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CATALOG OF MATERIALS AS POTENTIAL SOURCES OF INDOOR AIR EMISSIONS

Volume 1. Insulation, Wallcoverings, Resilient Floor Coverings, Carpet, Adhesives, Sealants and Caulks, and Pesticides

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a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Carpets	Pollution Control	13B	11E
Emission	Adhesives	Stationary Sources	14G	11A
Houses	Sealing Compounds	Indoor Air	13M	
Office Buildings	Pesticides	Materials		06F
Insulation		Wallcoverings		
Wallpaper			11L	
Floor Coverings			13C	

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ABSTRACT

This Catalog of Materials as Sources of Indoor Air Emissions presents a discussion of and data on constituents and emissions from products that have the potential to impact the indoor air environment. The Catalog is intended as a tool to be used by researchers to help organize the study of materials as potential sources of indoor air emissions. Included in this Catalog are sections on seven product categories: insulation, wallcoverings, resilient floor coverings, carpet, adhesives, sealants and caulks, and pesticides. Each section presents a classification scheme for the product category, sales and usage volume data, qualitative data on product composition, and quantitative and qualitative data on emission rates to the indoor air. Emissions information is presented only for volatile organic compounds (VOCs) because these are the compounds most likely to be emitted from materials found in homes and office buildings. Data tables summarizing available emissions and constituent data are provided, and are organized according to the classification scheme presented for each product category.

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INTRODUCTION

A variety of research efforts, both U.S. and international, have focused on materials as potential sources of indoor air emissions. These research efforts are not concentrated on any one group of products, nor are standard sampling and analytical methods used in the research. In addition, there is no consistency in the terminology used to describe the products tested. For instance, while one researcher may describe the product tested as simply an adhesive, another researcher may describe the product tested as an ethylene/vinyl acetate adhesive used on wood products. Test methods include chamber studies, test homes, and headspace studies. This lack of consistency in test methods and terminology makes the data generated in the research efforts difficult to compare.

In 1990 the Air and Energy Engineering Research Laboratory (AEERL) of the U. S. Environmental Protection Agency (U.S. EPA) published the Classification of Materials as Potential Sources of Indoor Air Pollution,[1] EPA-600/8-90-074. It presents a classification of building materials, fixtures and furnishings, and consumer products used or found in homes or offices, regardless of their potential to emit. A subset of materials and products was identified that is thought to represent the population of manufactured items that warrant further study as sources of indoor air emissions. This Catalog provides additional information on the subset of materials and products thought to be a potential source of indoor air emissions deserving further study. The objectives of developing the Catalog of Materials as Sources of Indoor Air Emissions were: (1) to generate a useful scheme for presenting the variety of material sources of indoor air emissions in homes and offices; and (2) to present available usage, constituent, and emissions data for these material sources.

The Catalog is presented as a tool for researchers to help organize study of materials as potential sources of indoor air emissions. Sales and usage information provide an indication of the relative importance of products and the magnitude of potential exposure on a national scale. Information on the volatile constituents in products gives an indication of compounds that could potentially be emitted. A summary compilation of existing volatile organic compound (VOC) emissions data indicates how well characterized different products are in terms of their contribution to indoor air contamination. The data tables present summaries of existing emissions data identified in the literature or through direct contact with researchers. The emissions data presented in the literature were generated over a variety of time scales. The data presented in the data tables are single points, often resulting from time averaging. They do not reflect the time dependency often associated with emission rates. In most cases, emission rates of VOCs from a product will decrease over time. Emission rates are generally highest when the product is new, or the coating or adhesive is initially applied.

It should also be noted that there is a variety of testing and analytical methods used to develop data, and each method has inherent limitations. For instance, Tenax tubes are often used to collect samples by drawing the air through a cartridge containing Tenax. Compounds captured on the Tenax are determined by thermal desorption techniques, and generally have boiling points in the range of 80-200°C. Compounds outside of this range may break through the sorbent and not be collected.

The remainder of this introduction describes the Catalog and its development, including the product classification system, a description of the sources of information used to develop the Catalog, a discussion of data management, and conclusions based on the information presented. Sections 1-7 comprise the Catalog itself.

Classification of Materials as Sources

Our understanding of the more subtle effects of indoor air emissions is largely incomplete. Identification of the sources of emissions, beyond those few that are obvious problems, is a particularly important gap in our understanding of the problem. The Classification of Materials as Potential Sources of Indoor Air Pollution[1] was designed to lay a foundation for a systematic analysis of the role of materials in influencing indoor air quality. The approach involved a systematic identification and categorization of all products that are:

- Construction components of buildings;
- Fixtures and furnishings; and
- Consumer goods that are brought into buildings in the course of normal use.

A number of sources of information containing categorization or classification of materials were identified during the course of the study, and are described in the classification report. The products and sales information in these sources were compared for usefulness of classification divisions and level of detail. It was concluded that the Census of Manufactures presented the most comprehensive list of the realm of products of interest to the study, and employed categories useful to indoor air quality study. A decision was therefore made to use data presented in the Current Industry Series Reports of the Census of Manufactures as a basis for initial studies.[2] The census data are based on the Standard Industrial Classification (SIC) system, which is commonly used by industry and government agencies.

The next step involved identifying those products or materials in the classification that were thought to be potential sources of indoor air emissions. This was a subjective process, based on consideration of the following factors:

- The quantity produced: how pervasive is the product in the environment?
- Compositional information: based on readily available published information, what volatile compounds could potentially be emitted?
- The nature of its use: what is the likelihood of human contact with emissions from these materials?

Fourteen categories of products were organized for further study. Seven of these product categories are included in this Catalog of Materials as Sources of Indoor Air Emissions. The additional categories will be published in a second volume of this Catalog. The categories were chosen based on their high potential to emit potentially harmful compounds to the indoor air in homes and office buildings on a widespread basis. These fourteen categories are:

- Insulation Products*
- Wallcoverings*
- Resillent Floor Covering*
- Carpet*
- Adhesives*
- Caulks and Sealants*
- Pesticide Products*
- Paints and Coatings
- Wood Products
- Upholstered Furniture
- Fabricated Rubber Products
- Mineral Products
- Plastic Products
- Construction Paper Products

The published classification system was used initially to help focus data-gathering efforts in each product category. However, refinement of the classification system was needed as the study progressed. In many cases, it was more reasonable to classify the products based on how they were used in the home. This was especially true of the adhesives, and caulks and sealants categories, where some products are used in only one application (e.g., gluing ceramic tiles to a wooden floor). In other instances, classification of products based on the manufacturing process was more appropriate. For instance, insulation can be manufactured as mineral fibers, foams, and cellulose fibers. Each of these types of insulation may be used in a variety of applications (e.g., in walls, ceilings etc.). In the case of

*Included in this volume.

the carpet category, it was necessary to divide the product into its component parts (e.g., backing, foam underlayment, fibers) to provide a reasonable classification scheme.

Therefore, it was necessary to further define each product category studied to develop this classification scheme. In all cases, classification schemes were developed with two goals in mind: to develop a useful scheme to present the variety of products in the category; and to present usage, constituent and emissions data for the various products in each product category in a manner that allowed easy comparison of available information. This was especially important in many categories (carpets, for example) where different components of the product could have different constituents and emissions. However, the starting point for all product category organization was based on the published classification report and, therefore, all product categories still follow the SIC system to some extent. The classification schemes used for each product category are presented in Figure 1. Included as an appendix to this Catalog are tables that provide information that allows the user to compare emission rates of a single VOC from different materials. For example, all materials that were found to emit formaldehyde are listed in one table.

Sources of Information

There are a wide variety of information sources available that provide fairly limited data on chemical constituents and emissions from materials that may be brought into the home or office. Much of this information is found in technical reports summarizing research efforts, but trade associations, academic institutions, and retailers/wholesalers often provide information on the composition of products and provide perspective on which products within a specific category are most commonly used and which products may be more likely to emit pollutants. A summary of the types of information sources used to develop this Catalog is presented in Table 1.

Although the technical references presented good sources of emissions and constituent data, the amount and level of detail of data are not consistent among the product categories. While emissions of one chemical from a product (e.g., formaldehyde from carpets) may be well characterized, emissions of other VOCs from that same product may not be as well understood. This type of inconsistency in available information was typical for most of the product categories.

The trade associations, trade publications, retailers, distributors, and many of the journals researched provided product constituent information as well as useful sales data.

I. INSULATION PRODUCTS

- A. Fibrous
  - 1. Mineral fiber
    - a. batts, blankets, rolls
    - b. loose fibers
    - c. rigid
  - 2. Cellulose, loose fibers
- B. Foam
  - 1. Rigid
    - a. polystyrene
    - b. polyurethane and polyisocyanurate
    - c. phenolic-based
  - 2. Foamed-in-place
    - a. polyurethane
    - b. polyisocyanurate
    - c. urea-based foams
  - 3. Elastomeric (foam rubber)
- C. Reflective

II. WALLCOVERING

- A. Wallpaper
  - 1. Paper with less than 2 mils[a] of coating
    - a. non-strippable
    - b. dry-strippable
  - 2. Paper-backed, coated, or laminated with 2 mils[a] of plastics or more
    - a. pre-pasted
    - b. non-pasted
  - 3. Fabric-backed, coated, or laminated with vinyl chloride polymer
    - a. woven
    - b. non-woven
  - 4. Fabric-backed, coated, or laminated with other plastics
    - a. woven
    - b. non-woven
- B. Paneling
- C. Other wallcoverings

[a] Note: 1 mil = 1/1000 of an inch.

Figure 1. Classification Scheme for All Product Categories

III. RESILIENT FLOOR COVERINGS

A. Sheet vinyl flooring
B. Floor tile
   1. Vinyl tile
   2. Vinyl composition tile
C. Other (nonvinyl) resilient floor coverings (linoleum, rubber, cork)

IV. CARPET

A. Synthetic fiber carpets
   1. Common fiber processing and finishing treatments
      a. stain guard
      b. soil release (e.g., fluorocarbon)
      c. antimicrobial treatment
B. Wool fiber carpets
   1. Common fiber processing and finishing treatments
      a. stain guard
      b. insect repellents
C. Backings and backing adhesives
   1. Polypropylene
   2. Jute
   3. Backing adhesives
D. Cushion materials
   1. Bonded urethane
   2. Prime urethane
   3. Others

Figure 1. (Continued)

V. ADHESIVES

A. Natural-based adhesives
   1. Natural vegetable-based adhesives
      a. starches
      b. dextrins
   2. Natural animal-based adhesives
      a. casein
   3. Other natural adhesives
      a. oleoresinous
      b. bituminous (asphaltics)

B. Synthetic-based adhesives
   1. Solid polymer/solid rubber
      a. styrene butadiene rubber (SBR)
      b. neoprene rubber
      c. nitrile rubber
      d. butyl rubber
      e. natural rubber
      f. polyvinyl chloride (PVC)
      g. polyurethane (PUR)
   2. Liquid polymer
      a. epoxy
      b. polyurethane (PUR)
      c. phenolics (resorcinol)
      d. polyvinyl alcohol (PVOH)
      e. amino (urea formaldehyde/melamine formaldehyde)
      f. nitrile
      g. silicone
   3. Emulsions
      a. latex acrylics
      b. polyvinyl acetate (PVAC)
      c. styrene butadiene latex
      d. neoprene latex
      e. natural rubber latex
   4. Hot melts
      a. ethylene vinyl acetate
   5. Pressure-sensitive
      a. natural rubber
      b. styrene butadiene rubber
   6. Latex acrylics

Figure 1. (Continued)

VI. CAULKS AND SEALANTS

A. Natural-based sealants
   1. Natural oil-based sealants
      a. oleoresinous
   2. Natural bituminous-based sealants
      a. asphaltics
B. Synthetic-based sealants
   1. Solid rubber/solid polymer
      a. butyl rubber
      b. chlorosulfonated polyethylene (Hypalon)
      c. acrylic rubber
      d. nitrile rubber
      e. neoprene rubber
      f. styrene butadiene rubber
   2. Emulsions
      a. polyvinyl chloride (PVC)
      b. latex acrylics
      c. polyvinyl acetate (PVAC)
      d. natural rubber latex
      e. styrene butadiene latex
   3. Liquid polymers
      a. polysulfide
      b. polyurethane (PUR)
      c. silicones
      d. polyisobutylene (PIB)
      e. epoxy
      f. polybutene
   4. Tapes and foams
      a. butyl (post/preformed tape)
      b. polyvinyl chloride (foam tape)
      c. polyurethane (foam)
      d. polybutene (preformed tape)
      e. polyisobutylene (preformed tape)
      f. thermoplastic rubber

Figure 1. (Continued)

VII. PESTICIDES[b]

A. Insecticides
   1. Crawling insects
      a. aerosols
      b. nonaerosols
   2. Flying insects
      a. aerosols
      b. nonaerosols
B. Insect repellents (Includes attractants for insects, birds, fish, and other animals)
C. Fungicides
   1. Household mildew remover
   2. Fungicides for plants
D. Rodenticides
E. Herbicides
F. Household pesticidal preparations, including commercial exterminants and termiticides
G. Outdoor pesticides

[b] This list contains the types of pesticides included in this catalog. Other pesticides have not yet been investigated.

