400	410	380	4.0	12.0	26.7	27.3	25.3
1830	1.8	30	6	60	180	300	410	570	2.2	6.6	11.0	15.0	20.9
1840	1.8	40	0	120	360	600	830	1,240	0.0	0.0	0.0	0.0	0.0
1930	1.9	30	7	60	180	300	410	570	2.8	8.4	14.0	19.1	26.6
1940	1.9	40	1	100	300	500	690	860	0.7	2.0	3.3	4.6	5.7
>2020	2.5	25	0	500	1,500	2,400	3,710	6,840	0.0	0.0	0.0	0.0	0.0
								Total	55	165	330	335	380

MEMORANDUM

Date: June 17, 1996

Subject: Baseline Emissions for the Flexible Polyurethane Foam Production Industry

From: Amanda Williams, EC/R Incorporated
Phil Norwood, EC/R Incorporated

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

The purpose of this memorandum is to present the baseline hazardous air pollutant (HAP) emissions for the flexible polyurethane foam production source category. Two basic mechanisms were used to generate the baseline emission estimates presented in this memorandum. The first was to directly use information submitted by industry in response to an information collection request (ICR) distributed by the Environmental Protection Agency (EPA). However, in several instances the ICR responses did not contain adequate information to allow the direct determination of baseline emissions. In these cases, nationwide baseline emission estimates were extrapolated from the ICR responses.

This memorandum is organized into three sections. The first section gives a summary of the ICR responses. The second section provides a discussion of how "model plants," and other data from the ICR responses, were used to determine baseline emissions. The final section presents the baseline HAP emissions for this source category. The flexible polyurethane foam source category has been divided into three subcategories: slabstock foam, molded foam, and rebond foam. In each of the sections of this memorandum, these subcategories are discussed separately.

SUMMARY OF INFORMATION COLLECTION REQUESTS (ICRs)

A primary basis for baseline emission estimates for this industry was information submitted to the Environmental Protection Agency (EPA) by the flexible foam manufacturers in response to information collection activities conducted under the EPA's Section 114 authority. In July of 1993, the EPA sent a "generic" ICR, approved by the Office of Management and Budget (OMB), to all identified slabstock and molded foam producers. The July 1993 questionnaire was designed to obtain production, emission, and emission control information from the manufacturers of flexible polyurethane foam. The following sections summarize

the HAP emissions information reported in these responses. A complete summary of the ICR responses is provided in a separate memorandum.[1]

Slabstock Foam

The ICRs were sent to 87 foam facilities that were believed to produce flexible slabstock foam. Information was received from 78 of these facilities, with the other nine reporting that they do not produce flexible polyurethane foam. For the majority of the reporting facilities emission, production, and other facility data were for 1992.

The total HAP emissions reported by these facilities was 16,748 tons per year. The main emission points for flexible slabstock foam were HAP auxiliary blowing agent (ABA), equipment cleaning, chemical handling, and on-site rebond operations. The HAP emissions for each of the emission points are provided in Table 1. The table also presents emissions broken out into the individual HAP for each emission point. Attachment 1 contains reported HAP emissions for each slabstock foam facility.

Emission information was also provided for on-site fabrication operations at slabstock foam facilities. However, this information is not included in Table 1, or in any further discussion of baseline emissions, because fabrication operations have been designated a separate source category (61 FR 28197).

Molded Foam

ICR's were sent to 73 facilities that were believed to manufacture flexible polyurethane foam. Eighteen of these facilities responded that they did not manufacture flexible polyurethane foam, and 10 facilities either did not complete an ICR, or provided incomplete information. Completed responses were received for 46 molded foam facilities (one slabstock facility reported that they also had molded operations, increasing the count). The reported HAP emissions from molded flexible polyurethane foam producers totalled 269 tons. The largest emission points for flexible molded foam were mixhead flush and foam repair. The other reported emissions points were chemical handling, foam dispensing, in-mold coatings, demolding, and equipment cleaning. Molded foam facilities also reported several other small emissions points that were combined and reported as emissions from miscellaneous chemical handling or miscellaneous foam production. These sources were reported infrequently and resulted in small HAP emissions.

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[1] Memorandum. Norwood, P., Williams, A., and Battye, B., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Summary of Flexible Polyurethane Foam Information Collection Requests. January 24, 1994.

TABLE 1. SUMMARY OF PROCESS EMISSIONS BY PROCESS OPERATION: SLABSTOCK ICR RESPONSES

Emission Source	Reported HAP Emissions (tons/yr)						
	Total HAP's	Individual HAP's					
		$MeCl_2$	Methyl chloroform	Propylene Oxide	TDI	DEOA	Other HAP's
Chemical Unloading/ Storage	39	26	9	0[a]	2	0[a]	0[a]
Pump and Valve Leaks	16	6	2	0[a]	7	0[a]	0[a]
Foam Production							
ABA	16,551	14,372	2,078	101	-	-	-
Other	8	-	-	-	8	-	-
Equipment Cleaning	135	109	23	-	-	-	2
TOTAL[b]	16,748	14,514	2,112	101	20	1	3

[a] HAP emissions were reported but were less than 0.5 tons

[b] Numbers in each column may not add to totals due to rounding.

The reported HAP emissions for each of the molded emission points are provided in Table 2. The table also presents emissions broken out into the individual HAP for each emission point. Attachment 2 contains reported HAP emissions for each molded foam facility.

The ICR responses were received from only a fraction of the molded foam industry. As discussed in a separate EC/R memorandum[2], there are now estimated to be 228 molded facilities nationwide. Therefore, it was necessary to extrapolate the information from the 46 molded foam ICR responses to obtain nationwide baseline emission estimates. This extrapolation is discussed in the next section.

Rebond Foam

Information was received from 21 rebond foam operations that were co-located at slabstock production facilities. The total reported emissions from these rebond operations was 11 tons per year. Ten of these tons were methylene chloride ($MeCl_2$) and one was toluene diisocyanate (TDI). The $MeCl_2$ emissions were reported from a single facility, which has since reported that the use of this HAP has been discontinued.[3]

THE USE OF MODEL PLANTS AND OTHER INFORMATION TO DETERMINE BASELINE EMISSIONS

As discussed earlier, there were several instances where the direct use of the ICR response data as the nationwide baseline emissions was not appropriate. Therefore, it was necessary to use the available information to estimate nationwide baseline emissions. Two different methods were used: the extrapolation of model plant emission estimates for primary emission sources, and extrapolation of ICR emission estimates for minor emission sources.

Model Plants

The molded and slabstock segments of the foam industry were treated separately in the development of the model plants. In both cases, model plants were developed based on available information, including data in company responses to the ICRs,

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[2] Memorandum from Williams, A., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Flexible Polyurethane Foam Molded Plants: New Count and Nationwide Model Plant Representation. November 3, 1995.

[3] Memorandum. Williams, A. and Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Summary of November 28, 1995 Environmental Protection Agency/Ohio Decorative Products Meeting. May 31, 1996.

TABLE 2. SUMMARY OF PROCESS EMISSIONS BY PROCESS OPERATION: MOLDED ICR RESPONSES

Emission Source	Reported HAP Emissions (tons/yr)									
	Total HAP's	Individual HAP's								
		$MeCl_2$	TCA	MDI	TDI	DEOA	MEK	Methanol	Toluene	Other
Chemical Handling										
Chemical Unloading	1.8	0.2	-	0[a]	1.3	0.2	-	0.01	-	-
Chemical Storage	0.1	-	-	0[a]	0.01	0.1	-	-	-	-
Pumps and Valves	10.7	1.3		4.0	3.9	1.6	-	-	-	-
Day Tanks	4.8	0.4	-	4.4	-	0[a]	-	0.01	-	-
Misc.	0.08	-	-	-	-	0.04	0.02	-	0.01	0.01
Foam Production										
Dispensing	0.8	-	-	0.1	0.6	0.02	-	-	-	0.03
Mixhead Flush	204.9	195.4	3.5	-	-	-	-	6.1	-	-
Mold Release Agent	7.8	6.3	0.7	-	-	-	-	-	0.9	0.03
Demolding	2.3	1.7	-	-	0.3	0.04	-	-	-	0.3
In-mold Coating	6.3	-	-	-	-	-	3.6	0.01	2.2	0.5
Misc.	2.2	0.01	0.02	0.1	0.3	0.04	1.6	-	0.1	-
Equipment Cleaning	1.9	1.4	-	-	-	-	-	0.4	0.1	0.03
Foam Repair	26.1	-	26.1	0[a]	-	0[a]	-	-	-	-
TOTAL[b]	269	207	30	9	6	2	5	7	3	1

[a] HAP emissions were reported but were less than 0.005 tons
[b] Numbers in each column may not add to totals due to rounding.

observations made during site visits, and information received from Polyurethane Foam Association (PFA) representatives, vendors, manufacturers, and foam producers.[4] This extrapolation of model plant emissions to determine nationwide baseline emissions is discussed below.

Slabstock Foam

The slabstock model plants were used in two ways to determine nationwide emissions. For HAP ABA emissions and equipment cleaning, it is believed that the information provided in the ICR responses accurately represents the nationwide emissions. In these cases, the combination of model plant baseline emissions and the estimate of the number of facilities represented by each model plant were determined so that the nationwide emissions calculated from the model plants matched the ICR responses as closely as possible. Since the regulatory alternative impacts are determined on a model plant basis, the nationwide baseline emissions are based on the these estimates.

Table 3 shows the calculation of nationwide baseline HAP ABA emissions. For HAP ABA emissions, the total reported HAP emissions were 16,551 tons/yr. This consisted of $MeCl_2$, methyl chloroform, and propylene oxide. It is assumed that the use of methyl chloroform as an ABA will be phased out, and replaced by $MeCl_2$ at baseline. Propylene oxide is contained in very small amounts as a stabilizer in $MeCl_2$, and was not included in the baseline emission estimates. Therefore, the only HAP ABA emissions in the slabstock foam model plants are $MeCl_2$, and the nationwide total calculated from the is 16,250 tons/yr.

The calculation of nationwide baseline equipment cleaning emissions was calculated in a similar manner. The total reported emissions from this source was 135 tons/yr, with 25 of these tons HAP's other than $MeCl_2$. For the purpose of the baseline emission estimate, it was assumed that all HAP emissions from equipment cleaning were $MeCl_2$. All model plants were assumed to emit 5 tons $MeCl_2$ per year for equipment cleaning, and it was assumed that 26 facilities use $MeCl_2$ as an equipment cleaner (6 MP1, 9 MP2, 5 MP3, 4 MP4, and 2 MP4). Therefore, the total baseline HAP emissions from equipment cleaning is 130 tons/yr.

The ICR responses were not relied upon for baseline HAP emissions from storage/unloading and equipment leaks. For these sources, model plant emission estimates were calculated using standard EPA emission estimating techniques. These model plant estimates were multiplied by the number of actual facilities represented by each of the model plants to obtain nationwide

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[4] Memorandum from Williams, A., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Flexible Polyurethane Foam Model Plants. June 17, 1996.

TABLE 3. NATIONWIDE HAP ABA EMISSIONS CALCULATED FROM SLABSTOCK FOAM MODEL PLANTS

	Model Plant				
	1	2	3	4	5
Baseline HAP. ABA Emissions (tons/yr)	55	165	330	335	380
Number of Facilities Represented	19	28	14	11	6
Total HAP ABA Emissions for Model Plant (tons/yr)	1,045	4,620	4,620	3,685	2,280
Total Nationwide HAP ABA Emissions (tons/yr)	16,250				

estimates, which are in Table 4. More details on how these emission estimates were calculated follows.

Storage and unloading. Storage and unloading emissions were reported by some facilities in the ICRs. Because the majority of storage tanks at foam facilities are located indoors, where temperature is controlled, it was assumed that breathing loss emissions were minimal. For the model plants, unloading (working loss) emissions were calculated using AP-42 emission factors for chemical storage tanks.[5] Since some model plants assume storage tank controls, the baseline HAP emissions consist of a combination of controlled and uncontrolled emissions. This is described in detail in the model plant memorandum cited earlier.

Equipment leaks. Emission information was submitted in the ICR responses for pumps and valves. However, the assumptions made in calculating these emissions (discussed below) were inconsistent with typical EPA assumptions, and no information was received for other components in HAP service (flanges/connectors, open-ended lines, or pressure relief valves). Therefore, model plant emissions from components in HAP service were calculated using assumed component counts and synthetic organic chemical

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[5] Compilation of Air Pollutant Emission Factors. Volume I: Stationary Point and Area Sources. 5th Edition. U.S. Environmental Protection Agency. January 1995. Section 7.

TABLE 4. NATIONWIDE SLABSTOCK STORAGE/UNLOADING AND EQUIPMENT LEAK EMISSIONS CALCULATED FROM MODEL PLANTS

Emission Source	Annual Nationwide Emissions (tons/yr)
Storage/Unloading	
$MeCl_2$	17
TDI	0.03
Storage/unloading total	17
Equipment Leaks	
$MeCl_2$	
Pumps	58
Valves	48
Flanges/connectors	27
Pressure relief valves	157
Open-ended lines	8
Total $MeCl_2$	298
TDI	
Pumps	16
Valves	4
Flanges/connectors	0
Pressure relief valves	0
Open-ended lines	0
Total TDI	20
Equipment leak total	318

manufacturing industry (SOCMI) average emission factors.[6] The nationwide estimates were then calculated by multiplying the model plant emissions by the number of facilities represented by each model plant.

There is a significant difference in the reported pump and valve HAP emissions from the ICR responses and the baseline

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[6] Protocol for Equipment Leak Emission Estimates (EPA-453/R-93-026). U.S. Environmental Protection Agency. Table 2-10.

emissions estimated from the model plants. The primary reason for this difference is that when the facilities did report emissions for these components, they used hours of actual pouring per year in the emission calculation (typically between 600 and 800 hours per year). The model plant emissions were calculated based on 24 hours per day, 365 days per year (8760 hours per year), because the potential for leaks is present whenever HAP liquids are present in the equipment, not just when liquid is flowing through the line.

Molded Foam

As noted earlier, ICR responses were received from only 46 of the estimated 228 nationwide molded foam facilities. Therefore, it was necessary to extrapolate information from these facilities to approximate nationwide HAP emissions. Two different methods were used to accomplish this estimation. The first was to calculate nationwide emissions using model plants, as discussed below. The second was to extrapolate directly from the ICR response totals, as discussed in the next section.

Emissions from three sources were consistently reported by all molded foam producers. These sources were mixhead flush, mold release agents, and adhesives used in foam repair. It was therefore assumed that these sources were common to all molded facilities. Due to this fact, as well as the fact that these were the only emission sources where control was reported, these were the only three emission sources included in the molded foam model plants.

The model plant emissions were calculated by dividing the total emissions from the reporting facilities represented by each model plant by the number of facilities reporting emissions from each of the sources. These emissions were then multiplied by the number of facilities represented by each model plant to obtain the nationwide baseline emission estimates shown in Table 5.

Other Information

There were many other small HAP emission sources identified in the ICRs. However, the emissions were very small, and the occurrence of the emission points was too inconsistent to accurately create a model for these emissions. Therefore, baseline HAP emissions were estimated by direct extrapolation of the emission information reported in the ICR responses. This extrapolation was based on the percentage of facilities reporting emissions from each emission source, and an assumption that the same percentage of the remainder of the industry would also report comparable emissions from the same source. An example of this calculation follows.

The 6.3 tons per year of HAP emissions from in-mold coatings shown in Table 2 were reported by three facilities, or

TABLE 5. NATIONWIDE MOLDED MIXHEAD FLUSH, MOLD RELEASE AGENT, AND REPAIR ADHESIVE HAP EMISSIONS CALCULATED FROM MODEL PLANTS

Emission Source	Annual Nationwide Emissions (tons/yr)
Mixhead flush	2,561
Mold release agent	287
Repair adhesives	116

6.5 percent of the total reporting facilities (3 ÷ 46). To estimate nationwide emissions, the average facility emissions (2.1 tons/yr) were multiplied by 6.5 percent of the estimated nationwide facility population, as follows.

$$E_{nationwide} = \left(\frac{2.1\ tons/year}{facility}\right)(228\ facilities)(6.5\%) = 31\ tons/yr$$

The nationwide baseline estimates calculated in this manner are summarized in Table 6.

The 21 rebond facilities co-located with slabstock production facilities reported a total of 1.0 tons per year of HAP emissions. As noted earlier, one facility originally reported emissions from a HAP-based mold release agent and a HAP cleaner, but it has subsequently discontinued the use of these products. Therefore, the total nationwide HAP emissions from the production of rebond foam is 2.5 tons per year, which is a linear extrapolation of the emission estimates for the 21 facilities to the estimated 52 nationwide facilities.

BASELINE HAP EMISSIONS

The baseline HAP emission estimates, determined as described in previous sections, are shown in Tables 7 and 8. Table 7 presents baseline emissions for slabstock polyurethane foam production, and Table 8 presents baseline emissions for molded foam production.

TABLE 6. BASELINE HAP EMISSIONS FOR MOLDED FOAM PRODUCTION CALCULATED BY DIRECT EXTRAPOLATION OF ICR RESULTS

Emission Source	Baseline Total HAP Emissions (tons/yr)
Chemical Unloading/Storage	10
Equipment Leaks	55
Day Tanks	25
Foam Production	
Dispensing	67
Demolding	12
In-mold Coating	32
Other Production	11
Equipment Cleaning	10

TABLE 7. BASELINE HAP EMISSIONS FOR SLABSTOCK FOAM PRODUCTION

Emission Source	Baseline HAP Emissions (tons/yr)		
	Total HAP's	Individual HAP's	
		$MeCl_2$	TDI
Chemical Storage/Unloading	17	17	0.0a
Equipment Leaks	318	298	20
Foam Production			
ABA	16,250	16,250	-
Other	9	-	9
Equipment Cleaning	130	130	-
On-Site Rebond	11	10	1
TOTALS	16,735	16,705	30

TABLE 8. BASELINE HAP EMISSIONS FOR MOLDED FOAM PRODUCTION

Emission Source	Baseline Total HAP Emissions (tons/yr)
Chemical Unloading/Storage	10
Equipment Leaks	55
Day Tanks	25
Foam Production	
Dispensing	67
Mixhead Flush	2,561
Mold Release Agent	287
Demolding	12
In-mold Coating	32
Other Production	11
Equipment Cleaning	10
Foam Repair	116
TOTAL	3,186

Attachment 1

REPORTED HAP EMISSIONS BY FACILITY – SLABSTOCK FOAM
1992 ICR Responses (tons/yr)

Facility Name	Total HAP	Methylene Chloride	Methyl Chloroform	Propylene Oxide	TDI	DEAO	Other HAP
Armaly Brands	0				0.0		
Austin Urethane, Incorporated	93	93			0.1		
Burkart Foam, Inc.	312	311			0.2	0.01	
Crain Industries – Compton CA	527	296	229		1.1		
Crain Industries – Conover NC	156	155			0.3	0.06	
Crain Industries – Easton, PA	142	142			0.2		
Crain Industries – Elkhart IN	81	79			1.3		
Crain Industries – FT.Smith AR	68	67			0.9	0.06	
Crain Industries – Kent WA	128	128			0.3	0.21	
Crain Industries – Newnan GA	136	136			0.2		
Crain Industries – San Leandro CA	2		1		0.6		
Crain Industries – Verona, MS	124		122		1.8		
Crest Foam Company, Incorporated	82	81	0		0.2		
Crest Foam Industries–NJ	0	0			0.0		
E–A–R Division/Cabot Corporation	7	7					
E–A–R Specialty Composites/Indianapolis	24	24	0				
E.R. Carpenter Co., Inc. – Conover NC	88	87		1	0.3		0.01
E.R. Carpenter Co., Inc. – Elkhart IN	345	340		5	0.2		
E.R. Carpenter Co., Inc. – Lathrop CA	204	200		3	0.2		
E.R. Carpenter Co., Inc. – Richmond VA	447	440		7	0.3	0.01	
E.R. Carpenter Co., Inc. – Riverside CA	389	68	320	1	0.2	0.01	
E.R. Carpenter Co., Inc. – Russellville KY	571	562		8	0.4	0.02	
E.R. Carpenter Co., Inc. – Temple TX	18	17		0	0.1	0.00	
E.R. Carpenter Co., Inc. – Verona MS	709	700		8	0.2		
Flexible Foam – Spencerville, OH	1089	1,089			0.5		
Flexible Foam Products– Miami, FL	60	60			0.3		
Flexible Foam Products, Inc. – Elkhart, IN	508	508			0.6		
Flexible Foam Products, Terrell, TX	1314	1,314			0.7		
Florifoam	47	47			0.0		
Foamex – LaPorte IN	53	53		0	0.0	0.00	
Foamex LP, Conyers GA	97	97			0.1		
Foamex LP, San Bernadino CA	210	9	201		0.1	0.01	
Foamex LP, Verona MS	348	348			0.1	0.00	
Foamex L.P. Corry, PA	495	495			0.1		0.01
Foamex L.P. Elkhart, IN	430	430			0.1		
Foamex L.P. Mesquite TX	58	1	57		0.1		
Foamex L.P., Cornelius, NC	153	153			0.0	0.00	0.01
Foamex L.P., Milan, TN	413	413			0.0	0.00	
Foamex L.P., Morristown TN	194	194			0.2	0.13	
Foamex, LP, Eddystone PA	19	17			2.0		

Attachment 1

REPORTED HAP EMISSIONS BY FACILITY – SLABSTOCK FOAM
1992 ICR Responses (tons/yr)

Facility Name	Total HAP	Methylene Chloride	Methyl Chloroform	Propylene Oxide	TDI	DEAO	Other HAP
Foamex, LP, Ft. Wayne IN	65	65			0.1	0.03	0.01
Foamex, LP, Orange CA	561		561		0.0	0.00	
Foamex, L.P. Orlando FL	234	234			0.1	0.01	
Foamex, L.P. Santa Teresa NM	0				0.0*		
Foamex, L.P., Auburn IN	176	176			0.1		0.07
Future Foam, Inc – Council Bluffs IA	133	133			0.0	0.00	
Future Foam, Inc – Fullerton CA	272		272		0.1		
Future Foam, Inc – Middleton WI	109	109			0.0		
Future Foam, Inc – Newton KS	65	65			0.0		
General Foam – E. Rutherford NJ	0				0.0		
General Foam Corporation – Bridgeview IL	302	287		14	0.8		
General Foam of Minnesota – St. Paul	33	31		1	0.5		
General Foam, W. Hazelton PA	322	317	2	2	0.0		1.98
Hickory Springs Manufacturing Company – Americus GA	169	169		1	0.0		
Hickory Springs Manufacturing Company – Conover NC	391	385		6	0.1	0.00	
Hickory Springs Manufacturing Company – Ft. Smith AR	6		6		0.0		
Hickory Springs Manufacturing Company, Verona, MS	503	495		8	0.0	0.00	0.01
Hickory Springs of California – Commerce CA	209	116	92	1	0.2	0.00	
Hickory Springs of California – Portland, OR	72	70		1	0.0		
Hickory Springs\Eastern Foam Products, Inc.	21	20		0	0.0		
MPI, Inc.	81	78		3	0.3	0.00	
North Carolina Foam Industries	273	268		5	0.1		0.07
No–Sag Foam Products	116	112		4	0.1	0.02	
Nu–Foam Products, Inc.– Chattanooga	406	405			0.3		0.36
Olympic Products Company – Greensboro NC	223	222		1	0.1		
Olympic Products Company – Tupelo MS	230	228		2	0.1		
Omnifoam, Incorporated	53	53			0.0		
Plastomer Corporation	0		0		0.3		
Prestige Fabricators Incorporated	143	143					
Scottdell, Inc.	0				0.0		
Superior Product Sales Inc.	205	197		8	0.1		
Texas Fibers Branch 1708	306	129	176	1	0.2		
Trinity American Corporation	285	285			0.0		
Universal Urethanes, Incorporated	73		73		0.1		
Vitafoam, Incorporated – High Point NC	195	188		7	0.1		
Vitafoam, Incorporated – Tupelo MS	335	335			0.3		
William T. Burnett and Company	0				0.1		0.00
Woodbridge Foam Fabricating, Inc.	39	39			0.0		0.13
Slabstock Total HAP Emissions	16748	14,514	2,112	100	18.1	0.59	2.66

Attachment 2

REPORTED HAP EMISSIONS BY FACILITY – MOLDED FOAM
1992 ICR Responses (tons/yr)

COMPANY	Plant Total	MeCl2	MDI	TDI	DEOA	TCA	Methanol	Toluene	MEK	MISC
Aero Specialties Corporation	0	0.3	0.01			0.00				
American Poly–Therm Company, Inc.	0	0.0								
American Seating Company	1		0.00					0.87		
Automotive Industries, Inc., Plants 2,3 & Visor Foam	9	6.0	0.01	0.23			2.60			
Cartex/Woodbridge Group	3		0.09	1.30		1.70				
Conover Molding	11	9.5		0.00	0.01	1.69				0.03
Conway Industries, Incorporated	2	2.0	0.21							
Douglas & Lomason Company	0		0.01	0.00						
Douglas & Lomason Company	0		0.00							
Dyneflex Division of Cartex Corporation	0		0.01	0.04						
E–A–R Specialty Composites/Indianapolis	2	1.1				0.12				0.30
Farwell Plant, Renosol Corporation	41	40.4	0.04	0.11						
Foam Molders and Specialties	7	3.8				3.45				0.03
FOAMEX L.P. Morristown Molded Plant #3	3	0.5	0.11	0.64	0.02	1.35				
Foamtec	8	7.8				0.20				
Ford Motor Company – Utica Plant	12	10.8		1.41						
Furon Company	1	1.1	0.00			0.01	0.01	0.08	0.07	0.03
Goodyear Tire & Rubber Company – Logan Plant	0		0.01							
Herman Miller – Holland Operations	1		0.01	0.75						
H.L. Blachford – Troy Plant	4		4.40							
H.L. Blachford – West Chicago	2		2.10							
Integram – St. Louis Seating, Foam	0		0.09			0.21				
Johnson Controls – Greenfield Plant	5		0.01	0.24	0.11	4.64				
Johnson Controls – Jefferson City Plant	5		0.02	0.13	0.30	4.19			0.28	
Johnson Controls – Livermore Plant	0			0.08	0.13					
Johnson Controls – Protype Laboratory	0		0.03	0.08	0.06	0.03				
Johnson Controls – Pulaski Plant	3		0.01	0.16	0.06	3.12				
Johnson Controls Inc. – Ossian Plant	1			0.09	0.07	1.30				
Johnson Controls, Inc. – Belcamp Plant	5			0.13	0.08	4.36				
Kalamazoo Plastic Company	0									
Kern Foam Products Corporation	0	0.1								
Kustom Foam Manufacturing	6	6.1	0.00			0.23				0.00
Perry Chemical & Manufacturing Company, Inc.	28	23.8			0.21		1.13	0.25	2.51	0.01
Pureforms, Inc.	59	59.0								
Scott–Port–A–Fold	18	12.6	0.01				1.40	2.12	2.41	
Stephenson & Lawyer Incorporated	5	5.1	0.00							
Swenson Company	18	16.7	0.01			0.12	1.42			
Tempress Inc.	0		0.00							
Universal Urethane, Inc.	0									
Woodbridge – Kansas City	0			0.15	0.04					
Woodbridge Corporation	0			0.11	0.25					
Woodbridge Corporation – St. Peters Facility	3			0.16	0.23	2.95				
Woodbridge Foam – Whitmore Lake Facility	2		0.29	0.28	0.56	0.54				
Woodbridge Inoac Inc.	1		0.92							
Woodbridge Romulus Corporation	0			0.24						
Foam Design, Incorported	0		0.23							
TOTAL	269	206.6	8.62	6.33	2.13	30.20	6.56	3.31	5.27	0.40

MEMORANDUM

Date: June 17, 1996

Subject: MACT Floors for Flexible Polyurethane Foam Production

From: Amanda Williams, EC/R Incorporated
Phil Norwood, EC/R Incorporated

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

This memorandum presents the Maximum Available Control Technology (MACT) floors for the flexible polyurethane foam production source category. The first section of this memorandum discusses the Clean Air Act (CAA) requirements for MACT floors, followed by a discussion of necessary considerations in MACT floor determinations. The final section presents the conclusions of the MACT floor analyses.

CLEAN AIR ACT (CAA) REQUIREMENTS FOR MACT FLOORS

Section 112(d) of the 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," or "the average emission limitation achieved by the best performing 5 sources" for categories or subcategories with less than 30 sources.

CONSIDERATIONS IN DETERMINING MACT FLOORS

There are several fundamental decisions that must be made before the MACT floor can be determined. These decisions are discussed below.

Subcategorization

Since a separate MACT floor must be developed for each subcategory, the first thing that must be determined is if subcategorization of the industry is warranted. As discussed in

a separate memorandum,[1] the flexible polyurethane foam production source category was divide into three subcategories: slabstock foam production, molded foam production, and rebond foam production.

Major Source Determination

The EPA determined that for this source category, only major sources would be used to develop MACT floors. Therefore, the next step was to identify the major sources in each subcategory. The facility-wide hazardous air pollutant (HAP) emission totals reported in the Information Collection Request (ICR) responses[2,3] were used to identify the major sources within each subcategory, along with a facility's "potential to emit" (PTE).

A facility's PTE is calculated by considering all the emission source types at a facility, using assumptions that would constitute maximum HAP emission potential such as maximum operational hours, highest HAP content, etc. Inherent limitations based on a facility's operations can be considered, such as the production rate being limited by storage space. However, operational practices that reduce emissions are not considered unless they are due to an enforceable requirement. For example, assume some facilities used a non-HAP solvent for cleaning, and other similar facilities used a HAP solvent for the same purpose. In the determination of PTE, it must be assumed that all facilities use a HAP solvent, unless a facility is prohibited from using the HAP solvent by an enforceable requirement.

Within the molded foam segment, all facilities wigh high-pressure (HP) mixheads reported HAP emissions below the major source thresholds. It is not believed that any HP facilities could be considered major sources based on their PTE. Only a conversion from HP to low-pressure (LP) mixheads would increase these facility's PTE above the major source threshold. This

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[1] Memorandum. Williams, A. and Norwood, P. EC/R Incorporated to Svendsgaard, D., Environmental Protection Agency. Subcategorization of the Flexible Polyurethane Foam Production Source Category. June 17, 1996.

[2] Memorandum from Norwood, P., Williams, A., and Battye, B. EC/R Incorporated, to Svendsgaard, D. U.S. Environmental Protection Agency. Summary of Flexible Polyurethane Foam Information Collection Requests. January 24, 1994.

[3] Memorandum from Williams, A., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Baseline Emissions for the Flexible Polyurethane Foam Production Industry. March 8, 1996.

conversion would be expensive, as well as impractical, requiring significant operational and equipment changes.

Five LP facilities reported emissions greater than the major source thresholds.[2,3] The remaining facilities are also major sources due to their PTE. While the reported HAP emissions were below the major source thresholds for these facilities, no enforceable requirements were reported that would prohibit any facility from switching to a HAP solvent to flush their mixhead. Based on the available information, it would be expected that the combination of the use of a HAP mixhead flush and maximum potential operation would cause HAP emissions at all LP molded facilities to be above the major source level.

Seven slabstock facilities reported actual emissions below the major source thresholds.[2,3] However, it is possible for these facilities to change their product mix, or types of foam produced, in a manner that would make their HAP emissions greater than the major source cutoffs. There were no enforceable limits identified restricting their HAP emissions below major source levels. Therefore, all slabstock production facilities were considered to be major sources in this analysis.

It was assumed that no rebond foam production process emitted HAP above the major source levels. However, the 21 rebond processes co-located with slabstock production operations are considered major sources, since the plant-wide emissions are above the major source thresholds. It was assumed that the remaining 31 rebond facilities were area sources.

Grouping of Emission Sources

After the subcategories and major sources within them were identified, the groups for which separate MACT floors were to be determined were established. Under each subcategory, individual emission points were separated into several general emission source types. Additional grouping decisions were then made in the determination of MACT floors within each emission source type. Consideration was given to the following: equipment type, equipment size, equipment contents, stream characteristics, and other elements that can affect the emission potential or the ability to reduce emissions from that point.

The following are the emission source groupings chosen for molded facilities:

- storage (including unloading emissions)
- in-process vessels (includes day and mix tanks)
- components in HAP service (e.g. pumps and valves)
- in-mold coatings
- foam reactant dispensing
- mixhead cleaning

- mold release agent application
- demolding
- foam repair

For slabstock facilities the following emission source groupings were chosen:

- storage (including unloading emissions)
- in-process vessels (includes day tanks)
- components in HAP service
- ABA related emission sources (i.e. foam tunnel, curing, foam storage)
- equipment cleaning

In addition, MACT floors were determined for three emission sources at rebond operations.

- diisocyanate emissions from rebond production
- equipment cleaning
- mold-release agent application

Approach to Determining the MACT Floor

MACT floors were identified for each emission source grouping within each subcategory. For existing sources, the MACT floor levels were established by determining some measure of central tendency of the emission control for the top 12 percent, or top 5, facilities in each emission source type in each subcategory. This "average" emission limitation is expressed in several different manners for different emission source types.

When possible, each MACT floor for existing sources was expressed as emission limits that represent the average emission limitation achieved by the top 12 percent. Where the MACT floor was determined to be a technology or work practice, engineering judgement was used to select the performance criteria that best characterized the "average" means of HAP reduction at the top 12 percent.

For new sources, the MACT floor levels were established by determining the emission control for the best controlled facility in the subcategory for each emission source type. The format of the MACT floors for new sources varies in the manner they are expressed, but are consistent with those of existing sources for each emission source type (e.g. work practice standards, equipment specifications, etc.).

MACT FLOOR CONCLUSIONS

Following are the MACT floor conclusions for all emission source types identified in each subcategory. All emissions

reported and used in calculating the MACT floors were taken from the ICRs, and are generally based on 1992 information.[2]

Molded Foam

As mentioned previously, all HP molded facilities were identified as area sources, and all LP facilities were identified as major sources. Therefore, the MACT floors for molded foam are based only on LP facilities. Since there are less than 30 LP facilities, the MACT floor for each emission source type was based on the top 5 performing facilities. The top five facilities were determined on a case by case basis for each emission source type; therefore, the same 5 facilities were not always used in the floor determinations. In the LP molded foam subcategory, information is available for 19 facilities.

Storage/unloading

HAP emissions from storage and unloading at LP molded foam facilities were reported to be less than 1 ton per year. Only 11 facilities provided information on their storage emissions, and they all reported no control for these storage and/or unloading emissions. Since all facilities reported no control, the MACT floor for storage/unloading for both new and existing LP molded foam facilities was concluded to be no control.

Mixhead flush

HAP emissions from mixhead cleaning occur when HAP solvents are used to "flush" the mixhead between foam shots to remove residual foam material. Total HAP flush emissions from this source were reported at 205 tons/year, approximately 76 percent of the total reported HAP emissions for the molded subcategory.

Unlike the other emission source types for the LP molded subcategory, the identification of the five "best performing" facilities for the mixhead flush emission source type was not straightforward. The reported HAP emissions varied among facilities from less than 1 ton per year to almost 60 tons per year. In order to assist in the comparison of facilities, several approaches were considered. The first was an emission factor approach based on the reported HAP emissions per weight of product. However, this approach did not provide a legitimate means of comparison, because the number of flushes (and consequently, the resulting HAP emissions) is dependent on the number of "pieces" produced and not the weight of foam produced. Thus, producers of small foam parts would have artificially high HAP emission factors. Another approach was to simply consider the annual reported HAP emissions. While this is more reflective of a facility's HAP reducing activities, it does not take into account substantial differences in the operating schedules reported, or the size of a facility. Therefore, the annual flush

emissions were divided by the annual hours of operation. This HAP emissions per hour of operation factor was used to identify the 5 "best performing" facilities.

None of the 5 facilities identified as the best performing reported any control techniques in the ICR responses. In each case, process-specific factors were responsible for the low emissions. For example, one facility designed its molds to be closer together than normal, reducing the frequency of flushing needed. Another facility had such small pieces that the volume of flush needed per shot was very small, resulting in lowered total emissions. Therefore, the MACT floor for this emission source type was determined to be the average emission limitation of the best performing 5 facilities, or "no control." These facilities are the best performing because of unique process considerations that are not applicable at all LP molded foam facilities.

Mold release agents

Approximately 3 percent (7.8 tons/yr) of the reported HAP emissions from molded foam facilities was from the evaporation of the HAP carrier solvent from mold release agents. When the mold release agents are sprayed on the mold, the carrier is designed to evaporate, leaving a waxy material on the mold to prevent the foam from sticking.

Of the 18 facilities reporting the use of mold release agents, 10 reported using a non-HAP based agent, resulting in zero HAP emissions. The remaining eight facilities reported HAP emissions, and no controls. Since the top 5 facilities all used non-HAP based mold release agents, the floor for mold release emissions for both new and existing sources is judged to be the total elimination of the use of HAP-based mold release agents.

Foam repair

The main use of adhesives in molded foam facilities is for the repair of voids and tears in the molded pieces. The adhesives used are approximately 20 to 40 percent solids, while the remainder consists of a solvent carrier, such as methyl chloroform or $MeCl_2$. The HAP emissions occur as this solvent carrier evaporates after the adhesive is applied. There were 26.1 tons of HAP emissions reported from this source at molded facilities.

Eight LP facilities did not report having any repair operations. Four of the remaining facilities reported HAP emissions from this activity, with no control identified. The remaining seven facilities reported repair operations, but zero HAP emissions. Since the top 5 facilities were repairing foam without any HAP emissions, the MACT floor for foam repair for

both new and existing sources was concluded to be the elimination of HAP-based adhesives in repair operations.

In-process vessels, components in HAP service, in-mold coatings, foam reactant dispensing, and demolding

In the ICRs, HAP emissions were reported for each of these emission source types. The total reported emissions for all of these combined was 25 tons/yr, which is approximately 9 percent of the total reported molded foam HAP emissions. No control was reported for any of these emission source types in the ICR responses. Therefore, the floor for both new and existing sources for these emission source types is concluded to be no control.

Slabstock Foam

There are 78 slabstock foam facilities in this subcategory. The MACT floor for each emission source type were based on the top 12 percent of the subcategory (top 10 facilities). Total reported HAP emissions for this subcategory were approximately 16,750 tons per year. The top performing facilities were determined on a case by case basis for each emission source type, therefore, the same facilities were not always used in the floor determinations.

Storage/unloading

HAP emissions from storage/unloading accounted for less than 1 percent of the total reported slabstock HAP emissions (39 tons/yr). Of the facilities reporting HAP ABA and/or TDI storage breathing loss emissions, no control was reported for either HAP. For HAP ABA unloading, 17 facilities reported using vapor balancing for emission control. The remaining facilities reported no control. For TDI unloading, 29 facilities reported using vapor balancing. The remaining facilities reported using no control. It was concluded that the floor for TDI and HAP ABA storage/unloading at new and existing sources is vapor balance.

Components in HAP service

HAP emissions from pumps and valves accounted for 16 tons of the reported emissions per year. Thirty-three of the 77 facilities reporting TDI emissions from pumps and valves reported using "canned pumps," a type of sealess pump. Since more than 10 plants reported canned pumps for TDI, the new and existing source MACT floors for TDI pumps were concluded to be canned, or "sealless" pumps. Four facilities reported using canned pumps for $MeCl_2$, and no other facilities reported any type of control. A median-based approach was used to determine the existing source floor for $MeCl_2$ pumps. Since "no control" was most frequent in

the top 10 list, the floor was determined to be no control for existing sources, and sealless $MeCl_2$ pumps for new sources.

In addition, no facility reported the control of HAP emissions from any other components in HAP service (valves, connectors, etc.). Therefore, the new and existing source floors for all components except pumps was concluded to be no control.

Equipment cleaning

Methylene chloride is used as a cleaner to rinse and/or soak foam machine parts such as mixheads and foam troughs. This use resulted in 135 tons/yr of reported emissions.

Eight of the 73 slabstock facilities reporting equipment cleaning operations use non-HAP products or other non-HAP cleaning methods for cleaning of foam equipment. The remainder used no control. A median-based approach was used to determine the existing source floor for equipment cleaning. Since 8 out of the top 10 facilities reported using a non-HAP cleaning method, the floor for both new and existing sources was determined to be the use of non-HAP cleaning solvents.

ABA emission sources

Methylene chloride ($MeCl_2$) is the principal auxiliary blowing agent (ABA) used. The role of the methylene chloride is simply to volatilize and expand the foam, it does not directly participate in the polyurethane reaction. Therefore, all of the methylene chloride that is added to the process eventually is emitted. The use of $MeCl_2$ as an ABA was the largest emission source of HAP's for slabstock facilities reported in the ICRs, at over 14,372 tons (80 percent of the total HAP emissions from slabstock facilities). In addition, methyl chloroform (another HAP) was used by some facilities, resulting in over 2,078 tons of estimated HAP emissions. There were several alternatives identified in the ICRs that facilities are using to either reduce or eliminate the use of $MeCl_2$ as an ABA in the manufacture of flexible slabstock polyurethane foam.

The mix of foam grades produced at a plant has a strong influence on the amount of ABA that is used and emitted. There are many grades of foam that can be produced without any ABA, while for some soft and light foams, ABA usage can be as high as 24 parts per hundred parts polyol (pph), or almost 300 pounds per ton of foam produced . Industry representatives have stressed the need to take this difference into account in determining the floor, emphasizing that low-ABA and high-ABA grades of foam are not interchangeable, either from a production cost standpoint, from an emission standpoint, or from an end-use standpoint.

Existing sources. The EPA has agreed that differentiation between foam grades is appropriate, and concluded that any ABA emissions limitation should be a function of the grades produced. Therefore, the following equation was developed to calculate the allowable HAP ABA emissions from foam production:

$$emiss_{allow} = \sum_{i=1}^{n} \frac{(limit_i)(polyol_i)}{100}$$

where,

$emiss_{allow}$ = Allowable emissions due to use of a HAP ABA for a specified time period, Megagrams

$limit_i$ = HAP ABA formulation limit for foam grade i, parts ABA per 100 parts polyol

$polyol_i$ = Amount of polyol used in the time period in the production of foam grade i, pounds

n = Number of foam grades produced in the time period

Using this equation, the MACT floor HAP ABA emissions level is defined by determining a MACT floor set of HAP ABA formulation limits.

In the ICR, foam producers were asked to provide formulation information (i.e., parts HAP ABA per 100 parts polyol, or pph) for all foam grades produced at the facility. Therefore, the EPA was able to separate the formulation information by grade (where a grade is represented by its density and indentation force deflection, or IFD).[2] Foamers claimed all formulation information confidential; therefore, the actual formulation database and summary is not publicly available.

The foam grades were combined into density/IFD "groups." The Polyurethane Foam Association (PFA) suggested the following eight-group classification system:[4]

- IFD greater than 20 pounds, density greater than 1.4 pounds per cubic foot (pcf)
- IFD greater than 20, density from 1.15 to 1.4 pcf
- IFD greater than 20, density from 1.05 to 1.15 pcf
- IFD greater than 20, density from 0.95 to 1.05 pcf
- IFD greater than 20, density less than 0.95 pcf
- IFD from 15 to 20, at any density

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[4] Letter from Sullivan, D., Hickory Springs Manufacturing Company, to Svendsgaard, D., U.S. Environmental Protection Agency. February 24, 1994. PFA-recommended subcategorization strategy.

- IFD from 10 to 15, at any density
- IFD less than 10, at any density

The EPA's initial attempt at determining the MACT floor HAP ABA formulation limits was to simply calculate the average of the lowest 12 percent of the formulations reported for each of the grade ranges suggested by the PFA. However, this approach led to inconsistent results (see summary of initial presumptive MACT roundtable meeting[5]). Therefore, the approach described below was developed and used to determine the MACT floor HAP ABA formulation limitations.

This approach could simply be described as the determination of a baseline, and the application of MACT floor reductions to this baseline. The initial step in this approach was to determine baseline formulations. As part of this analysis, PFA-recommended foam grade groupings were re-examined.[6] This analysis, which used the formulation database to examine ABA usage/emission trends by IFD and density, concluded that the PFA-recommended needed revisions in two areas. The PFA-recommended groupings assumed that (1) ABA usage was not dependent on density for foam grades with IFDs less than 20 pounds, and (2) ABA usage was not dependent on IFD for IFDs greater than 30 pounds. The analysis found both of these assumptions to be inaccurate. Therefore, all subsequent analysis was conducted on a 30-group grid, using the five PFA-recommended density ranges, and six IFD ranges (0-10, 11-15, 15-20, 21-25, 26-30, and 31+ pounds).

Again, an attempt was made to use the overall average of formulation information submitted for each grade group. As discussed above for the average of the top 12 percent, the overall average formulations often did not follow a reasonable pattern. For instance, the average ABA level would increase with increasing IFD, and with increasing density. This problem was primarily attributed to the low number of data points for several density/IFD groups. Table 1 shows the number of plants represented in the database for the 30 density/IFD groups.

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[5] Memorandum. Norwood, P. EC/R Incorporated to Svendsgaard, D. U.S. Environmental Protection Agency. Summary of May 23, 1995, Flexible Polyurethane Foam Presumptive MACT Roundtable Meeting. June 14, 1995.

[6] Memorandum from Norwood, P. EC/R Incorporated, to Svendsgaard, D. U.S. Environmental Protection Agency. Status of Flexible Polyurethane Foam Auxiliary Blowing Agent MACT Floor Determinations. June 22, 1995.

TABLE 1. NUMBERS OF PLANTS REPRESENTED IN FORMULATION DATABASE

Table values are numbers of plants reporting formulation information in each group		Density ranges (pounds per cubic foot)				
		0-0.95	0.96-1.05	1.06-1.15	1.16-1.40	1.41+
IFD	0-10		7	4		<9
	11-15	4	17	9		12
	16-20	5	14	15	7	19
	21-25		17	15	12	23
	26-30	24	22	7	20	31
	31+	15	26	21	36	36

In the development of EPA's Flexible Polyurethane Foam Emission Reduction Technologies Cost Document,[7] a representative facility was created. The foam formulations used for this representative facility were generated in a cooperative effort between the EPA and the PFA, and the EPA believes they represent typical formulations for the industry. Table 2 shows both the average (or range) formulation information from the ICR responses, and the representative facility formulation. From this information, baseline formulation levels were selected for each foam grade grouping, which are shown in Table 3.

The next step was to apply reductions, that represent MACT floor reductions, to these baseline formulation values. The amount of reduction achievable also varies by foam grade. Numerous technologies exist that allow the production of higher-density, higher-IFD foams with significantly less, or even no, HAP ABA. However, the amount of HAP ABA reduction that can be achieved for low-density, low-IFD, foam grades of acceptable quality is much less. Therefore, the reductions had to be determined on a grade-specific basis.

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[7] Flexible Polyurethane Foam Emission Reduction Technologies Cost Analysis. EPA-453/R-95-011. U.S. Environmental Protection Agency. September 1996.

TABLE 2. BASELINE HAP ABA FORMULATIONS

Table values in parts ABA per hundred parts polyol		Density ranges (pounds per cubic foot)				
		0-0.95	0.96-1.05	1.06-1.15	1.16-1.40	1.41+
IFD	0-10		22 *(18)*	*(20)*		*(2)*
	11-15	*(21)*	19 *(15)*	*(13-18)*	*(10)*	*(2-6)*
	16-20	*(16-18)*	14 *(11-13)*	14 *(12-14)*	*(10)*	10-13 *(6-8)*
	21-25	*(16-18)*	*(12-15)*	*(12)*	*(7-8)*	*(4-5)*
	26-30	10 *(10)*	8 *(7)*	7 *(6-8)*	5-6 *(5-6)*	6-7 *(5)*
	31+	*(9-10)*	*(7-8)*	*(4-5)*	2 *(3)*	1-2 *(2)*

NOTES: Top numbers are the estimates provided by the PFA and chemical suppliers in comments on the cost report. Numbers in parentheses and italics are from the ICR data.

The problems discussed above, associated with insufficient numbers of data points in certain density/IFD groups, would have caused similar problems if reductions were determined for individual groups. Therefore, groups were combined until at least 30 data points were available. For instance, the six groups with IFDs of 20 pounds or less and densities of 1.16 pcf or less were combined. This resulted in 41 data points in this combined group.

TABLE 3. BASELINE HAP ABA FORMULATIONS

Table values in parts ABA per hundred parts polyol		Density ranges (pounds per cubic foot)				
		0-0.95	0.96-1.05	1.06-1.15	1.16-1.40	1.41+
IFD	0-10		20	20		6
	11-15	21	19	18	10	6
	16-20	18	14	14	10	6
	21-25	16	13	12	8	5
	26-30	10	8	7	6	5
	31+	9	7	5	2	2

For each combined group, the overall average formulation was calculated, as well as the average formulation for the 12 percent of the data points with the lowest HAP ABA formulations. Then the reduction from the overall average to the top 12 percent average was calculated. For example, if the overall average formulation was 9 pph and the top 12 percent average was 5 pph, the percentage reduction was calculated as follows:

$$PercentReduction = \frac{(9pph - 5pph)}{(9pph)} (100) = 44\ percent$$

The results of the percentage reduction determination are shown in Table 4. These percentage reductions were then applied to the individual density/IFD group baseline formulation levels in Table 2 to obtain the existing source MACT floor HAP ABA formulation limitations, which are shown in Table 5. It should be noted that this analysis resulted in equivalent HAP ABA formulation limits for more than one density/IFD group. Therefore, the result was actually 18 density/IFD groups in the MACT floor HAP ABA formulation limits table.

TABLE 4. MACT FLOOR PERCENTAGE REDUCTIONS

<table>
<tr><th rowspan="2">Table values are percentage reduction from baseline</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-0.95</th><th>0.96-1.05</th><th>1.06-1.15</th><th>1.16-1.40</th><th>1.41+</th></tr>
<tr><td rowspan="6">IFD</td><td>0-10</td><td colspan="4" rowspan="5">45</td><td rowspan="5">75</td></tr>
<tr><td>11-15</td></tr>
<tr><td>16-20</td></tr>
<tr><td>21-25</td></tr>
<tr><td>26-30</td></tr>
<tr><td>31+</td><td colspan="3">68</td><td>100</td></tr>
</table>

New sources. In the ICR responses, several facilities did not report any HAP ABA emissions. It could be concluded that the new source HAP ABA MACT floor was the total elimination of HAP ABA emissions. However, this approach would not consider the differences in the amount of HAP ABA used for different grades, since these plants did not produce a complete range of foam grades. Therefore, the new source HAP ABA MACT floor formulation limitations were determined by examining the lowest reported HAP ABA formulation for each of the 30 density/IFD blocks.

Formulations for foam grades only produced in small amounts were not considered. This analysis found that the production of many foam grades were reported with no HAP ABA. However, the results were not always logical. For instance, all foam grades with densities between 0.96 and 1.05 pcf were reported to be produced with no HAP ABA (with the exception of IFDs less than 15 pounds), but there were no foam grades with densities between 1.06 and 1.15 pcf that were reported to be produced with no HAP ABA. The EPA concluded that this was more a function of the randomness of the foam grades reported, rather than the inability to produce foams of densities between 1.06 and 1.15 pcf with no HAP ABA. In fact, the Agency believes that if foam grades with densities between 0.96 and 1.05 pcf can be produced with no HAP ABA, then foam grades of corresponding IFDs with densities greater than 1.05 pcf can also be produced with no HAP ABA. The lack of sufficient data for the foam grades where the new source MACT floor was not determined to be zero led the Agency to

TABLE 5. MACT FLOOR HAP ABA FORMULATION LIMITATIONS FOR EXISTING SOURCES

<table>
<tr><th colspan="2" rowspan="2">Table values in parts ABA per hundred parts polyol</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-0.95</th><th>0.96-1.05</th><th>1.06-1.15</th><th>1.16-1.40</th><th>1.41+</th></tr>
<tr><td rowspan="6">IFD</td><td>0-10</td><td rowspan="2">12</td><td colspan="2" rowspan="2">11</td><td rowspan="3">6</td><td rowspan="3">2</td></tr>
<tr><td>11-15</td></tr>
<tr><td>16-20</td><td>10</td><td colspan="2">8</td></tr>
<tr><td>21-25</td><td>9</td><td colspan="2">7</td><td>4</td><td rowspan="2">2</td></tr>
<tr><td>26-30</td><td>6</td><td>4</td><td colspan="2">3</td></tr>
<tr><td>31+</td><td>5</td><td>4</td><td>2</td><td>1</td><td>0</td></tr>
</table>

conclude that the new source MACT floor for these grades was equal to the existing source MACT floor, as shown in Table 5. Therefore, the EPA concluded that the MACT floor HAP ABA formulation limitations for new sources are as shown in Table 6.

Rebond

Some slabstock facilities have rebond operations. Rebond is the process where scrap foam is cut up and placed in a mold with a small amount of TDI and treated with steam. This causes the small pieces to adhere and form a solid cylinder of foam. This cylinder is then peeled into sheets, which is mainly used as carpet padding. A small amount of TDI is emitted during this process. The HAP emissions from rebond operations accounted for 11 tons, or less than 1 percent of the total slabstock HAP emissions. However, only 1 ton of these emissions was TDI, with the remainder being $MeCl_2$. These $MeCl_2$ emissions were reported by only one facility. They came from a mold release agent in the rebond operation, and from cleaning of the rebond equipment.

No control for the TDI emissions was reported, and all TDI emissions were calculated using standard industry emission factors. Since all facilities reported no control for TDI, and only one of the 22 rebond operations reported other HAP

TABLE 6. MACT FLOOR HAP ABA FORMULATION LIMITATIONS FOR NEW SOURCES

Emissions - parts ABA per hundred parts polyol		Density ranges (pounds per cubic foot)				
		0-0.95	0.96-1.05	1.06-1.15	1.16-1.40	1.41+
IFD	0-10	12	11		6	
	11-15					
	16-20	10	0			
	21-25	9				
	26-30	6				
	31+	5				

emissions, it was concluded the floor for rebond at both new and existing sources is "no control" for TDI emissions, and the elimination of any HAP cleaners or mold release agents.

Summary

Table 7 summarizes the MACT floor conclusions for both new and existing source for each emission source type.

TABLE 7. FLEXIBLE FOAM MACT FLOOR CONCLUSIONS

EMISSION SOURCE	MACT FLOOR - Existing Sources	MACT FLOOR - New Sources
LP Molded Foam		
Storage/unloading	No control	No control
Mixhead flush	No control	No control
Mold release agents	Elimination of HAP-based products	Non-HAP based products
Foam repair	Elimination of HAP-based products	Non-HAP based products
In-process vessels, components in HAP service, in-mold coatings, foam dispensing, demolding	No control	No control
Slabstock Foam		
Storage/unloading	Vapor balance	Vapor balance
Components in HAP service	TDI - sealess pumps other HAPs - no control	TDI and $MeCl_2$ - sealess pumps other HAP - no control
Equipment cleaning	Elimination of HAP-based product	Non-HAP based product
HAP ABA emissions	Emission limitation based on HAP ABA formulation limitations	Formulation limitations
Rebond Foam	TDI - no control Elimination of HAP cleaners and mold release agents	TDI - no control Elimination of HAP cleaners and mold release agents

MEMORANDUM

Date: June 17, 1996

Subject: Regulatory Alternatives for New and Existing Sources in the Flexible Polyurethane Foam Industry

From: Amanda Williams, EC/R Incorporated
Phil Norwood, EC/R Incorporated

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

The purpose of this memorandum is to present regulatory alternatives for Maximum Achievable Control Technology (MACT) standards for new and existing sources in the flexible polyurethane foam industry. This memorandum is separated into two sections. The first section describes the possible levels of control for the individual emission source types at flexible polyurethane foam facilities, along with the control options that are available to meet each level of control. The second section combines these levels of control into regulatory alternatives.

The flexible polyurethane foam source category has been divided into two subcategories: slabstock and molded foam production. A separate set of regulatory alternatives was developed for each subcategory.

POTENTIAL LEVELS OF CONTROL

This section discusses levels of control that could be used as the basis for developing regulatory alternatives for the flexible polyurethane foam industry. For each emission source type, the potential levels of control are identified. For both new and existing sources, the first level of control is the MACT "floor" level. The determination of MACT floors is discussed in a separate memorandum.[1] Levels of control more stringent than the MACT floor level are also presented.

For each level of control more stringent than the MACT floor level, the control options available to meet the level are presented. The control options discussed in this memorandum were

[1] Memorandum. Norwood, P. and Williams, A. EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. MACT floor determination for Flexible Polyurethane Foam Production. June 17, 1996.

identified during one of two previous efforts: (1) information obtained from industry in response to the Environmental Protection Agency's (EPA's) information collection request (ICR), and (2) information gathered in connection with EPA's document entitled "Flexible Polyurethane Foam Emission Reduction Technologies Cost Analysis."[2]

Molded Foam Facilities

Hazardous air pollutant (HAP) emissions are attributable to three predominant emission source types at molded foam facilities: (1) HAP mixhead flushes, (2) HAP-based mold release agents, and (3) HAP-based adhesives for foam repair. The control options for each of these emission source types are discussed in the following sections. Additional emission source types were identified at molded facilities. However, emissions from each of the additional sources were only reported by a few facilities. In addition, emissions were very low and no control was reported. Therefore, control options for these emission source types were not included in any regulatory alternative.

Mixhead Flush

The MACT floor for this emission source type was identified as no control for existing sources. For new sources, the MACT floor was identified as the prohibition of the use of HAP flush agents. There were two levels of control above the existing source MACT floor identified: work practices that reduce HAP emissions, and the prohibition of the use of HAP flush agents.

Work practices. Many foam facilities do not make any attempt to capture or contain the emissions that occur when the methylene chloride ($MeCl_2$) used to flush the mixhead evaporates. Placing a lid over open containers (typically 55-gallon drums), and other work practices would reduce $MeCl_2$ emissions from this source. One facility reported in the ICR responses that they cover the $MeCl_2$ container, and use a solvent recovery system to allow the re-use of the $MeCl_2$ solvent. They also have a "closed-loop system" for capturing the $MeCl_2$ vapors from the area around the 55-gallon drum used to capture the flush. This system consists of a fan that draws the vapors generated in the flush area through a carbon canister, which captures the solvent vapors

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[2] Flexible Polyurethane Foam Emission Reduction Technologies Cost Analysis. EPA-453/R-95-011. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. September 1996.

before the air is released to the atmosphere.[3] This facility estimates that this system reduces its $MeCl_2$ emissions by 80 percent.[4]

Prohibition of HAP flush agents. Several methods were identified that would eliminate the need to use a HAP-based mixhead flush. One method is to change the type of mixhead used to a high-pressure (HP) mixhead or a self-cleaning mixhead. Either of these mixheads would eliminate the need for a HAP flush, but they may not be feasible for smaller molded foam manufacturers. The HP mixheads have two main disadvantages for the smaller molders. First, the initial capital cost may be prohibitive for small molders. Also, the low throughput range required for smaller parts may be too low for the HP system to achieve the necessary mixing of the foam ingredients. The self-cleaning mixheads were not reported to be in use by any flexible polyurethane foam facilities in the United States. They also have a small throughput range and could not be used to manufacture larger foam pieces.

While the alternative mixheads mentioned above have limitations for small molders, the third option does not. The third option is to replace the HAP-based flush with a non-HAP based product. Several of these products were identified and reported to be in use in the industry.

Mold Release Agents and Foam Repair

The MACT floor for both new and existing sources for these two emission sources was identified as the total elimination of HAP-based products. Therefore, no level of control above the MACT floor is possible.

Other Molded Emission Sources

The MACT floors for new and existing sources were identified as no control for the following emission source types: in-mold coatings, storage/unloading, in-process vessels, components in HAP service, foam froth dispensing, and demolding. No levels of control above the MACT floor were identified for these emission points at molded polyurethane foam facilities, with the exception of in-mold coatings. The total amount of HAP emissions reported from these sources is also relatively low, comprising only

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[3] Telecon. Williams, A., EC/R Incorporated to Majeski, D., Renosol Corporation. June 10, 1994. Methylene chloride capture and recovery system.

[4] Telecon. Williams, A., EC/R Incorporated, to Peck, D., Renosol Corporation. June 7, 1994. Methylene chloride capture and recovery system.

7 percent of the reported HAP emissions for molded foam manufacturers.[5]

Slabstock Foam Facilities

At slabstock foam facilities, there are four primary HAP emission source types: (1) the storage/unloading of HAP compounds, (2) leaking components in HAP service, (3) the use of a HAP as an equipment cleaner, and (4) the use of HAP auxiliary blowing agents (ABA's). The levels of control for each of these emission source types are discussed in the following paragraphs.

Storage/Unloading

The MACT floor for tank truck/railcar unloading of both toluene diisocyanate (TDI) and HAP ABA at new and existing sources was identified as either the use of a vapor balance or carbon canister system. No control options that would result in a level of control above the MACT floor were reported to be in use in the industry.