Figure 1. (Continued)

Table 1. Summary of Data Sources

Literature Searches	Industry Contacts	Other Sources
Published Technical Studies Conference Proceedings On-line Technical Databases Journals Trade Publications	Manufacturers Trade Associations Retailers/Distributors Architects Contractors Installers	Independent Researchers State and Federal Agencies Academic Institutions Databases

These information sources did not necessarily provide technical data, but the anecdotal information provided on trends in the industry (e.g., increased use of water-based paints and nylon carpets), helped focus data-gathering efforts.

Contacts with independent researchers, personnel at academic institutions, and State and Federal agencies provided a mix of information. Often, this information was qualitative, where a researcher performed qualitative emission studies identifying chemicals emitted from products but did not quantify them (e.g., headspace studies). In other cases, it was learned that very little work has been performed on certain categories.

In addition to literature searches and industry contacts, "industry studies" were performed on many of the products in which a review of the manufacturing process determined the volatile constituents in products that could potentially be emitted. These studies had several components. The first step involved investigating general references on manufacturing processes, including references such as the Kirk-Othmer Encyclopedia of Manufacturing,[3] Chemical Processes Use Trees,[4] EPA Industrial Process Profiles Series,[5] and general formulary references. A second component of the industry study involved contacting individuals familiar with the industry being investigated. These people included technical researchers, personnel at academic institutions, and trade association representatives. The third component involved directly contacting product manufacturers and distributors. These contacts often provided useful information and literature on manufacturing of the products.

It should be noted that the data presented in this Catalog did not go through EPA quality assurance. Rather, data from published sources is assumed to have undergone quality assurance and peer review checks prior to publication. For information and assessment of the quality of any particular

study presented here, the reader should refer to the original cited reference. A summary of the limitations of the data presented in this Catalog is presented in Figure 2.

- Data did not go through EPA quality assurance. The data are reported directly from the reference in which it appears and presented in the Catalog.
- Data are archival (i.e., there is no interpretation of the data presented). The Catalog is a summary of available data found at the time of the data gathering efforts.
- Data presented are the result of a variety of test and analytical methods.
- Data are not part of a directed study, but rather the result of individual research efforts.

Figure 2. Limitations of Data Presented in the Catalog

Several databases were identified that contain information potentially useful for this Catalog. Table 2 provides a summary of these databases. The most useful database identified was the National Aeronautics and Space Administration (NASA) database,[6] which contains a variety of test results from approximately 5,000 different products. Although the primary test performed on these products was for flammability as an indicator of their appropriateness for use in the space shuttle, some products were also tested for their potential to offgas chemicals. Many of the products are specialty products, designed and used exclusively in the aerospace industry, however, some of the products tested are commonly used products that are routinely found in homes and office buildings. This is especially true of the Adhesives, and Paints and Coatings categories.

There are some specific limitations to the usefulness of the NASA database. For example, the chamber studies conducted to determine emissions were conducted under extreme conditions that might be found in the space shuttle environment, (high temperature and low pressure) and do not necessarily represent typical conditions in residential settings. Emissions data are not presented for every product in the database. Emissions are reported as microgram of chemical emitted per gram of product over a 72-hour period. Due to these conditions the data are not felt to provide representative quantitative information on emissions. However, the NASA database does provide useful information for determining product constituents as well as relative amounts of those constituents emitted from products.

The Concentration of Indoor Pollutants (CIP) database,[7] developed at the Lawrence Berkeley Laboratories, contains data on concentrations of indoor pollutants measured in buildings. No effort was made to identify which specific material sources contributed to the indoor concentrations.

Table 2

Databases Identified

Database Name	Responsible Organization	Type of Data	Usefulness to Current Study
NASA Database	Lockheed Engineering and Sciences Company	Contains test chamber information, flammability, odor and toxicity ratings on numerous products and materials.	Database provides useful constituent information for the adhesives and paints/coatings material categories.
Concentration of Indoor Air Pollutants (CIP) Database	Lawrence Berkeley Laboratories	Contains measurements of concentrations of indoor air pollutants and references citing measured field results.	Database is not directly useful as there is no way of relating indoor air concentrations to specific materials.
Building Performance Database	Theodor Sterling Associates	Provides detailed information of studies on the performance of office, commercial, institutional, and residential buildings. Parameters investigated include building materials, energy use, ventilation, lighting, acoustics, and pollutant levels.	Database is not directly useful as there is no way of relating indoor air pollutant levels to product emissions.
Navy Database	U.S. Department of the Navy	It is thought that this database will contain emissions information similar to what is found in the NASA database. It is currently under evaluation.	Data provided are from closed-chamber headspace analyses. May be useful for constituent information, but will provide no emission rates.
NIOSH Database	National Institute of Occupational Safety and Health	Contains information on the composition of products and trade name chemicals.	Database is still under evaluation.
FIFRA and TSCA Enforcement System (FATES) Database	Radian Corporation	Database contains a variety of information pertaining to FIFRA and TSCA including pesticide production. Relevant information may include pesticide registration and product reporting activities mandated by FIFRA, and effluent guidelines for pesticide manufacturers.	Useful information regarding pollutants in trade name chemicals may be available. Database is under evaluation.
Non-occupational Pesticide Exposure Study (NOPES)	U.S. Environmental Protection Agency/ Atmospheric Research and Exposure Assessment Laboratory	Contains information on initial estimates of nonoccupational exposure levels and the nature of the variability in exposure.	Provides useful constituent information for many pesticide products.
Eco-Search Database	Eco-Search	Database contains information useful to chemically sensitives including: chemicals and their effect in the home, pertinent legislation, alternative consumer products, resources for non-toxic living.	Database not directly useful as information it contains is not based on technical research.

The Building Performance Database,[8] developed by Theodor Sterling Associates, presents field studies conducted in facilities with known indoor air pollution. As with the CIP database, only concentrations are presented and the database focuses more on design considerations than on identifying the source of the emissions.

The National Institute of Occupational Safety and Health (NIOSH) database presents fairly comprehensive chemical constituent data for a variety of products. For instance, for latex-based adhesives, over 700 chemical constituents are identified. This database has the potential to provide useful information on the composition of some of the products currently being studied, as well as formulas for trade name chemicals. However, there are some obstacles to the usefulness of this database for the present study. The most current information in the database is from 1983. For many product categories, formulas and manufacturing processes change, so that this information may no longer be representative of products currently on the market. A second difficulty with using this database for the Catalog study is that the information is subjectively classified and has some obvious inconsistencies that make it difficult to merge with the Catalog's classification of products. Finally, much of the data from manufacturers are confidential and therefore not accessible. Because of these difficulties, no information from the NIOSH database is included in this report. However, this database may provide useful information for future studies of material sources of indoor air, and the EPA is continuing to work with NIOSH to resolve the identified problems.

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and Toxic Substances Control Act (TSCA) Enforcement System (FATES) database contains a variety of information pertaining to FIFRA- and TSCA-regulated products, including pesticides. The database provides pesticide registration and product-reporting activities mandated by FIFRA.

The Eco-Search database was developed by a chemically sensitive individual and contains information on chemicals and their effects in the home, organizations providing support for the chemically sensitive, alternative consumer products, and pertinent legislation.

The Navy database is still being evaluated. From preliminary discussions with Navy personnel, it was learned that the Navy conducts similar testing of materials to be used in submarines as NASA does for materials to be used in the space shuttle. Most of the data are derived from headspace studies which will provide qualitative, not quantitative data. This database proved much more difficult to access and discussions are still underway to learn more about the potential usefulness of the reported data to indoor air studies.

compare emissions data, a number of pieces of information are needed describing how the tests were conducted. This type of information includes sampling and analytical methods, test methods, and test conditions such as temperature, relative humidity, duration of test, and ventilation rates. Where available, this information is included in the database, and is presented as an appendix to each set of data tables for each product category. Each study also includes references that will allow researchers to trace back to the original reference for more information on test methods.

Conclusions

Each product section in this Catalog has its own classification scheme that is compatible with the initial, universal scheme, and which promotes consistent use of terminology as well as complete coverage of all products within a product category. The Catalog tables and associated text point out a need for the use of standardized nomenclature. In some cases, emissions data are difficult to compare because the material tested is not clearly identified. For example, in a reference on flooring, the term "linoleum" is used for what appears (based on constituents) to be vinyl flooring. If researchers adopt the classification system used in this Catalog, the need for standardized nomenclature would be addressed.

The approaches used to identify and collect relevant constituent and emissions information for building materials, fixtures and furnishings, and consumer products were successful in most product sections. Literature surveys and telephone contacts with trade associations proved useful in all product categories. Industry studies, in which manufacturing processes were examined and retailers/wholesalers contacted, were good sources of information for products that were not well-characterized elsewhere. For example, there are numerous formulary references describing the constituents in most adhesives, but no such reference was identified for wallcoverings. A variety of databases were also identified that proved to contain useful information. As with the industry studies, these databases were most useful in providing information for certain product sections. Information on adhesives, sealants and caulks were often found in databases such as the NASA database, while information on carpets was rarely presented.

Information presented in each product section provides an indication of a product's potential to emit chemicals to the indoor air. How a product is formulated often determines its potential to emit. For example, the polymer base used in adhesives differentiates the emission potential of that adhesive. Those adhesives formulated with large amounts of organic solvent will be more likely to emit compounds than a nonsolvent-based adhesive. The extent to which the relative importance of each product in a product section could be determined varied from section to section, based on the extent of constituent and emissions data available for that product section.

Emissions data presented in these sections are presented as single data points. In many cases the data have been developed by time averaging over the duration of a particular test. It should be noted that there is a time-dependency associated with most emission rates, with emissions from the product generally being higher when the product is new and decreasing as the product ages. Where available, information on the age of the product tested is provided in the appendix to each section.

There was no definitive information allowing comparison of emissions from products across the sections. Most product sections contain information on emissions of a variety of chemicals. However, there is no clear basis for concluding, for example, that carpeting presents more or less potential to emit chemicals than does resilient flooring. A scheme to organize the parameters affecting a product's potential to emit chemicals to indoor air (e.g., quantity used, chemicals emitted) would enable the use of the Catalog to compare relative importance of products between the sections.

This Catalog represents a valuable resource for developing emission testing plans, experimental design parameters, and protocols. For example, the Sealants and Caulks Section describes the emission mechanisms for chemicals that are emitted, and the Insulation Section describes differences in wet versus dry samples. In addition, some of the product categories describe how consumer use may affect emission rate (e.g., one consumer may operate an aerosol can for 15 seconds, another for 5 seconds; one consumer may let carpet age before installing in the home, another may not). Tests designed with these factors in mind could accommodate the differences in consumer behavior. Where possible, the classification schemes for each product also detail the components of the product (e.g., a carpet system can consist of face fibers, a backing, and an adhesive). Tests should be designed to measure emissions from specific components of the product.

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1.0 INSULATION PRODUCTS

1.1 Description of Product Category

Insulations, as defined in this Catalog, include all thermal insulation material in roll, foam, looselay, panel, and blown fiber form that is used in homes and office buildings. This definition does not include insulations that are no longer available on the market, such as urea-formaldehyde foam and asbestos, or the adhesive materials that are purchased separately and used during installation.

1.1.1 Product Classification

In this Catalog, insulation products are classified into three categories, based on materials content and product form: fibrous, foam, and reflective (Figure 1-1).

Fibrous Insulations

Fibrous insulations are divided into two main groups: man-made vitreous fiber (MMVF) insulations and natural fiber insulations. Fibrous insulations are made up of discontinuous or entangled (wool) fibers held together with a binder.

Man-made vitreous fiber (MMVF) insulations include glass wool, rock wool, and slag wool insulations.[1] The chief oxide ingredient of MMVF insulations is silica (SiO_2), which is in a glassy or vitreous state.[1] Historically, MMVF insulations have been placed under the broad classification of man-made mineral fibers (MMMF). However, TIMA Inc. (TIMA Inc. is a not-for-profit association of firms engaged in the manufacture, and sale, within North America, of insulation, acoustical ceiling tiles, and other products containing man-made vitreous fibers) points out in its publication "The Nomenclature of Man-Made Vitreous Fibers" that these materials are not minerals and should not be placed in the same category as the "true" mineral fiber insulations such as asbestos. Therefore, these insulations are placed under the classification MMVF.