The floor for both new and existing sources for storage was determined to be no control. While floating roofs and other traditional storage tank controls could be considered for this industry, the size of the storage tanks at foam facilities is almost always below the capacity thresholds of other rules like the Hazardous Organic NESHAP (HON). It is therefore anticipated that the costs and other impacts would not be reasonable for such options. Therefore, no levels of control are included in the regulatory alternatives for storage emissions.

Components in HAP Service (Equipment Leaks)

The MACT floor for new and existing sources for this emission source type was determined to be leakless pumps for TDI components (except for high pressure metering pumps), and no control for all other components in HAP service. A level of control identified above the MACT floor for new and existing sources was a leak detection and repair (LDAR) program for all other components in HAP service. The details of this LDAR program would be created based on this industry. A third level of control that was considered was leakless pumps for TDI combined with the Subpart H equipment leak requirements from the Hazardous Organic NESHAP (HON) for other components in HAP service. However, the EPA decided that the complexity of the HON requirements was not appropriate for inclusion in a regulatory

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[5] Memorandum. Williams, A., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Non-confidential summary of Flexible Polyurethane Foam ICR Data. February 10, 1995.

alternative for the foam industry. The primary reason for this decision was the relatively low number of components at foam production facilities when compared to HON affected sources.

Equipment Cleaning

The MACT floor for both new and existing sources for this emission source were identified as the total elimination of HAP-based products. No levels of control above the MACT floor are possible.

Auxiliary Blowing Agent

There are many "grades" of flexible polyurethane slabstock foam produced, each with slightly different end-uses that require slightly different foam properties. Different grades can require varying levels of HAP ABA. The levels of control discussed below account for this variation.

Existing sources. The existing source MACT floor for HAP ABA was determined to be a limit on the amount of HAP ABA emissions. The limit, calculated using Equation 1, is based on the grades of foam and amount of each grade produced at a facility, and is determined using grade-specific HAP ABA formulation limitations.

$$emiss_{allow} = \sum_{i=1}^{n} \frac{(limit_i)(polyol_i)}{100}$$

where,

$emiss_{allow}$=	Allowable emissions due to use of a HAP ABA for a specified time period, Megagrams
$limit_i$ =	HAP ABA formulation limit for foam grade i, parts ABA per 100 parts polyol
$polyol_i$ =	Amount of polyol used in the time period in the production of foam grade i, pounds
n =	Number of foam grades produced in the time period

The MACT floor HAP ABA formulation limitations, which are shown in Table 1, were determined by applying a percentage reduction to the baseline formulation values shown in Table 2. The MACT floor ABA percentage reductions, which are shown in Table 3, represent the reductions from baseline for the 12 percent of the facilities reporting the lowest HAP ABA formulations (i.e., best performing facilities). More detail on the calculation of the MACT floor HAP ABA formulation limitations is provided in the MACT floor memorandum.[6]

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[6] Reference 1.

TABLE 1. EXISTING SOURCE MACT FLOOR HAP ABA FORMULATION LIMITATIONS

<table>
<tr><th colspan="2" rowspan="2">HAP ABA Formulation Limitations - parts ABA per hundred parts polyol</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-
0.95</th><th>0.96-
1.05</th><th>1.06-
1.15</th><th>1.16-
1.40</th><th>1.41+</th></tr>
<tr><td rowspan="5">IFD</td><td>0-15</td><td>12</td><td colspan="2">11</td><td rowspan="2">6</td><td rowspan="2">2</td></tr>
<tr><td>16-20</td><td>10</td><td colspan="2">8</td></tr>
<tr><td>21-25</td><td>9</td><td colspan="2">7</td><td>4</td><td rowspan="2">2</td></tr>
<tr><td>26-30</td><td>6</td><td rowspan="2">4</td><td colspan="2">3</td></tr>
<tr><td>31+</td><td>5</td><td>2</td><td>1</td><td>0</td></tr>
</table>

TABLE 2. BASELINE HAP ABA FORMULATIONS

<table>
<tr><th colspan="2" rowspan="2">Table values in parts ABA per hundred parts polyol</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-
0.95</th><th>0.96-
1.05</th><th>1.06-
1.15</th><th>1.16-
1.40</th><th>1.41+</th></tr>
<tr><td rowspan="6">IFD</td><td>0-10</td><td></td><td>20</td><td>20</td><td></td><td>6</td></tr>
<tr><td>11-15</td><td>21</td><td>19</td><td>18</td><td>10</td><td>6</td></tr>
<tr><td>16-20</td><td>18</td><td>14</td><td>14</td><td>10</td><td>6</td></tr>
<tr><td>21-25</td><td>16</td><td>13</td><td>12</td><td>8</td><td>5</td></tr>
<tr><td>26-30</td><td>10</td><td>8</td><td>7</td><td>6</td><td>5</td></tr>
<tr><td>31+</td><td>9</td><td>7</td><td>5</td><td>2</td><td>2</td></tr>
</table>

TABLE 3. PERCENTAGE REDUCTIONS FROM BASELINE ACHIEVED BY THE BEST PERFORMING 12 PERCENT OF FOAM FACILITIES

Percentage reductions		Density ranges (pounds per cubic foot)				
		0-0.95	0.96-1.05	1.06-1.15	1.16-1.40	1.41+
IFD	0-30	45				75
	31+			68		100

There are a variety of control options available and in use in the industry to meet the MACT floor level of control for HAP ABA emissions. These include chemical alternatives, forced cooling, variable pressure foaming, acetone as an ABA, liquid carbon dioxide as an ABA, and carbon adsorption.

For existing sources, an infinite number of potential levels of control could be developed by varying the formulation limits for foam grades with different densities and indentation deflection force (IFD). However, there are no sound technical grounds for many of these combinations. Three methods were identified to produce levels of control more stringent than the MACT floor, but less stringent than the total elimination of HAP ABA emissions. For each of these methods, the format of the control level would be a HAP ABA emission limit. The increased stringency would be the result of using lower HAP ABA formulation limitations to calculate the emission limit.

The "extended range method" was the straightforward simplification of the MACT floor ABA. This method extended the MACT floor IFD/density "blocks," and took the lowest MACT floor HAP ABA formulation limitation represented in the combined blocks. For example, in Table 1 there are four IFD/density blocks with densities less than 1.15 pounds per cubic foot (pcf) and IFDs less than 20 pounds. The corresponding HAP ABA formulation limitations are 12, 11, 10, and 8 parts HAP ABA per hundred parts polyol (pph). In creating the level of control under the first method, these four blocks were combined and 8 pph assigned as the HAP ABA formulation limitation. The HAP ABA formulation limitations created using this method are provided in Table 4.

TABLE 4. HAP ABA FORMULATION LIMITATIONS BASED ON EXTENDED GRADE GROUPS

<table>
<tr><th colspan="2" rowspan="2">Parts ABA per hundred parts polyol</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-0.95</th><th>0.96-1.05</th><th>1.06-1.15</th><th>1.16-1.40</th><th>1.41+</th></tr>
<tr><td rowspan="3">IFD</td><td>0-20</td><td colspan="3">8</td><td rowspan="2">4</td><td>2</td></tr>
<tr><td>21-25</td><td colspan="3">7</td><td rowspan="2">0</td></tr>
<tr><td>26+</td><td>5</td><td>4</td><td colspan="2">1</td></tr>
</table>

The "top three method" used the same procedure that was used to determine the MACT floor HAP ABA formulation limitations, except that the percentage reductions applied were the reductions achieved by the best performing three facilities, rather than the best performing 12 percent of the facilities. The percentage reductions from baseline for the best performing three facilities are shown in Table 5, and the resulting HAP ABA formulation limitations are shown in Table 6.

TABLE 5. PERCENTAGE REDUCTIONS FROM BASELINE ACHIEVED BY THE THREE BEST PERFORMING FOAM FACILITIES

<table>
<tr><th colspan="2" rowspan="2">Percentage reductions</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-0.95</th><th>0.96-1.05</th><th>1.06-1.15</th><th>1.16-1.40</th><th>1.41+</th></tr>
<tr><td rowspan="2">IFD</td><td>0-30</td><td colspan="4">60</td><td>85</td></tr>
<tr><td>31+</td><td colspan="2">55</td><td colspan="2">76</td><td>100</td></tr>
</table>

The "carbon adsorption method" also used the same procedure that was used to determine the MACT floor HAP ABA formulation limitations, except that percentage reductions reported from the

TABLE 6. HAP ABA FORMULATION LIMITATIONS BASED ON THREE BEST PERFORMING FOAM FACILITIES

<table>
<tr><th colspan="2" rowspan="2">Emissions - parts ABA per hundred parts polyol</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-0.95</th><th>0.96-1.05</th><th>1.06-1.15</th><th>1.16-1.40</th><th>1.41+</th></tr>
<tr><td rowspan="5">IFD</td><td>0-15</td><td colspan="3">8</td><td rowspan="2">4</td><td rowspan="4">1</td></tr>
<tr><td>16-20</td><td>7</td><td colspan="2">6</td></tr>
<tr><td>21-25</td><td>6</td><td colspan="2">5</td><td>3</td></tr>
<tr><td>26-30</td><td rowspan="2">4</td><td colspan="2">3</td><td>2</td></tr>
<tr><td>31+</td><td>1</td><td>0.5</td><td>0</td></tr>
</table>

use of carbon adsorption[7] were used in instances where the percentage reduction of the best performing 12 percent of the facilities (see Table 3) was less than the percent reduction for carbon adsorption. This resulted in the HAP ABA formulation limitations shown in Table 7.

Comparison of the three sets of HAP ABA formulation limitations in Tables 4, 6, and 7 shows that the limitations are similar for many grades of foam. The emission reduction that would be achieved by each of these sets were calculated for the cost document representative slabstock facility.[8] As shown in Table 8, there is little difference in the emission reduction between the three sets. Since there is so little difference in HAP ABA formulation limitations and the representative facility emission reduction, EC/R concludes that these three sets truly

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[7] Memorandum. Williams, A. EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Summary of the April 26, 1995, conversation between EPA and Ohio Decorative Products regarding the use of carbon adsorption to control auxiliary blowing agent emissions at the Flexible Foam Facility in Terrell, Texas. May 31, 1996.

[8] "Flexible Polyurethane Foam Emission Reduction Technologies - Cost Analysis. EPA-453/D-95-004. May 1995.

TABLE 7. HAP ABA FORMULATION LIMITATIONS BASED ON PERCENTAGE REDUCTION ACHIEVED BY CARBON ADSORPTION

<table>
<tr><th colspan="2" rowspan="2">Emissions - parts ABA per hundred parts polyol</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-0.95</th><th>0.96-1.05</th><th>1.06-1.15</th><th>1.16-1.40</th><th>1.41+</th></tr>
<tr><td rowspan="6">IFD</td><td>0-10</td><td rowspan="2">7</td><td rowspan="2">7</td><td rowspan="2"></td><td rowspan="4">4</td><td rowspan="5">2</td></tr>
<tr><td>11-15</td><td>6</td></tr>
<tr><td>16-20</td><td>6</td><td colspan="2">5</td></tr>
<tr><td>21-25</td><td>6</td><td>5</td><td>4</td><td>3</td></tr>
<tr><td>26-30</td><td>4</td><td>3</td><td>2.5</td><td>2</td></tr>
<tr><td>31+</td><td>3</td><td>2.5</td><td>2</td><td>1</td><td>0</td></tr>
</table>

TABLE 8. REPRESENTATIVE FACILITY EMISSION REDUCTIONS FOR HAP ABA FORMULATION LIMITATION OPTIONS

Option	Representative Facility Percent Emission Reduction
MACT Floor	53
Intermediate Options	
Extended Range	67
Top Three	69
Carbon Adsorption	70
Total Elimination	100

only represent a single level of control, hereafter referred to as the intermediate level of control. The control options necessary to meet the HAP ABA MACT floor discussed above can also be used to meet this intermediate level of control.

The final recommended existing source level of control is the complete elimination of HAP ABA emissions. The number of control options available to achieve the complete elimination of HAP ABA emissions is limited, but available information indicates that at least three options, variable pressure foaming, acetone as an ABA, and liquid carbon dioxide as an ABA, are available. Each of these technologies is being used in full-scale production in the United States to produce a complete range of foam grades.

TABLE 9. NEW SOURCE MACT FLOOR HAP ABA FORMULATION LIMITATIONS

<table>
<tr><th colspan="2" rowspan="2">Emissions - parts ABA per hundred parts polyol</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-0.95</th><th>0.96-1.05</th><th>1.06-1.15</th><th>1.16-1.40</th><th>1.41+</th></tr>
<tr><td rowspan="6">IFD</td><td>0-10</td><td rowspan="2">12</td><td colspan="2" rowspan="2">11</td><td rowspan="2">6</td><td rowspan="2"></td></tr>
<tr><td>11-15</td></tr>
<tr><td>16-20</td><td>10</td><td colspan="4" rowspan="4">0</td></tr>
<tr><td>21-25</td><td>9</td></tr>
<tr><td>26-30</td><td>6</td></tr>
<tr><td>31+</td><td>5</td></tr>
</table>

New sources. The new source MACT floor for HAP ABA was determined to be a limit on the amount of HAP ABA emissions calculated with Equation 1 using the new source MACT floor grade-specific HAP ABA formulation limitations are shown in Table 9. Using the same concept as discussed above for existing sources, an intermediate level of HAP ABA emission reduction was identified. For this new source intermediate level of control, the HAP ABA formulation limitations are set to zero for the same grades as the new source MACT floor limitations that were shown in Table 9, while the formulation limitations for the other grades are set equal to the existing source intermediate level of control. The third level of control for new sources is the complete elimination of HAP ABA emissions.

Rebond

The MACT floor for HAP emissions at rebond facilities for both new and existing sources was determined to be no control for TDI/MDI (methylene diphenyl diisocyanate) emissions, and the elimination of HAP-based cleaners and mold release agents. No levels of control above the MACT floor were identified.

REGULATORY ALTERNATIVES

The following section presents and discusses the regulatory alternatives developed for new and existing polyurethane foam facilities. The amount of emission reduction achieved increases with each alternative above the floor. It is also expected that costs will increase with each more stringent alternative.

Molded Foam

For molded foam production, two existing source regulatory alternatives above the MACT floor were developed. These alternatives are summarized in Table 10. Alternative 1 would require facilities to use work practices to reduce the HAP emissions from mixhead flushing. The work practice requirements may take many forms, one of which may be to simply require operators to cover the barrel used to collect the HAP mixhead flush. The other emission sources at the facility would be require to control at the MACT floor level. Alternative 2 prohibits the use of any HAP-based mixhead flush. While TDI and methylene diphenyl diisocyanate (MDI) could still be used in the foam formulation, this alternative would practically eliminate HAP emissions from molded foam facilities.

The MACT floor level of control for all applicable emission sources at new sources is the prohibition of the use of HAP-based products. Therefore, the MACT floor regulatory alternative, which is shown in Table 11, is the only one offered.

It should be noted that the EPA, in conjunction with industry, State agencies, and other "partners," has made Presumptive MACT (P-MACT) determinations for the Flexible Polyurethane Foam Production Source Category.[9] For molded foam, Regulatory Alternative 3 (for existing sources), and Regulatory Alternative 1 (for new sources) were selected as P-MACT.

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[9] Memorandum. Williams, A. and Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Summary of August 22, 1995 Flexible Polyurethane Foam Production Presumptive MACT Roundtable Meeting. October 1995.

TABLE 10. REGULATORY ALTERNATIVES FOR MOLDED FOAM - EXISTING SOURCES

Regulatory Alternative	Mixhead Flush	Mold Release Agents	Repair Adhesives
MACT Floor	no control	HAP prohibition	HAP prohibition
1	work practice	↓	↓
2	HAP prohibition	↓	↓

TABLE 11. REGULATORY ALTERNATIVES FOR MOLDED FOAM - NEW SOURCES

Regulatory Alterative	Mixhead Flush	Mold Release Agents	Repair Adhesives
MACT Floor	HAP prohibition	HAP prohibition	HAP prohibition

Slabstock Foam

Two existing source alternatives above the MACT floor were developed for slabstock production. These alternatives are presented in Table 12. Alternative 1a adds a unique LDAR program for equipment leak emissions, and increases the level of control for HAP ABA emissions to the intermediate emission limit. Alternative 1a was selected as P-MACT.

Alternative 1b is approximately equivalent to Alternative 1a in stringency, but incorporates a novel implementation approach that would reduce the reporting, recordkeeping, and monitoring burden on the industry. During the P-MACT process, industry was concerned that the cost of controlling ABA emissions from storage/unloading and equipment leaks was unreasonable, given the relatively low emissions from these sources (around 50 tons per year, or 0.2 percent). Under Alternative 1a, the amount of HAP ABA allowed to be emitted from the entire facility would be determined using the HAP ABA emission limit equation and formulation limitations. This limit would then apply to the entire facility, rather than only to the HAP ABA added at the mixhead. In the absence of add-on control, the entire amount of HAP ABA used is emitted. Therefore, the total amount of HAP ABA used during the compliance time period would be compared to the emission limit to determine compliance. Under this alternative, the amount of ABA used could be determined using simple inventory procedures, in lieu of more expensive LDAR techniques. This approach would encourage the source to reduce storage and

equipment leak emissions so more ABA would be available to be used in foam formulations, while giving them considerable flexibility.

Alternative 2 would totally eliminate HAP ABA emissions, and would require controls for TDI storage/unloading and equipment leaks.

There are also two regulatory alternatives above the new source MACT floor developed for new slabstock sources, which are shown in Table 13. These alternatives mirror the existing source alternatives discussed above, except that the new source HAP ABA formulation limitations are used.

TABLE 12. REGULATORY ALTERNATIVES FOR SLABSTOCK FOAM - EXISTING SOURCES

Reg. Alt.	Storage/ Unloading	Components in HAP Service	Equipment Cleaning	HAP ABA Emissions
MACT Floor	HAP ABA & TDI - vap bal/ carbon	TDI pumps - leakless Other HAP components - no control	HAP prohibition	Existing source MACT floor HAP ABA emission limit
1a	↓	TDI & HAP ABA pumps - leakless Other HAP components - LDAR	↓	Intermediate HAP ABA emission limit
1b	TDI - vapor balance, leakless pumps, and LDAR HAP ABA - Intermediate HAP ABA emission limit for total facility			
2	↓	TDI pumps - leakless Other TDI components - LDAR	↓	HAP ABA prohibition

TABLE 13. REGULATORY ALTERNATIVES FOR SLABSTOCK FOAM - NEW SOURCES

Reg. Alt.	Storage/ Unloading	Components in HAP Service	Equipment Cleaning	HAP ABA Emissions
MACT Floor	HAP ABA & TDI - vap bal/ carbon	TDI pumps - leakless Other HAP components - no control	HAP prohibition	Existing source MACT floor HAP ABA emission limit
1a	↓	TDI pumps - leakless Other HAP components - LDAR	↓	Intermediate new source HAP ABA emission limit
1b	TDI - vapor balance, leakless pumps, and LDAR HAP ABA - New Source intermediate HAP ABA emission limit for total facility			
2	TDI - vap bal/ carbon	TDI pumps - leakless Other TDI components - LDAR	↓	HAP ABA prohibition

MEMORANDUM

Date: June 17, 1996

Subject: Estimated Regulatory Alternative Impacts for Flexible Polyurethane Foam Production

From: Phil Norwood, EC/R Incorporated
Amanda Williams, EC/R Incorporated

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

The purpose of this memorandum is to present the estimated cost and primary environmental impacts of the hazardous air pollutant (HAP) regulatory alternatives for existing sources. These regulatory alternatives are under consideration by the Environmental Protection Agency (EPA) for the proposed flexible polyurethane foam production National Emission Standard for HAP (NESHAP). This memorandum is organized as follows: the first section presents the regulatory alternatives; the second section provides the model plant costs and HAP emission reductions; and the final sections present the nationwide regulatory alternative costs and HAP emission reductions. There are no anticipated new source impacts for this source category. The industry has stated that there is enough unused capacity at existing facilities to handle any increased demand for foam products.[1] Therefore, no impacts are expected for new sources.

REGULATORY ALTERNATIVES

For purposes of the Foam Production NESHAP, the EPA has separated the flexible polyurethane foam production source category into three subcategories: Slabstock Foam Production and Molded Foam Production. Rationale for this decision is provided in a separate memorandum.[2]

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[1] Memorandum. Seaman, J., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Summary of the March 7, 1996 Meeting Between the EPA and Polyurethane Foam Association Representatives. April 22, 1996.

[2] Memorandum from Williams, A. and Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Subcategorization of the Flexible Polyurethane Foam Production Source Category. June 17, 1996.

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For each subcategory, the first regulatory alternative represents the maximum achievable control technology (MACT) "floor" level of control. This level of control is the minimum stringency for a NESHAP developed in accordance with section 112(d) of the Clean Air Act. Existing source regulatory alternatives more stringent than the floor level were also developed for each of these subcategories. Control options more stringent than the new source floor levels were not identified for either subcategory; therefore, no alternatives more stringent than the new source floors were developed. Documentation of the MACT floor determinations and explanation of regulatory alternative development are provided in separate memoranda.[3,4]

Molded Foam Production

The regulatory alternatives for molded foam production are provided in Tables 1 and 2. Each regulatory alternative contains requirements for HAP emissions from three emission sources: mixhead cleaning, or "flushing"; mold release agent usage; and the use of HAP-based adhesives to repair damaged foam.

TABLE 1. REGULATORY ALTERNATIVES FOR MOLDED FOAM - EXISTING SOURCES

Regulatory Alternative	Mixhead Flush	Mold Release Agents	Repair Adhesives
MACT Floor	no control	HAP prohibition	HAP prohibition
1	work practice	↓	↓
2	HAP prohibition	↓	↓

Table 1 shows the three existing source regulatory alternatives. Since the MACT floor prohibits the use of HAP-based mold release agents and adhesives, the only emission source with the potential for more stringent requirements is mixhead flushing. The first regulatory alternative requires work

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[3] Memorandum, Williams, A. and Norwood, P., EC/R Incorporated to Svendsgaard, D., U.S. Environmental Protection Agency. MACT Floors for Flexible Polyurethane Foam Production. June 17, 1996.

[4] Memorandum, Williams, A. and Norwood, P., EC/R Incorporated to Svendsgaard, D., U.S. Environmental Protection Agency. Regulatory Alternatives for New and Existing Source in the Flexible Polyurethane Foam Industry. June 17, 1996.

practices to reduce mixhead flushing emissions, and the second prohibits the use of HAP-based mixhead flushes.

TABLE 2. REGULATORY ALTERNATIVES FOR MOLDED FOAM - NEW SOURCES

Regulatory Alterative	Mixhead Flush	Mold Release Agents	Repair Adhesives
MACT Floor*	HAP prohibition	HAP prohibition	HAP prohibition

Table 2 shows the single new source regulatory alternative, which represents the new source MACT floor. This alternative is equivalent to existing source regulatory alternative 2.

Slabstock Foam Production

The regulatory alternatives for slabstock foam production are provided in Tables 3 and 4. Attachment 1 provides more detail on the HAP ABA limitations. Each regulatory alternative contains requirements from four emission sources: storage/ unloading, equipment cleaning, equipment leaks, and auxiliary blowing agent (ABA) usage. The storage and equipment leak alternatives specify separate requirements for toluene diisocyanate (TDI), which is a reactant in the formation of polyurethane foam, and HAP ABA. Methylene chloride ($MeCl_2$) is the HAP frequently used as both an ABA and as an equipment cleaner. Throughout this memorandum, HAP ABA and $MeCl_2$ are used interchangeably.

As shown in Table 3, there are three existing source regulatory alternatives for slabstock foam. The first alternative beyond the MACT floor, which has two implementation options (1a and 1b), increases the stringency of the requirements for equipment leak and ABA usage emissions. Option 1a requires the combination of equipment modifications and the execution of a leak detection and repair (LDAR) program to reduce equipment leak emissions. It also includes a lower allowable HAP ABA emission level. Option 1b is considered to be equivalent to 1a in the level of stringency, but it provides the flexibility for a source to select controls for storage/unloading, equipment leaks, equipment cleaning, and HAP ABA usage. Option 1b would require the same controls for TDI as Option 1a.

Option 2 prohibits HAP ABA emissions. This would, in effect, prohibit the usage of any $MeCl_2$ as an ABA. Since no HAP ABA would be allowed, there is no need for HAP ABA storage or equipment leak requirements.

TABLE 3. REGULATORY ALTERNATIVES FOR SLABSTOCK FOAM - EXISTING SOURCES

Reg. Alt.	Storage/ Unloading	Components in HAP Service	Equipment Cleaning	HAP ABA Emissions
MACT Floor	HAP ABA & TDI - vap bal/ carbon	TDI pumps - leakless Other HAP components - no control	HAP prohibition	Existing source MACT floor HAP ABA emission limit
1a	↓	TDI pumps - leakless Other HAP components - unique LDAR	↓	Intermediate HAP ABA emission limit
1b	TDI - vapor balance, leakless pumps HAP ABA - Intermediate HAP ABA emission limit for total facility			
2[a]	TDI - vap bal/carbon	TDI pumps - leakless	↓	HAP ABA prohibition

[a] Since the use/emission of HAP ABA is prohibited under regulatory alternative 2, there are no requirements needed for storage/unloading of HAP ABA or for equipment leaks in HAP ABA service.

There are also two regulatory alternatives above the new source MACT floor developed for new slabstock sources, which are shown in Table 4. These alternatives mirror the existing source alternatives discussed above, except that the new source HAP ABA formulation limitations are used.

MODEL PLANT COSTS AND EMISSION REDUCTIONS

This section presents the model plant costs and primary environmental impacts (i.e., HAP emission reductions) for technologies needed to meet the levels contained in the regulatory alternatives discussed earlier. While the bases for the model plants are provided in a separate memorandum,[5] the baseline model plant parameters are provided in Attachment 2.

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[5] Memorandum. Williams, A., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Flexible Polyurethane Foam Model Plants. June 17, 1996.

TABLE 4. REGULATORY ALTERNATIVES FOR SLABSTOCK FOAM - NEW SOURCES

Reg. Alt.	Storage/ Unloading	Components in HAP Service	Equipment Cleaning	HAP ABA Emissions
MACT Floor	HAP ABA & TDI - vap bal/ carbon	TDI pumps - leakless Other HAP components - no control	HAP prohibition	Existing source MACT floor HAP ABA emission limit
1a	↓	TDI pumps - leakless Other HAP components - LDAR	↓	Intermediate new source HAP ABA emission limit
1b	TDI - vapor balance, leakless pumps, and LDAR HAP ABA - New Source intermediate HAP ABA emission limit for total facility			
2	TDI - vap bal/ carbon	TDI pumps - leakless Other TDI components - LDAR	↓	HAP ABA prohibition

The EPA document, "Flexible Polyurethane Foam Emission Reduction Technologies - Cost Analysis,"[6] was used as the basis for the majority of the model plant costs. This document went through various review phases by the EPA and the flexible polyurethane foam industry. This document will hereafter be referred to as the "Cost Document."

There are several situations where all or some portion of the model plant annual costs are negative (i.e., cost savings). Throughout this memorandum, cost savings will be denoted in parentheses.

Molded Foam Production

There are four molded foam production model plants. One of these model plants represents larger molded foam facilities using high-pressure mixheads, primarily to produce automobile seats.

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[6] Flexible Polyurethane Foam Emission Reduction Technologies Cost Analysis. EPA-453/R-95-011. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. September 1996.

The remaining three model plants represent smaller producers that use low-pressure mixheads to produce a variety of foam products.

The molded foam production model plant costs were developed directly from the Cost Document, except that the costs were adjusted to the characteristics of the model plants. All technologies, except for work practices to reduce mixhead flushing emissions, totally eliminate HAP emissions. These model plant costs are applicable both to new and existing sources. The following sections provide brief descriptions of the technologies and model plant impacts estimations for each emission source. More details regarding the molded foam model plant costs are provided in Attachment 3.

Mixhead flushing

Model plant impacts were developed for four technologies to reduce or eliminate mixhead flushing emissions: work practices for regulatory alternative 1; and non-HAP flushes, high-pressure mixheads, and self-cleaning mixheads for regulatory alternative 2. Costs were developed for the work practice of an emission suppression and solvent recovery system for the $MeCl_2$ used to flush the mixhead. The emission reduction efficiency for such a system was reported at around 75 percent.[7] For the three remaining technologies, the emission reduction was 100 percent. Table 5 presents a summary of the model plant costs for mixhead flushing.

Mold release agents

The MACT floor level of control for mold release agents is the prohibition of the use of HAP-based mold release agents, resulting in a 100 percent emission reduction. Model plant impacts were developed for three technologies that can achieve this level: reduced volatile organic compound (VOC) mold release agents, naphtha-based mold release agents, and water-based mold release agents. A summary of mold release agent model plant costs is contained in Table 6.

Repair adhesives

The MACT floor level of control for repair adhesives is also the prohibition of the use of HAP-based adhesives, resulting in a 100 percent emission reduction. Model plant impacts were developed for three technologies that can achieve this level: hot-melt adhesives, water-based adhesives, and hydrofuse adhesive. Table 7 provides a summary of the repair adhesive model plant costs.

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[7] Reference 6, page 4-9.

TABLE 5. MOLDED FOAM MODEL PLANT COSTS FOR TECHNOLOGIES TO REDUCE MIXHEAD FLUSHING HAP EMISSIONS

Technology	Costs (1994 dollars)			
	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
Non-HAP Flush				
Capital Investment ($)	$0	$0	$0	$0
Annual Cost ($/yr)	$0	($920)	($3,823)	($8,065)
Emission Reduction (tons/yr)	0	5.14	19.69	21.31
Cost Effectiveness ($/ton)	$0	-[a]	-[a]	-[a]
High-pressure Mixhead				
Capital Investment ($)	$0	$658,125	$658,215	$658,125
Annual Cost ($/yr)	$0	$163,815	$146,107	$112,535
Emission Reduction (tons/yr)	0	5.14	19.69	21.31
Cost Effectiveness ($/ton)	$0	$31,871	$7,420	$5,281
Self-Cleaning Mixhead				
Capital Investment ($)	$0	$225,688	$225,688	$225,688
Annual Cost ($/yr)	$0	$34,938	$17,231	($16,341)
Emission Reduction (tons/yr)	0	5.14	19.69	21.31
Cost Effectiveness ($/ton)	$0	$6,797	$875	-[a]
Solvent Recovery System				
Capital Investment ($)	$0	$47,250	$47,250	$47,250
Annual Cost ($/yr)	$0	$23,412	$10,131	($15,048)
Emission Reduction (tons/yr)	0	3.86	14.77	15.98
Cost Effectiveness ($/ton)	$0	$6,073	$686	-[a]

[a] Cost effectiveness not calculated because net annualized cost is a negative quantity (cost savings).