MMVF insulations are subdivided into the following product forms: preformed mats (batts, blankets and rolls), loose fibers, and rigid panels. The terms batts, blankets, and rolls generally refer to the length of a strip of MMVF insulation. Batts are generally 4 feet long or less, blankets are 8 feet long, and rolls can be as long as 50 to 100 feet. Batts, blankets, and rolls come in a variety of thicknesses and widths, and can be sold plain, with a paper, plastic, or foil backing, or completely sealed in a paper "envelope." Loose fiber insulation, also called loose-fill, is made up of loose fibers which are installed by pouring from bags or by blowing into place with compressed air.[2]

I. FIBROUS

A. Man-made vitreous fibers

1. Batts, blankets, rolls
   a. glass wool (fiberglass)
   b. slag and rock wool

2. Loose fibers
   a. glass wool (fiberglass)
   b. slag and rock wool

3. Rigid
   a. glass wool (fiberglass)
   b. slag and rock wool

B. Natural fibers
   1. Cellulose
   2. Mineral

II. FOAM

A. Rigid

1. Polystyrene
2. Polyurethane and polyisocyanurate
3. Phenolic-based foams

B. Foamed-in-place

1. Polyurethane
2. Polyisocyanurate
3. Urea-based foams

C. Elastomeric (foam rubber)

III. REFLECTIVE

Figure 1-1. Classification of Insulation Products by Material and Product Form

Each of the MMVF product form categories are further subdivided into glass wool insulation and slag and rock wool insulation. Glass wool insulation (a.k.a. fiberglass) is so called because it is approximately 55 to 70 percent silica.[1] Glass wool is produced using the rotary process. In this production process, the molten glass is placed into a "rotating spinner, which is a metal bowl with perforated sidewalls, and is extruded through the sidewall holes into many small streams."[1] The resulting fibers have an average diameter of 3 to 10 μm and a length of greater than 250 μm. "Fiber diameter and length are two of the most important properties of insulation glass fiber wool."[1] The fibers are either left loose or a binder is added to create mats or boards.

Slag wool gets its name from the iron ore blast furnace slag which makes up 70 to 90 percent (by weight) of the slag wool raw materials.[1] Rock wool gets its name from the basaltic rock which is the primary raw material used in its manufacture. Slag wool and rock wool are manufactured using either the wheel centrifuge process or the Downey process. In the wheel centrifuge process the molten material is poured onto a series of spinning wheels and is then thrown off by centrifugal force. An air stream carries the fibers away from the wheels to a collecting chamber where the fibers are left loose or formed into a mat or board.[1] In the Downey process the molten material is placed on a single spinning dish-shaped wheel. Centrifugal force carries the molten material off the wheel and air jets pull the molten streams into fibers. Again, if mats or boards are being made, a binder is added to the fibers after they are formed.[1]

Natural fiber insulations include cellulose and mineral insulations. Cellulose insulations are made up of wood or paper fibers and usually are used in the form of loose fibers. Cellulose insulations are usually installed by the blowing technique. The mineral insulation category includes asbestos. However, since asbestos is no longer used in homes and office buildings, it is not covered in this document.

Foam Insulations

Foam insulations are grouped into three categories: rigid, foamed-in-place, and elastomeric. Rigid foams are plastic substances that are expanded into foam by mixing with air, carbon dioxide, or other gaseous media and are then molded into rigid boards.[3] There are three major types of rigid foams: polystyrene, polyurethane and polyisocyanurate, and phenolic-based.

Foamed-in-place insulations are also plastic substances. During installation of foamed-in-place insulations, foaming and hardening agents are combined and forced under air pressure into voids or cavities in wall or roof construction, or are sprayed over exposed wall or roof surfaces.[3] There are also three major types of foamed-in-place insulations: polyurethane, polyisocyanurate, and urea-based foams.

Elastomeric foams are flexible foam insulations such as foam rubber.

Reflective Insulations

Reflective insulations are made from aluminum or copper foil and have a paper backing. These insulations reflect heat off their bright surfaces and to be effective as thermal insulation require an air space of at least 3/4 of an inch adjacent to the reflective surface.[3]

1.1.2 Product Major Uses

Table 1-1 presents the common uses and locations of insulation products. Man-made vitreous fiber batts, blankets, and rolls are used in ducts, air conditioners, walls, ceilings, between floors, and in attics as thermal and/or acoustic insulation. Loose fiber insulations (both MMVF and cellulose) are mainly used in horizontal applications, such as attics, because they have a tendency to settle and create "cold spots," or uninsulated areas, at the tops of walls. An exception to this is retrofitting applications, where loose fiber insulations are blown into cavities that were previously uninsulated. To be most effective, all of the fibrous insulations must be kept dry and uncompacted.[4]

Rigid foam insulation is used in roofs, exterior nonstructural sheathing for framed construction, masonry walls, and foundations.[3] Foamed-in-place foam insulation is mainly used in wall, floor, and roof assemblies. It is also excellent for retrofit applications, where it is pressure-injected into existing walls.[3] Elastomeric foam, or foam rubber, is commonly used to insulate pipes because of its excellent flexibility. Reflective insulations serve as thermal insulators, and are often laminated to batts or blankets of fibrous insulation or to gypsum wallboard to serve as a vapor barrier.

1.1.3 Sales and Production

Table 1-2 presents information on the value of insulation product shipments for 1987. Not enough data are available to make comparisons on the basis of usage amounts. However, the dollar value of shipments can give a rough estimate of relative usage amounts. Man-made vitreous fiber insulation has the highest dollar value of shipments. Of the products reported under MMVF, batts and blankets make up over 50% of the total shipment value. Foam insulations are also widely used with a total value of shipments of $690.4 million. Unfortunately, no breakdowns of foam insulation shipment

Table 1-1[a]

Common Uses and Locations For Insulation Products

Product	Use			Location					
	Thermal	Acoustic	Other	Walls	Ceilings	Floors	Attic	Roof	Other
FIBROUS									
Man-made vitreous Fiber									
Batts, blankets, and rolls	X[b]	X		X	X	X	X		Duct liner, air conditioners
Loose fibers	X			R[c]	X		X		
Natural fiber									
Cellulose	X			R	X		X		
FOAM									
Rigid	X	X		X	X			X	Exterior sheathing, foundations
Foamed-in-place	X	X		X		X	X	X	Retrofit applications
Elastomeric	X								Pipes, weather stripping
REFLECTIVE	X		Vapor barrier	X	X	X	X	X	Rafters

[a]References 4,5,6,7,8,9.
[b]Indicates a common use or location
[c]Used mainly in retrofit applications

Table 1-2[a]

Value of Insulation Product Shipments for 1987

Insulation Category	$ Value of 1987 Shipments (In Millions)	SIC[b]
Fibrous Insulation		
MMVF	2,066.2	3296
MMVF - Batts and blankets	1,119.2[c]	32961-31,35,38
MMVF - Loose fibers	95.5	32961-11
MMVF - Rigid	718.0	32961-51,61
MMVF - Other	133.5	32961-98
Cellulose	58.4	26795-31
Foam Insulation, Including Pipe and Block	690.4	30863-10
All Reflective Insulations	NA[d]	NA

[a]Reference 5.
[b]SIC = Standard Industrial Code.
[c]Only for -38.
[d]NA = Not available.

dollar values are available. Cellulose insulation makes up a minor part of the insulation market. Cellulose insulation sales declined from $96 million in 1982 to $58.4 million in 1987.

1.2 Major Constituents of Concern

The data tables at the end of this document summarize the constituent information that was identified. Information on insulation product constituents was obtained from a variety of sources. Information on the binders used in insulations was found in the TIMA document and an adhesives text.[1,10] General information on insulation constituents was obtained from the 1989 Annual Books of the American Society for Testing and Materials, indoor air studies, the TIMA document, and phone conversations with associations and manufacturers.[1,2,7,10,12-37] Detailed information on the constituents of glass wool fibers and polyurethane foam was identified in the Kirk-Othmer Encyclopedia of Chemical Technology.[15,31]

1.2.1 Fibrous Insulation

Fibers of fibrous insulations contain many inert materials such as sand, clay, limestone, dolomite, basalt, soda ash, borax, scrap glass, and iron ore blast furnace slag. From an indoor air perspective, these inert materials are of little concern. Of more concern are the binders which hold these inert fibers together. In glass wool the fibers are held together with a binder based mainly on phenol formaldehyde resins. This binder can make up to 25 percent of the product by weight. However, TIMA Inc. elaborates that, "during the curing process, the binder is converted into an insoluble polymer containing no significant amounts of formaldehyde."[1] Rock and slag wool fibers are bound together exclusively with phenolic resin, which makes up approximately 10 percent of the product by weight.[1] In addition to the primary raw materials and binders, fibrous insulations may also contain, lubricants (such as, mineral oil, and polypropylene glycol), wetting agents, antistatic agents, and extruders and stabilizers.[1]

The constituent information that was identified for cellulose insulations is more limited. Cellulose insulations contain paper or wood fibers that are bound together by acrylic adhesives.[10] Cellulose insulation is treated with boric acid as a fire retardant.[38]

1.2.2 Foam Insulation

Urea-formaldehyde foam dominated the literature on foam insulation. However, since this product has been removed from the North American market, it will not be covered here. A lot of constituent information was also identified on polyurethane foam insulation. Very little information was found on phenolic, polystyrene, elastomeric, and urea-based foams.

1.2.3 Reflective Insulation

Reflective insulations consist of foil and an optional paper backing. Reflective insulations do not appear to have any major constituents that are of concern from an indoor air perspective.

1.3 Emissions Information

The data tables at the end of this document summarize all the emissions data that were identified. Urea-formaldehyde foam and glass wool insulations were found to be the most widely tested insulation materials. In almost all of the emissions studies, the measurement of formaldehyde emissions was the major emphasis.

1.3.1 Fibrous Insulation

A variety of emission test methods have been applied to glass wool batt, blanket, and roll insulation products, including chamber studies, headspace analyses, formaldehyde surface emission monitor (FSEM) testing, and desiccator analysis. In chamber studies, formaldehyde emissions from unfaced glass wool insulation ranged from 0.009 to 0.13 mg/m^2-hour.[16,39-41] Generally, the higher the temperature and humidity, the higher the formaldehyde emissions. Unquantified amounts of formaldehyde were also identified in a chamber study on duct board and duct liner glass wool insulation.[17]

In another study, measurements of formaldehyde were taken from faced and unfaced glass wool batt insulation using an FSEM.[39] Formaldehyde emission rates from these products ranged from 0.011 to 0.038 mg/m^2-hour.[39] This study showed that as conditioning periods (i.e., age of product) increase, formaldehyde emissions decrease, and as temperature and humidity increase, formaldehyde emissions increase. It should be noted that, because measurements from the faced insulations were taken only from the unfaced side, the faced and unfaced glass wool formaldehyde emission rates were at similar levels. Preliminary formaldehyde emission measurements from the faced side of the insulation were reported to be equal to background levels.[39]

Formaldehyde emissions from glass wool insulation have also been measured by desiccator procedures.[42] In this study, formaldehyde emission rates from batts and ceiling panels ranged from 0.002 to 0.026 mg/m^2-hour, at room temperature and high humidity.

In addition to formaldehyde emissions, toluene, acetone, methylene chloride, hexane and other compounds were detected in emissions from glass wool duct liner.[41] In a headspace experiment, it was found that glass wool with a plastic backing had emission rates that were half those of glass wool with an aluminum foil backing.[7]

In a chamber study performed by Lars Molhave and a desiccator study performed by van der Wal emissions were measured from "mineral wool."[43,44] It is unclear whether this insulation material is glass wool, slag wool, rock wool, or a "true" mineral insulation such as asbestos. Because of the lack of clarity, the material used in these tests is assumed to be a general fibrous insulation material. (Although in the data sheets at the end of this document the original term "mineral wool" is retained.)

Fibrous insulation has a total volatile organic compound (TVOC) emission rate of 0.012 mg/m^2-hour, as measured by Molhave in a chamber study.[43] In a desiccator study by van der Wal, 18

chemicals were detected in emissions from moistened fibrous insulation.[44] This same researcher found that,

> "The moistened samples of mineral wool (fibrous insulation) emitted aliphatic and aromatic aldehydes and higher ketones at 50°C in quantities about a hundredfold of those emitted from dry samples at 50°C."[44]

It is speculated that the elevated temperature and moisture accelerates the decomposition of the binder material that holds the insulating fibers together.[44] In addition to the emission of organics, another indoor air concern regarding fibrous insulations is the release of fibers into the air. Approximately 1 to 2% of the insulation material has the potential to become airborne during handling.[12]

No emission studies were identified for loose and rigid fiberglass and rock and slag wool insulations, or for cellulose fibrous insulations.