Slabstock Foam Production

There are five basic model plants for slabstock foam, representing varying levels of production. Each basic model plant is separated into facilities that use $MeCl_2$ as an equipment cleaner, and facilities that do not.

Several sources were used to estimate costs for the slabstock foam production model plants. Information developed for other EPA efforts was used for equipment leak and storage tank impacts, supplemented by vendor quotes. The HAP ABA and equipment cleaning costs were primarily derived from the Cost Document. The following sections provide more discussion on the derivation of impact estimates for each emission source type.

TABLE 6. MOLDED FOAM MODEL PLANT COSTS FOR TECHNOLOGIES TO REDUCE MOLD RELEASE AGENT HAP EMISSIONS

Technology	Costs (1994 dollars)			
	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
Reduced-VOC Agent				
Capital Investment ($)	$0	$0	$0	$0
Annual Cost ($/yr)	$0	$50	$39	$1,023
Emission Reduction (tons/yr)	0	0.15	0.12	6.00
Cost Effectiveness ($/ton)	$0	$337	$328	$171
Naphtha-Based Agent				
Capital Investment ($)	$0	$0	$0	$0
Annual Cost ($/yr)	$0	$375	$293	$7,599
Emission Reduction (tons/yr)	0	0.15	0.12	6.00
Cost Effectiveness ($/ton)	$0	$2,500	$2,439	$1,267
Water-Based Agent				
Capital Investment ($)	$0	$0	$0	$0
Annual Cost ($/yr)	$0	$48	$38	$981
Emission Reduction (tons/yr)	0	0.15	0.12	6.0
Cost Effectiveness ($/ton)	$0	$323	$315	$163

Storage/unloading

The MACT floor level of control for storage and unloading of both TDI and HAP ABA is an equipment standard that requires either a vapor balance system to return the displaced HAP vapors to the tank truck or rail car, or a carbon canister through which emissions must be routed prior to being emitted to the atmosphere. The subsequent regulatory alternatives do not contain more stringent requirements. However, since there are no HAP ABA emissions allowed under regulatory alternative 2, there will be no storage tanks containing HAP ABA under regulatory alternative 2. While the storage/unloading emissions will be zero, it is not appropriate to attribute this reduction to a storage tank control program. Therefore, the emission reductions are indirectly attributed to the HAP ABA requirements of regulatory alternative 2.

The model plant impacts are based on the installation of vapor balance. The basis for estimating vapor balance impacts was the Background Information Document for the proposed gasoline

TABLE 7. MOLDED FOAM MODEL PLANT COSTS FOR TECHNOLOGIES TO REDUCE HAP EMISSIONS FROM THE USE OF FOAM REPAIR ADHESIVES

Technology	Costs (1994 dollars)			
	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
Hot-Melt Adhesive				
Capital Investment ($)	$6,804	$0	$0	$6,804
Annual Cost ($/yr)	$6,377	$0	$0	$1,869
Emission Reduction (tons/yr)	2.09	0	0	1.35
Cost Effectiveness ($/ton)	$3,047	$0	$0	$1,384
Hydrofuse Adhesive				
Capital Investment ($)	$5,670	$0	$0	$5,670
Annual Cost ($/yr)	$738	$0	$0	$1,001
Emission Reduction (tons/yr)	2.09	0	0	1.35
Cost Effectiveness ($/ton)	$353	$0	$0	$741
Water-Based Adhesive				
Capital Investment ($)	$0	$0	$0	$0
Annual Cost ($/yr)	($854)	$0	$0	($97)
Emission Reduction (tons/yr)	2.09	0	0	1.35
Cost Effectiveness ($/ton)	-[a]	$0	$0	-[a]

[a] Cost effectiveness not calculated because net annualized cost is a negative quantity (cost savings).

distribution NESHAP.[8] This document asserts that the emission reduction for vapor balance is 95 percent. The bulk plant model plant costs in the referenced document include costs for vapor balancing both incoming and outgoing loads. The unloading of TDI and $MeCl_2$ at flexible polyurethane foam facilities is comparable to "incoming loads" at bulk plants. The capital cost (1990 base year) of incoming loads at bulk plants ($7,981) was divided by two (there were two tanks in the bulk plant model plant), and adjusted to 1994 dollars using the Chemical Engineering Plant Cost Index (368.1 ÷ 357.4).[9] Therefore, the capital cost of vapor balancing used in this analysis was $4,110 per storage vessel. The annual costs were calculated with the following elements:

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[8] Gasoline Distribution Industry (Stage I) - Background Information for Proposed Standards. EPA-453/R-94-002a. U.S. Environmental Protection Agency. Research Triangle Park, North Carolina. January 1994. Pages 4-34 and 7-17.

[9] Chemical Engineering Economic Indicators. *Chemical Engineering*. June 1995. Page 158.

- Operating and maintenance costs (3 percent of total capital costs),
- Capital recovery costs (7 percent interest rate for 10 years, for a capital recovery factor of 14.24 percent), and
- Taxes and insurance (4 percent of total capital investment).

In addition, recovery credits were included in the annual costs to recognize the savings that will occur due to the TDI or $MeCl_2$ that will no longer be lost to the atmosphere. The chemical costs used to calculate recovery credits were $0.40 per pound for $MeCl_2$ and $1.00 per pound for TDI.

The slabstock foam production model plant costs for storage/unloading emission control are provided in Table 8. There are no costs for model plants 4 and 5 because all TDI and $MeCl_2$ storage tanks for these model plants were assumed to be controlled at baseline. Also, TDI storage tanks at model plant 3 were assumed to be controlled. More detail on these model plant impacts is provided in Attachment 4.

TABLE 8. SLABSTOCK FOAM MODEL PLANT COSTS FOR VAPOR BALANCING

	Costs (1994 dollars)		
	Model Plant 1	Model Plant 2	Model Plant 3
Regulatory Alternative 1			
Capital Investment ($)	$8,220	$12,330	$4,110
Annual Cost ($/yr)	$1,673	$2,402	$438
Emission Reduction (tons/yr)	0.083	0.247	0.494
Cost Effectiveness ($/ton)	$20,244	$9,723	$887
Regulatory Alternative 2			
Capital Investment ($)	$4,110	$8,220	
Annual Cost ($/yr)	$873	$1,746	
Emission Reduction (tons/yr)	~0	~0	
Cost Effectiveness ($/ton)	$9,100,000	$3,700,000	

Equipment cleaning

The MACT floor level of control for chemical cleaning is the complete elimination of HAP emissions. The subsequent regulatory alternatives do not contain more stringent requirements. While there are several alternatives available to eliminate the use of $MeCl_2$ or other HAP's to clean the mixhead and other equipment, model plant costs were developed for only one alternative: non-HAP cleaners. Details of these model plant impacts are provided in Attachment 5.

The amount of $MeCl_2$ to clean the equipment is consistent for all model plants. Therefore, the impacts shown below are applicable for all model plants. The basis for the model plant costs is the Cost Document.[10]

Capital Cost -	$0
Annual Cost -	($275)/yr
Emission Reduction -	5.0 tons/yr
Cost Effectiveness	not applicable

Equipment leaks

The MACT floor level of control for equipment leaks was determined to be sealless pumps for TDI transfer pumps. The first regulatory alternative adds a unique LDAR program for HAP ABA components. Since regulatory alternative 2 does not allow the emission of any HAP ABA (which, in effect, prohibits the use of $MeCl_2$ or any other HAP as an ABA), this alternative only contains the MACT floor requirement for TDI pumps.

MACT floor. For the MACT floor regulatory alternative, the cost would simply be the cost of replacing existing TDI transfer pumps with sealless pumps for model plant 1. All other model plants have sealless TDI transfer pumps at baseline. The capital cost of a sealless pump was estimated by a foam producer to be $5,000 per pump.[11] The annual cost was calculated as the capital recovery (7 percent for 10 years) minus the recovery credit. It was assumed that a sealless pump would achieve a 100 percent emission reduction. Therefore, the impacts of the slabstock foam production MACT floor for equipment leaks for model plant 1 are as follows:

Capital Cost -	$5,000
Annual Cost -	$1,265/yr
Emission Reduction -	0.17 tons/yr
Cost Effectiveness	$7,600/ton

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[10] Reference 6, page 5-19.

[11] Telecon, Norwood, P., EC/R Incorporated with Barger, S., Olympic Products. Discussing cost of sealless TDI pumps. December 12, 1995.

Regulatory alternative 1. As noted above, regulatory alternative 1 includes an LDAR program for HAP ABA. The elements of the program for which impacts were developed are provided in Table 9, along with the emission reduction used for each type of component. The percentage emission reductions are based on EPA's Equipment Leak Protocol Document.[12]

TABLE 9. SLABSTOCK FOAM REGULATORY ALTERNATIVE 1 EQUIPMENT LEAK PROGRAM

Component	Control Options	Technology for which impacts developed	Emission reduction
TDI			
Pumps	Sealless pumps for transfer pumps No control for metering pumps	Sealless pumps	100%
Other Components	No control		
$MeCl_2$			
Pumps	Quarterly LDAR - 10,000 ppm leak definition OR Sealless pumps	Quarterly LDAR	45%
Valves	Quarterly LDAR - 10,000 ppm leak definition	Quarterly LDAR	67%
Connectors	Annual LDAR (see HON)	Annual	93%
Open-ended lines	Blind, cap, plug, or second valve	Second valve	100%

Costs from the impacts analysis for the proposed Hazardous Organic NESHAP (HON)[13] were used to estimate equipment leak impacts for regulatory alternative 1, which are shown in

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[12] Protocol for Equipment Leak Emission Estimates. EPA-453/R-93-026. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. June 1993. Page 5-9.

[13] Hazardous Air Pollutant Emissions from Process Units in the Synthetic Organic Chemical Manufacturing Industry -- Background Information for Proposed Standards. Volume 1B: Control Technologies. EPA-453/D-92-016b. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. November 1992. Pages 3-27 through 3-60.

Table 10. The costs were updated from the 1989 base year to 1994 using the Chemical Engineering Plant Cost Index.[14] Component-specific impacts are provided in Attachment 6.

TABLE 10. SLABSTOCK FOAM REGULATORY ALTERNATIVE 1 EQUIPMENT LEAK MODEL PLANT IMPACTS

	Costs (1994 dollars)				
	Model Plant 1	Model Plant 2	Model Plant 3	Model Plant 4	Model Plant 5
Capital Investment ($)	$12,544	$7,544	$7,544	$7,544	$7,431
Annual Cost ($/yr)	$7,245	$5,980	$5,980	$5,980	$5,810
Emission Reduction (tons/yr)	1.2	1.0	1.0	1.0	0.8
Cost Effectiveness ($/ton)	$6,193	$5,960	$5,960	$5,960	$6,996

Regulatory alternative 2. Since there are no HAP ABA emissions allowed under regulatory alternative 2, there will be no components in HAP ABA service. While the equipment leak emissions will be zero, it is not appropriate to attribute this reduction to an equipment leak control program. Therefore, the only direct equipment leak impacts under this regulatory alternative will be the TDI cost and emission reduction associated with the MACT floor regulatory alternative. The HAP ABA equipment leak emission reductions are indirectly attributed to the HAP ABA requirements of regulatory alternative 2.

HAP ABA emissions

There are three levels of control for HAP ABA emissions. The MACT floor and first regulatory alternative levels are emission limits based on formulation limitations (see Attachment 1). Applying the two sets of formulation limitations to the product mix of the model plants results in the emission reductions shown in Table 11. More detail on the determination of these emission reductions is provided in Attachment 7. The second regulatory alternative requires the complete elimination of HAP ABA emissions.

For each level of control, model plant impacts were developed for several technologies. While there are numerous technologies available to reduce HAP ABA emissions, the

[14] Reference 9.

TABLE 11. MODEL PLANT HAP ABA REGULATORY ALTERNATIVE EMISSION REDUCTIONS

Model Plant	Baseline HAP ABA Emissions (tons/yr)	HAP ABA Emission Reduction (tons/yr)		
		MACT Floor	Reg Alt 1	Reg Alt 2
1	55	31.3	37.9	55
2	165	93.8	113.7	165
3	330	184.0	222.7	330
4	335	195.9	237.7	335
5	380	220.4	268.0	380

effectiveness of individual technologies is widely disputed within the foam industry. Therefore, EC/R made assumptions, based on our knowledge of the industry, regarding the technologies that could be used to meet each of the three HAP ABA levels of control. Table 12 shows the technologies assumed for each regulatory alternative level.

As can be seen in Table 12, it is assumed that some technologies can be used to meet more than one level of control. In these cases, it was assumed that the technologies would only be used to the degree necessary to meet the level of the regulatory alternative. In other words, although variable pressure foaming can be used to totally eliminate the use of HAP ABA, it was assumed that at the MACT floor level, the amount of $MeCl_2$ allowed would still be used and emitted.

The HAP ABA emission reduction technology costs from the Cost Document provide the basis for the model plant costs. However, as noted above, it was assumed that each technology was used only to meet the level of the regulatory alternative. In addition to changing the emission reduction, this also affected the annual costs. The elements of the annual costs most frequently affected were the material cost savings from the discontinued use of $MeCl_2$ and the licensing fees, which were often based on the amount of foam produced using the licensed technology. The assumptions made in deriving the annual costs are described below.

Chemical alternatives. It is assumed that the only regulatory alternative that can be met solely by the use of chemical alternatives is the MACT floor alternative. The capital costs of the use of chemical alternatives are the same for all

TABLE 12. TECHNOLOGIES ASSUMED TO ACHIEVE THE HAP ABA REGULATORY ALTERNATIVE LEVELS

Regulatory Alternative	Technology
MACT Floor Level	Chemical alternatives Carbon dioxide as an ABA Acetone as an ABA Variable pressure foaming Forced cooling
Regulatory Alternative 1	Carbon dioxide as an ABA Acetone as an ABA Variable pressure foaming Forced cooling
Regulatory Alternative 2	Carbon dioxide plus chemical alternatives Acetone as an ABA Variable pressure foaming Forced cooling plus chemical alternatives

model plants. Therefore, the capital recovery and other indirect annual costs (which are a function of the total capital investment) are also uniform. The other contribution to the annual cost is the materials cost. This is the cost of the chemical alternatives minus the cost of the $MeCl_2$ no longer used. The model plant chemical alternative costs are summarized in Table 13. Details of these costs are provided in Attachment 8.

Carbon dioxide as an ABA. It is assumed that the HAP ABA requirements for the MACT floor and first regulatory alternative can be met using carbon dioxide as an ABA. While there are other carbon dioxide systems available, the model plant costs presented for carbon dioxide as an ABA are costs of the licensed CarDio technology. The model plant costs for CarDio are summarized in Table 14, and details are provided in Attachment 9. The capital costs for the installation of the CarDio technology are uniform for all regulatory alternatives for all model plants. Therefore, the annual capital recovery charges are also analogous for all situations. Similarly, the carbon dioxide tank rental fee is the same in all situations. The materials costs consist of the costs of the liquid carbon dioxide minus the $MeCl_2$ savings.

TABLE 13. SLABSTOCK FOAM MODEL PLANT COSTS FOR CHEMICAL ALTERNATIVES
HAP ABA EMISSION REDUCTION

	Model Plant Costs (1990 dollars)				
	MP1	MP2	MP3	MP4	MP5
MACT Floor					
Capital Investment ($)	$31,725	$31,725	$31,725	$31,725	$31,725
Annual Cost ($/yr)	$54,523	$151,713	$274,276	$335,202	$378,997
Emission Reduction (tons/yr)	31.3	93.8	184.0	195.9	220.4
Cost Effectiveness ($/ton)	$1,742	$1,617	$1,491	$1,711	$1,720

TABLE 14. SLABSTOCK FOAM MODEL PLANT COSTS FOR CARDIO HAP ABA EMISSION REDUCTION

	Model Plant Costs (1990$)				
	MP1	MP2	MP3	MP4	MP5
MACT Floor					
Capital Investment ($)	$429,300	$429,300	$429,300	$429,300	$429,300
Annual Cost ($/yr)	$69,395	$32,453	($18,512)	($14,525)	($23,505)
Emission Reduction (tons/yr)	31.3	93.8	184.0	195.9	220.4
Cost Effectiveness ($/ton)	$2,217	$346	-[a]	-[a]	-[a]
Regulatory Alternative 1					
Capital Investment ($)	$429,300	$429,300	$429,300	$429,300	$429,300
Annual Cost ($/yr)	$66,354	$23,254	($42,403)	($38,631)	($43,559)
Emission Reduction (tons/yr)	37.9	113.7	222.7	237.7	268.0
Cost Effectiveness ($/ton)	$1,751	$204	-[a]	-[a]	-[a]
Regulatory Alternative 2 - CarDio plus chemical alternatives					
Capital Investment ($)	$461,025	$461,025	$461,025	$461,025	$461,025
Annual Cost ($/yr)	$84,163	$27,660	($29,666)	$17,561	$16,227
Emission Reduction (tons/yr)	55	165	330	335	380
Cost Effectiveness ($/ton)	$1,530	$168	-[a]	$52	$43

[a] Cost effectiveness not calculated because net annualized cost is a negative quantity (cost savings).

The licensing fee for Cardio is 1 percent of the chemical cost for foams made with Cardio. The industry representative states that the chemical cost for making Cardio was $0.72 per pound. Therefore, to estimate the licensing fee for each regulatory alternative for each model plant, it was necessary to predict which foam grades each model plant would chose to make using CarDio. It was assumed that each model plant would chose to make the foams that had the largest amount of $MeCl_2$ used/emitted until the necessary emission reduction was achieved. The chemical costs and licensing fees were then calculated, based on the weight of the selected grades produced. More detail on this calculation is provided in Attachment 9.

It was assumed that the total elimination of HAP ABA (regulatory alternative 2) could not be achieved using only CarDio. This was because the base formulation would need more than 3 parts $MeCl_2$ per hundred parts polyol to allow the substitution of carbon dioxide as an ABA. However, these low-ABA foam grades could be produced using chemical alternatives. Therefore, the combination of CarDio and chemical alternatives was assumed to achieve the complete elimination of the use of HAP ABA. The capital costs, capital recovery, and other indirect annual costs for this combination were simply the sum of the capital costs of CarDio and chemical alternatives.

For regulatory alternative 2, the procedure for calculating the licensing fee for the foam grades made using Cardio was the same as for the MACT floor and regulatory alternative 1 described above. To calculate the material costs for the combination of the two technologies, the material cost of making the foam grades with CarDio (those with base formulations with greater than 3 parts $MeCl_2$ per 100 parts polyol, or pph) was calculated and added to the material cost of making the remaining foam grades (less than 3 pph polyol grades) using only chemical alternatives. Attachment 9 also illustrates this calculation.

<u>Acetone as an ABA.</u> It is assumed that acetone can be used to meet the HAP ABA requirements for all three regulatory alternatives. The model plant costs for acetone as an ABA are summarized in Table 15, and detailed in Attachment 10. As with CarDio, the capital costs, capital recovery, and other indirect costs are the same for all model plants and for all regulatory alternatives. The differences in annual costs are the result of the differences in material costs and licensing fees. The material costs were simply the cost of the acetone minus the $MeCl_2$ savings.

The licensing fee for acetone as an ABA operates on a graded cost scale dependent on the amount of acetone used by the facility. For the first 50,000 pounds of acetone used, the fee is $0.16/lb, for the next 75,000 pounds the fee is $0.14/lb, and for any additional acetone the fee is $0.12/lb. This fee is subject to change with trends in acetone and $MeCl_2$ costs. The

licensing fee for each model plant was calculated using these fees and the corresponding amount of acetone used for each model plant.

Variable pressure foaming. It is assumed that the HAP ABA requirements for all three regulatory alternatives can be met using variable pressure foaming technology. The capital costs are consistent across all model plants for all regulatory alternatives. Similarly, the utilities and labor costs, and capital recovery and other indirect annual costs are also consistent. Therefore, the only element that changes in the variable pressure foaming model plant annual costs is the material costs. Since there is not a need for additional chemicals or other materials, this simply represents the cost savings from the unused $MeCl_2$. The variable pressure foaming model plant costs are summarized in Table 16. Details are provided in Attachment 11.

Forced cooling. It is assumed that the HAP ABA requirements for the MACT floor and first regulatory alternative can be met using forced cooling. While there are numerous forced cooling systems in operation or under development in the United States, the model plant costs presented are based on the Envirocure technology. The model plant costs for forced cooling are provided in Table 17. Details of these model plant costs are provided in Attachment 12. The capital costs for the installation of forced cooling are uniform for model plants 2 through 5 for all regulatory alternatives. The capital costs for model plant 1 are lower, assuming that a smaller forced cooling unit could be installed. Therefore, the annual capital recovery charges and other indirect annual costs are analogous for all regulatory alternatives. The utilities charges, which were provided by the vendor, are also the same for all regulatory alternatives. While the cost of the Envirocure technology would include licensing fees, the model plant costs did not include such fees.

It was assumed that the total elimination of HAP ABA (regulatory alternative 2) could not be achieved using forced cooling only. This assumption was made due to the many doubts within the industry that low density, low internal force deflection (IFD) foams of acceptable quality can be made using forced cooling without any ABA. However, it was assumed that these foam grades could be produced using the combination of forced cooling and chemical alternatives. The capital costs, capital recovery, and other indirect annual costs for this combination were simply the sum of the capital costs of forced cooling and chemical alternatives. More detail of this calculation is provided in Attachment 12.

For regulatory alternative 2, as mentioned above, it was assumed that forced cooling and chemical alternatives would be used in tandem to make the low-density, low-IFD foam grades.

TABLE 15. SLABSTOCK FOAM MODEL PLANT COSTS FOR ACETONE HAP ABA EMISSION REDUCTION

	Model Plant Costs (1990 dollars)				
	MP1	MP2	MP3	MP4	MP5
MACT Floor					
Capital Investment ($)	$194,000	$194,000	$194,000	$194,000	$194,000
Annual Cost ($/yr)	$35,121	$8,783	($31,165)	($36,497)	($47,473)
Emission Reduction (tons/yr)	31.3	93.8	184.0	195.9	220.4
Cost Effectiveness ($/ton)	$1,122	$94	-[a]	-[a]	-[a]
Regulatory Alternative 1					
Capital Investment ($)	$194,000	$194,000	$194,000	$194,000	$194,000
Annual Cost ($/yr)	$32,455	$330	($48,503)	($55,223)	($68,797)
Emission Reduction (tons/yr)	37.9	113.7	222.7	237.7	268.0
Cost Effectiveness ($/ton)	$856	$3	-[a]	-[a]	-[a]
Regulatory Alternative 2					
Capital Investment ($)	$194,000	$194,000	$194,000	$194,000	$194,000
Annual Cost ($/yr)	$25,306	($22,633)	($99,520)	($101,750)	($121,840)
Emission Reduction (tons/yr)	55	165	330	335	380
Cost Effectiveness ($/ton)	$460	-[a]	-[a]	-[a]	-[a]

[a] Cost effectiveness not calculated because net annualized cost is a negative quantity (cost savings).

TABLE 16. SLABSTOCK FOAM MODEL PLANT COSTS FOR VARIABLE PRESSURE FOAMING HAP ABA EMISSION REDUCTION

	Model Plant Costs (1990 dollars)				
	MP1	MP2	MP3	MP4	MP5
MACT Floor					
Capital Investment ($)	$4,500,000	$4,500,000	$4,500,000	$4,500,000	$4,500,000
Annual Cost ($/yr)	$774,400	$724,400	$652,240	$642,720	$623,120
Emission Reduction (tons/yr)	31.3	93.8	184.0	195.9	220.4
Cost Effectiveness ($/ton)	$24,741	$7,723	$3,545	$3,281	$2,827
Regulatory Alternative 1					
Capital Investment ($)	$4,500,000	$4,500,000	$4,500,000	$4,500,000	$4,500,000
Annual Cost ($/yr)	$769,120	$708,480	$621,280	$609,280	$585,040
Emission Reduction (tons/yr)	37.9	113.7	222.7	237.7	268.0
Cost Effectiveness ($/ton)	$20,293	$6,231	$2,790	$2,563	$2,183
Regulatory Alternative 2					
Capital Investment ($)	$4,500,000	$4,500,000	$4,500,000	$4,500,000	$4,500,000
Annual Cost ($/yr)	$755,440	$667,486	$535,531	$531,546	$495,679
Emission Reduction (tons/yr)	55	165	330	335	380
Cost Effectiveness ($/ton)	$13,735	$4,047	$1,623	$1,587	$1,305

TABLE 17. SLABSTOCK FOAM MODEL PLANT COSTS FOR FORCED COOLING HAP ABA EMISSION REDUCTION

	Model Plant Costs (1994 dollars)				
	MP1	MP2	MP3	MP4	MP5
MACT Floor					
Capital Investment ($)	$1,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000
Annual Cost ($/yr)	$162,500	$305,180	$243,300	$243,318	$237,310
Emission Reduction (tons/yr)	31.3	93.8	184.0	195.9	220.4
Cost Effectiveness ($/ton)	$5,192	$3,254	$1,322	$1,243	$1,077
Regulatory Alternative 1					
Capital Investment ($)	$1,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000
Annual Cost ($/yr)	$157,220	$289,260	$212,340	$209,978	$199,230
Emission Reduction (tons/yr)	37.9	113.7	222.7	237.7	268.0
Cost Effectiveness ($/ton)	$4,148	$2,544	$953	$883	$743
Regulatory Alternative 2 Envirocure plus chemical alternatives					
Capital Investment ($)	$1,031,725	$2,031,725	$2,031,725	$2,031,725	$2,031,725
Annual Cost ($/yr)	$167,441	$308,350	$227,636	$241,513	$239,989
Emission Reduction (tons/yr)	55	165	330	335	380
Cost Effectiveness ($/ton)	$3,044	$1,869	$690	$721	$632

This resulted in a difference in the annual cost from the MACT floor and regulatory alternative 1 described above: the additional material cost of using chemical alternatives for the low-density, low-IFD foam grades. Details on this calculation are also contained in Attachment 12.

NATIONWIDE REGULATORY ALTERNATIVE COSTS AND HAP EMISSION REDUCTIONS

This section presents the nationwide costs and HAP emission reductions associated with the existing source regulatory alternatives presented earlier. The basic approach used to estimate these nationwide impacts was to apply the model plant impacts presented in the previous section to those facilities represented by the model plants.

In several instances, more than one technology could be used to achieve the level of control required by the regulatory alternative. In these cases, EC/R made assumptions regarding the number of facilities represented by each model plant that would use the various technologies. The following sections present these assumptions, and describe the calculation of the nationwide cost and HAP emission reductions.

Molded Foam Production

Only major sources of HAP will be subject to the Foam Production NESHAP. Since the high-pressure molded model plant and the smallest low-pressure molded model plant have emissions below the major source thresholds, it was assumed that the facilities represented by this model plant would not be affected by the Foam Production NESHAP. It could be maintained that these facilities, particularly the low-pressure facilities, have the potential to emit major source levels of HAP. However, EC/R assumed that these facilities would obtain federally enforceable permit requirements limiting HAP emissions below major source levels, rather than installing controls in accordance with the Foam Production NESHAP. Therefore, the nationwide regulatory alternative impacts are based on low-pressure model plants 2 and 3. The following paragraphs briefly discuss how the model plant impacts were used to estimate nationwide impacts. The distribution of technologies used to estimate the molded foam nationwide regulatory alternative costs by model plant is provided in Table 18.

<u>Mixhead flush</u>

Regulatory alternative 1 requires work practices to reduce mixhead flush emissions. As was shown in Table 5, the EPA developed model plant costs for four technologies: one for regulatory alternative 1 (solvent recovery) and three for regulatory alternative 2 (non-HAP flushes, high-pressure mixheads, and self-cleaning mixheads). While the three

TABLE 18. DISTRIBUTION OF TECHNOLOGIES USED TO ESTIMATE THE MOLDED FOAM NATIONWIDE REGULATORY ALTERNATIVE COSTS BY MODEL PLANT

Emission Source/Technology	Number of Facilities Using the Technology	
	Low-Pressure Model Plant 2	Low-Pressure Model Plant 3
Mixhead Flush		
Reg Alt I		
Solvent recovery	54	44
Reg Alt II		
Non-HAP flush	49	35
HP mixheads	5	9
Mold Release Agents		
MACT Floor		
Reduced VOC agents	18	15
Naphtha-based agents	18	14
Water-based agents	18	15
Repair Adhesives		
MACT Floor		
Hot-melt adhesives	N/A	22
Water-based adhesives	N/A	22

technologies that totally eliminate mixhead flush emissions could also be used to comply with regulatory alternative 1, it was assumed that no facility would totally eliminate HAP mixhead flushes to comply with the work practice standard. Therefore, the cost and HAP emission reduction for HAP mixhead flushes for regulatory alternative 1 are entirely based on the application of the solvent recovery model plant impacts to the 98 facilities represented by low-pressure model plants 2 and 3.

Regulatory alternative 2 prohibits the use of HAP mixhead flushes. As noted above, model plant costs were developed for three technologies that could be used to meet this requirement. To determine nationwide costs, self-cleaning mixheads were not considered an option, because they have significant limitations and are currently not in use in the industry.

It was assumed that more facilities would use non-HAP mixhead flushes than would use high-pressure mixheads, due to the high capital cost of high-pressure mixheads. In addition, fewer changes to the foam line are needed when converting to non-HAP flushes. Therefore, it was assumed that 90 percent of low-pressure model plant 2 facilities (49 facilities) and 80 percent of low-pressure model plant 3 facilities (35 facilities) would utilize non-HAP flushes, and the remainder would install high-pressure mixheads. The different assumptions associated with the two model plants are attributable to the assumption that a higher percentage of the larger facilities would be able to incur the capital cost of high-pressure mixheads.

Mold Release Agents

The emission limitation for mold release agents was the prohibition of HAP-based mold release agents for all three regulatory alternatives. As discussed earlier, model plant costs were developed for three technologies that meet this level: naphtha-based release agents, reduced-VOC release agents, and water-based release agents. It was assumed that the majority of facilities would choose either water-based or reduced-VOC release agents, as it was assumed that many facilities could not switch to naphtha-based release agents due to VOC emission limits. For each model plant it was assumed that 1 percent would use naphtha-based agents, and the remainder would be split evenly between the other two options.

Repair Adhesives

The emission limitation for repair adhesives was the prohibition of the use of HAP-based adhesives for all three regulatory alternatives. There were three technologies for which model plant costs were developed that meet this level: hot-melt adhesives, water-based adhesives, and hydrofuse. Hydrofuse was not considered in the regulatory cost analysis, because there are no known facilities in this industry using this technology. As there was no other information available regarding industry preference, it was assumed that 50 percent of the facilities would use water-based adhesives, and 50 percent would use hot-melt adhesives.

Slabstock Foam Production

The following sections describe the derivation of impacts for each of the four slabstock foam production emission sources.

Storage/unloading, equipment leaks, and equipment cleaning

As discussed earlier, model plant costs and HAP emission reductions were only developed for one technology for each emission source. Therefore, the nationwide regulatory alternative costs were simply determined by multiplying the model plant costs for each technology by the number of facilities represented by each model plant.

HAP ABA emissions

As discussed in the model plant section, there are a variety of technologies that reduce or eliminate the use of HAP ABA. Table 12 listed the assumptions regarding the technologies that could be utilized to meet each of the regulatory alternatives. In estimating the nationwide regulatory alternative costs, it was necessary to make assumptions regarding the number of facilities that would use each available technology to comply with the HAP ABA requirements. The distribution of technologies used to estimate the HAP ABA slabstock foam nationwide regulatory alternative costs by model plant is provided in Table 19.

MACT floor. For the MACT floor regulatory alternative, it was assumed that the majority of the facilities represented by the smaller model plants would choose to comply through the use of chemical alternatives. This is because of the low capital costs associated with chemical alternatives, and the fact that using this technology would result in less need for personnel retraining. At the other end of the spectrum is variable pressure foaming. Due to the high capital costs, it was assumed that only two of the largest facilities would install this technology.

It was assumed that most of the facilities not using chemical alternatives would comply through the use of either CarDio or forced cooling. The reduction of HAP ABA usage through forced cooling is a technology that has already penetrated the industry to a large degree.

While CarDio is a relatively new technology, it (and other liquid carbon dioxide systems) has generated considerable interest in the foam industry. Several companies that have already begun the installation of CarDio.

While acetone is a relatively low-cost technology, it was assumed that it would be used by a smaller number of facilities due to two issues often cited by industry. These are (1) anxieties surrounding the flammability of acetone, and (2) the fact that they would be forced to pay licensing fees to a competitor (Hickory Springs, a foam producer, holds the United States patent for the use of acetone as an ABA).

TABLE 19. DISTRIBUTION OF ABA EMISSION REDUCTION TECHNOLOGIES USED TO ESTIMATE THE SLABSTOCK FOAM NATIONWIDE REGULATORY ALTERNATIVE COSTS BY MODEL PLANT

Technology	Number of Facilities Using the Technology				
	MP1	MP2	MP3	MP4	MP5
MACT Floor					
CarDio	4	9	4	4	1
Acetone	1	1	1	1	0
VPF	0	0	0	0	2
Forced cooling	2	4	3	3	2
Chem Alts	12	14	6	3	1
Reg Alt I					
CarDio	13	18	6	5	1
Acetone	3	4	3	2	1
VPF	0	0	0	0	2
Forced cooling	3	6	5	4	2
Reg Alt II					
CarDio + Chem Alts	10	15	5	3	1
Acetone	3	3	2	2	1
VPF	0	1	1	2	2
Forced cool + Chem Alts	6	9	6	4	2

Regulatory alternative 1. Table 12 reported that chemical alternatives were not considered to be one of the technologies capable of meeting the HAP ABA emission levels of regulatory alternative 1. The assumption that was made regarding variable pressure foaming for the MACT floor regulatory alternative was maintained for regulatory alternative 1. Therefore, the technologies available were acetone, forced cooling, and CarDio. The high capital and annual costs associated with forced cooling led to the assumption that few smaller facilities would select this technology. Due to the limitations of acetone discussed previously, it was assumed that the majority of smaller facilities would select CarDio. For model plants 3 and 4, where it was assumed that capital costs were less of a problem, a smaller percentage were assumed to choose the CarDio technology. For model plant 5, it was assumed that the four technologies would be used in equal amounts.

Regulatory alternative 2. The rationale for the regulatory alternative 2 assumptions was basically the same as that discussed above for regulatory alternative 1 (noting of course that CarDio and forced cooling also use chemical alternatives for regulatory alternative 2). The one exception is that it was assumed that a few more large facilities would choose to spend the resources to install variable pressure foaming under regulatory alternative 2.

SUMMARY AND DISCUSSION OF REGULATORY ALTERNATIVE COSTS

This section summarizes the regulatory alternative costs. In addition to costs of the technologies to control HAP emissions, facilities will also incur costs for the associated monitoring, recordkeeping and reporting (MRR). For the purposes of this analysis, these MRR costs were estimated to be 8 percent of the control costs. Therefore, the total control costs calculated using the model plant costs was multiplied by 108 percent to obtain the total cost of control for each regulatory alternative.

Molded Foam Production

The nationwide regulatory alternative impacts for molded foam production are provided in Table 20. As shown in Table 20, the overall cost effectiveness values for all alternatives are less than $1,300 per ton of HAP emission reduction. However, due to the cost savings in controlling mixhead flush emissions under regulatory alternative 1, the incremental annual cost from the MACT floor regulatory alternative to regulatory alternative 1 is negative, resulting in a negative incremental cost effectiveness. The incremental cost effectiveness from regulatory alternative 1 to regulatory alternative 2 is $827 per ton of HAP emission reduction.

TABLE 20. MOLDED FOAM REGULATORY ALTERNATIVE COSTS

Regulatory Alternative	Impacts by Emission Source			
	Mixhead Flush	Mold Release Agent	Repair Adhesive	Total
MACT Floor				
Capital Investment ($)	$0	$0	$149,688	$149,688
Annual Control Cost ($/yr)	$0	$143,106	$38,984	$182,090
MRR Cost ($/yr)	$0	$10,859	$2,958	$13,817
Total Annual Cost ($/yr)	$0	$153,965	$41,942	$195,907
Emission Reduction (tons/yr)	0	271	61	332
Cost Effectiveness ($/ton)	$0	$569	$693	$592
Regulatory Alternative 1				
Capital Investment ($)	$4,630,500	$0	$149,688	$4,780,188
Annual Control Cost ($/yr)	($115,038)	$143,106	$38,984	$67,052
MRR Cost ($/yr)	($8,729)	$10,859	$2,958	$5,088
Total Annual Cost ($/yr)	($123,767)	$153,965	$41,942	$72,140
Emission Reduction (tons/yr)	1,501	270	61	1,832
Cost Effectiveness ($/ton)				
Overall	-[a]	$569	$693	$39
Incremental	-[b]	NA[c]	NA[c]	-[a]
Regulatory Alternative 2				
Capital Investment ($)	$5,923,125	$0	$149,688	$6,072,813
Annual Control Cost ($/yr)	$524,098	$143,106	$38,984	$706,188
MRR Cost ($/yr)	$39,769	$10,859	$2,958	$53,587
Total Annual Cost ($/yr)	$563,867	$153,965	$41,942	$759,775
Emission Reduction (tons/yr)	2,001	271	61	2,332
Cost Effectiveness ($/ton)				
Overall	$282	$569	$693	$326
Incremental	$1,375	NA[c]	NA[c]	$1,375

[a] Cost effectiveness not calculated because net annual cost is a negative quantity (cost savings).
[b] Incremental cost effectiveness not calculated because incremental annual cost is a negative quantity.
[c] There are no incremental impacts since the requirements of the regulatory alternative for the emission source are identical to the requirements of the previous alternative.

Slabstock Foam Production

The nationwide regulatory alternative impacts for slabstock foam production are provided in Table 21. There are two sets of impacts shown for regulatory alternative 2. The first only takes into account the "direct" HAP emission reductions associated with the regulatory alternative emission requirements. However, as discussed earlier, the elimination of the use and emission of HAP ABA will also result in the elimination of HAP ABA emissions from storage and equipment leaks. The second set of impacts include these "indirect" HAP emission reductions.

The cost effectiveness of all three regulatory alternatives are less than $600 per ton of emission reduction, with the highest being the MACT floor level of control at $592 per ton. Due to the incremental annual cost savings for the regulatory alternative 1 HAP ABA requirements, the overall incremental cost effectiveness from the MACT floor to regulatory alternative 1 is negative. The incremental cost effectiveness from regulatory alternative 1 to regulatory alternative 2 is $1,375 per ton, considering the indirect emission reductions.

While the overall cost effectiveness of regulatory alternative 2, and the incremental cost effectiveness from regulatory alternative 1 to regulatory alternative 2, are within ranges typically considered reasonable by the EPA, there are other considerations that should be pointed out. Primarily, there is substantial concern within the industry whether a complete range of foams of acceptable market quality can be produced without any $MeCl_2$ ABA. The manufacturers of the HAP ABA reduction technologies maintain that the foam quality does not suffer with the use of these technologies. However, the use of these technologies in the total absence of the use of HAP ABA, while still producing a complete product line, is very limited. A second consideration is the issue of plant safety. Use of a flammable solvent (acetone) as an ABA, and dangers associated with the extremely exothermic nature of the foam polymerization reaction, create potential fire hazards. While the designs of these systems include safeguards against potential hazards, it should be noted that the use of one of these technologies resulted in a recent plant fire that consumed the entire facility.

TABLE 21. SLABSTOCK FOAM REGULATORY ALTERNATIVE COSTS

	Impacts by Emission Source				
	Storage/ Unloading	Equipment Leaks	Equipment Cleaning	ABA	Total
MACT Floor					
Capital Investment ($)	$558,960	$95,000	$0	$46,362,700	$47,016,660
Annual Control Cost ($/yr)	$105,119	$24,035	($7,150)	$10,925,497	$11,047,501
MRR Cost ($/yr)	$7,977	$1,824	($543)	$829,045	$838,302
Total Annual Cost ($/yr)	$113,096	$25,859	($7,693)	$11,754,542	$11,885,803
Emission Reduction (tons/yr)	15	3	130	9,273	9,422
Cost Effectiveness ($/ton)	$7,342	$8,006	-[a]	$1,268	$1,262
Regulatory Alternative 1					
Capital Investment ($)	$558,960	$682,754	$0	$66,981,900	$68,223,614
Annual Control Cost ($/yr)	$105,119	$489,455	($7,150)	$6,241,347	$6,828,771
MRR Cost ($/yr)	$7,977	$37,141	($543)	$473,604	$518,178
Total Annual Cost ($/yr)	$113,096	$526,596	($7,693)	$6,714,951	$7,346,949
Emission Reduction (tons/yr)	15	80	130	11,262	11,488
Cost Effectiveness ($/ton)					
Overall	$7,342	$6,552	-[a]	$596	$640
Incremental	NA[b]	$6,491	NA[g]	-[c]	-[c]
Regulatory Alternative 2					
Capital Investment ($)	$308,250	$95,000	$0	$93,665,425	$94,068,675
Annual Control Cost ($/yr)	$65,447	$24,035	($7,150)	$10,509,858	$10,592,190
MRR Cost ($/yr)	$4,966	$1,824	($543)	$797,505	$803,753
Total Annual Cost ($/yr)	$70,413	$25,859	($7,693)	$11,307,363	$11,395,943
Emission Reduction (tons/yr)	0	3	130	16,250	16,383
Cost Effectiveness ($/ton)					
Overall	$4,661,584	$8,006	-[a]	$696	$696
Incremental	NA[e]	$6,491	NA[b]	$921	$827
With Indirect Emission Reductions					
HAP ABA Emission Reduction	16.7	141.5	-[d]	-[d]	158.2
Cost Effectiveness					
Overall	-[f]	-[f]	-[d]	-[d]	$689
Incremental					$801

Footnotes for Table 21

[a] Cost effectiveness not calculated because net annual cost is a negative quantity (cost savings).

[b] There are no incremental impacts since the requirements of the regulatory alternative for the emission source are identical to the requirements of the previous alternative.

[c] Incremental cost effectiveness not calculated because incremental annual cost is a negative quantity.

[d] There are no indirect emission reductions associated with regulatory alternative 2 for this emission source.

[e] Since regulatory alternative 2 prohibits the emissions of HAP ABA, there are no storage/unloading or equipment leak requirements under this alternative for HAP ABA storage vessels or components in HAP ABA service. Therefore, the incremental cost effectiveness for these emissions is not appropriate.

[f] There are no costs associated with these indirect emission reductions, therefore cost effectiveness was not calculated.

ATTACHMENTS

Attachment Number	Description of Attachment
1	HAP ABA Regulatory Alternative Requirements
2	Model Plant Information
3	Molded Foam Model Plant Costs
4	Slabstock Foam Vapor Balance Costs
5	Slabstock Foam Non-HAP Equipment Cleaner Costs
6	Slabstock Foam Equipment Leak Model Plant Costs
7	Slabstock Foam Model Plant HAP ABA Regulatory Alternative Emissions
8	Slabstock Foam Model Plant Costs for Chemical Alteratives
9	Slabstock Foam Model Plant Costs for CarDio
10	Slabstock Foam Model Plant Costs for Acetone
11	Slabstock Foam Model Plant Costs for Variable Pressure Foaming
12	Slabstock Foam Model Plant Costs for Forced Cooling

ATTACHMENT 1

HAP ABA REGULATORY ALTERNATIVE REQUIREMENTS

- The allowable HAP ABA emissions for a single month are determined using the following equation:

$$emiss_{allow,month_j} = \sum_{i=1}^{n} \frac{(limit_i)(polyol_i)}{100}$$

where,

$emiss_{allow,month_j}$ = Allowable emissions due to use of a HAP auxiliary blowing agent for month j, megagrams

$polyol_i$ = Amount of polyol used in the month in the production of foam grade i, megagrams

n = Number of foam grades produced in the month

$limit_i$ = HAP ABA formulation limit for foam grade i, parts ABA per 100 parts polyol. For the MACT floor, the HAP ABA formulation limits are obtained the table on the following page. For regulatory alternative 1, the HAP ABA formulation limitations are obtained using the equation on the following page.

Attachment 1
HAP ABA Regulatory Alternative Requirements

MACT FLOOR HAP ABA FORMULATION LIMITATIONS

Table values in parts ABA per hundred parts polyol		Density ranges (pounds per cubic foot)				
		0-0.95	0.96-1.05	1.06-1.15	1.16-1.40	1.41+
IFD	0-10	12	11		6	2
	11-15					
	16-20	10	8			
	21-25	9	7		4	2
	26-30	6	4	3		
	31+	5	4	2	1	0

EQUATION TO CALCULATE HAP ABA FORMULATION LIMITATIONS FOR REGULATORY ALTERNATIVE 1

$$ABA_{limit} = -0.25(IFD) - 19.1\left(\frac{1}{IFD}\right) - 16.2(DEN) - 7.56\left(\frac{1}{DEN}\right) + 36.5$$

- For either alternative, the IFD and density of the foam will be determined using standard industry quality control techniques on a sample from the core of the foam bun.

Attachment 1
HAP ABA Regulatory Alternative Requirements

- The allowable emissions for the 12-month period are calculated using the following equation:

$$emiss_{allow,12\text{-}month} = \sum_{j=1}^{12} (emiss_{allow,month_j})$$

where,

$emiss_{allow,12\text{-}month}$ = Allowable emissions due to the use of a HAP auxiliary blowing agent for the previous 12-month period, Megagrams

- Compliance with the HAP ABA emission requirements is determined each month, by comparing the allowable emissions for the previous 12-month period with the actual HAP ABA emissions for the same 12-month period. Allowable and actual HAP ABA emissions are rounded to the nearest megagram, with 0.5 megagrams rounded up.

- If add-on control (e.g., carbon adsorption, incineration, etc.) is used to reduce emissions, the emissions after control will have to be verified using source testing.

ATTACHMENT 2

MODEL PLANT INFORMATION

Molded model plant parameters 2-2

Slabstock model plant parameters

Basic parameters 2-3

Formulation, production, and cost parameters 2-4 thru 2-8

MOLDED FOAM BASELINE MODEL PLANT PARAMETERS

	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
Baseline Operating Parameters				
Foam production range (tons/yr)	0–15000	0–99	100–499	>500
Average Foam Production (tons/yr)	3,331	26	308	2,718
Number of carousels	2	5	5	5
Number of Repair Stations	2	1	2	2
MeCl2 used as mixhead flush (drums/year)	0	19	72	177
MeCl2 used as mixhead flush (tons/year)	0	6	22	54
Waste MeCl2 from flush (55–g drum/year)	0	2	8	18
Waste MeCl2 from flush (tons/year)	0	1	2	5
HAP Mold release agent (gal/yr)	0	41	32	831
Amount of adhesive used for repair (gal/year)	581	0	0	66
HAP content of adhesive	70	0	0	70
Number of Facilities represented nationwide	27	109	54	44
Baseline Cost Parameters				
Cost of MeCl2 ($/lb)	$0	$0	$0	$0
Cost of MeCl2 ($/ton)	$800	$800	$800	$800
Cost of MeCl2 ($/55–gal drum)	$244	$244	$244	$244
Cost of Non–HAP Flush ($/55–gal drum)	$0	$838	$838	$838
Disposal cost of waste MeCl2 ($/55–gallon drum)	$800	$800	$800	$800
Cost of HAP based MR agent for plant ($/yr)	$0	$198	$154	$4,005
Cost of HAP adhesive for plant ($/yr)	$4,939	$0	$0	$561
Baseline Emissions (tons/year)				
Emissions from mixhead flush	0	5.14	19.69	21.31
Emissions from mold release agents	0	0.15	0.12	6.00
Emissions from repair	2.09	0.00	0.00	1.35
Model Plant Total	2.09	5.29	19.81	28.66

SLABSTOCK FOAM MODEL PLANT PARAMETERS

	Model Plant 1		Model Plant 2		Model Plant 3		Model Plant 4		Model Plant 5	
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
MeCl2 cost	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Baseline Operating Parameters										
Foam Production Range (1000 tons/yr)	0–3.9	0–3.9	4.0–7.9	4.0–7.9	8.0–11.9	8.0–11.9	12.0–15.9	12.0–15.9	>16	>16
Average foam production (tons/yr)	2,000	2,000	6,000	6,000	10,000	10,000	13,750	13,750	19,000	19,000
Number of MeCl2 Storage Tanks (10,000 gal)	1	1	1	1	1	1	1	1	1	1
Number of TDI Storage tanks (10,000 gal)	1	1	2	2	3	3	3	3	3	3
Number of components in HAP service										
MeCl2										
Transfer pumps	1	1	1	1	1	1	1	1	1	1
Metering pumps	1	1	1	1	1	1	1	1	1	1
Valves	16	16	16	16	16	16	16	16	16	16
Flanges/connectors	20	20	20	20	20	20	20	20	20	20
Pressure–relief valves	2	2	2	2	2	2	2	2	2	2
Open–ended lines	6	6	6	6	6	6	6	6	6	6
TDI										
Transfer pumps	1	1	2	2	3	3	3	3	3	3
Metering pumps	1	1	1	1	1	1	1	1	1	1
Valves	16	16	24	24	32	32	32	32	32	32
Flanges/connectors	200	200	250	250	300	300	300	300	300	300
Pressure–relief valves	0	0	0	0	0	0	0	0	0	0
Open–ended lines	12	12	15	15	18	18	18	18	18	18
Number of Production Lines	1	1	1	1	1	1	1	1	1	1
Speed of Line (ft/min)	15	15	15	15	15	15	15	15	15	15
Line electricity Use (kw)	120	120	120	120	120	120	120	120	120	120
MeCL2 used as ABA (gal)	9,900	9,900	29,800	29,800	59,600	59,600	60,500	60,500	68,600	68,600
MeCL2 used as ABA (tons)	55	55	165	165	330	330	335	335	380	380
MeCl2 used as Cleaner (gallons)	994	0	994	0	994	0	994	0	994	0
Waste MeCl2 from Cleaning (gallons)	99	0	99	0	99	0	99	0	99	0
MeCl2 used as cleaner/barrels	18	0	18	0	18	0	18	0	18	0
Number of plants represented nationwide	6	13	9	19	5	9	4	7	2	4
Baseline Cost Parameters										
Cost of MeCl2/gal (@ $0.40/lb)	$4.43	$4.43	$4.43	$4.43	$4.43	$4.43	$4.43	$4.43	$4.43	$4.43
Cost of MeCl2/ton	$800	$800	$800	$800	$800	$800	$800	$800	$800	$800
Cost of HAP ABA ($/yr)	$44,000	$44,000	$131,954	$131,954	$263,909	$263,909	$267,894	$267,894	$303,761	$303,761
Cost of HAP cleaner ($/yr)	$4,401	$0	$4,401	$0	$4,401	$0	$4,401	$0	$4,401	$0
Total Chemical Cost ($/yr)	$2,726,516	$2,722,116	$8,583,400	$8,579,000	$14,360,400	$14,356,000	$19,645,400	$19,641,000	$26,974,400	$26,970,000
ABA–blown Chemical Cost ($/yr)	$2,172,298	$2,172,298	$6,517,000	$6,517,000	$11,057,000	$11,057,000	$14,541,000	$14,541,000	$17,568,000	$17,568,000
Total facility Operating Costs ($/yr)	$3,408,148	$3,402,648	$10,729,250	$10,724,000	$17,950,500	$17,945,000	$24,556,750	$24,551,000	$33,718,000	$33,713,000
Disposal cost of waste MeCl2 ($/yr)	$1,446	$0	$1,446	$0	$1,446	$0	$1,446	$0	$1,446	$0
Baseline Emissions (tons/yr)										
TDI										
Storage	0	0	0	0	0	0	0	0	0	0
Equipment Leaks	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
TDI Total	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
MeCl2										
Storage	0.09	0.09	0.26	0.26	0.52	0.52	0.03	0.03	0.03	0.03
ABA	55	55	165	165	330	330	335	335	380	380
Equipment cleaning	5.0	0.0	5.0	0.0	5.0	0.0	5.0	0.0	5.0	0.0
Equipment leaks	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.1	3.1
MeCl2 Total	64	59	174	169	339	334	343	338	388	383
Model Plant Total	64	59	174	169	339	334	343	338	388	383

MODEL PLANT 1

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Baseline annual chem cost ($/yr)
0930	0.9	30	80	10	5.3	$126,550
1010	1.0	10	40	22	5.9	$60,784
1015	1.0	15	40	19	4.9	$60,831
1020	1.0	20	40	14	3.7	$60,941
1030	1.0	30	80	8	4.0	$123,559
1120	1.1	20	40	14	3.6	$59,609
1130	1.1	30	60	7	2.6	$90,710
1230	1.2	30	100	5	3.3	$148,042
1330	1.3	30	60	6	2.2	$87,835
1340	1.3	40	60	2	0.8	$88,883
1440	1.4	40	60	2	0.8	$87,446
1520	1.5	20	40	13	3.3	$56,584
1530	1.5	30	40	6	1.6	$56,920
1540	1.5	40	120	2	1.6	$172,324
1640	1.6	40	120	1	0.8	$170,955
1740	1.7	40	120	1	0.8	$168,493
1820	1.8	20	60	10	4.0	$82,164
1830	1.8	30	60	6	2.2	$82,890
1840	1.8	40	120	0	0.0	$166,439
1930	1.9	30	60	7	2.8	$82,599
1940	1.9	40	100	1	0.7	$137,740
>2020	2.5	25	500	0	0.0	$549,820
				Total	55	

w/o MeCl2 Cleaning	baseline
ABA cost	$44,000 /yr
chem cost	$2,722,118 /yr
ABA foam	$2,172,298 /yr
Total cost	$3,402,648 /yr
With MeCl2 Cleaning	
ABA cost	$44,000 /yr
Clean Cost	$4,400 /yr
chem cost	$2,726,518 /yr
ABA foam	$2,172,298 /yr
Total cost	$3,408,148 /yr

MODEL PLANT 2

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Baseline annual chem cost ($/yr)
0930	0.9	30	240	10	16.0	$379,649
1010	1.0	10	120	22	17.6	$182,353
1015	1.0	15	120	19	14.8	$182,493
1020	1.0	20	120	14	11.2	$182,823
1030	1.0	30	240	8	12.0	$370,678
1120	1.1	20	120	14	10.8	$178,827
1130	1.1	30	180	7	7.8	$272,130
1230	1.2	30	300	5	10.0	$444,127
1330	1.3	30	180	6	6.6	$263,505
1340	1.3	40	180	2	2.4	$266,648
1440	1.4	40	180	2	2.4	$262,337
1520	1.5	20	120	13	10.0	$169,752
1530	1.5	30	120	6	4.8	$170,760
1540	1.5	40	360	2	4.8	$516,972
1640	1.6	40	360	1	2.4	$512,866
1740	1.7	40	360	1	2.4	$505,460
1820	1.8	20	180	10	12.0	$246,492
1830	1.8	30	180	6	6.6	$248,671
1840	1.8	40	360	0	0.0	$499,317
1930	1.9	30	180	7	8.4	$247,796
1940	1.9	40	300	1	2.0	$413,219
>2020	2.0	25	1,500	0	0.0	$2,061,825
				Total	165	

w/o MeCl2 Cleaning	baseline
ABA cost	$132,000 /yr
chem cost	$8,579,000 /yr
ABA foam	$6,517,000 /yr
Total cost	$10,724,000 /yr
With MeCl2 Cleaning	
ABA cost	$132,000 /yr
Clean Cost	$4,400 /yr
chem cost	$8,583,400 /yr
ABA foam	$6,517,000 /yr
Total cost	$10,729,250 /yr

MODEL PLANT 3

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Baseline annual chem cost ($/yr)
0930	0.9	30	600	10	40.0	$949,123
1010	1.0	10	300	22	44.0	$455,882
1015	1.0	15	300	19	37.0	$456,233
1020	1.0	20	200	14	18.7	$304,706
1030	1.0	30	500	8	25.0	$772,245
1120	1.1	20	200	14	18.0	$298,044
1130	1.1	30	300	7	13.0	$453,550
1230	1.2	30	500	5	16.7	$740,212
1330	1.3	30	300	6	11.0	$439,175
1340	1.3	40	200	2	2.7	$296,275
1440	1.4	40	300	2	4.0	$437,229
1520	1.5	20	300	13	25.0	$424,380
1530	1.5	30	200	6	8.0	$284,599
1540	1.5	40	500	2	6.7	$718,016
1640	1.6	40	400	1	2.7	$569,852
1740	1.7	40	400	1	2.7	$561,645
1820	1.8	20	400	10	26.7	$547,760
1830	1.8	30	300	6	11.0	$414,452
1840	1.8	40	600	0	0.0	$832,195
1930	1.9	30	300	7	14.0	$412,993
1940	1.9	40	500	1	3.3	$688,698
>2020	2.0	25	2,400	0	0.0	$3,298,920
				Total	330	

w/o MeCl2 Cleaning	**baseline**
ABA cost	$264,000 /yr
chem cost	$14,356,000 /yr
ABA foam	$11,057,000 /yr
Total cost	$17,945,000 /yr
With MeCl2 Cleaning	
ABA cost	$264,000 /yr
Clean Cost	$4,400 /yr
chem cost	$14,360,400 /yr
ABA foam	$11,057,000 /yr

MODEL PLANT 4

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Baseline annual chem cost ($/yr)
0930	0.9	30	550	10	36.7	$870,029
1010	1.0	10	140	22	20.5	$212,745
1015	1.0	15	140	19	17.3	$212,909
1020	1.0	20	140	14	13.1	$213,294
1030	1.0	30	550	8	27.5	$849,469
1120	1.1	20	280	14	25.2	$417,262
1130	1.1	30	410	7	17.8	$619,851
1230	1.2	30	690	5	23.0	$1,021,492
1330	1.3	30	410	6	15.0	$600,206
1340	1.3	40	550	2	7.3	$814,757
1440	1.4	40	410	2	5.5	$597,546
1520	1.5	20	280	13	23.3	$396,088
1530	1.5	30	410	6	16.4	$583,429
1540	1.5	40	690	2	9.2	$990,863
1640	1.6	40	830	1	5.5	$1,182,442
1740	1.7	40	830	1	5.5	$1,165,412
1820	1.8	20	410	10	27.3	$561,453
1830	1.8	30	410	6	15.0	$566,418
1840	1.8	40	830	0	0.0	$1,151,203
1930	1.9	30	410	7	19.1	$564,424
1940	1.9	40	690	1	4.6	$950,404
>2020	2.0	25	3,710	0	0.0	$5,099,580
				Total	335	

	baseline
w/o MeCl2 Cleaning	
ABA cost	$267,900 /yr
chem cost	$19,641,000 /yr
ABA foam	$14,541,000 /yr
Total cost	$24,551,000 /yr
With MeCl2 Cleaning	
ABA cost	$267,900 /yr
Clean Cost	$4,400 /yr
chem cost	$19,645,400 /yr
ABA foam	$14,541,000 /yr
Total cost	$24,556,750 /yr

MODEL PLANT 5

Grade	Density (pcf)	IFD (25%)	%prod normalized	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Baseline annual chem cost ($/yr)
0930	0.9	30	3.0	570	10	38.0	$901,667
1010	1.0	10	1.0	190	22	27.9	$288,725
1015	1.0	15	1.0	190	19	23.4	$288,947
1020	1.0	20	1.0	190	14	17.7	$289,470
1030	1.0	30	3.0	570	8	28.5	$880,359
1120	1.1	20	1.0	190	14	17.1	$283,142
1130	1.1	30	3.0	570	7	24.7	$861,744
1230	1.2	30	5.0	950	5	31.7	$1,406,402
1330	1.3	30	3.0	570	6	20.9	$834,433
1340	1.3	40	3.0	570	2	7.6	$844,384
1440	1.4	40	3.0	570	2	7.6	$830,735
1520	1.5	20	1.0	190	13	15.8	$268,774
1530	1.5	30	2.0	380	6	15.2	$540,739
1540	1.5	40	5.0	950	2	12.7	$1,364,231
1640	1.6	40	5.0	950	1	6.3	$1,353,398
1740	1.7	40	5.0	950	1	6.3	$1,333,906
1820	1.8	20	2.0	380	10	25.3	$520,372
1830	1.8	30	3.0	570	6	20.9	$787,460
1840	1.8	40	6.5	1,240	0	0.0	$1,719,869
1930	1.9	30	3.0	570	7	26.6	$784,686
1940	1.9	40	4.5	860	1	5.7	$1,184,561
>2020	2.0	25	36.0	6,840	0	0.0	$9,401,921
					Total	380	

w/o MeCl2 Cleaning	baseline
ABA cost	$304,000 /yr
chem cost	$26,970,000 /yr
ABA foam	$17,568,000 /yr
Total cost	$33,713,000 /yr
With MeCl2 Cleaning	
ABA cost	$304,000 /yr
Clean Cost	$4,400 /yr
chem cost	$26,974,400 /yr
ABA foam	$17,568,000 /yr
Total cost	$33,716,000 /yr