1.3.2 Foam Insulation

Total VOC emissions from polystyrene foam insulation were measured at a rate of 1.4 mg/m^2-hour by Molhave in a chamber study performed at average room conditions.[43] Fifteen compounds were identified in polystyrene emissions using headspace and chamber study test methods.[7] Total VOC emissions from polyurethane foam insulation were measured at a rate of 0.12 mg/m^2-hour by Molhave in a chamber study performed at room temperature and humidity.[43]

No emissions data were identified for polyisocyanurate, phenolic, urea-based, or elastomeric foam insulation products.

1.3.3 Reflective Insulation

Attention on reflective insulations has not focused on emissions from the insulation material itself, but rather on how it blocks emissions from other sources. These reflective insulations, as well as the plastic and foil backings on other insulations, act as vapor barriers, reducing the migration of emissions from other building materials.

1.4 Data Tables

The following data tables summarize information identified in the literature relating to the insulation product category. Only VOCs are presented in these data tables; components such as

nonvolatile inert ingredients, fillers, and inorganics that may be constituents of a product are not included. Each VOC is identified as a constituent or an emission. In many cases, compounds were identified in the literature as constituents, but had not specifically been identified through emissions testing. In addition, a few compounds were identified as being emitted from a product, but not listed as a constituent. In these cases, emissions may be the result of a chemical reaction within the product.

Emission rates are presented for those compounds that were identified in the literature as being emitted. These rates are presented as ranges where multiple emission rates were identified.

Chemicals that are hazardous air pollutants (as defined in the Clean Air Act as amended in November, 1990), carcinogens, or which have a threshold limit value established are designated by an "H", "C", or "T", respectively, in the column following the chemical.

Full reference citations for all information presented in the tables are included at the end of the section. The appendix at the end of this section presents additional information, where available, concerning test conditions for literature cited.

ORGANIZATION OF DATA TABLES

FIBROUS INSULATION

Man-Made Vitreous Fibers

Glass wool (Unspecified) 1-12

Mineral wool (Unspecified) 1-13

Batts, Blankets, Rolls -- Glass wool 1-14

Batts, Blankets, Rolls -- Mineral wool 1-16

Rigid -- Glass wool 1-17

FOAM INSULATION

Foam (Unspecified) 1-18

Polyurethane (Unspecified) 1-19

Foamed-in-Place -- Polyurethane 1-20

Rigid -- Phenolic 1-21

Rigid -- Polystyrene 1-22

Rigid -- Polyurethane 1-23

APPENDIX TO DATA TABLES 1-25

Chapter	Fibrous-Man-Made Vitreous Fibers	Product	Glass Wool (Fiberglass)
SIC	3296		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2-Methylpentanol				NQ				44
2-Methylpropanol				NQ				44
3-Methylpentanol				NQ				44
Benzaldehyde		100-52-7		NQ				44
Dimethylhydroxylbenzaldehyde				NQ				44
Formaldehyde	C,H,T	50-00-0		14	2	26	ug/m2-hr	17,40
Hydroxylbenzaldehyde		123-08-0		NQ				44
i-Butanol	H,T	78-92-2		NQ				44
Methylhydroxylbenzaldehyde				NQ				44
n-Heptanol		111-70-6		NQ				44
n-Hexanol		111-27-3		NQ				44
SUBPRODUCT: Binder								
Phenol-Formaldehyde Resin			X					18
Resole Resins-Phenol Based			X					11
Urea		57-13-6	X					18

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

INDOOR AIR CATALOG - Insulation

Chapter	Fibrous-Man-Made Vitreous Fibers	Product	Mineral Wool
SIC	3296		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2-Heptanone	T	110-43-0		NQ				44
2-Hexanone	T	591-78-6		NQ				44
2-Methylpentanol				NQ				44
2-Methylpropanol				NQ				44
2-Pentanone	T	107-87-9		NQ				44
3-Hexanone		589-38-8		NQ				44
3-Methylpentanol				NQ				44
3-Pentanone	T	96-22-0		NQ				44
Benzaldehyde		100-52-7		NQ				44
Dimethylhydroxylbenzaldehyde				NQ				44
Hydroxybenzaldehyde		90-02-8		NQ				44
i-Butanol	H,T	78-92-2		NQ				44
Methylhydroxylbenzaldehyde				NQ				44
n-Decanol				NQ				44
n-Heptanol		111-70-6		NQ				44
n-Hexanol		111-27-3		NQ				44
n-Nonanol		143-08-8		NQ				44
n-Octanol		111-87-5		NQ				44
Total Volatile Organic Compounds				12			ug/m2-hr	43

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Fibrous-Man-Made Vitreous Fibers	Product	Glass Wool-Batts, Blankets, Rolls
SIC	3296	SIC	32961-00
Usage/Sales	ND	Usage/Sales	2.99E+09 pounds

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Aluminum foil-backed								
1,2,3-Trimethylbenzene		95-63-6		0.04			ug/m2-hr	8
1,2,4-Trimethylbenzene		95-63-6		0.08			ug/m2-hr	8
Aliphatic and Oxygenated Hydrocarbons				0.13			ug/m2-hr	8
Aromatic Hydrocarbons				0.15			ug/m2-hr	8
m-Ethyltoluene				0.03			ug/m2-hr	8
n-Undecane		1120-21-4		0.13			ug/m2-hr	8
SUBPRODUCT: Plastic-backed								
1,2,3-Trimethylbenzene		95-63-6		0.03			ug/m2-hr	8
1,2,4-Trimethylbenzene		95-63-6		0.03			ug/m2-hr	8
Aromatic Hydrocarbons				0.08			ug/m2-hr	8
m,p-Xylene				0.02			ug/m2-hr	8
SUBPRODUCT: Faced								
Formaldehyde	C,H,T	50-00-0		30	12	58	ug/m2-hr	39
SUBPRODUCT: Unfaced								
Formaldehyde	C,H,T	50-00-0		29	6	93	ug/m2-hr	39

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Fibrous-Man-Made Vitreous Fibers	Product	Glass Wool-Batts, Blankets, Rolls
SIC	3296	SIC	32961-00
Usage/Sales	ND	Usage/Sales	2.99E+09 pounds

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Formaldehyde	C,H,T	50-00-0		47.5	8	130	ug/m2-hr	39,40,42
Acrylic Adhesives			X					11
Phenolic Adhesive			X					11
SUBPRODUCT: Duct liner								
2-Butoxyethanol	T	111-76-2		NQ				41
2-Methylnaphthalene		91-57-6		NQ				41
Acetone	T	67-64-1		NQ				41
Benzene	C,H,T	71-43-2		NQ				41
Formaldehyde	C,H,T	50-00-0		NQ				17
Hexane	H,T	110-54-3		NQ				41
Methylcyclohexane	T	108-87-2		NQ				41
Methylene Chloride	C,H,T	75-09-2		NQ				41
Piperdine				NQ				41
Propyl Acetate	T	109-60-4		NQ				41
Propylbenzene		103-65-1		NQ				41
Pyrrolidine		123-75-1		NQ				41
p-Dichlorobenzene		106-46-7		NQ				41
Tetrachloroethane	H,T	79-34-5		NQ				41
Toluene	H,T	108-88-3		NQ				41

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Fibrous-Man-Made Vitreous Fibers	Product	Mineral Wool-Batts, Blankets, Rolls
SIC	32961	SIC	3296
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Acrylic Adhesives			X					11
Melamine-Formaldehyde Resin (binder)			X					15
Phenol-Formaldehyde Resin (binder)			X					15
Urea-Formaldehyde Resin (binder)			X					15

ND - No data.

Chapter	Fibrous-Man-Made Vitreous Fibers	Product	Glass Wool-Rigid
SIC	3296		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Ceiling panel								
Formaldehyde	C,H,T	50-00-0		19.4	16.3	22.5	ug/m2-hr	40
SUBPRODUCT: Duct board								
Formaldehyde	C,H,T	50-00-0		NQ				17

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Foam	Product	NP
SIC	30863		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Acrylic Adhesives			X					11
Pentane	T	109-66-0	X					11
p-Toluenesulfonic Acid		104-15-4	X					11
Trichlorotrifluoroethane	T	76-13-1	X					11

T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.

INDOOR AIR CATALOG - Insulation

Chapter	Foam	Product	Polyurethane
SIC	30863		
Usage/Sales	$9.407E+08	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
CFC-11			X					12
Fluorocarbon Gas			X					10
Polyhydroxy Compounds			X					10
Polyisocyanate Compound			X					10
Total Volatile Organic Compounds				120			ug/m2-hr	43

ND - No data.

INDOOR AIR CATALOG - Insulation

Chapter	Foam-Foamed in Place	Product	Polyurethane
SIC	30863		
Usage/Sales	$9.407E+08	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Polyester Resin			X					2
Polyisocyanate Resin			X					2
Trichlorofluoromethane	T	75-69-4	X					2

T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Foam-Rigid	Product	Phenolic
SIC	30863		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Phenolic Resin			X					10

ND - No data.

Chapter	Foam-Rigid	Product	Polystyrene
SIC	30863		
Usage/Sales	$9.407E+08	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
1,2,3-Trimethylbenzene		95-63-6		0.08	0.03	0.12	ug/m2-hr	8
1,2,4-Trimethylbenzene		95-63-6		0.31	0.17	0.44	ug/m2-hr	8
1,3,5-Trimethylbenzene		108-67-8		0.09	0.08	0.1	ug/m2-hr	8
Chlorobenzene	H,T	108-90-7		0.42	0.38	0.46	ug/m2-hr	8
Ethylbenzene	H,T	100-41-4		12.5	10	15	ug/m2-hr	8
Isopropylbenzene	T	98-82-8		1.55	1.4	1.7	ug/m2-hr	8
m,p-Xylene				1.6	1.5	1.7	ug/m2-hr	8
m-Ethyltoluene				0.59	0.44	0.73	ug/m2-hr	8
n-Propylbenzene		103-65-1		0.78	0.7	0.86	ug/m2-hr	8
n-Undecane		1120-21-4		0.19			ug/m2-hr	8
o-Dichlorobenzene	T	95-50-1		0.19	0.17	0.2	ug/m2-hr	8
o-Ethyltoluene		611-14-3		0.09	0.07	0.1	ug/m2-hr	8
o-Xylene	H,T	95-47-6		0.36	0.33	0.39	ug/m2-hr	8
p-Dichlorobenzene		106-46-7		0.59	0.47	0.71	ug/m2-hr	8
Polymerized Styrene Resin			X					10
Styrene	H,T	100-42-5		5.55	4.9	6.2	ug/m2-hr	8
Total Volatile Organic Compounds				1400			ug/m2-hr	43

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Foam-Rigid	Product	Polyurethane
SIC	30863		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
1,1,1-Trimethylolpropane			X					16
1,2,6-Hexanetriol		106-69-4	X					16
1,3-Butylene Glycol		107-88-0	X					16
1,4-Butylene Glycol		110-63-4	X					16
Adipic Acid		124-04-9	X					16
alpha-Methyl Styrene	T	98-83-9	X					31
Diethylene Glycol		111-46-6	X					16
Diphenylmethane Diisocyanate	T	101-68-8	X					31
Ethylene Glycol	H,T	107-21-1	X					16
Fluorotrichloromethane	T	75-69-4	X					31
Glycerol		56-81-5	X					16
Mannitol		69-65-8	X					16
n-Ethylmorpholine	T	100-74-3	X					16
Pentaerythritol		115-77-5	X					16
Phosphate Ester-Based, Flame-Retardant			X					31
Phthalic Anhydride	H,T	85-44-9	X					16
Polyether Triol, 3000 mol. wt.			X					16
Polyhydroxy Compounds			X					31

(Continued)

Chapter	Foam-Rigid	Product	Polyurethane
SIC	30863		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
(Continued)								
Propylene Glycol		57-55-6	X					16
Silicon Oil Copolymer			X					31
Silicone Copolymer L-520			X					16
Sorbitol		50-70-4	X					16
Stannous Oleate	T	1912-84-1	X					16
Toluene Diisocyanate (TDI)	H,T	584-84-9	X					16
Trichlorofluoromethane	T	75-69-4	X					16

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

Insulation

8 Reference: Sheldon, et. al., 1988
Test Method: Chamber Study
Sampling Method: Tenax Tubes
Analysis Method: GC/FID, GC/MS

	Value	Min	Max	Units
RH	48			%
Temp	25			° C
ACH	0.5			
Testing Duration				

Comment:

8 Reference: Sheldon, et. al., 1988
Test Method: Headspace
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH		0	48	%
Temp		25	34	° C
ACH		0.5	11	
Testing Duration				

Comment:

17 Reference: Miele, 1989
Test Method: Chamber Study
Sampling Method:
Analysis Method: NIOSH

	Value	Min	Max	Units
RH		10	50	%
Temp		25	43	° C
ACH	0.5			
Testing Duration	1			hr

Comment:

39 Reference: Matthews and Westley, 1987
Test Method: Formaldehyde Surface Emission Monitor
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration	3			hr

Comment: R-11 foil faced fiberglass;
0-10 day conditioning period.

39 Reference: Matthews and Westley, 1987
Test Method: Chamber Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH		50	68	%
Temp		23	38	° C
ACH				
Testing Duration				

40 Reference: Pickrell, et. al., 1984
Test Method: JIS Dessicator Procedure
Sampling Method: JIS Dessicator Procedure
Analysis Method: Modified Pararosaniline Method

	Value	Min	Max	Units
RH	100			%
Temp				° C
ACH				
Testing Duration	24			hr

Comment:

40 Reference: Pickrell, et. al., 1984
Test Method: Chamber Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH	90			%
Temp	25			° C
ACH				
Testing Duration				

Comment:

41 Reference: Bayer and Black, 1988
Test Method: Chamber Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH		45	55	%
Temp		33	27	° C
ACH	2.2			
Testing Duration				

Comment:

41 Reference: Bayer and Black, 1988
Test Method: Headspace
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH				
Temp	26.7			° C
ACH				
Testing Duration	1			hr

Comment:

42 Reference: Pickrell, et. al., 1983
Test Method: Standard Dessicator
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH		90		%
Temp	24			° C
ACH				
Testing Duration				

Comment:

43 Reference: Molhave, 1982
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS

	Value	Min	Max	Units
RH		35	40	%
Temp	21.1			° C
ACH	1			
Testing Duration				

Comment:

44 Reference: van der Wal, 1987
Test Method: Dessicator
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH				%
Temp	50			° C
ACH				
Testing Duration				

Comment: Moist mineral wool.

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2.0 WALLCOVERING

2.1 Description of Product Category

Wallcoverings, as defined here, include materials applied to an exposed surface of a wall for aesthetic and/or functional (i.e., moisture protection) purposes rather than for structural purposes. The category includes wallpaper as well as several other wallcovering products such as ceramic and plastic tiles. To avoid overlap with the wood products category, which will be published in Volume II, wood-based paneling products are not included in the wallcoverings category. Wood-based paneling products are shown in Figure 2-1 only to illustrate how they relate to other wallcoverings. Complete information on these wood-based paneling products will be presented in the Wood Products Section in Volume II of this Catalog.

Also not included in the definition of wallcoverings are materials that are covered in other categories, such as paint, structural components of walls, or adhesives that are purchased separately from the wallcovering material. However, the paste in pre-pasted wallpaper is considered here as part of the wallcovering.

2.1.1 Product Classification

Two classification schemes were considered for wallpaper products: the Census of Manufactures Standard Industrial Classification (SIC) and the American Society for Testing and Materials (ASTM) classification.[1,2] The ASTM classification is based primarily on durability, and groups wallpaper products into six categories on the basis of colorfastness, washability, scrubbability, abrasion resistance, breaking strength, and other measures of durability. The ASTM wallpaper categories are:

Category	Description
1	Decorative only
2	Decorative with limited serviceability
3	Decorative with medium serviceability
4	Decorative with high serviceability
5	Medium commercial serviceability
6	Full commercial serviceability

The main drawback of using this classification for the purposes of this report is that it does not relate the categories to particular wallpaper materials.

The Census of Manufactures SIC classification organizes wallpaper by type of backing and facing material and facing thickness in mils (1 mil = 1/1000 of an inch). The SIC classification, shown in Figure 2-1, was chosen for this report because it is both material- and product-oriented, making associations of emissions to products much easier than with the ASTM classification. In this section, the SIC classification for wallpaper is described in detail. The relationship between the SIC categories and the ASTM categories is provided for additional information.

Category A, paper with less than 2 mils of coating, is basically paper with the least amount of coating that can be used and still provide an even layer.[3] This type of wallpaper is referred to as "washable," and correlates best with Categories 1 and 2 of the ASTM classification. Category A wallpaper represents a common wallpaper construction for residential do-it-yourself applications. Whether this type of wallpaper is considered to be nonstrippable or dry-strippable is mainly a function of the glue that is used and the wall preparation prior to hanging. Strippable wallpaper, as defined by the ASTM, is "capable of being dry-stripped without leaving appreciable residue or otherwise damaging the wall."[2]

Category B wallpaper, which is paper-backed, coated, or laminated with 2 mils or more of plastics is a heavier, more durable residential wallpaper. This type of wallpaper is referred to as "scrubbable," and probably falls somewhere between Categories 3 and 4 of the ASTM classification. The thicker coating on this wallpaper gives it added water resistance, making it well-suited for kitchen and bathroom use. The difference between prepasted and nonpasted wallpaper in this category is that prepasted wallpaper has factory-applied paste while nonpasted does not.

Categories C and D wallpapers, which are fabric backed, coated, or laminated with vinyl chloride polymer or other plastics (e.g., mylar), are even heavier and more durable than Category B wallpaper. These wallpapers can be used in residences for special purposes such as wall reinforcement, but are generally used for commercial applications. These wallpapers have commercial serviceability (i.e., high durability), and correlate with Categories 4, 5, and 6 of the ASTM classification. Woven-backed wallpaper has greater strength than the nonwoven-backed wallpaper.

Category E, other wallpapers, includes fiberglass wallpapers, wallpapers containing silk, bamboo, grass cloth and other natural materials, and scenic or mural panel decorations that contain fabric or paper.

Under the "paneling" classification, the plastic panel category includes decorative plastic laminates and molded sheets of plastic reinforced with glass fiber. Decorative plastic laminates consist

I. WALLPAPER

A. Paper with less than 2 mils[a] of coating

1. Nonstrippable
2. Dry-strippable

B. Paper-backed, coated, or laminated with 2 mils of plastics or more.

1. Pre-pasted
2. Nonpasted

C. Fabric-backed, coated, or laminated with vinyl chloride polymer

1. Woven
2. Nonwoven

D. Fabric-backed, coated, or laminated with other plastics

1. Woven
2. Nonwoven

E. Other wallpapers

II. PANELING

A. Wood-based panels[b]

B. Plastic panels

III. OTHER WALLCOVERINGS

[a]Note: 1 mil = 1/1000 of an inch or 0.0254 mm.

[b]Complete information regarding wood-based paneling will be presented in the Wood Products chapter in Volume II of this Catalog. They are shown here only to illustrate how they relate to other wallcoverings.

Figure 2-1. Classification of Wallcoverings

of three or more layers of resin-impregnated paper and tissue. Plastic laminates provide "hard, durable, wear-, heat-, light-, and stain-resistant surfaces."[4]

The "other wallcoverings" classification mainly includes plastic and ceramic tiles. Ceramic tiles consist of clay coated with a glaze. Additional materials such as chromium oxide are sometimes added to change the color of the clay.[4] Plastic tiles are made of polystyrene and urea-formaldehyde resins.[4]

2.1.2 Product Major Uses

Wallcoverings are used on the surface of walls for decorative and/or functional purposes. Category A wallpaper is a do-it-yourself residential wallpaper used in dry, low-traffic areas. Category B wallpaper is a do-it-yourself residential wallpaper used in medium-traffic areas where moisture resistance is needed. Categories C and D wallpapers are commercial-grade wallpapers used in high-traffic areas where extra durability is needed. Plastic laminates are used on room dividers, wall panels, and areas where extra durability is required.

One of the major products under the SIC "other wallcoverings" classification is wall tiles (plastic and clay). Wall tiles are generally used where water resistance is most needed, such as in bathrooms, kitchens, and washrooms. Tiles are also used as a dado (i.e., a decoration adorning the lower part of an interior wall), or in tile mosaics. Ceramic tiles are usually more durable than plastic tiles.[4]

2.1.3 Sales and Production

Sales data, in the form of the dollar value of annual product shipments, are shown in Table 2-1 for wallpaper and tile. Sales data in the form of the amount of material shipped were not available. Dry-strippable wallpaper with less than 2 mils of coating (typically vinyl chloride polymer) has the greatest dollar value of annual shipments at $206.4 million. This lightweight, washable, thinly vinyl-coated paper is the most widely used residential wallpaper. Woven fabric-backed wallpaper, which is coated with vinyl chloride polymer, also has a high dollar value of annual shipments at $186.1 million. The majority of this type of wallpaper is used in commercial applications.[5]

Two estimates were obtained for the retail value of wallpaper sold in 1990. A value of $2.2 billion, which includes both residential and commercial wallcoverings, was quoted by the National Decorating Products Association.[6] An estimate of $3.5 billion (or 170 million rolls) which includes residential and commercial wallcoverings in addition to draperies and bedding, was quoted by Wallcoverings Magazine.[7,8] The total value of wallpaper shipments, as shown in Table 2-1, was $530.2 million in 1987.[1] The large difference between the value of shipments and the retail value

Table 2-1

Annual Product Shipments of Wallcoverings[a]

Category	Value (in Millions of $)
I. Wallpaper	530.2
A. Paper with less than 2 mils of coating	214.0
1. Nonstrippable	7.6
2. Dry-strippable	206.4
B. Paper-backed, coated, or laminated with 2 mils of plastics or more	62.0
1. Pre-pasted	38.2
2. Nonpasted	23.8
C. Fabric-backed, coated, or laminated with vinyl chloride polymer	219.4
1. Woven	186.1
2. Nonwoven	33.3
D. Fabric-backed, coated, or laminated with other plastics	
1. Woven	3.0
2. Nonwoven	
E. Other Wallpapers	
II. Paneling	NA[b]
III. Other Wallcoverings	
A. Clay tile, including floor tile	616.6
B. Plastic tile, including ceiling tile	48.7

[a] Reference 1.
[b] NA = Not available.

estimates of the products is probably due to price markups at various stages of the products' movement from the factory to the retail store. Additionally, while the number of rolls of wallpaper sold has actually declined in the last few years, the price per roll has increased.[6]

As shown in Table 2-1, the shipment value for clay tiles was $616.6 million in 1987. This value includes wall and floor tile. The product shipment value of $48.7 million for plastic tiles includes both wall and ceiling tile. Without knowing what portion of these product shipment values represents tiles used on walls, it is difficult to compare these figures to the figures for wallpaper. The figures do seem to indicate, however, that the product shipment value of clay wall tiles was higher than that for plastic wall tiles.

2.2 Major Constituents of Concern

Wallpaper can have as many as four major layers: the facing, an intermediate layer, the backing, and the paste.[9] A variety of materials can be used to make up each of these layers. Chemical level constituent data on wallcoverings are very limited. One general text on building materials cites the composition of the hanging papers that are used to make wallpaper as inert substances such as groundwood, clay, rosin, sodium silicate, and talc.[4]

A study of the flexible vinyl coating and printing industry manufacturing process provided information on the constituents of the vinyl and the inks used to make vinyl wallpaper. From an indoor air perspective, the printing solvents that are used, such as ketones (methyl ethyl ketone), tetrahydrafuran, toluene, and xylene, can be a concern. However, some wallpaper manufacturers are using water-based rather than solvent-based inks. These water-based inks would be expected to have lower emissions of solvents, thereby reducing overall emissions from the wallpaper.

According to one general adhesive reference, the major constituents of wallpaper pastes are starch, cellulose, and urea.[10] Additionally, one paste was found to contain mineral spirits.

Constituent information on wallcoverings other than wallpaper is very limited. Data were identified for plastic paneling materials, plastic tiles, and clay tiles. The most notable of these constituents was urea-formaldehyde resins in the plastic tiles.[4]

In addition to the type of materials that make up a product, the amount of material that is used is also important from an indoor air perspective. Generally, a product containing a greater amount of material would be expected to have a higher emissions potential than a similar product containing less of the same type and quality of materials. Of all the wallpaper categories, Category A wallpaper

contains the least amount of paper and plastic by weight, while category B wallpaper is a heavier product, with a thicker paper backing and a thicker plastic coating. The substitution of the paper backing with a fabric backing makes the wallpaper in Categories C and D the heaviest and most durable.

2.3 Emissions Information

Data on wallcovering emissions are very limited; only three wallcovering emission studies were identified.[11-13] These emission tests were all environmental test chamber studies performed at standard room conditions.