ATTACHMENT 3

MOLDED FOAM MODEL PLANT COSTS

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MOLDED FOAM MODEL PLANT COSTS

MODEL PLANT COSTS FOR MIXHEAD FLUSH EMISSION REDUCTION

TECHNOLOGY: Non-HAP Flushes

	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
CAPITAL INVESTMENT				
Purchased equipment cost	$0	$0	$0	$0
Direct installation	$0	$0	$0	$0
indirect installation	$0	$0	$0	$0
TOTAL CAPITAL INVESTMENT	$0	$0	$0	$0
ANNUAL COSTS (vendor supplied)				
Direct cost				
materials	$0	$680	$2,577	$6,335
waste treatment	$0	($1,600)	($6,400)	($14,400)
Indirect Costs				
capital recovery	$0	$0	$0	$0
administrative charges	$0	$0	$0	$0
TOTAL ANNUAL COST	$0	($920)	($3,823)	($8,065)
EMISSION REDUCTION (TONS/YR)	0.00	5.14	19.69	21.31
COST EFFECTIVENESS ($/TON)	$0	($179)	($194)	($378)

MOLDED FOAM MODEL PLANT COSTS

	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
MODEL PLANT COSTS FOR MIXHEAD FLUSH EMISSION REDUCTION				
TECHNOLOGY: High-pressure mixheads				
CAPITAL INVESTMENT				
Purchased equipment cost (vendor + 3% tax + 5% freight)	$0	$526,500	$526,500	$526,500
Direct installation (20% PEC)	$0	$105,300	$105,300	$105,300
indirect installation (5% PEC)	$0	$26,325	$26,325	$26,325
TOTAL CAPITAL INVESTMENT	$0	$658,125	$658,125	$658,125
ANNUAL COSTS				
Direct cost (vendor supplied)				
maintenance	$0	$50,000	$50,000	$50,000
materials	$0	($4,627)	($17,535)	($43,107)
waste treatment	$0	($1,600)	($6,400)	($14,400)
Indirect Costs				
capital recovery (14.24% - 7% for 10 years)	$0	$93,717	$93,717	$93,717
administrative charges (4% of TCI)	$0	$26,325	$26,325	$26,325
TOTAL ANNUAL COST	$0	$163,815	$146,107	$112,535
EMISSION REDUCTION (TONS/YR)	0.0	5.14	19.69	21.31
COST EFFECTIVENESS ($/TON)	$0	$31,871	$7,420	$5,281

MOLDED FOAM MODEL PLANT COSTS

	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
MODEL PLANT COSTS FOR MIXHEAD FLUSH EMISSION REDUCTION				
TECHNOLOGY: Self Cleaning Mixheads				
CAPITAL INVESTMENT				
Purchased equipment cost (vendor + 3% tax + 5% freight)	$0	$180,550	$180,550	$180,550
Direct installation (20% PEC)	$0	$36,110	$36,110	$36,110
indirect installation (5% PEC)	$0	$9,028	$9,028	$9,028
TOTAL CAPITAL INVESTMENT	$0	$225,688	$225,688	$225,688
ANNUAL COSTS				
Direct cost (vendor supplied)				
materials	$0	($4,627)	($17,535)	($43,107)
waste treatment	$0	($1,600)	($6,400)	($14,400)
Indirect Costs				
capital recovery (14.24% – 7% for 10 years)	$0	$32,138	$32,138	$32,138
administrative charges (4% of TCI)	$0	$9,028	$9,028	$9,028
TOTAL ANNUAL COST	$0	$34,938	$17,231	($16,341)
EMISSION REDUCTION (TONS/YR)	0.00	5.14	19.69	21.31
COST EFFECTIVENESS ($/TON)	$0	$6,797	$875	($767)

MOLDED FOAM MODEL PLANT COSTS

	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
MODEL PLANT COSTS FOR MIXHEAD FLUSH EMISSION REDUCTION				
TECHNOLOGY: Solvent Recovery System				
CAPITAL INVESTMENT				
Purchased equipment cost (vendor + 3% tax + 5% freight)	$0	$37,800	$37,800	$37,800
Direct installation (20% PEC)	$0	$7,560	$7,560	$7,560
indirect installation (5% PEC)	$0	$1,890	$1,890	$1,890
TOTAL CAPITAL INVESTMENT	$0	$47,250	$47,250	$47,250
ANNUAL COSTS				
Direct cost (vendor supplied)	$0			
materials	$0	($3,470)	($13,151)	($32,330)
operating labor	$0	$9,600	$9,600	$9,600
supervisory labor		$1,440	$1,440	$1,440
waste treatment	$0	$600	($3,000)	($9,000)
Indirect Costs				
capital recovery (14.24% – 7% for 10 years)	$0	$6,728	$6,728	$6,728
overhead (60% of labor costs)	$0	$6,624	$6,624	$6,624
administrative charges (4% of TCI)	$0	$1,890	$1,890	$1,890
TOTAL ANNUAL COST	$0	$23,412	$10,131	($15,048)
EMISSION REDUCTION (TONS/YR)	0.00	3.86	14.77	15.98
COST EFFECTIVENESS ($/TON)	$0	$6,073	$686	($942)

MOLDED FOAM MODEL PLANT COSTS

	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
MODEL PLANT COSTS FOR MOLD RELEASE AGENT EMISSION REDUCTION				
TECHNOLOGY: Reduced VOC Mold Release Agents				
CAPITAL INVESTMENT				
TOTAL CAPITAL INVESTMENT	$0	$0	$0	$0
ANNUAL COSTS				
Direct cost (vendor supplied)				
materials	$0	$50	$39	$1,023
Indirect Costs				
capital recovery	$0	$0	$0	$0
administrative charges	$0	$0	$0	$0
TOTAL ANNUAL COST	$0	$50	$39	$1,023
EMISSION REDUCTION (TONS/YR)		0.15	0.12	6.00
COST EFFECTIVENESS ($/TON)		$337	$328	$171
TECHNOLOGY: Naphtha-based mold release agents				
CAPITAL INVESTMENT				
TOTAL CAPITAL INVESTMENT	$0			
ANNUAL COSTS				
Direct cost (vendor supplied)				
materials	$0	$375	$293	$7,599
Indirect Costs				
capital recovery	$0	$0	$0	$0
overhead	$0	$0	$0	$0
TOTAL ANNUAL COST	$0	$375	$293	$7,599
EMISSION REDUCTION (TONS/YR)	0	0.15	0.12	6
COST EFFECTIVENESS ($/TON)		$2,500	$2,439	$1,267

MOLDED FOAM MODEL PLANT COSTS

	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
MODEL PLANT COSTS FOR MOLD RELEASE AGENT EMISSION REDUCTION				
TECHNOLOGY: Water-based mold release agent				
CAPITAL INVESTMENT				
TOTAL CAPITAL INVESTMENT	$0	$0	$0	$0
ANNUAL COSTS				
Direct cost (vendor supplied) materials	$0	$48	$38	$981
TOTAL ANNUAL COST	$0	$48	$38	$981
EMISSION REDUCTION (TONS/YR)	0.00	0.15	0.12	6.00
COST EFFECTIVENESS ($/TON)	$0	$323	$315	$163

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MOLDED FOAM MODEL PLANT COSTS

	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
MODEL PLANT COSTS FOR REPAIR ADHESIVE EMISSION REDUCTION				
TECHNOLOGY: Hot-melt adhesives				
CAPITAL INVESTMENT				
Purchased equipment cost (vendor + 3% tax + 5% freight)	$6,480	$0	$0	$6,480
Indirect installation (5% PEC)	$324	$0	$0	$324
TOTAL CAPITAL INVESTMENT	$6,804	$0	$0	$6,804
ANNUAL COSTS				
Direct cost (vendor supplied)				
materials	$5,087	$0	$0	$578
utilities	$50			$50
Indirect Costs		$0	$0	
capital recovery (14.24% – 7% for 10 years)	$969	$0	$0	$969
administrative charges (4% of TCI)	$272	$0	$0	$272
TOTAL ANNUAL COST	$6,377	$0	$0	$1,869
EMISSION REDUCTION (TONS/YR)	2.09	0.00	0.00	1.35
COST EFFECTIVENESS ($/TON)	$3,047	$0	$0	$1,384
TECHNOLOGY: Water-based adhesives				
CAPITAL INVESTMENT				
TOTAL CAPITAL INVESTMENT	$0	$0	$0	$0
ANNUAL COSTS				
Direct cost (vendor supplied)				
materials	($854)	$0	$0	($97)
Indirect Costs				
capital recovery	$0	$0	$0	
overhead	$0	$0	$0	
TOTAL ANNUAL COST	($854)	$0	$0	($97)
EMISSION REDUCTION (TONS/YR)	2.09	0.00	0.00	1.35
COST EFFECTIVENESS ($/TON)	($408)	$0	$0	($72)

MOLDED FOAM MODEL PLANT COSTS

	HP Model Plant	LP Model Plant 1	LP Model Plant 2	LP Model Plant 3
MODEL PLANT COSTS FOR REPAIR ADHESIVE EMISSION REDUCTION				
TECHNOLOGY: Hydrofuse Adhesive				
CAPITAL INVESTMENT				
Purchased equipment cost (vendor + 3% tax + 5% freight)	$5,400	$0	$0	$5,400
Indirect installation (5% PEC)	$270	$0	$0	$270
TOTAL CAPITAL INVESTMENT	$5,670	$0	$0	$5,670
ANNUAL COSTS				
Direct cost				
materials	($296)	$0	$0	($34)
Indirect Costs				
capital recovery (14.24% – 7% for 10 years)	$807	$0	$0	$807
administrative charges (4% of TCI)	$227	$0	$0	$227
TOTAL ANNUAL COST	$738	$0	$0	$1,001
EMISSION REDUCTION (TONS/YR)	2.09	0.00	0.00	1.35
COST EFFECTIVENESS ($/TON)	$353	$0	$0	$741

ATTACHMENT 4

SLABSTOCK FOAM VAPOR BALANCE COSTS

VAPOR BALANCE COSTS FOR FOAM STORAGE VESSELS

Capital cost for vapor balance — $4,110 p. 7–28 of Gasoline Distribution Proposal BID (EPA–453/R–94–002a)
Taking difference in cost of balancing incoming and outgoing loads ($31,208)
and cost of balancing outgoing loads ($23,227)
and dividing by two (since this cost is for a bulk plant with two storage tanks)
and then adjusting using Chemical Engineering Plant Cost Index from 1990 (357.6) to 1994 (368.1)

	MP1	MP2	MP3	MP4	MP5
Number of MeCl2 uncontrolled tanks	1	1	1		
MeCl2 Emissions (Mg/yr)	0.087	0.26	0.52	0.03	0.03
Number of TDI uncontrolled tanks	1	2			
TDI Emissions (Mg/yr)	0.0001	0.0005			
Costs for vapor balance – MACT floor and regulatory alternative 1					
Capital Costs	$8,220	$12,330	$4,110		
Annual O&M (3%)	$247	$370	$123		
Capital Charges (14.24%)	$1,171	$1,756	$585		
Taxes, Ins. (4%)	$329	$493	$164		
Recovery credit	$73	$218	$435		
Total Annual Costs	$1,673	$2,400	$438		
Emission reduction	0.082745	0.247475	0.494		
MeCl2	0.08265	0.247	0.494		
TDI	0.000095	0.000475	0		
Cost Effectiveness	$20,218	$9,700	$887		
Costs for vapor balance – regulatory alternative 2					
Capital Costs	$4,110	$8,220			
Annual O&M (3%)	$123	$247			
Capital Charges (14.24%)	$585	$1,171			
Taxes, Ins. (4%)	$164	$329			
Recovery credit	$0	$1			
Total Annual Costs	$873	$1,745			
Emission reduction	0.000095	0.000475			
MeCl2	0	0			
TDI	0.000095	0.000475			
Cost Effectiveness	$9,186,710	$3,673,295			
Indirect emission reduction for reg alt 2	0.087	0.26	0.52	0.03	0.03

SLABSTOCK FOAM MODEL PLANT COSTS

	Model Plant 1		Model Plant 2		Model Plant 3		Model Plant 4		Model Plant 5	
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
MODEL PLANT COSTS FOR NON-HAP EQUIPMENT CLEANERS										
CAPITAL INVESTMENT	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
ANNUAL COSTS – All regulatory alternative levels of control										
Direct cost (vendor supplied)										
materials	$1,135	$0	$1,135	$0	$1,135	$0	$1,135	$0	$1,135	$0
Waste treatment	($1,410)	$0	($1,410)	$0	($1,410)	$0	($1,410)	$0	($1,410)	$0
Indirect Costs										
capital recovery	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
administrative charges	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL ANNUAL COST	($275)	$0	($275)	$0	($275)	$0	($275)	$0	($275)	$0
EMISSION REDUCTION (TONS/YR)	$5	$0	$5	$0	$5	$0	$5	$0	$5	$0
COST EFFECTIVENESS ($/TON)	($56)	$0	($56)	$0	($56)	$0	($56)	$0	($56)	$0

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ATTACHMENT 5

SLABSTOCK FOAM NON-HAP
EQUIPMENT CLEANER COSTS

ATTACHMENT 6

SLABSTOCK FOAM EQUIPMENT LEAK MODEL PLANT COSTS

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SLABSTOCK FOAM MODEL PLANT EQUIPMENT LEAK COSTS

	Model Plant 1	Model Plant 2	Model Plant 3	Model Plant 4	Model Plant 5
MACT FLOOR COSTS					
Capital Costs					
TDI transfer pumps	$5,000				
Total Capital Costs	$5,000				
Annual Costs					
TDI transfer pump cost	$1,598				
Recovery credit	$333				
Total Annual Cost	$1,265				
Emission reduction	0.17				
Cost Effectiveness	$7,599				
REG ALT I COSTS					
Capital Costs					
TDI transfer pumps	$5,000				
Instrument	$6,732	$6,732	$6,732	$6,732	$6,732
Pressure–relief valves	$0	$0	$0	$0	$0
Open–ended lines	$636	$636	$636	$636	$636
Initial Monitoring Costs					
MeCl2 pumps	$113	$113	$113	$113	
MeCl2 valves	$63	$63	$63	$63	$63
Total capital costs	$12,544	$7,544	$7,544	$7,544	$7,431
Annual costs					
Instrument	$5,962	$5,962	$5,962	$5,962	$5,962
Pressure–relief valves	$0	$0	$0	$0	$0
Open–ended lines	$150	$150	$150	$150	$150
MeCl2 pumps	$308	$308	$308	$308	
TDI transfer pumps	$1,598				
MeCl2 valves	$363	$363	$363	$363	$363
Recovery credits	$1,136	$803	$803	$803	$664
Total annual costs	$7,245	$5,980	$5,980	$5,980	$5,810
Emission Reductions	1.2	1.0	1.0	1.0	0.8
Cost Effectiveness	$6,193	$5,960	$5,960	$5,960	$6,996

REG ALT II COSTS – same as MACT Floor

MODEL PLANT COMPONENT COUNTS

MODEL PLANT DATA	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
MeCl2 transfer pumps	1	1	1	1	1	1	1	1	1	1
MeCl2 metering pumps	1	1	1	1	1	1	1	1	1	1
Total MeCl2 pumps	2	2	2	2	2	2	2	2	2	2
TDI transfer pumps	1	1	2	2	3	3	3	3	3	3
TDI metering pumps	1	1	1	1	1	1	1	1	1	1
TDI pumps total	2	2	3	3	4	4	4	4	4	4
TDI valves	16	16	24	24	32	32	32	32	32	32
MeCl2 valves	16	16	16	16	16	16	16	16	16	16
TDI flanges/connectors	20	20	30	30	40	40	40	40	40	40
MeCl2 flanges/connectors	20	20	20	20	20	20	20	20	20	20
TDI p/v valves	0	0	0	0	0	0	0	0	0	0
MeCl2 p/v vlaves	0	0	0	0	0	0	0	0	0	0
TDI open-ended lines	6	6	9	9	12	12	12	12	12	12
MeCl2 open-ended lines	6	6	6	6	6	6	6	6	6	6
NUMBER OF PLANTS	6	13	9	19	5	9	4	7	2	4

COMPONENT–SPECIFIC EMISSIONS (tons/yr)

BASELINE EMISSIONS	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	TOTALS
MeCl2 transfer pumps	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.000	0.000	27.7
MeCl2 metering pumps	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	30.0
MeCl2 pumps total	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.384	0.384	57.6
TDI transfer pumps	0.166	0.166	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.2
TDI metering pumps	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	13.0
TDI pumps total	0.333	0.333	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	16.1
TDI valves	0.036	0.036	0.053	0.053	0.071	0.071	0.071	0.071	0.071	0.071	4.4
MeCl2 valves	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	48.6
TDI flanges/connectors	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
MeCl2 flanges/connectors	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	27.6
TDI p/v valves	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
MeCl2 p/v valves	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
TDI open–ended lines	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0
MeCl2 open–ended lines	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	7.7
	2.212	2.212	2.063	2.063	2.081	2.081	2.081	2.081	1.696	1.696	
	1.843	1.843	1.843	1.843	1.843	1.843	1.843	1.843		Total MECL2	141.5
							1.459	1.459		Total TDI	20.5
										Total	162.0

COMPONENT–SPECIFIC EMISSIONS (tons/yr)

MACT FLOOR EMISSIONS	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	TOTALS	% RED
MeCl2 transfer pumps	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.000	0.000	27.7	0.0%
MeCl2 metering pumps	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	0.384	30.0	0.0%
MeCl2 pumps total	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.769	0.384	0.384	57.6	0.0%
TDI transfer pumps	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	100.0%
TDI metering pumps	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	13.0	0.0%
TDI pumps total	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	13.0	19.6%
TDI valves	0.036	0.036	0.053	0.053	0.071	0.071	0.071	0.071	0.071	0.071	4.4	0.0%
MeCl2 valves	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	0.623	48.6	0.0%
TDI flanges/connectors	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	ERR
MeCl2 flanges/connectors	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.353	27.6	0.0%
TDI p/v valves	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	---
MeCl2 p/v valves	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	ERR
TDI open–ended lines	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	ERR
MeCl2 open–ended lines	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	0.098	7.7	0.0%
	2.045	2.045	2.063	2.063	2.081	2.081	2.081	2.081	1.696	1.696		

Total MECL2	141.5	0.0%
Total TDI	17.4	15.4%
Total	158.8	2.0%
Reduction from Base	3.2	
MeCl2	0	$0
TDI	3.2	$6,326

COMPONENT–SPECIFIC EMISSIONS (tons/yr)

REG ALT I EMISSIONS	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	TOTALS	% RED
MeCl2 transfer pumps	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.000	0.000	15.2	45.0%
MeCl2 metering pumps	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.211	16.5	45.0%
MeCl2 pumps total	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.423	0.211	0.211	31.7	45.0%
TDI transfer pumps	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	100.0%
TDI metering pumps	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	13.0	0.0%
TDI pumps total	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	13.0	19.6%
TDI valves	0.036	0.036	0.053	0.053	0.071	0.071	0.071	0.071	0.071	0.071	4.4	0.0%
MeCl2 valves	0.392	0.392	0.392	0.392	0.392	0.392	0.392	0.392	0.392	0.392	30.6	37.0%
TDI flanges/connectors	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	ERR
MeCl2 flanges/connectors	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	1.9	93.0%
TDI p/v valves	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	---
MeCl2 p/v valves	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	ERR
TDI open–ended lines	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	ERR
MeCl2 open–ended lines	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	100.0%
	1.042	1.042	1.060	1.060	1.077	1.077	1.077	1.077	0.866	0.866		

Total MECL2	64.2	54.6%
Total TDI	17.4	15.4%
Total	81.6	49.6%
Reduction from Base	80.4	
MeCl2	77.2	$61,784
TDI	3.2	$6,326

COMPONENT–SPECIFIC EMISSIONS (tons/yr)

REG ALT II EMISSIONS	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B	TOTALS	% RED
MeCl2 transfer pumps	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	100.0%
MeCl2 metering pumps	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	100.0%
MeCl2 pumps total	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	100.0%
TDI transfer pumps	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	100.0%
TDI metering pumps	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	13.0	0.0%
TDI pumps total	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	13.0	19.6%
TDI valves	0.036	0.036	0.053	0.053	0.071	0.071	0.071	0.071	0.071	0.071	4.4	0.0%
MeCl2 valves	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	100.0%
TDI flanges/connectors	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	ERR
MeCl2 flanges/connectors	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	100.0%
TDI p/v valves	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	---
MeCl2 p/v valves	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	ERR
TDI open–ended lines	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	ERR
MeCl2 open–ended lines	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	100.0%
	0.202	0.202	0.220	0.220	0.238	0.238	0.238	0.238	0.238	0.238		

Total MECL2	0.0	100.0%
Total TDI	17.4	15.4%
Total	17.4	89.3%
Reduction from Base	144.6	
MeCl2	141.5	$113,169
TDI	3.2	$6,326

COSTS USED IN EQUIPMENT LEAK IMPACTS ANALYSIS

Capital and Annual Costs by Component for Equipment Modifications

Pressure Relief Valves

Capital Cost	
Rupture disk assembly	$4,070 per PR–valve
Annual Indirect Costs	
Capital recovery	$2,251 per PR–valve per year
Misc charges (4% of TCI)	$163 per PR–valve per year
Total indirect costs	$2,414 per PR–valve per year
Annual Direct Costs	
Maintenance charges (5% of TCI)	$204 per PR–valve per year
Total Annual Costs	$2,618 per PR–valve per year

Open–ended lines

Capital Cost	
Gate valve	$106 per line
Indirect Annual Costs	
Capital recovery	$15 per line per year
Misc charges (4% of TCI)	$4 per line per year
Total indirect costs	$19 per line per year
Direct Annual Costs	
Maintenance charges (5% of TCI)	$5 per line per year
Total Annual Costs	$25 per line per year

COSTS USED IN EQUIPMENT LEAK IMPACTS ANALYSIS

Capital and Annual Costs by Component for LDAR

Information used in LDAR cost calculations

Subcontractor fee	
initial monitoring	$2.50 per component
subsequent monitoring	$2.00 per component
Labor cost for repair	$22.50 per hour

Monitoring instrument costs

capital cost	$6,732 per facility
capital recovery	$1,412 per facility per year
annual miscellaneous (4% of TCI)	$269 per facility per year
total indirect annual cost	$1,682 per facility per year
annual maintenance (5% of TCI)	$4,280 per facility per year
total direct annual cost	$4,280 per facility per year
Total Annual Cost	$5,962

Pumps in light liquid service

Monitoring frequency	4 times per year
Initial leak freq. (new programs)	20% leakers
Existing leak frequency	
uncontrolled	7.48% leakers
Quarterly – 10,000 ppm	3.75% leakers
Pumps needing additional repair	75% of total leakers
Time needed for additional repair	16 hours per pump
Cost of new pump seal	$186

Initial monitoring

Initial monitoring costs	$2.50 per pump
Initial repair costs–labor	$54.00 per pump
Initial repair costs–pump seals	$27.96 per pump
	$56.50 per pump

Subsequent monitoring

incremental monitoring cost	$8.00 per pump per year
incremental repair cost–labor	$40.50 per pump per year
annual maintenc–pump seals	$20.97 per pump per year
annual misc charges	$16.78 per pump per year
administrative/support costs	$67.90 per pump per year
	$154.15 per pump per year

COSTS USED IN EQUIPMENT LEAK IMPACTS ANALYSIS

Valves in light liquid service

Monitoring frequency	4 times per year
Initial leak freq. (new programs)	6.5% leakers
Existing leak frequencies	
Uncontrolled	4.34% leakers
Quarterly–10,000ppm	1.60% leakers
Valves needing additional repair	25% of total leakers
Time needed for additional repair	4 hours

Initial monitoring

Initial monitoring costs	$2.50 per valve
Initial repair costs–labor	$1.46 per valve
	$3.96 per valve

Subsequent monitoring

incremental monitoring cost	$8.00 per valve per year
incremental repair cost–labor	$1.44 per valve per year
administrative/support costs	$13.22 per valve per year
	$22.66 per valve per year

CAPITAL RECOVERY FACTORS

Interest Rate = 7%

Time Period (yrs)	Cap. Rec. Factor	Application
6	0.2098	Monitoring Equipment
2	0.5531	Rupture Disks
10	0.1424	Control Equipment

ATTACHMENT 7

SLABSTOCK FOAM MODEL PLANT HAP ABA REGULATORY ALTERNATIVE EMISSIONS

MODEL PLANT 1

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Regulatory Alternative Emissions MACT Floor Limit	MACT Floor Emissions	Reg Alt 1 Limit	Reg Alt 1 Emissions
0930	0.9	30	80	10	5.3	6	3.2	5	2.9
1010	1.0	10	40	22	5.9	11	2.9	6	2.2
1015	1.0	15	40	19	4.9	11	2.9	6	2.1
1020	1.0	20	40	14	3.7	6	2.1	7	1.8
1030	1.0	30	80	8	4.0	4	2.1	5	2.5
1120	1.1	20	40	14	3.6	6	2.1	6	1.6
1130	1.1	30	60	7	2.6	3	1.2	4	1.5
1230	1.2	30	100	5	3.3	3	2.0	3	1.7
1330	1.3	30	60	6	2.2	3	1.2	1	0.6
1340	1.3	40	60	2	0.8	1	0.4	0	0.0
1440	1.4	40	60	2	0.8	0	0.0	0	0.0
1520	1.5	20	40	13	3.3	2	0.5	1	0.3
1530	1.5	30	40	6	1.6	2	0.5	0	0.0
1540	1.5	40	120	2	1.6	0	0.0	0	0.0
1640	1.6	40	120	1	0.8	0	0.0	0	0.0
1740	1.7	40	120	1	0.8	0	0.0	0	0.0
1820	1.8	20	60	10	4.0	2	0.8	0	0.0
1830	1.8	30	60	6	2.2	2	0.8	0	0.0
1840	1.8	40	120	0	0.0	0	0.0	0	0.0
1930	1.9	30	60	7	2.8	2	0.8	0	0.0
1940	1.9	40	100	1	0.7	0	0.0	0	0.0
>2020	2.5	25	500	0	0.0	0	0.0	0	0.0
				Total	55	Emissions	23.7		17.1
				Total Polyol Used		Reduction	31.3		37.9
				Total TDI Use tons		Percentage	56.8%		68.9%
				gallons					
				TDI Tank Turnovers					
				1 – 10000 gallon tank					

MODEL PLANT 2

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Regulatory Alternative Emissions: MACT Floor Limit	MACT Floor Emissions	Reg Alt 1 Limit	Reg Alt 1 Emissions
0930	0.9	30	240	10	16.0	6	9.6	5	8.6
1010	1.0	10	120	22	17.6	11	8.8	8	6.7
1015	1.0	15	120	19	14.8	11	8.8	8	6.2
1020	1.0	20	120	14	11.2	8	6.4	7	5.4
1030	1.0	30	240	8	12.0	4	6.4	5	7.4
1120	1.1	20	120	14	10.8	8	6.4	6	4.7
1130	1.1	30	180	7	7.8	3	3.6	4	4.4
1230	1.2	30	300	5	10.0	3	6.0	3	5.2
1330	1.3	30	180	6	6.6	3	3.6	1	1.8
1340	1.3	40	180	2	2.4	1	1.2	0	0.0
1440	1.4	40	180	2	2.4	0	0.0	0	0.0
1520	1.5	20	120	13	10.0	2	1.6	1	1.0
1530	1.5	30	120	6	4.8	2	1.6	0	0.0
1540	1.5	40	360	2	4.8	0	0.0	0	0.0
1640	1.6	40	360	1	2.4	0	0.0	0	0.0
1740	1.7	40	360	1	2.4	0	0.0	0	0.0
1820	1.8	20	180	10	12.0	2	2.4	0	0.0
1830	1.8	30	180	6	6.6	2	2.4	0	0.0
1840	1.8	40	360	0	0.0	0	0.0	0	0.0
1930	1.9	30	180	7	8.4	2	2.4	0	0.0
1940	1.9	40	300	1	2.0	0	0.0	0	0.0
>2020	2.0	25	1,500	0	0.0	0	0.0	0	0.0
				Total	165	Emissions	71.2		51.3
				Total Polyol Used		Reduction	93.8		113.7
				Total TDI Use		Percentage	56.8%		68.9%
				gallons					
				TDI Tank Turnovers					
				2 – 10000 gallon tanks					

MODEL PLANT 3

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Regulatory Alternative Emissions: MACT Floor Limit	MACT Floor Emissions	Reg Alt 1 Limit	Reg Alt 1 Emissions
0930	0.9	30	600	10	40.0	6	24.0	5	21.5
1010	1.0	10	300	22	44.0	11	22.0	8	16.7
1015	1.0	15	300	19	37.0	11	22.0	8	15.4
1020	1.0	20	200	14	18.7	8	10.7	7	9.0
1030	1.0	30	500	8	25.0	4	13.3	5	15.3
1120	1.1	20	200	14	18.0	8	10.7	6	7.8
1130	1.1	30	300	7	13.0	3	6.0	4	7.3
1230	1.2	30	500	5	16.7	3	10.0	3	8.7
1330	1.3	30	300	6	11.0	3	6.0	1	3.0
1340	1.3	40	200	2	2.7	1	1.3	0	0.0
1440	1.4	40	300	2	4.0	0	0.0	0	0.0
1520	1.5	20	300	13	25.0	2	4.0	1	2.4
1530	1.5	30	200	6	8.0	2	2.7	0	0.0
1540	1.5	40	500	2	6.7	0	0.0	0	0.0
1640	1.6	40	400	1	2.7	0	0.0	0	0.0
1740	1.7	40	400	1	2.7	0	0.0	0	0.0
1820	1.8	20	400	10	26.7	2	5.3	0	0.0
1830	1.8	30	300	6	11.0	2	4.0	0	0.0
1840	1.8	40	600	0	0.0	0	0.0	0	0.0
1930	1.9	30	300	7	14.0	2	4.0	0	0.0
1940	1.9	40	500	1	3.3	0	0.0	0	0.0
>2020	2.0	25	2,400	0	0.0	0	0.0	0	0.0
				Total	330	Emissions	146.0		107.3
				Total Polyol Used		Reduction	184.0		222.7
				Total TDI Use		Percentage	55.8%		67.5%
				gallons					
				TDI Tank Turnovers					
				3 – 10000 gallon tanks					