The study performed by Molhave[11] reports only the total VOC emissions. Another study, conducted by Sheldon,[12] reports emissions from wallpaper glued to sheetrock. In this study, it was not specified what type of wallpaper was used, and it cannot be determined whether the wallpaper, glue, or sheetrock was the source of the emissions. Sheldon noted emissions of xylene, undecane, decane, dichloroethane, and trichloroethane from the wallpaper and sheetrock assemblage. The xylene detected in this study may be from the solvents used in wallpaper printing.

van der Wal[13] reports measurable emissions of toluene, aromatic hydrocarbons, chlorinated hydrocarbons, and formaldehyde from vinyl coated wallpaper. The toluene detected in this study was possibly from the solvents used in wallpaper printing.

Two manufacturers identified solvents from the printing and finishing of vinyl wallpaper as potential sources of methyl ethyl ketone or toluene emissions.[9,14] However, these emissions drop sharply after 1 to 2 weeks, and are reduced when the solvents are driven off when the wallpaper is heated during manufacturing.[9,14] In addition, some of the plasticizers from vinyl wallpaper may be emitted, but this occurs only at high temperatures.[14]

Two studies have been identified that show that the application of wallcovering materials to wood products can help prevent formaldehyde emissions from wood products from entering living areas. In one study,[15] a 2-mil vinyl film was applied to high formaldehyde-emitting hardwood plywood panels. The result was a 90% reduction in formaldehyde emissions from the panels. In another study,[16] a paper wallpaper and a vinyl wallpaper were applied to particleboard and emissions were measured in a chamber. The vinyl wallpaper reduced formaldehyde emissions from the particleboard by 85%, whereas the paper wallpaper had a limited effect. The vinyl coating on the heavier wallpaper acted as a vapor barrier, preventing the formaldehyde from escaping the particleboard.

2.4 Data Tables

The following data tables summarize information identified in the literature relating to the wallcovering product category. Only VOCs are presented in these data tables; components such as nonvolatile inert ingredients, fillers, and inorganics that may be constituents of a product are not included. Each VOC is identified as a constituent or an emission. In many cases, compounds were identified in the literature as constituents, but had not specifically been identified through emissions testing. In addition, a few compounds were identified as being emitted from a product, but not listed as a constituent. In these cases, emissions may be the result of a chemical reaction within the product.

Emission rates are presented for those compounds that were identified in the literature as being emitted. These rates are presented as ranges where multiple emission rates were identified.

Chemicals that are hazardous air pollutants (as defined in the Clean Air Act as amended in November, 1990), carcinogens, or which have a threshold limit value established are designated by an "H", "C", or "T", respectively, in the column following the chemical.

Full reference citations for all information presented in the tables are included at the end of the section. The appendix at the end of this section presents additional information, where available, concerning test conditions for literature cited.

ORGANIZATION OF DATA TABLES

WALLPAPER

Wallpaper (Unspecified) 2-10

Wallpaper (Unspecified and glued to sheetrock) 2-11

Wallpaper -- Paper with less than 2 mils of coating 2-12

Wallpaper -- Paper Backed, Coated, or Laminated with 2 mils of Plastic or more -- Prepasted 2-13

Wallpaper -- Vinyl and Glass Fibers 2-14

Wallpaper -- Vinyl Coated 2-15

Wallpaper -- PVC 2-16

Other Wallpaper -- Hessian (Burlap) 2-17

Other Wallpaper -- Textile 2-18

PANELING

Plastic Panels 2-19

OTHER WALLCOVERINGS

Plastic Tile 2-20

APPENDIX TO DATA TABLES 2-21

Chapter	Wallpaper	Product	NP
SIC	26791		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Paste								
4-Chloro-meta-cresol			X					10
Acrylamide Polymer			X					9
Anionic Polyacrylamide			X					10
Carboxymethyl Cellulose		9004-32-4	X					10
Hydroxyethyl Cellulose			X					10
Mineral Spirits			X					9
Parachloro-meta Cresol		59-50-7	X					10
Polyacrylamide		9003-05-8	X					10
Urea		57-13-6	X					10
SUBPRODUCT: Ink								
Glycols (Water-Based)			X					9
Methyl Ethyl Ketone (MEK)	H,T	78-93-3	X					9
Methyl Methacrylate	H,T	8062-6	X					9
Toluene	H,T	108-88-3	X					9
SUBPRODUCT: Waterproofing								
Formamide	T	75-12-7	X					18

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.

Chapter	Wallpaper (glued to sheetrock)	Product	NP
SIC	26791		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
1,1,1-Trichloroethane	H,T	71-55-6		5			ug/m2-hr	12
1,2-Dichloroethane		107-06-2		18.6			ug/m2-hr	12
m,p-Xylene				1.6			ug/m2-hr	12
n-Decane		124-18-5		11.4			ug/m2-hr	12
n-Undecane		1120-21-4		18			ug/m2-hr	12
o-Xylene	H,T	95-47-6		0.4			ug/m2-hr	12
p-Xylene		106-42-3		1.6			ug/m2-hr	12

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.

Chapter	Wallpaper	Product	Paper with Less than 2 mils of Coating
SIC	26791		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Acrylic (Binder)			X					9
Polyvinyl Acetate (Binder)			X					9
Total Volatile Organic Compounds				30			ug/m2-hr	11

ND - No data.

Chapter	Wallpaper	Product	Paper Backed, Coated, or Laminated with 2 mils of Plastic or More-Prepasted
SIC	26791		
Usage/Sales	ND	Usage/Sales	$3.82E+07

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Polyvinyl Chloride		9002-86-2	X					9

ND - No data.

INDOOR AIR CATALOG - Wallcoverings

Chapter	Wallpaper	Product	Vinyl and Glass Fibers
SIC	26791		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Total Volatile Organic Compounds				300			ug/m2-hr	11

ND - No data.

INDOOR AIR CATALOG - Wallcoverings

Chapter	Wallpaper	Product	Vinyl Coated
SIC	26791		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Chlorinated Hydrocarbons				13.33	10	20	ug/m2-hr	13
Formaldehyde	C,H,T	50-00-0		15			ug/m2-hr	13
Other Aromatic Hydrocarbons				10	5	15	ug/m2-hr	13
Toluene	H,T	108-88-3		21.67	5	50	ug/m2-hr	13
SUBPRODUCT: Printing solvents								
Ketones			X					17
Tetrahydrofuran	T	109-99-9	X					17
Toluene	H,T	108-88-3	X					17
Xylene	H,T	1330-20-7	X					17
SUBPRODUCT: Vinyl web								
Polyvinyl Chloride (PVC) Resins		9002-86-2	X					17
Vinyl Chloride/Vinyl Acetate Copolymers	H		X					17
SUBPRODUCT: Waterborne inks and resins								
Total Volatile Organic Compounds			X					17

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

INDOOR AIR CATALOG - Wallcoverings

Chapter	Wallpaper	Product	PVC
SIC	26791		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Total Volatile Organic Compounds				100			ug/m2-hr	11

ND - No data.

INDOOR AIR CATALOG - Wallcoverings

Chapter	Other Wallpapers	Product	Hessian (Burlap)
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Total Volatile Organic Compounds				5.0			ug/m2-hr	11

ND - No data.

INDOOR AIR CATALOG - Wallcoverings

Chapter	Other Wallpapers	Product	Textile
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Total Volatile Organic Compounds				840	80	1600	ug/m2-hr	11

ND - No data.

INDOOR AIR CATALOG - Wallcoverings

Chapter	Paneling	Product	Plastic Panels
SIC	30898-01	SIC	30898-06
Usage/Sales	ND	Usage/Sales	$52.5 million

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Plastic laminate								
Melamine Resin			X					4
SUBPRODUCT: Vinyl and paper								
Total Volatile Organic Compounds				40			ug/m2-hr	11

ND - No data.

INDOOR AIR CATALOG - Wallcoverings

Chapter	Other Wallcoverings	Product	Plastic Tile
		SIC	30898-07
Usage/Sales	ND	Usage/Sales	$4.87E+07

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Polystyrene		9003-53-6	X					9
Urea-Formaldehyde Resins			X					4

ND - No data.

11 Reference: Molhave, 1982
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS

	Value	Min	Max	Units
RH		35	40	%
Temp	21.1			° C
ACH	1			
Testing Duration				

Comment:

12 Reference: Sheldon, et. al., 1988
Test Method: Chamber Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH		60	75	%
Temp		25	26.5	° C
ACH		0.59	0.61	
Testing Duration		>12		hr

Comment:

13 Reference: van der Wal, et. al., 1990
Test Method: Chamber Study
Sampling Method: Tenax Tubes, Charcoal Adsorption Tubes, Bubblers
Analysis Method: GC/MS, GC/FID, GC/ECD

	Value	Min	Max	Units
RH	50			%
Temp	23			° C
ACH	1			
Testing Duration		1	24	hr

Comment:

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3.0 RESILIENT FLOOR COVERING

3.1 Description of Product Category

Resilient floor coverings are produced in sheet or tile form and are composed of various resins, plasticizers, fibers, pigments, and fillers formed under heat and pressure.[1] Resilient flooring is capable of withstanding moderately heavy traffic, moisture, dirt, and some chemicals without permanent deformation or loss of shine.

The term "resilient flooring" is often considered synonymous with vinyl flooring, as most current resilient flooring is, in fact, vinyl flooring. However, a few nonvinyl flooring materials (e.g., linoleum, rubber, and cork) are included under this heading. Linoleum flooring has not been manufactured in the United States in about 20 years, but the term is often misused to refer to any type of resilient or vinyl flooring in roll or sheet form. Rubber and cork flooring will not be discussed here in as much detail as other types of flooring because they have a relatively low market share.

3.1.1 Product Classification

The product classification for resilient floor coverings presented in Figure 3-1 was developed primarily from the Census of Manufactures SIC Classification, although information obtained from other sources was also used.[1,2,3,4] The classification is based on the composition of the various types of resilient floor coverings. The two major categories of resilient floor coverings are sheet vinyl flooring and vinyl tile.

I. SHEET VINYL FLOORING

II. FLOOR TILE

1. Vinyl tile
2. Vinyl composition tile

III. OTHER (NONVINYL) RESILIENT FLOOR COVERINGS (LINOLEUM, RUBBER, AND CORK)

Figure 3-1. Classification of Resilient Flooring Products

Sheet Vinyl Flooring

Sheet vinyl flooring is produced in rolls and typically is installed with adhesives by professional flooring installers. Water- or solvent-based adhesives can be used for installing all types of resilient floor coverings. In many cases, the manufacturer's warranty requires that a specific adhesive be used.[4] (See Section 5.0 for specific information on adhesives.) Off-gassing of organic vapors can occur during and after installation from both the flooring itself and the adhesives. Data indicate that vapor emission rates decrease substantially within 24 hours after installation.[4] The use of adhesives may be avoided by stretching the sheet over the floor surface and securing the edges with floor molding. Some sheet vinyl flooring can be stapled at the perimeter and adhered only at the seams and portions of the perimeter.

Most residential sheet vinyl floorings produced today are considered "no-wax" floors because they do not require the application of a wax or finish, which may itself be a source of emissions.[5,6,7]

Floor Tile

Resilient floor tile can be subdivided into two types: vinyl tile and vinyl composition tile. Vinyl tile, also referred to as "homogeneous vinyl," contains a higher proportion of vinyl constituents (e.g., vinyl polyvinyl chloride resin) to fillers than does vinyl composition tile. Vinyl composition tile formerly contained asbestos as a filler; however, vinyl asbestos tile is no longer manufactured domestically. Common fillers currently used include limestone and clay.

Both vinyl and vinyl composition tiles are available plain-backed or adhesive-backed. Plain-backed tile requires adhesives and is normally professionally installed. Commercial tile is normally available in dry-backed form only. Adhesive-backed tile is popular with the "do-it-yourself' homeowner because installation consists of merely peeling a protective paper off the back of a tile and pressing the tile in place. Some adhesive-backed tiles produce less odor during and immediately after installation than tiles requiring applied adhesives.[4]

Other (Nonvinyl) Resilient Floor Coverings

Linoleum flooring is no longer manufactured in the United States, although some is imported from Europe.[3] It has good resistance to abrasion, but poor resistance to some spills. Linoleum flooring is made by laying a mixture of solidified linseed oil and gums, cork dust and/or wood flour, and (usually) pigments on a jute or saturated felt backing. Linoleum, like most vinyl flooring, requires adhesives for installation. The adhesives, as well as the saturated backing, may be sources of emissions.[6,8]

Rubber flooring provides excellent resistance to indentation, whereas cork tile (which is composed of compressed granulated cork bonded with a heat-processed resinous binder) displays poor wear resistance.[1]

3.1.2 Major Product Uses

Resilient floor coverings are suitable for indoor use only in areas that are subject to light-to-heavy foot traffic (depending on the thickness and composition of the material). Table 3-1 summarizes the major uses of resilient flooring.[1-5]

Table 3-1

Major Uses of Resilient Flooring

Resilient Flooring	Uses
Vinyl Flooring	
Sheet vinyl	Residential (such as in entrance ways)
Vinyl tile	Some residential, but primarily commercial/institutional
Vinyl composition tile	Exclusively commercial/institutional
Nonvinyl Flooring	
Linoleum	Imported for commercial/institutional use
Rubber	Commercial/institutional (stair covering, locker room, skating rink)
Cork	Residential (light foot-traffic area)

Sheet vinyl flooring is most popular in homes, and its residential use is increasing.[3] Homeowners are attracted to the variety of colors and patterns, affordability, and ease of upkeep. The newer vinyl tiles, which have laminated or embossed designs, are becoming popular with residential interior designers and architects.

Vinyl composition tile is used in institutions and commercial settings because of its competitive advantages over sheet vinyl. Some vinyl composition tile is available with slip-resistant features. Static dissipative vinyl and vinyl composition tile is also available for use in offices, computer centers, and other applications where static electricity presents potential problems.[7]

Linoleum flooring installed in the past 15 years is primarily found in commercial settings. Designers and architects are attempting to make linoleum popular again by introducing new patterns

and colors. Rubber flooring material is useful for floor runners, stair tread covering, and in locker rooms. Cork tile is normally used in light-foot-traffic areas in residential settings.

3.1.3 Sales and Production

The resilient floor covering industry consists of two or three very large companies and a number of smaller companies.[4] The Department of Commerce's Census of Manufactures data indicate that approximately 350.1 million square yards of resilient flooring were produced in 1987 with a product shipment value of $1,236.5 million.[2]

The Census information does not show separate values for sheet vinyl and floor tile. Because plain-backed vinyl composition tile is used almost exclusively in office buildings, schools, hospitals, and other commercial and institutional settings, sales reportedly are very dependent on the general economy and the number of buildings being constructed in a given area.

Table 3-2 provides one source's 1989 and projected 1994 sales data for resilient flooring by use.[9] Another source, however, gives sales figures that are approximately half of those shown in Table 3-2.[10] The current recession has decreased new housing and commercial construction, and a slow-down in sales of existing homes have weakened consumer demand and decreased retail profits for the industry.[10] The second source did agree that projected sales of resilient flooring in 1994 should show an overall increase of approximately 2.9 - 3.0% over 1989.[10]

Table 3-2

Resilient Flooring Sales and Projected Sales in the United States[a]
(in millions of square yards)

	1989	1994	% Change in 89/94
Total Resilient Flooring Sales	539	621	+ 2.9
Commercial	262	299	+ 2.7
Residential	172	200	+ 3.1
Institutional	80	94	+ 3.3
Construction/Industrial	25	28	+ 2.3

[a] Reference 9.

3.2 Major Constituents of Concern

The resilient floor coverings constituent data included in Section 3.4 of this Catalog were obtained from research references, industry process descriptions, a New Source Performance Standards background information document, product brochures, and industry contacts.[11-30] The data include some generic chemical classes rather than specific constituents, and are not very detailed due, in part, to the fact that much of the chemical constituent information is considered proprietary by the manufacturer.

Vinyl flooring is composed of synthetic resins, primarily polyvinyl chloride (PVC) or copolymers of vinyl chloride/vinyl acetate. Vinyl chloride is initially made by the oxychlorination of ethylene, which produces dichloroethane. The dichloroethane is reacted to produce vinyl chloride monomer, which is then polymerized to produce polyvinyl chloride resin.[6,14,15] Polyvinyl chloride polymers are the largest segment of the vinyl family because of their ability to be compounded for a wide range of applications, their ease of processing, their relatively low cost, and their excellent properties. Copolymers of vinyl chloride retain the toughness and chemical resistance of PVC but are generally more flexible.[15]

To obtain certain properties in vinyl flooring, additional components are added to the PVC resin, including plasticizers, stabilizers, lubricants, processing aids, fillers, and pigments.[15,16] It is the ratio of binder (PVC resins and plasticizer) to filler (all other ingredients) and the particular vinyl compound used that ultimately differentiates one type of vinyl flooring from another.[6,17] In general, however, vinyl flooring contains 10 - 68% PVC resin, 3.5 - 32% plasticizers, and 0 - 8% urethane.[17] Most sheet vinyl floorings contain a higher proportion of plasticizer than vinyl tile floorings because the sheet requires greater flexibility.

Plasticizers in vinyl flooring reduce viscosity during processing by making shaping and forming easier, and they impart flexibility to the product. Chemically, plasticizers are frequently aliphatic esters of dibasic acids such as phthalic, adipic, azelaic, and sebacic acids. Epoxidized unsaturated natural esters (soybean oil) and similar unsaturated esters, as well as phosphate esters, polyester resins, and aromatic hydrocarbons of high molecular weight, are also found in plasticizers.[15] Plasticizers, stabilizers, or other ingredients may produce the "plastic" smell in vinyl flooring and in other products such as vinyl shower curtains, toys, and car seats. Vinyl containing large amounts of plasticizer is called "plasticized vinyl," while vinyl containing little or no plasticizer is called "rigid vinyl." Plasticized vinyl is more chemically unstable than rigid vinyl and tends to off-gas more into the air.[6,18]

Some vinyl floor tiles are manufactured by laminating a decorated surface vinyl film to a filled vinyl base at elevated temperatures. The laminated surface film may or may not contain di(2-ethylhexyl)

phthalate and butyl benzyl phthalate, compounds which are commonly used as plasticizers.[6,19] Minor amounts of the process ingredients evaporate during the manufacturing process, and the balance of the ingredients are stabilized in the product.[6]

Some older vinyl flooring tiles contained asbestos to strengthen the flooring and help resist wear. Although asbestos is not banned from use in flooring tile, U.S. manufacturers have not produced flooring with asbestos since the mid-1980s.[18] Asbestos fibers normally cannot escape from the flooring surface, but grinding or sanding the flooring can release fibers. Resilient flooring manufacturers recommend that resilient flooring material not be sanded, dry scraped, beadblasted, or mechanically pulverized.

3.3 Emissions Information

Methods of studying emissions from resilient flooring include environmental test chamber studies, and, less frequently, headspace analyses.[19-30] Air samples for most of the referenced studies were collected using tenax tubes, which were subsequently analyzed using gas chromatography/mass spectrometry. Tests are normally conducted at 25°C and 50% relative humidity using air flows of 0.5 to 1.0 air changes per hour.[6] Much of the data collected were qualitative rather than quantitative; that is, constituents were identified but amounts of constituents were not determined. This makes emissions comparisons difficult. In addition, the referenced studies are not necessarily representative of flooring manufactured and sold in the United States.[6] In some cases, the emissions references did not specify what type of flooring was tested--there was no differentiation between sheet vinyl flooring, vinyl tile, and others. One study labeled the flooring "linoleum," but from the emissions data it appears it may actually have been vinyl flooring.[8] As far as can be determined, none of the emissions studies identified were performed on installed flooring, so the reported emissions may or may not have included the adhesive. However, several studies did test adhesive-backed vinyl tile.[19,29]

Many resilient flooring emissions may come from less volatile solvent additives such as trimethylbenzene and aliphatic hydrocarbons (from nonane MW 128.26 to tetradecane MW 198.4).[24] Phenol products may originate from PVC materials.[24] Other emissions may originate from impurities in the raw materials used to manufacture the flooring. This could account for compounds being identified as emissions but not constituents. For example, one study revealed that emissions from vinyl tile consisted of benzyl chloride and benzal chloride, contaminants of butyl benzyl phthalate, a constituent of vinyl tile.

Some studies detected emissions of formaldehyde from certain types of resilient flooring materials. The amount emitted was less than from wood products, fiberglass, and clothing, but more

than from carpeting and upholstery fabric.[24,26,27] Some modeling studies identified flooring materials as volatile organic compound (VOC) emitters. In one study of European floor coverings, homogeneous vinyl tile emitted more VOCs than linoleum or carpet floor materials.[20] Another study revealed high concentrations of VOC emissions from the tested vinyl tiles; the solvents originated from the dyes used to make patterned tiles.[19]

One source revealed that in 1984, while analyzing for VOCs in buildings, an unknown compound was detected.[21] It was later determined to be 2,2,4-trimethyl-1,3-pentane-diol-di-i-butyrate, or TXIB. Vinyl flooring was found to be the source of this material. TXIB is used as a plasticizer in some sheet vinyl flooring. According to toxicological data, there is no evidence of health effects at the air levels tested.[21]

Other studies revealed emissions of aromatic hydrocarbons, aliphatic hydrocarbons, and halogenated hydrocarbons.[23] One study that compared emissions 1 to 2 hours after installation with those after 24 hours, showed a 60% reduction in hydrocarbons within that time period.

3.4 Data Tables

The following data tables summarize information identified in the literature relating to the resilient floor covering product category. Only VOCs are presented in these data tables; components such as nonvolatile inert ingredients, fillers, and inorganics that may be constituents of a product are not included. Each VOC is identified as a constituent or an emission. In many cases, compounds were identified in the literature as constituents, but had not specifically been identified through emissions testing. In addition, a few compounds were identified as being emitted from a product, but not listed as a constituent. In these cases, emissions may be the result of a chemical reaction within the product.

Emission rates are presented for those compounds that were identified in the literature as being emitted. These rates are presented as ranges where multiple emission rates were identified.

Chemicals that are hazardous air pollutants (as defined in the Clean Air Act as amended in November, 1990), carcinogens, or which have a threshold limit value established are designated by an "H", "C", or "T", respectively, in the column following the chemical.

Full reference citations for all information presented in the tables are included at the end of the section. The appendix at the end of this section presents additional information, where available, concerning test conditions for literature cited.

The tables include active and volatile inert product constituent data and emissions data that were obtained from references, contacts, and label inventories.

The tables include resilient floor covering constituent data and emissions data that were obtained from references and contacts. Limitations in the data include:

- Proprietary constituents;
- Differing testing methods produce data of incomparable format; and
- Generic (not product-specific) nature of some constituent and emissions data.

ORGANIZATION OF DATA TABLES

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Sheet Vinyl Flooring 3-11

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Other (Nonvinyl) Resilient Floor Coverings

Linoleum 3-15

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APPENDIX TO DATA TABLES 3-19

INDOOR AIR CATALOG - Floor Coverings

Chapter	Resilient Floor Coverings	Product	NP
SIC	39960	SIC	
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Aliphatic Esters of Dibasic Acids			X					14
Aromatic Hydrocarbons			X					14
Epoxidized Unsaturated Esters			X					14
Formaldehyde	C,H,T	50-00-0		<240			ug/m2-day	26
Phosphate Esters			X					14
Polyester Resin			X					14
Vinyl Chloride	C,H,T	75-01-4	X					14

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Resilient Floor Coverings	Product	Sheet Vinyl Flooring
SIC	39960	SIC	39960
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2-(2-Ethoxyethoxy)ethanol (Carbitol)		111-90-0		NQ				29
Acetone	T	67-64-1		NQ				29
Aliphatic Hydrocarbons				NQ				29
Benzaldehyde		100-52-7		NQ				29
Butyl Acetate	T	123-86-4		NQ				29
Dimethyl Dioxane		25136-55-4		NQ				29
Ketones			X					16
Methyl Ethyl Ketone (MEK)	H,T	78-93-3		NQ				29
Tetrahydrofuran	T	109-99-9	X					16
Toluene	H,T	108-88-3	X	NQ				16,29
Trichloroethylene	H,T	79-01-6		NQ				29
Vinyl Acetate	H,T	108-05-4	X					16
Vinyl Chloride	C,H,T	75-01-4	X					16
Xylene	H,T	1330-20-7	X					16

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Resilient Floor Coverings	Product	Sheet Vinyl Flooring
SIC	39960	SIC	39960
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2,2,4-Trimethyl-1,3-pentanediol Diisobutyrate				550	100	1000	ug/m3*	21
2-Ethyl-1-hexanol		104-76-7		140			ug/m2-hr	23
Ethylbenzene	H,T	100-41-4		65	40	90	ug/m2-hr	23
Ethyltoluene Isomers				2075	1150	3000	ug/m2-hr	23
Formaldehyde	C,H,T	50-00-0		30			ug/m2-hr	23
Glycol Ether	H			2575	2400	2750	ug/m2-hr	23
Iso-alkanes				19625	11250	28000	ug/m2-hr	23
Toluene	H,T	108-88-3		65	60	70	ug/m2-hr	23
n-Alkanes				6800	3900	9700	ug/m2-hr	23
Total Volatile Organic Compounds				0.59			mg/m2-hr	20