MODEL PLANT 4

				Baseline		Regulatory Alternative Emissions			
						MACT Floor		Reg Alt 1	
Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	MeCl2 (pph polyol)	tons MeCl used/ emitted	Limit	Emissions	Limit	Emissions
0930	0.9	30	550	10	36.7	6	22.0	5	19.7
1010	1.0	10	140	22	20.5	11	10.3	8	7.8
1015	1.0	15	140	19	17.3	11	10.3	8	7.2
1020	1.0	20	140	14	13.1	8	7.5	7	6.3
1030	1.0	30	550	8	27.5	4	14.7	5	16.9
1120	1.1	20	280	14	25.2	8	14.9	6	10.9
1130	1.1	30	410	7	17.8	3	8.2	4	10.0
1230	1.2	30	690	5	23.0	3	13.8	3	12.1
1330	1.3	30	410	6	15.0	3	8.2	1	4.1
1340	1.3	40	550	2	7.3	1	3.7	0	0.0
1440	1.4	40	410	2	5.5	0	0.0	0	0.0
1520	1.5	20	280	13	23.3	2	3.7	1	2.2
1530	1.5	30	410	6	16.4	2	5.5	0	0.0
1540	1.5	40	690	2	9.2	0	0.0	0	0.0
1640	1.6	40	830	1	5.5	0	0.0	0	0.0
1740	1.7	40	830	1	5.5	0	0.0	0	0.0
1820	1.8	20	410	10	27.3	2	5.5	0	0.0
1830	1.8	30	410	6	15.0	2	5.5	0	0.0
1840	1.8	40	830	0	0.0	0	0.0	0	0.0
1930	1.9	30	410	7	19.1	2	5.5	0	0.0
1940	1.9	40	690	1	4.6	0	0.0	0	0.0
>2020	2.0	25	3,710	0	0.0	0	0.0	0	0.0
				Total	335	Emissions	139.1		97.3
				Total Polyol Used		Reduction	195.9		237.7
				Total TDI Use		Percentage	58.5%		71.0%
					gallons				
				TDI Tank Turnovers					
				3 – 10000 gallon tanks					

MODEL PLANT 5

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Regulatory Alternative Emissions MACT Floor Limit	MACT Floor Emissions	Reg Alt 1 Limit	Reg Alt 1 Emissions
0930	0.9	30	570	10	38.0	6	22.8	5	20.5
1010	1.0	10	190	22	27.9	11	13.9	8	10.6
1015	1.0	15	190	19	23.4	11	13.9	8	9.8
1020	1.0	20	190	14	17.7	8	10.1	7	8.6
1030	1.0	30	570	8	28.5	4	15.2	5	17.5
1120	1.1	20	190	14	17.1	8	10.1	6	7.4
1130	1.1	30	570	7	24.7	3	11.4	4	13.9
1230	1.2	30	950	5	31.7	3	19.0	3	16.6
1330	1.3	30	570	6	20.9	3	11.4	1	5.7
1340	1.3	40	570	2	7.6	1	3.8	0	0.0
1440	1.4	40	570	2	7.6	0	0.0	0	0.0
1520	1.5	20	190	13	15.8	2	2.5	1	1.5
1530	1.5	30	380	6	15.2	2	5.1	0	0.0
1540	1.5	40	950	2	12.7	0	0.0	0	0.0
1640	1.6	40	950	1	6.3	0	0.0	0	0.0
1740	1.7	40	950	1	6.3	0	0.0	0	0.0
1820	1.8	20	380	10	25.3	2	5.1	0	0.0
1830	1.8	30	570	6	20.9	2	7.6	0	0.0
1840	1.8	40	1,240	0	0.0	0	0.0	0	0.0
1930	1.9	30	570	7	26.6	2	7.6	0	0.0
1940	1.9	40	860	1	5.7	0	0.0	0	0.0
>2020	2.0	25	6,840	0	0.0	0	0.0	0	0.0
				Total	380	Emissions	159.6		112.0
				Total Polyol Used		Reduction	220.4		268.0
				Total TDI Use		Percentage	58.0%		70.5%

ATTACHMENT 8

SLABSTOCK FOAM MODEL PLANT
COSTS FOR CHEMICAL ALTERNATIVES

MACT FLOOR REGULATORY ALTERNATIVE

	page
Grade-specific model plant materials costs	8-2 through 8-6
Model plant costs	8-7

MODEL PLANT 1

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Baseline annual chem cost ($/yr)	annual chem alt chem cost ($/yr)
0930	0.9	30	80	10	5.3	$126,550	$129,500
1010	1.0	10	40	22	5.9	$60,784	$61,587
1015	1.0	15	40	19	4.9	$60,831	$62,392
1020	1.0	20	40	14	3.7	$60,941	$62,356
1030	1.0	30	80	8	4.0	$123,559	$130,169
1120	1.1	20	40	14	3.6	$59,609	$62,294
1130	1.1	30	60	7	2.6	$90,710	$92,397
1230	1.2	30	100	5	3.3	$146,042	$151,391
1330	1.3	30	60	6	2.2	$87,835	$92,817
1340	1.3	40	60	2	0.8	$88,883	$92,147
1440	1.4	40	60	2	0.8	$87,446	$87,584
1520	1.5	20	40	13	3.3	$56,584	$58,175
1530	1.5	30	40	6	1.6	$56,920	$58,949
1540	1.5	40	120	2	1.6	$172,324	$179,022
1640	1.6	40	120	1	0.8	$170,955	$170,408
1740	1.7	40	120	1	0.8	$168,493	$168,862
1820	1.8	20	60	10	4.0	$82,164	$88,060
1830	1.8	30	60	6	2.2	$82,890	$84,919
1840	1.8	40	120	0	0.0	$166,439	$167,207
1930	1.9	30	60	7	2.8	$82,599	$82,629
1940	1.9	40	100	1	0.7	$137,740	$138,168
>2020	2.5	25	500	0	0.0	$549,820	$549,820

w/o MeCl2 Cleaning	baseline	chem alts
ABA cost	$44,000 /yr	$22,764
chem cost	$2,722,118 /yr	$2,770,654
ABA foam	$2,172,298 /yr	$2,221,034
Total cost	$3,402,648 /yr	$3,463,568

MODEL PLANT 2

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Baseline annual chem cost ($/yr)	annual chem alt chem cost ($/yr)
0930	0.9	30	240	10	16.0	$379,649	$388,501
1010	1.0	10	120	22	17.6	$182,353	$184,761
1015	1.0	15	120	19	14.8	$182,493	$187,176
1020	1.0	20	120	14	11.2	$182,823	$187,068
1030	1.0	30	240	8	12.0	$370,678	$390,508
1120	1.1	20	120	14	10.8	$178,827	$186,881
1130	1.1	30	180	7	7.8	$272,130	$277,190
1230	1.2	30	300	5	10.0	$444,127	$454,172
1330	1.3	30	180	6	6.6	$263,505	$278,450
1340	1.3	40	180	2	2.4	$266,648	$276,442
1440	1.4	40	180	2	2.4	$262,337	$262,753
1520	1.5	20	120	13	10.0	$169,752	$174,526
1530	1.5	30	120	6	4.8	$170,760	$176,847
1540	1.5	40	360	2	4.8	$516,972	$537,065
1640	1.6	40	360	1	2.4	$512,866	$511,224
1740	1.7	40	360	1	2.4	$505,480	$506,585
1820	1.8	20	180	10	12.0	$246,492	$264,180
1830	1.8	30	180	6	6.6	$248,671	$254,757
1840	1.8	40	360	0	0.0	$499,317	$501,621
1930	1.9	30	180	7	8.4	$247,796	$247,888
1940	1.9	40	300	1	2.0	$413,219	$414,505
>2020	2.0	25	1,500	0	0.0	$2,061,825	$2,061,825

w/o MeCl2 Cleaning	baseline	chem alts
ABA cost	$132,000 /yr	$68,293
chem cost	$6,579,000 /yr	$8,724,926
ABA foam	$6,517,000 /yr	$6,663,101
Total cost	$10,724,000 /yr	$10,906,158

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MODEL PLANT 3

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Baseline annual chem cost ($/yr)	annual chem alt chem cost ($/yr)
0930	0.9	30	600	10	40.0	$949,123	$971,252
1010	1.0	10	300	22	44.0	$455,882	$461,902
1015	1.0	15	300	19	37.0	$456,233	$467,941
1020	1.0	20	200	14	18.7	$304,706	$311,781
1030	1.0	30	500	8	25.0	$772,245	$813,559
1120	1.1	20	200	14	18.0	$298,044	$311,468
1130	1.1	30	300	7	13.0	$453,550	$461,984
1230	1.2	30	500	5	16.7	$740,212	$756,954
1330	1.3	30	300	6	11.0	$439,175	$464,083
1340	1.3	40	200	2	2.7	$296,275	$307,158
1440	1.4	40	300	2	4.0	$437,229	$437,922
1520	1.5	20	300	13	25.0	$424,380	$436,315
1530	1.5	30	200	6	8.0	$284,599	$294,745
1540	1.5	40	500	2	6.7	$718,016	$745,923
1640	1.6	40	400	1	2.7	$569,852	$568,027
1740	1.7	40	400	1	2.7	$561,645	$562,872
1820	1.8	20	400	10	26.7	$547,760	$567,066
1830	1.8	30	300	6	11.0	$414,452	$424,595
1840	1.8	40	600	0	0.0	$832,195	$836,034
1930	1.9	30	300	7	14.0	$412,993	$413,147
1940	1.9	40	500	1	3.3	$688,698	$690,842
>2020	2.0	25	2,400	0	0.0	$3,298,920	$3,298,920

w/o MeCl2 Cleaning	baseline	chem alts
ABA cost	$264,000 /yr	$146,324
chem cost	$14,356,000 /yr	$14,624,469
ABA foam	$11,057,000 /yr	$11,925,569
Total cost	$17,945,000 /yr	$18,280,611

MODEL PLANT 4

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	tons MeCl used/ emitted	annual chem cost ($/yr)	annual chem alt chem cost ($/yr)
0930	0.9	30	550	10	36.7	$870,029	$890,314
1010	1.0	10	140	22	20.5	$212,745	$215,554
1015	1.0	15	140	19	17.3	$212,909	$218,372
1020	1.0	20	140	14	13.1	$213,294	$218,246
1030	1.0	30	550	8	27.5	$849,469	$894,914
1120	1.1	20	280	14	25.2	$417,262	$436,055
1130	1.1	30	410	7	17.8	$619,851	$631,378
1230	1.2	30	690	5	23.0	$1,021,492	$1,044,596
1330	1.3	30	410	6	15.0	$600,206	$634,247
1340	1.3	40	550	2	7.3	$814,757	$844,685
1440	1.4	40	410	2	5.5	$597,546	$598,494
1520	1.5	20	280	13	23.3	$396,088	$407,227
1530	1.5	30	410	6	16.4	$583,429	$604,227
1540	1.5	40	690	2	9.2	$990,863	$1,029,374
1640	1.6	40	830	1	5.5	$1,182,442	$1,178,656
1740	1.7	40	830	1	5.5	$1,165,412	$1,167,960
1820	1.8	20	410	10	27.3	$561,453	$601,743
1830	1.8	30	410	6	15.0	$566,418	$580,280
1840	1.8	40	830	0	0.0	$1,151,203	$1,156,514
1930	1.9	30	410	7	19.1	$564,424	$564,634
1940	1.9	40	690	1	4.6	$950,404	$953,362
>2020	2.0	25	3,710	0	0.0	$5,099,580	$5,099,580

w/o MeCl2 Cleaning	baseline	chem alts
ABA cost	$267,900 /yr	$130,224
chem cost	$19,641,000 /yr	$19,970,415
ABA foam	$14,541,000 /yr	$14,870,835
Total cost	$24,551,000 /yr	$24,963,019

MODEL PLANT 5

Grade	Density (pcf)	IFD (25%)	amount produced (tons/yr)	Baseline MeCl2 (pph polyol)	Baseline tons MeCl used/ emitted	Baseline annual chem cost ($/yr)	annual *chem alt chem cost ($/yr)
0930	0.9	30	570	10	38.0	$901,667	$922,689
1010	1.0	10	190	22	27.9	$288,725	$292,538
1015	1.0	15	190	19	23.4	$288,947	$296,362
1020	1.0	20	190	14	17.7	$289,470	$296,192
1030	1.0	30	570	8	28.5	$880,359	$927,457
1120	1.1	20	190	14	17.1	$283,142	$295,895
1130	1.1	30	570	7	24.7	$861,744	$877,770
1230	1.2	30	950	5	31.7	$1,406,402	$1,438,212
1330	1.3	30	570	6	20.9	$834,433	$881,758
1340	1.3	40	570	2	7.6	$844,384	$875,401
1440	1.4	40	570	2	7.6	$830,735	$832,052
1520	1.5	20	190	13	15.8	$268,774	$276,333
1530	1.5	30	380	6	15.2	$540,739	$560,016
1540	1.5	40	950	2	12.7	$1,364,231	$1,417,254
1640	1.6	40	950	1	6.3	$1,353,398	$1,349,064
1740	1.7	40	950	1	6.3	$1,333,906	$1,336,821
1820	1.8	20	380	10	25.3	$520,372	$557,713
1830	1.8	30	570	6	20.9	$787,460	$806,730
1840	1.8	40	1,240	0	0.0	$1,719,869	$1,727,804
1930	1.9	30	570	7	26.6	$784,686	$784,979
1940	1.9	40	860	1	5.7	$1,184,561	$1,188,248
>2020	2.0	25	6,840	0	0.0	$9,401,921	$9,401,921

w/o MeCl2 Cleaning	baseline	chem alts
ABA cost	$304,000 /yr	$143,273 /yr
chem cost	$26,970,000 /yr	$27,343,210 /yr
ABA foam	$17,568,000 /yr	$17,941,289 /yr
Total cost	$33,713,000 /yr	$34,179,013 /yr

SLABSTOCK FOAM MODEL PLANT COSTS

	Model Plant 1		Model Plant 2		Model Plant 3		Model Plant 4		Model Plant 5	
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
MODEL PLANT COSTS FOR ABA EMISSION REDUCTION										
TECHNOLOGY: CHEMICAL ALTERNATIVES										
CAPITAL INVESTMENT										
Purchased equipment cost (vendor +3% tax + 5% freight)	$25,380	$25,380	$25,380	$25,380	$25,380	$25,380	$25,380	$25,380	$25,380	$25,380
Direct installation (6% of PEC)	$5,076	$5,076	$5,076	$5,076	$5,076	$5,076	$5,076	$5,076	$5,076	$5,076
Indirect installation (5% of PEC)	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269
TOTAL CAPITAL INVESTMENT	$31,725	$31,725	$31,725	$31,725	$31,725	$31,725	$31,725	$31,725	$31,725	$31,725
ANNUAL COSTS – MACT floor level of control										
Direct cost										
materials (vendor supplied)	$48,736	$48,736	$145,926	$145,926	$268,489	$268,489	$329,415	$329,415	$373,210	$373,210
Indirect Costs										
capital recovery (14.24% – 7% for 10 years)	$4,518	$4,518	$4,518	$4,518	$4,518	$4,518	$4,518	$4,518	$4,518	$4,518
administrative charges (4% of TCI)	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269
TOTAL ANNUAL COST	$54,523	$54,523	$151,713	$151,713	$274,276	$274,276	$335,202	$335,202	$378,997	$378,997
EMISSION REDUCTION (TONS/YR)	31	31	94	94	184	184	196	196	220	220
COST EFFECTIVENESS ($/TON)	$1,742	$1,742	$1,617	$1,617	$1,491	$1,491	$1,711	$1,711	$1,720	$1,720

ATTACHMENT 9

SLABSTOCK FOAM MODEL PLANT COSTS FOR CARDIO

	page
Model plant costs	9-2
Description of CarDio licensing costs	9-3 through 9-4
Description of costs for CarDio + Chem Alts	9-5 through 9-6

SLABSTOCK FOAM MODEL PLANT COSTS

	Model Plant 1		Model Plant 2		Model Plant 3		Model Plant 4		Model Plant 5	
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
MODEL PLANT COSTS FOR ABA EMISSION REDUCTION										
TECHNOLOGY: CARDIO										
CAPITAL INVESTMENT										
Purchased equipment cost (vendor +3% tax + 5% freight)	$405,000	$405,000	$405,000	$405,000	$405,000	$405,000	$405,000	$405,000	$405,000	$405,000
Direct installation (6% of PEC)	$24,300	$24,300	$24,300	$24,300	$24,300	$24,300	$24,300	$24,300	$24,300	$24,300
Indirect installation	$0	$0	$0	$0	$0	$0	$0		$0	$0
TOTAL CAPITAL INVESTMENT	$429,300	$429,300	$429,300	$429,300	$429,300	$429,300	$429,300	$429,300	$429,300	$429,300
ANNUAL – MACT floor level of control										
Direct cost (vendor supplied)										
materials	($23,981)	($23,981)	($71,867)	($71,867)	($140,976)	($140,976)	($150,094)	($150,094)	($168,865)	($168,865)
utilities	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600
CO2 tank rental	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000
licensing	$5,472	$5,472	$16,416	$16,416	$34,560	$34,560	$47,664	$47,664	$57,456	$57,456
Indirect Costs										
capital recovery (14.24% – 7% for 10 years)	$61,132	$61,132	$61,132	$61,132	$61,132	$61,132	$61,132	$61,132	$61,132	$61,132
administrative charges (4% of TCI)	$17,172	$17,172	$17,172	$17,172	$17,172	$17,172	$17,172	$17,172	$17,172	$17,172
TOTAL ANNUAL COST	$69,395	$69,395	$32,453	$32,453	($18,512)	($18,512)	($14,525)	($14,525)	($23,505)	($23,505)
EMISSION REDUCTION (TONS/YR)	31	31	94	94	184	184	196	196	220	220
COST EFFECTIVENESS ($/TON)	$2,217	$2,217	$346	$346	($101)	($101)	($74)	($74)	($107)	($107)
ANNUAL COSTS – Regulatory alternative 1 level of control										
Direct cost (vendor supplied)										
materials	($29,038)	($29,038)	($87,114)	($87,114)	($170,627)	($170,627)	($182,120)	($182,120)	($205,335)	($205,335)
utilities	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600
CO2 tank rental	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000
licensing	$7,488	$7,488	$22,464	$22,464	$40,320	$40,320	$55,584	$55,584	$73,872	$73,872
Indirect Costs										
capital recovery (14.24% – 7% for 10 years)	$61,132	$61,132	$61,132	$61,132	$61,132	$61,132	$61,132	$61,132	$61,132	$61,132
administrative charges (4% of TCI)	$17,172	$17,172	$17,172	$17,172	$17,172	$17,172	$17,172	$17,172	$17,172	$17,172
TOTAL ANNUAL COST	$66,354	$66,354	$23,254	$23,254	($42,403)	($42,403)	($38,631)	($38,631)	($43,559)	($43,559)
EMISSION REDUCTION (TONS/YR)	38	38	114	114	223	223	238	238	268	268
COST EFFECTIVENESS ($/TON)	$1,751	$1,751	$204	$204	($190)	($190)	($163)	($163)	($163)	($163)
TECHNOLOGY: CARDIO + CHEMICAL ALTERNATIVES										
CAPITAL INVESTMENT										
Purchased equipment cost (vendor +3% tax + 5% freight)	$430,380	$430,380	$430,380	$430,380	$430,380	$430,380	$430,380	$430,380	$430,380	$430,380
Direct installation (6% of PEC)	$29,376	$29,376	$29,376	$29,376	$29,376	$29,376	$29,376	$29,376	$29,376	$29,376
Indirect installation (5% of PEC)	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269
TOTAL CAPITAL INVESTMENT	$461,025	$461,025	$461,025	$461,025	$461,025	$461,025	$461,025	$461,025	$461,025	$461,025
ANNUAL COSTS – Regulatory alternative II level of control										
Direct cost (vendor supplied)										
materials	($26,808)	($26,808)	($100,591)	($100,591)	($191,037)	($191,037)	($151,442)	($151,442)	($165,016)	($165,016)
utilities	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600
CO2 tank rental	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000	$6,000
licensing	$17,280	$17,280	$34,560	$34,560	$67,680	$67,680	$75,312	$75,312	$87,552	$87,552
Indirect Costs										
capital recovery (14.24% – 7% for 10 years)	$65,650	$65,650	$65,650	$65,650	$65,650	$65,650	$65,650	$65,650	$65,650	$65,650
administrative charges (4% of TCI)	$18,441	$18,441	$18,441	$18,441	$18,441	$18,441	$18,441	$18,441	$18,441	$18,441
TOTAL ANNUAL COST	$84,163	$84,163	$27,660	$27,660	($29,666)	($29,666)	$17,561	$17,561	$16,227	$16,227
EMISSION REDUCTION (TONS/YR)	55	55	165	165	330	330	335	335	380	380
COST EFFECTIVENESS ($/TON)	$1,530	$1,530	$168	$168	($90)	($90)	$52	$52	$43	$43

DESCRIPTION OF CARDIO LICENSING COSTS CALCULATION

The licensing costs for CarDio are 1 percent of the total chemical costs for foams made with CarDio technology. It is estimated that the chemical cost for making CarDio foam was $0.72 per pound. Therefore, to estimate the licensing fee for each regulatory alternative for each model plant, it was necessary to predict which foam grades each model plant would chose to make using CarDio. It was assumed that each model plant would chose to make the foams that had the largest amount of $MeCl_2$ used/emitted until the necessary emission reduction was achieved. The following tables provide details of these assumptions for each regulatory alternative. The model plant foam grade-specific emissions and production amounts referred to are provided on pages 2-4 through 2-8 of Attachment 2.

CarDio licensing costs to meet the MACT Floor

Model Plant	Foam Grades Produced using CarDio	Weight of Foam Produced (lbs/yr)	Chemical cost at $0.72 per pound ($/yr)	Annual Liscensing Fees ($/yr)
1	0930-1120, 1820	760,000	$547,200	$5,472
2	0930-1120, 1820	2,280,000	$1,641,600	$16,416
3	0930-1015, 1030, 1520, 1820	4,800,000	$3,456,000	$34,560
4	0930, 1010, 2030, 1120, 1230, 1520, 1820, 1930	6,620,000	$4,766,400	$47,664
5	0930-1015, 1030, 1130, 1230, 1820,1930	7,980,000	$5,745,600	$57,456

DESCRIPTION OF CARDIO LICENSING COSTS CALCULATION (continued)

CarDio licensing costs to meet Regulatory Alternative 1

Model Plant	Foam Grades Produced using CarDio	Weight of Foam Produced (lbs/yr)	Chemical cost at $0.72 per pound ($/yr)	Annual Liscensing Fees ($/yr)
1	MACT floor + 1230, 1520	1,040,000	$748,800	$7,488
2	MACT floor + 1230, 1520	3,120,000	$2,246,400	$22,464
3	MACT floor + 1020, 1120	5,600,000	$4,032,000	$40,320
4	MACT floor + 1015, 1130	7,720,000	$5,558,400	$55,584
5	MACT floor + 1830, 1330	10,260,000	$7,387,200	$73,872

CarDio licensing costs to meet the Regulatory Alternative 2

Model Plant	Foam Grades Produced using CarDio	Weight of Foam Produced (lbs/yr)	Chemical cost at $0.72 per pound ($/yr)	Annual Liscensing Fees ($/yr)
1	All except 1340, 1440, 1540, 1640, 1740, 1840, 1940, >2020	2,400,000	$1,728,000	$17,280
2		4,800,000	$3,456,000	$34,560
3		9,400,000	$6,768,000	$67,680
4		10,460,000	$7,531,200	$75,312
5		12,160,000	$8,755,200	$87,552

DESCRIPTION OF COSTS FOR CARDIO PLUS CHEMICAL ALTERNATIVES FOR REGULATORY ALTERNATIVE 2

It was assumed that the total elimination of HAP ABA (regulatory alternative 2) could not be achieved using only CarDio. This was because the base formulation would need more than 3 parts $MeCl_2$ per hundred parts polyol to allow the substitution of carbon dioxide as an ABA. However, these low-ABA foam grades could be produced using chemical alternatives. Therefore, the combination of CarDio and chemical alternatives was assumed to achieve the complete elimination of the use of HAP ABA. The capital costs, capital recovery, and other indirect annual costs for this combination were simply the sum of the capital costs of CarDio and chemical alternatives.

For regulatory alternative 2, the procedure for calculating the licensing fee for the foam grades made using CarDio was the shown on page 9-4. To calculate the material costs for the combination of the two technologies, the chemical costs associated with the substitution of carbon dioxide for methylene chloride was added to the material cost of making the remaining foam grades using only chemical alternatives (see pages 8-2 through 8-6 of Attachment 8). The following table shows the chemical alternative costs in more detail, followed by a table pm page 9-6 which shows how the total annual material costs were calculated.

Chemical Alternative Costs for Selected Grades when used with CarDio to meet the requirements of Regulatory Alternative 2

Model Plant	Foam Grades Produced using Chem Alts	Baseline Chemical Costs ($/yr)	Chem Alts Chemical Costs ($/yr)	Incrementa l Material Costs for Chem Alts ($/yr)
1	1340, 1440, 1540, 1640, 1740, 1840, 1940, >2020	$1,542,100	$1,553,218	$11,118
2		$4,521,692	$4,534,955	$13,263
3		$7,402,830	$7,447,648	$44,868
4		$11,952,207	$12,028,625	$76,418
5		$18,033,005	$18,128,565	$95,560

DESCRIPTION OF COSTS FOR CARDIO PLUS CHEMICAL ALTERNATIVES FOR REGULATORY ALTERNATIVE 2 (continued)

Total Materials Costs for CarDio plus Chemical Alternatives to meet the requirements of Regulatory Alternative 2

Model Plant	Incremental materials cost of CO_2 versus $MeCl_2$ ($/yr)	Additional Material Costs for Chem Alts ($/yr)	Total material cost ($/yr)
1	($37,926)	$11,118	($26,808)
2	($113,854)	$13,263	($100,591)
3	($233,905)	$44,868	($191,037)
4	($227,860)	$76,418	($151,442)
5	($260,576)	$95,560	($165,016)

SLABSTOCK FOAM MODEL PLANT COSTS

	Model Plant 1		Model Plant 2		Model Plant 3		Model Plant 4		Model Plant 5	
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
MODEL PLANT COSTS FOR ABA EMISSION REDUCTION										
TECHNOLOGY: ACETONE										
CAPITAL INVESTMENT – (vendor supplied)										
Purchased equipment cost	$161,700	$161,700	$161,700	$161,700	$161,700	$161,700	$161,700	$161,700	$161,700	$161,700
Direct installation	$32,300	$32,300	$32,300	$32,300	$32,300	$32,300	$32,300	$32,300	$32,300	$32,300
Indirect installation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
TOTAL CAPITAL INVESTMENT	$194,000	$194,000	$194,000	$194,000	$194,000	$194,000	$194,000	$194,000	$194,000	$194,000
ANNUAL COSTS – MACT floor level of control										
Direct costs (vendor supplied)										
materials	($18,154)	($18,154)	($54,404)	($54,404)	($106,720)	($106,720)	($113,622)	($113,622)	($127,832)	($127,832)
utilities	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881
maintenance materials	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
licensing	$5,509	$5,509	$15,420	$15,420	$27,788	$27,788	$29,359	$29,359	$32,593	$32,593
maintenance labor	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
Indirect Costs										
capital recovery (14.24% – 7% for 10 years)	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626
overhead (6% of labor costs)	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500
administrative charges (4% of TCI)	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760
TOTAL ANNUAL COST	$35,121	$35,121	$8,783	$8,783	($31,165)	($31,165)	($36,497)	($36,497)	($47,473)	($47,473)
EMISSION REDUCTION (TONS/YR)	31	31	94	94	184	184	196	196	220	220
COST EFFECTIVENESS ($/TON)	$1,122	$1,122	$94	$94	($169)	($169)	($186)	($186)	($215)	($215)
ANNUAL COSTS – Regulatory alternative I level of control										
Direct costs (vendor supplied)										
materials	($21,982)	($21,982)	($65,946)	($65,946)	($129,166)	($129,166)	($137,866)	($137,866)	($155,440)	($155,440)
utilities	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881
maintenance materials	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
licensing	$6,670	$6,670	$18,510	$18,510	$32,896	$32,896	$34,876	$34,876	$38,876	$38,876
maintenance labor	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
Indirect Costs										
capital recovery (14 24% – 7% for 10 years)	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626
overhead (6% of labor costs)	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500
administrative charges (4% of TCI)	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760
TOTAL ANNUAL COST	$32,455	$32,455	$330	$330	($48,503)	($48,503)	($55,223)	($55,223)	($68,797)	($68,797)
EMISSION REDUCTION (TONS/YR)	38	38	114	114	223	223	238	238	268	268
COST EFFECTIVENESS ($/TON)	$856	$856	$3	$3	($218)	($218)	($232)	($232)	($257)	($257)
ANNUAL COSTS – Regulatory alternative II level of control										
Direct costs (vendor supplied)										
materials	($31,900)	($31,900)	($95,667)	($95,667)	($191,334)	($191,334)	($194,223)	($194,223)	($220,227)	($220,227)
utilities	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881	$5,881
maintenance materials	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
licensing	$9,439	$9,439	$25,267	$25,267	$44,047	$44,047	$44,707	$44,707	$50,620	$50,620
maintenance labor	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500	$2,500
waste treatment	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Indirect Costs										
capital recovery (14.24% – 7% for 10 years)	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626	$27,626
overhead (6% of labor costs)	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500	$1,500
administrative charges (4% of TCI)	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760	$7,760
TOTAL ANNUAL COST	$25,306	$25,306	($22,633)	($22,633)	($99,520)	($99,520)	($101,750)	($101,750)	($121,840)	($121,840)
EMISSION REDUCTION (TONS/YR)	55	55	165	165	330	330	335	335	380	380
COST EFFECTIVENESS ($/TON)	$460	$460	($137)	($137)	($302)	($302)	($304)	($304)	($321)	($321)

19-Jan-96

ATTACHMENT 10
SLABSTOCK FOAM MODEL PLANT COSTS FOR ACETONE

ATTACHMENT 11

SLABSTOCK FOAM MODEL PLANT COSTS FOR VARIABLE PRESSURE FOAMING

SLABSTOCK FOAM MODEL PLANT COSTS

	Model Plant 1		Model Plant 2		Model Plant 3		Model Plant 4		Model Plant 5	
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
MODEL PLANT COSTS FOR ABA EMISSION REDUCTION										
TECHNOLOGY: *VARIABLE PRESSURE FOAMING*										
CAPITAL INVESTMENT (vendor supplied)										
Purchased equipment cost										
Direct installation										
Indirect installation										
TOTAL CAPITAL INVESTMENT	$4,500,000	$4,500,000	$4,500,000	$4,500,000	$4,500,000	$4,500,000	$4,500,000	$4,500,000	$4,500,000	$4,500,000
ANNUAL COSTS – MACT floor level of control										
Direct cost (vendor supplied)										
materials	($25,040)	($25,040)	($75,040)	($75,040)	($147,200)	($147,200)	($156,720)	($156,720)	($176,320)	($176,320)
utilities	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600
labor	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)
Indirect Costs										
capital recovery (14 24% – 7% for 10 years)	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800
overhead (6% of labor costs)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)
administrative charges (4% of TCI)	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000
TOTAL ANNUAL COST	$774,400	$774,400	$724,400	$724,400	$652,240	$652,240	$642,720	$642,720	$623,120	$623,120
EMISSION REDUCTION (TONS/YR)	31	31	94	94	184	184	196	196	220	220
COST EFFECTIVENESS ($/TON)	$24,741	$24,741	$7,723	$7,723	$3,545	$3,545	$3,281	$3,281	$2,827	$2,827
ANNUAL COSTS – Regulatory alternative I level of control										
Direct cost (vendor supplied)										
materials	($30,320)	($30,320)	($90,960)	($90,960)	($178,160)	($178,160)	($190,160)	($190,160)	($214,400)	($214,400)
utilities	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600
labor	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)
Indirect Costs										
capital recovery (14.24% – 7% for 10 years)	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800
overhead (6% of labor costs)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)
administrative charges (4% of TCI)	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000
TOTAL ANNUAL COST	$769,120	$769,120	$708,480	$708,480	$621,280	$621,280	$609,280	$609,280	$585,040	$585,040
EMISSION REDUCTION (TONS/YR)	38	38	114	114	223	223	238	238	268	268
COST EFFECTIVENESS ($/TON)	$20,293	$20,293	$6,231	$6,231	$2,790	$2,790	$2,563	$2,563	$2,183	$2,183
ANNUAL COSTS – Regulatory alternative II level of control										
Direct cost (vendor supplied)										
materials	($44,000)	($44,000)	($131,954)	($131,954)	($263,909)	($263,909)	($267,894)	($267,894)	($303,761)	($303,761)
utilities	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600	$15,600
labor	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)	($23,100)
Indirect Costs										
capital recovery (14 24% – 7% for 10 years)	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800	$640,800
overhead (6% of labor costs)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)	($13,860)
administrative charges (4% of TCI)	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000	$180,000
TOTAL ANNUAL COST	$755,440	$755,440	$667,486	$667,486	$535,531	$535,531	$531,546	$531,546	$495,679	$495,679
EMISSION REDUCTION (TONS/YR)	55	55	165	165	330	330	335	335	380	380
COST EFFECTIVENESS ($/TON)	$13,735	$13,735	$4,047	$4,047	$1,623	$1,623	$1,587	$1,587	$1,305	$1,305

ATTACHMENT 12

SLABSTOCK FOAM MODEL PLANT COSTS FOR FORCED COOLING

	page
Model plant costs	12-2
Description of costs for Forced Cooling + Chem Alts	12-3

SLABSTOCK FOAM MODEL PLANT COSTS

	Model Plant 1		Model Plant 2		Model Plant 3		Model Plant 4		Model Plant 5	
	1A	1B	2A	2B	3A	3B	4A	4B	5A	5B
MODEL PLANT COSTS FOR ABA EMISSION REDUCTION										
TECHNOLOGY: FORCED COOLING										
CAPITAL INVESTMENT (vendor supplied)										
Purchased equipment cost	$1,000,000	$1,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000
TOTAL CAPITAL INVESTMENT	$1,000,000	$1,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000	$2,000,000
ANNUAL COSTS – MACT floor level of control										
Direct cost (vendor supplied)										
materials	($25,040)	($25,040)	($75,040)	($75,040)	($147,200)	($147,200)	($156,720)	($156,720)	($176,320)	($176,320)
utilities	$5,140	$5,140	$15,420	$15,420	$25,700	$25,700	$35,338	$35,338	$48,830	$48,830
licensing	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Indirect Costs										
capital recovery (14.24% – 7% for 10 years)	$142,400	$142,400	$284,800	$284,800	$284,800	$284,800	$284,800	$284,800	$284,800	$284,800
administrative charges (4% of TCI)	$40,000	$40,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000
TOTAL ANNUAL COST	$162,500	$162,500	$305,180	$305,180	$243,300	$243,300	$243,418	$243,418	$237,310	$237,310
EMISSION REDUCTION (TONS/YR)	31	31	94	94	184	184	196	196	220	220
COST EFFECTIVENESS ($/TON)	$5,192	$5,192	$3,254	$3,254	$1,322	$1,322	$1,243	$1,243	$1,077	$1,077
ANNUAL COSTS – Regulatory alternative I level of control										
Direct cost (vendor supplied)										
materials	($30,320)	($30,320)	($90,960)	($90,960)	($178,160)	($178,160)	($190,160)	($190,160)	($214,400)	($214,400)
utilities	$5,140	$5,140	$15,420	$15,420	$25,700	$25,700	$35,338	$35,338	$48,830	$48,830
licensing	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Indirect Costs										
capital recovery (14.24% – 7% for 10 years)	$142,400	$142,400	$284,800	$284,800	$284,800	$284,800	$284,800	$284,800	$284,800	$284,800
administrative charges (4% of TCI)	$40,000	$40,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000
TOTAL ANNUAL COST	$157,220	$157,220	$289,260	$289,260	$212,340	$212,340	$209,978	$209,978	$199,230	$199,230
EMISSION REDUCTION (TONS/YR)	38	38	114	114	223	223	238	238	268	268
COST EFFECTIVENESS ($/TON)	$4,148	$4,148	$2,544	$2,544	$953	$953	$883	$883	$743	$743
TECHNOLOGY: FORCED COOLING + CHEMICAL ALTERNATIVES										
CAPITAL INVESTMENT (vendor supplied)										
Purchased equipment cost	$1,025,380	$1,025,380	$2,025,380	$2,025,380	$2,025,380	$2,025,380	$2,025,380	$2,025,380	$2,025,380	$2,025,380
Direct installation (5% of PEC of chemalts)	$5,076	$5,076	$5,076	$5,076	$5,076	$5,076	$5,076	$5,076	$5,076	$5,076
Indirect installation (5% of PEC of chemalts)	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269	$1,269
TOTAL CAPITAL INVESTMENT	$1,031,725	$1,031,725	$2,031,725	$2,031,725	$2,031,725	$2,031,725	$2,031,725	$2,031,725	$2,031,725	$2,031,725
ANNUAL COSTS – Regulatory alternative II level of control										
Direct cost (vendor supplied)										
utilities	$5,140	$5,140	$15,420	$15,420	$25,700	$25,700	$35,338	$35,338	$48,830	$48,830
licensing	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Materials – Envirocure	($31,200)	($31,200)	($93,600)	($93,600)	($196,800)	($196,800)	($197,920)	($197,920)	($218,400)	($218,400)
Materials – Chem Alts	$5,314	$5,314	$15,943	$15,943	$28,149	$28,149	$33,509	$33,509	$38,972	$38,972
Indirect Costs										
capital recovery (14.24% – 7% for 10 years)	$146,918	$146,918	$289,318	$289,318	$289,318	$289,318	$289,318	$289,318	$289,318	$289,318
administrative charges (4% of TCI)	$41,269	$41,269	$81,269	$81,269	$81,269	$81,269	$81,269	$81,269	$81,269	$81,269
TOTAL ANNUAL COST	$167,441	$167,441	$308,350	$308,350	$227,636	$227,636	$241,513	$241,513	$239,989	$239,989
EMISSION REDUCTION (TONS/YR)	55	55	165	165	330	330	335	335	380	380
COST EFFECTIVENESS ($/TON)	$3,044	$3,044	$1,869	$1,869	$690	$690	$721	$721	$632	$632

DESCRIPTION OF COSTS FOR FORCED COOLING PLUS CHEMICAL ALTERNATIVES FOR REGULATORY ALTERNATIVE 2

It was assumed that the total elimination of HAP ABA (regulatory alternative 2) could not be achieved using forced cooloing. This assumption was made due to the many doubts within the industry that low density, low IFD foams of acceptable quality can be made by forced cooling without any ABA. However, it was assumed that these foam grades could be produced using the combination of forced cooling and chemical alternatives. The capital costs, capital recovery, and other indirect annual costs for this combination were simply the sum of the capital costs of forced cooling and chemical alternatives.

For regulatory alternative 2, it was assumed that forced cooling and chemical alternatives would be used simultaneously to make the low-density, low-IFD foam grades. This resulted in two differences in the annual cost from the MACT floor and regulatory alternative 1 costs. One is the additional material cost of using chemical alternatives for the low-density, low-IFD foam grades, which is shown below.

Chemical Alternative Costs for Selected Grades when used with forced cooling to meet the requirements of Regulatory Alternative 2

Model Plant	Foam Grades Produced using Chem Alts	Baseline Chemical Costs ($/yr)	Chem Alts Chemical Costs ($/yr)	Incremental Annual Materials Costs ($/yr)
1	0930, 1010, 1015	$248,165	$253,479	$5,314
2	0930, 1010, 1015	$744,495	$760,438	$15,943
3	0930, 1010	$1,405,005	$1,433,154	$28,149
4	0930, 1020	$1,508,977	$1,542,486	$33,509
5	0930, 1020	$1,768,809	$1,807,781	$38,972

MEMORANDUM

Date: September 24, 1996

Subject: Development of Equation to Calculate Auxiliary Blowing Agent Formulation Limitation

From: Phil Norwood, EC/R
Steve Fudge, EC/R

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

The purpose of this memorandum is to discuss the development of an equation to calculate the hazardous air pollutant (HAP) auxiliary blowing agent (ABA) formulation limitations for the National Emission Standards for Hazardous Air Pollutants (NESHAP) for Flexible Polyurethane Foam Production. This memorandum is separated into two sections. The first provides background, followed by a discussion of the development and selection of the equation.

BACKGROUND

For Flexible Polyurethane Foam NESHAP, the Environmental Protection Agency (EPA) considered three levels of control for the reduction of HAPs used as ABAs in the production of slabstock foam.[1] The maximum achievable control technology (MACT) "floor" level of control and the first regulatory alternative consisted of HAP ABA formulation limitations, which were used to calculate an allowable HAP emissions level based on the product mix. The second regulatory alternative required the complete elimination of HAP ABA.

In the analysis of regulatory alternatives, HAP ABA formulation limitations for the MACT floor and first regulatory alternative were presented tabularly. The MACT floor HAP ABA formulation limitations are shown in Table 1. As discussed in the regulatory alternatives memorandum, three methods were used to develop alternatives between the MACT floor and the total elimination of HAP ABA emissions: (1) extending the MACT floor grade ranges, (2) basing the limitations on the emission reductions achieved by the top three facilities, and (3) basing the limitations on the reductions believed achievable

[1] Memorandum. Williams, A. and Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Regulatory Alternatives for New and Existing Sources in the Flexible Polyurethane Foam Industry. June 17, 1996.

TABLE 1. EXISTING SOURCE MACT FLOOR HAP ABA FORMULATION LIMITATIONS

<table>
<tr><th colspan="2" rowspan="2">HAP ABA Formulation Limitations - parts ABA per hundred parts polyol</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-0.95</th><th>0.96-1.05</th><th>1.06-1.15</th><th>1.16-1.40</th><th>1.41+</th></tr>
<tr><td rowspan="5">IFD</td><td>0-15</td><td>12</td><td colspan="2">11</td><td rowspan="2">6</td><td rowspan="2">2</td></tr>
<tr><td>16-20</td><td>10</td><td colspan="2">8</td></tr>
<tr><td>21-25</td><td>9</td><td colspan="2">7</td><td>4</td><td rowspan="2">2</td></tr>
<tr><td>26-30</td><td>6</td><td rowspan="2">4</td><td colspan="2">3</td></tr>
<tr><td>31+</td><td>5</td><td>2</td><td>1</td><td>0</td></tr>
</table>

by carbon adsorption. The limitations achieved by each of these methods were similar, as were the predicted emission reductions for a representative facility. This led the EPA to consider these as a single "intermediate" level of control. The EPA subsequently selected this intermediate level of control for proposal. The HAP ABA formulation limitations generated by the extended range method are shown in Table 2. The "top three facility" limitations are shown in Table 3. Due to the

TABLE 2. HAP ABA FORMULATION LIMITATIONS BASED ON EXTENDED GRADE GROUPS

<table>
<tr><th colspan="2" rowspan="2">Parts ABA per hundred parts polyol</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-0.95</th><th>0.96-1.05</th><th>1.06-1.15</th><th>1.16-1.40</th><th>1.41+</th></tr>
<tr><td rowspan="3">IFD</td><td>0-20</td><td colspan="3">8</td><td rowspan="2">4</td><td>2</td></tr>
<tr><td>21-25</td><td colspan="3">7</td><td rowspan="2">0</td></tr>
<tr><td>26+</td><td>5</td><td>4</td><td colspan="2">1</td></tr>
</table>

TABLE 3. HAP ABA FORMULATION LIMITATIONS BASED ON THREE BEST PERFORMING FOAM FACILITIES

<table>
<tr><th colspan="2" rowspan="2">Emissions - parts ABA per hundred parts polyol</th><th colspan="5">Density ranges (pounds per cubic foot)</th></tr>
<tr><th>0-0.95</th><th>0.96-1.05</th><th>1.06-1.15</th><th>1.16-1.40</th><th>1.41+</th></tr>
<tr><td rowspan="6">IFD</td><td>0-15</td><td colspan="3">8</td><td rowspan="2">4</td><td rowspan="5">1</td></tr>
<tr><td>16-20</td><td>7</td><td colspan="2">6</td></tr>
<tr><td>21-25</td><td>6</td><td colspan="2">5</td><td>3</td></tr>
<tr><td>26-30</td><td rowspan="2">4</td><td colspan="2">3</td><td>2</td></tr>
<tr><td>31+</td><td>1</td><td>0.5</td><td>0</td></tr>
</table>

similarities between the limitations created by the top three facilities and carbon adsorption approaches, the table created by the carbon adsorption emission reduction was not considered in subsequent analyses.

During the presumptive MACT process, concern was expressed by the foam industry that the use of this table could result in some potentially damaging consequences.[2] The concern was related to the production of grades "on the border" of a foam grade grouping. For instance, if a foam was poured as a 1.15 pound per cubic foot (pcf) density and a 23 pound indentation force deflection (IFD), the HAP ABA formulation in Table 2 is 7 parts HAP ABA per hundred parts polyol (pph). However, if the core density of the actual foam was 1.17 pcf, the formulation limit that would be used in the allowable emissions calculation would be 4 pph. This significant drop would make compliance difficult. Therefore, the industry suggested that the EPA attempt to develop an equation that eliminates the large drops in HAP ABA formulation limitations across the foam grade groupings

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[2] Memorandum. Williams, A., and Norwood, P., EC/R Incorporated, to Svendsgaard, D., U.S. Environmental Protection Agency. Summary of the August 22, 1995 Flexible Polyurethane Foam Production Presumptive MACT (P-MACT) Roundtable Meeting. September 27, 1996.

in the table.[3] The EPA agreed that an equation would be preferable to the table, since an equation would be more user-friendly and would provide a more continuous and logical relationship between foam grades and HAP ABA limitations. This memorandum reports on the development of such an equation.

DEVELOPMENT AND SELECTION OF THE EQUATION

The established goal was that the formulation limitations calculated using an equation correspond to the formulation limitations in one of the intermediate level HAP ABA formulation limitation tables (Tables 2 and 3), while "smoothing" the transition across foam grade groupings. Instead of using the actual raw data, a data set was created containing foam grades and the corresponding formulation limitations from the table. This data was then input into the SAS® REG procedure with a list of eight variables, all using either the IFD or density (DEN). These variables are shown in Table 4.

TABLE 4. VARIABLES USED IN DEVELOPMENT OF HAP ABA EQUATION

IFD
DEN
1/IFD
1/DEN
IFD*DEN
IFD/DEN
DEN/IFD
1/(IFD*DEN)

The SAS REG procedure fits linear regression models by least-squares. Subsets of independent variables that "best" predict the dependent variable can be determined by various model-selection methods. Two model-selection methods were used to produce equations 1 and 2 from the extended range table (Table 2). Those methods are the forward-selection and the stepwise-selection.

The forward-selection technique begins with no variables in the model. For each of the independent variables, F statistics are calculated that reflect the variable's contribution to the model if it is included. The p-values for these F statistics are compared to a preset significance level, SLENTRY. If no F statistic has a significance level greater than SLENTRY, then the

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[3] Letter from Sullivan, D., Hickory Springs Manufacturing Company, to Norwood, P., EC/R Incorporated. Status of the MACT floor for auxiliary blowing agents. July 21, 1995.

method stops. Otherwise, the variable with the largest F statistic is added to the model.

The step-wise method is like the forward method except that variables already in the model do not necessarily stay there. Variables are added to the model using the same procedure as outlined above. After a variable is added, however, the stepwise method looks at all the variables already included in the model and deletes any variable that does not produce an F statistic significant at the preset value of SLSTAY. Only after this check is made and any necessary deletions accomplished can another variable be added to the model. The process ends when none of the variables outside the model has an F statistic significant at the SLENTRY level and every variable in the model is significant at the SLSTAY level, or when the variable to be added to the model is the one just deleted.

$$ABA_{limit} = -0.25(IFD) - 19.1\left(\frac{1}{IFD}\right) - 16.2(DEN) - 7.56\left(\frac{1}{DEN}\right) + 36.5$$

Equation (1)

$$ABA_{limit} = -0.85(IFD) + 0.0089(IFD)^2 - 41.01\left(\frac{1}{IFD}\right) + 14.01\left(\frac{1}{DEN}\right) + 0.104(DEN)(IFD) + 5.14$$

Equation (2)

In addition, Equation 3 was created from the table generated from the three best performing facilities (Table 3) using the step-wise method.

$$ABA_{limit} = -0.345(IFD) - 12.9\left(\frac{1}{IFD}\right) - 16.6(DEN) - 6.58(DEN) + 0.118(IFD)(DEN) + 34.4$$

Equation (3)

As discussed in the regulatory alternatives memorandum, the limitations were created by applying a percentage reduction to a set of baseline formulation values. Using this approach, an two-equation approach was also created. The first equation calculated the baseline formulation value for the grade, which was then multiplied by the percentage reduction, determined by the second equation. These equations are included as Equations 4 and 5.

$$ABA_{base} = -0.955(IFD) - 33.1(DEN) - 8.35\left(\frac{1}{DEN}\right) + 0.482(IFD)(DEN) + 64.7$$

Equation (4)

$$RED = 1-(-1521.27(DEN) + 554.79(DEN)^2 - 345.17\left(\frac{1}{DEN}\right) + 0.199(IFD)(DEN) + 1369.47$$

Equation (5)

SELECTION OF EQUATION

Three primary criteria were used to select the equation to be included in the proposed regulation: (1) agreement with the emission reduction achieved by the intermediate level of control HAP limitation table(s) for a representative facility, (2) performance across all foam grades, and (3) simplicity of the equation. Table 5 compares the residual HAP limitations and HAP ABA emission reductions for the equations (and intermediate tables), using the representative slabstock foam plant from EPA's Cost Report.[4] As can be seen in the table, the HAP ABA emission reductions for all equations are comparable to those achieved by the intermediate tables. Therefore, all meet the first criteria.

Figures 1 through 4 show the performance of the equations across a range of foam grades. As can be seen from Figures 1 and 3, Equations 1 and 3 have perform well across all foam grades. This means that the HAP ABA limitation gradually and smoothly decreases with increasing density and IFD. As seen in Figures 2 and 4, Equation 2 and the two equation approach (Equations 4 and 5) did not perform satisfactorily.

The application of the final criteria, simplicity, to Equations 1 and 3, led to the selection of Equation 1 due to the number of variables. Therefore, Equation 1 is used in the proposed rule to calculate HAP ABA formulation limitations. However, it will be necessary to clarify that all negative values would be set equal to zero.

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[4] Flexible Polyurethane Foam Emission Reduction Technologies Cost Analysis. EPA-453/R-95-011. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. September 1996.

TABLE 5. COMPARISON OF EQUATION RESULTS WHEN APPLIED TO REPRESENTATIVE PLANT

Representative Plant Foam Grades			HAP ABA Formulation Limitation (pph)					
Grade	Density (pcf)	IFD (25%)	Extended Range Table	Top 3 Table	Equation 1	Equation 2	Equation 3	Equations 4 and 5
0930	0.9	30	5	4	5	5	5	3
1010	1.0	10	8	8	8	8	8	7
1015	1.0	15	8	8	8	7	7	6
1020	1.0	20	8	6	7	6	6	5
1030	1.0	30	4	3	5	3	4	3
1120	1.1	20	8	6	6	5	5	5
1130	1.1	30	1	3	4	2	3	3
1230	1.2	30	1	2	3	2	2	3
1330	1.3	30	1	2	1	1	2	2
1340	1.3	40	1	0.5	0	1	0	1
1440	1.4	40	0	0.5	0	0	0	0
1520	1.5	20	0	1	1	2	1	0
1530	1.5	30	0	1	0	0	0	0
1540	1.5	40	0	0	0	0	0	0
1640	1.6	40	0	0	0	0	0	0
1740	1.7	40	0	0	0	0	0	0
1820	1.8	20	0	1	0	1	0	0
1830	1.8	30	0	1	0	0	0	0
1840	1.8	40	0	0	0	0	0	0
1930	1.9	30	0	1	0	0	0	0
1940	1.9	40	0	0	0	0	0	0
	>2.0	>20	0	0	0	0	0	0
Percentage Reduction of HAP ABA Emissions From Baseline			68%	67%	66%	70%	69%	73%

Figure 1. HAP ABA limitation equation results – equation 1

IFD (pounds)	HAP ABA limitation (parts HAP ABA per 100 parts polyol)*																			
	Density (pounds per square foot)																			
	0.8		0.9		1.0		1.1		1.2		1.3		1.4		1.5	1.6	1.7	1.8	1.9	2.0
10	10	10	9	9	8	8	7	7	6	6	5	5	4	3	3	1	0	0	0	0
12	9	9	9	9	8	8	7	7	6	6	5	4	4	3	3	1	0	0	0	0
14	9	9	9	8	8	7	7	6	6	5	5	4	4	3	2	1	0	0	0	0
16	9	9	8	8	8	7	7	6	6	5	4	4	3	3	2	1	0	0	0	0
18	9	9	8	8	7	7	6	6	5	5	4	3	3	2	2	0	0	0	0	0
20	8	8	8	7	7	6	6	5	5	4	4	3	2	2	1	0	0	0	0	0
22	8	8	7	7	6	6	5	5	4	4	3	3	2	1	1	0	0	0	0	0
24	7	7	7	6	6	5	5	5	4	3	3	2	2	1	0	0	0	0	0	0
26	7	7	6	6	6	5	5	4	4	3	2	2	1	1	0	0	0	0	0	0
28	6	6	6	5	5	5	4	4	3	3	2	1	1	0	0	0	0	0	0	0
30	6	6	5	5	5	4	4	3	3	2	1	1	0	0	0	0	0	0	0	0
32	5	5	5	5	4	4	3	3	2	2	1	0	0	0	0	0	0	0	0	0
34	5	5	4	4	4	3	3	2	2	1	1	0	0	0	0	0	0	0	0	0
36	5	5	4	4	3	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0
38	4	4	4	3	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0
40	4	4	3	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0
42	3	3	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
44	3	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	2	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* In some instances, equations yeild negative residual HAP limitations. In this table, negative values are shown as zero.

Figure 2. HAP ABA limitation equation results – equation 2

IFD (pounds)	HAP ABA limitation (parts HAP ABA per 100 parts polyol)*																			
	Density (pounds per square foot)																			
	0.8		0.9		1.0		1.1		1.2		1.3		1.4		1.5	1.6	1.7	1.8	1.9	2.0
10	12	11	10	9	8	8	7	7	6	6	6	5	5	5	4	4	3	3	3	3
12	11	10	9	9	8	7	7	6	6	6	5	5	5	4	4	4	3	3	3	2
14	11	10	9	8	8	7	6	6	5	5	5	4	4	4	4	3	3	2	2	2
16	10	9	8	8	7	6	6	5	5	5	4	4	4	3	3	3	2	2	2	2
18	9	9	8	7	6	6	5	5	4	4	4	3	3	3	3	2	2	2	1	1
20	9	8	7	6	6	5	5	4	4	3	3	3	3	2	2	2	1	1	1	1
22	8	7	7	6	5	5	4	4	3	3	3	2	2	2	2	1	1	1	1	0
24	8	7	6	5	5	4	4	3	3	2	2	2	2	1	1	1	1	0	0	0
26	7	6	5	5	4	4	3	3	2	2	2	2	1	1	1	1	0	0	−0	−0
28	7	6	5	4	4	3	3	2	2	2	1	1	1	1	1	0	0	−0	−0	−0
30	6	5	5	4	3	3	2	2	2	1	1	1	1	0	0	0	−0	−0	−0	−0
32	6	5	4	4	3	3	2	2	1	1	1	1	0	0	0	−0	−0	−0	−1	−1
34	6	5	4	3	3	2	2	2	1	1	1	0	0	0	−0	−0	−0	−1	−1	−1
36	5	5	4	3	3	2	2	1	1	1	1	0	0	0	−0	−0	−0	−1	−1	−1
38	5	4	4	3	3	2	2	1	1	1	1	0	0	0	−0	−0	−0	−0	−1	−0
40	5	4	4	3	3	2	2	1	1	1	1	0	0	0	−0	−0	−0	−0	−0	−0
42	5	4	4	3	3	2	2	1	1	1	1	0	0	0	0	−0	−0	−0	−0	−0
44	5	4	4	3	3	2	2	1	1	1	1	1	0	0	0	0	0	0	0	0
46	5	5	4	3	3	2	2	2	1	1	1	1	1	1	0	0	0	0	0	1
48	5	5	4	3	3	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1
50	6	5	4	4	3	3	3	2	2	2	2	1	1	1	1	1	1	1	1	1
52	6	5	5	4	4	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2
54	6	6	5	5	4	4	3	3	3	3	3	2	2	2	2	2	2	2	2	3

* In some instances, equations yeild negative residual HAP limitations. In this table, negative values are shown as zero.

Figure 3. HAP ABA limitation equation results – equation 3

IFD (pounds)	HAP ABA limitation (parts HAP ABA per 100 parts polyol)*																			
	Density (pounds per square foot)																			
	0.8		0.9		1.0		1.1		1.2		1.3		1.4		1.5	1.6	1.7	1.8	1.9	2.0
10	9	9	8	8	8	7	7	6	6	5	5	4	3	3	2	1	0	0	0	0
12	9	9	8	8	7	7	7	6	5	5	4	4	3	3	2	1	0	0	0	0
14	8	8	8	8	7	7	6	6	5	5	4	4	3	2	2	1	0	0	0	0
16	8	8	8	7	7	6	6	5	5	4	4	3	3	2	2	0	0	0	0	0
18	8	8	7	7	6	6	6	5	5	4	4	3	3	2	1	0	0	0	0	0
20	7	7	7	6	6	6	5	5	4	4	3	3	2	2	1	0	0	0	0	0
22	7	7	6	6	6	5	5	4	4	3	3	2	2	1	1	0	0	0	0	0
24	6	6	6	6	5	5	4	4	4	3	3	2	2	1	1	0	0	0	0	0
26	6	6	5	5	5	4	4	4	3	3	2	2	1	1	0	0	0	0	0	0
28	5	5	5	5	4	4	4	3	3	2	2	1	1	0	0	0	0	0	0	0
30	5	5	5	4	4	4	3	3	2	2	2	1	1	0	0	0	0	0	0	0
32	4	4	4	4	4	3	3	2	2	2	1	1	0	0	0	0	0	0	0	0
34	4	4	4	3	3	3	2	2	2	1	1	0	0	0	0	0	0	0	0	0
36	4	4	3	3	3	2	2	2	1	1	1	0	0	0	0	0	0	0	0	0
38	3	3	3	3	2	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0
40	3	3	2	2	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0
42	2	2	2	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
44	2	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
46	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

* In some instances, equations yeild negative residual HAP limitations. In this table, negative values are shown as zero.

Figure 4. HAP ABA limitation equation results – equations 4 and 5

IFD (pounds)	HAP ABA limitation (parts HAP ABA per 100 parts polyol)*																			
	Density (pounds per square foot)																			
	0.8		0.9		1.0		1.1		1.2		1.3		1.4		1.5	1.6	1.7	1.8	1.9	2.0
10	5	5	7	7	7	8	7	7	6	5	4	3	2	0	0	0	0	1	6	15
12	5	5	6	7	7	7	7	6	6	5	4	3	1	0	0	0	0	1	6	15
14	4	4	6	6	7	7	6	6	5	4	3	2	1	0	0	0	0	1	6	15
16	4	4	5	6	6	6	6	6	5	4	3	2	1	0	0	0	0	1	7	15
18	4	4	5	5	6	6	6	5	5	4	3	2	1	0	0	0	0	2	7	15
20	3	3	5	5	5	5	5	5	4	4	3	2	1	0	0	0	0	2	7	15
22	3	3	4	5	5	5	5	4	4	3	2	2	1	0	0	0	0	2	7	15
24	3	3	4	4	4	4	4	4	4	3	2	1	1	0	0	0	0	2	7	15
26	3	3	4	4	4	4	4	4	3	3	2	1	1	0	0	0	0	3	7	15
28	2	2	3	4	4	4	4	3	3	2	2	1	1	0	0	0	0	3	8	15
30	2	2	3	3	3	3	3	3	3	2	2	1	0	0	0	0	0	3	8	15
32	2	2	3	3	3	3	3	3	2	2	1	1	0	0	0	0	1	3	8	15
34	2	2	2	2	3	3	2	2	2	2	1	1	0	0	0	0	1	4	8	15
36	1	1	2	2	2	2	2	2	2	1	1	1	0	0	0	0	1	4	8	15
38	1	1	2	2	2	2	2	2	1	1	1	0	0	0	0	0	2	4	9	15
40	1	1	1	1	2	2	1	1	1	1	1	0	0	0	0	0	2	4	9	15
42	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	2	5	9	15
44	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	1	2	5	9	15
46	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	1	3	5	9	15
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	6	10	15
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	6	10	15
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3	6	10	15
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4	6	10	15

* In some instances, equations yeild negative residual HAP limitations. In this table, negative values are shown as zero.

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16. ABSTRACT

This document contains memoranda providing rationale and information used to develop the Flexible Polyurethane Foam Production proposal package. The data and information contained in these memoranda were obtained through literature searches, industry meetings, plant visits, and replies to section 114 questionnaires sent to industry.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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