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Resilient Floor Coverings	Product	Vinyl Tile
SIC	39960	SIC	39960
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
1-(2-Butoxyethoxy)ethanol				NQ				19
2-Butanone	H,T	78-93-3		NQ	-			19
2-Ethyl-1-hexanol		104-76-7		NQ				19
Benzal Chloride		98-87-3		4.5	2	7	ug/m2-hr	19
Benzaldehyde		100-52-7		NQ				19
Benzyl Butyl Ether				NQ				19
Benzyl Chloride	H,T	100-44-7		1.4	0.8	2	ug/m2-hr	19
Butanol	T	71-36-3		NQ				19
Cyclohexanone	T	108-94-1		NQ				19
Decanol		112-30-1		NQ				19
Hexanol		111-27-3		NQ				19
Phenol	H,T	108-95-2		NQ				19
Toluene	H,T	108-88-3		NQ				19
Trichloroethene	H,T	79-01-6		NQ				19
SUBPRODUCT: Adhesive-backed								
Aliphatic Hydrocarbons				NQ				29
Butyl Benzyl Phthalate		85-68-7	X					19
Di(2-ethylhexyl)phthalate	T	117-81-7	X					19
Dimethyl Cyclohexane				NQ				29
Polyvinyl Chloride		9002-86-2	X					19
Octane	T	111-65-9		NQ				29
SUBPRODUCT: Homogeneous PVC								
Total Volatile Organic Compounds				2.3			mg/m2-hr	20

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Resilient Floor Coverings	Product	Vinyl Tile
SIC	39960	SIC	39960
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Asbestos, adhesive-backed								
Nonane	T	111-84-2		NQ				29
Octane	T	111-65-9		NQ				29
Propylbenzene		103-65-1		NQ				29
Toluene	H,T	108-88-3		NQ				29
Trichloroethylene	H,T	79-01-6		NQ				29
Xylene	H,T	1330-20-7		NQ				29
SUBPRODUCT: Asbestos, plain-backed								
Acetophenone	H	98-86-2		NQ				29
Alkylbenzene				NQ				29
Benzaldehyde		100-52-7		NQ				29
Benzyl Alcohol		100-51-6		NQ				29
Butylbenzyl Ether				NQ				29
Toluene	H,T	108-88-3		NQ				29

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Resilient Floor Coverings	Product	Other Resilient Floor Coverings
SIC	39960	SIC	
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Linoleum tile								
Aliphatic Hydrocarbons				6			ug/m2-hr	8
Aromatic Hydrocarbons				35			ug/m2-hr	8
Chlorinated Hydrocarbons				1.3			ug/m2-hr	8
Ethylbenzene	H,T	100-41-4		0.45			ug/m2-hr	8
Halogenated Hydrocarbons				4			ug/m2-hr	8
Isopropylbenzene	T	98-82-8		0.41			ug/m2-hr	8
m-Ethyltoluene				3.2			ug/m2-hr	8
n-Dodecane		112-40-3		0.45			ug/m2-hr	8
n-Propylbenzene		103-65-1		0.84			ug/m2-hr	8
n-Undecane		1120-21-4		1.2			ug/m2-hr	8
o-Xylene	H,T	95-47-6		0.89			ug/m2-hr	8
Styrene	H,T	100-42-5		0.63			ug/m2-hr	8
Trichloroethylene	H,T	79-01-6		1.3			ug/m2-hr	8
m-Xylene	H,T	108-38-3		0.92			ug/m2-hr	8
1,3,5-Trimethylbenzene		108-67-8		1.4			ug/m2-hr	8
o-Ethyltoluene		611-14-3		1.3			ug/m2-hr	8
1,2,3-Trimethylbenzene		95-63-6		2.5			ug/m2-hr	8
1,2,4-Trimethylbenzene		95-63-6		4.7			ug/m2-hr	8

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Resilient Floor Coverings	Product	Other Resilient Floor Coverings
SIC	39960	SIC	
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Linoleum								
1,2,4-Trimethylbenzene		95-63-6		NQ				30
Butyl Acetate	T	123-86-4		NQ				30
Ethyl Acetate	T	141-78-6		NQ				30
Formaldehyde	C,H,T	50-00-0		NQ				30
Isobutyl Acetate	T	110-19-0		NQ				30
Toluene	H,T	108-88-3		NQ				30
i-Butanol	H,T	78-92-2		NQ				30
n-Butanol	H,T	71-36-3		NQ				30

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Resilient Floor Coverings	Product	Linoleum
SIC	39960	SIC	39960-98
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Total Volatile Organic Compounds				0.22			mg/m2-hr	20

ND - No data.

Chapter	Resilient Floor Coverings	Product	Other Resilient Floor Coverings
SIC	39960	SIC	
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Rubber								
Total Volatile Organic Compounds				1.4			mg/m2-hr	20

ND - No data.

8 Reference: Wallace, 1987
Test Method: Chamber Study
Sampling Method: Tenax Tubes
Analysis Method: GC, GC/MS

	Value	Min	Max	Units
RH	48			%
Temp	25			° C
ACH				
Testing Duration				

Comment: Samples were maximum of 4 months old. Testing duration not given.

19 Reference: Rittfeldt et al., 1984
Test Method: Chamber Study
Sampling Method: Tenax Tubes
Analysis Method: GC, GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH		0.07	0.5	
Testing Duration				

Comment: Qualitative data. Sample (vinyl tile) was newly manufactured. Duration of testing not known.

21 Reference: Rosell, 1990
Test Method: Test House
Sampling Method: Tenax Tubes
Analysis Method: GC, GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration				hr

Comment: Air quality measurements taken of non-industrial buildings such as offices, schools, daycare centers, and homes. Age of flooring varied. Concentrations of VOCs determined.

23 Reference: van der Wal, 1990
Test Method: Chamber Study
Sampling Method: Tenax Tubes, Charcoal Adsorption Tubes, HCl Bubbler
Analysis Method: GC, GC/MS

	Value	Min	Max	Units
RH	50			%
Temp	23			° C
ACH				
Testing Duration		1	24	hr

Comment: PVC floor covering samples were newly purchased and unwrapped in the test chamber. Floor samples were cut to the size of the chamber and laid on its floor (but not adhered). First sample taken immediately, and later samples subsequently after a conditioning period of 24 hours.
Test duration: 1 – 2 hours and 24 hours.

26 Reference: Godish, 1984
Test Method: Chamber Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration	1			day

Comment: Testing parameters not available; sampling and analytical methods not known.

29 Reference: Miksch et al., 1982
Test Method: Test House
Sampling Method: Tenax Tubes
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration				

Comment: Qualitative data. Sample was newly manufactured.

30 Reference: Tucker, 1988
Test Method: Chamber Study, Headspace Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH				%
Temp				°C
ACH				
Testing Duration				hr

Comment: Qualitative data; no other available information.

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4.0 CARPET

4.1 Description of Product Category

Carpet is a general term used to denote textile floor coverings.[1] The carpet product category includes all types of carpet and rugs, regardless of the weave used in construction. By definition, a rug is a carpet that is cut into room or area dimensions and is not affixed to the underlying substrate. However, no differentiation will be made here between carpet and rugs.[1] Available sales and production data are based on combined information on carpet and rugs.[2,3]

To include all relevant information with respect to indoor air quality, products that are integral components of carpet applications must be discussed along with carpet. These products include carpet backing, backing lattices, carpet cushions, and special finishing treatments such as stain guard. Adhesives used to apply carpet in "glue-down" applications, (i.e., where a carpet or carpet cushion is glued directly to the floor) are not discussed in detail here, but are presented in Section 5.0, Adhesives, where more detail can be found. Each of these components can influence the impact that carpet has on indoor air quality.[4] A carpet, its associated components, and the method of installation may be referred to as a carpet system.

4.1.1 Product Classification

Six primary compositional elements are used in the manufacture of carpet: face fiber, primary backing, latex, secondary backing, dye/colorant, and topical treatment. Using these basic elements, many different materials and processes are combined to produce the range of carpet products that are available in the current market.[5] Figure 4-1 presents a classification of carpet systems, that is based on the major compositional elements, with the type of yarn (face fiber) being the primary component. This classification system is similar to the Census of Manufactures SIC system, which also presents information on carpet value and quantity based on the type of face fiber.[2]

Other factors also contributed to the development of this classification. First, synthetic fibers are manufactured from assorted chemical feedstocks and intermediates and, therefore, may have the potential to emit residuals of these chemicals.[6] Additionally, individual fibers have variable affinities for the chemicals typically used in dyeing and finishing treatments.[7,8] Residual chemicals that remain after dyeing and finishing treatments are also potential sources of emissions.[9] The potential contributions to indoor air emissions vary between carpets that have different face fibers and that receive different treatments, dyes, and finishing agents.

I. SYNTHETIC FIBER CARPETS

A. Common fiber processing and finishing treatments

1. Stain resistance
2. Soil release (e.g., fluorocarbons)
3. Antimicrobial treatment

II. WOOL FIBER CARPETS

A. Common fiber processing and finishing treatments

1. Soil release (e.g., fluorocarbons)
2. Insect repellent (e.g., moth-proofing)

III. BACKINGS AND BACKING LATTICES

A. Polypropylene
B. Jute
C. Latex (e.g., SBR-formulated latex)

IV. CUSHION MATERIALS

A. Bonded urethane
B. Prime urethane
C. Others

Figure 4-1. Classification of Carpet by Major Components

Another reason for classifying carpet using face fiber as the primary component is that various fibers possess unique properties for wear and appearance. As a result, some fibers are more popular than others for specific situations (e.g., residential versus commercial versus outdoor applications).[2,10,11] Carpet sales reflect the differences in carpet performance and consumer preference associated with various face fibers (see Section 4.1.3).[2]

A third reason for using face fibers to classify carpet is that any face fiber may be used with a variety of backings, backing lattices, and cushions. The components of fiber, finishing treatment, and backing were identified in the EPA Carpet Policy Dialogue (discussed in Section 4.3) as the materials possibly having the most relevance to potential VOC emissions from carpet, although that assertion is not universally supported.[4,12] Therefore, the type of face fiber, especially in combination with component products, may have great potential to influence indoor air emissions. However, other factors, such as the type of construction (e.g., tufted carpet versus woven; see Section 4.1.3) may also affect emission potential.

4.1.2 Product Major Uses

Approximately 67% of the carpet produced annually in the United States is used as floor covering in residential settings, including hotels and motels.[1,13] Most of the remaining carpet that is produced is used in commercial applications, such as offices, institutions, and retail establishments.[1] Most residential carpet is installed using the "stretched-in" method -- that is, wood strip tacking and staples are applied at the carpet edges.[13] Commercial carpet is usually glued down, most commonly with a multipurpose adhesive (see Section 5.0).[5,13] Also, a small amount of carpet is used for outdoor applications, and in automobiles, boats, and aircraft.[2] Table 4-1 presents the usage of the most common components of carpet systems.

4.1.3 Sales and Production

Information on carpet sales and volume data was obtained from the Bureau of the Census reports, trade journals, and telephone conversations with representatives of the carpet industry.[2-4,13-17] United States sales of all types of carpet totalled $8.55 billion in 1990, which represents a drop from $8.62 billion in 1989.[2,17] The 1990 sales comprised 1.3450 billion square yards of carpet shipments, which is up from 1.3180 billion square yards in 1989. Nonetheless, the carpet industry has grown dramatically over the past decade, with sales rising from $5.10 billion in 1979.[2]

Even though carpet sales have climbed steadily over the previous decade, the number of carpet mills has declined dramatically. In 1980, there were approximately 300 U.S. mills; in 1990 there were

Table 4-1

Usage of the Most Common Components of Carpet Systems[a]

DESCRIPTION	USAGE (%)
Carpet Fiber[a]	
Nylon	75
Olefin (polypropylene)	16
Polyester	9
Wool	1
Backings[b,c]	
Primary	
Polypropylene	99
Jute	1
Secondary	
Polypropylene	85-90
Jute	10-15
Latex	d
Amorphous resin	d
Urethane foam	d
PVC hardback	d
Urethane hardback	d
Cushion Material[e,f]	
Bonded urethane[f,g]	56
Prime urethane	33
Rubber	6
Synthetic fibers	3
Rubberized jute	2
Installation Technique	
"Stretched-in" or wood strip tacking[b,h]	67
Glue-down[b,i]	33

[a] Percentages of fiber represent the market share of carpet produced from these fibers in recent years (Reference 4). Percentages of other components represent usage.

[b] References 5, 13, 14.

[c] Face fibers are secured to the primary backings, and the primary backing is secured to the secondary backing with an SBR latex adhesive that comprises 70 to 80% filler material, such as chalk. See adhesive chapter for more information.

[d] Exact percentage of use is unknown. Reference 5 indicates that the market share is small.

[e] Percentages represent cushions used in residential and commercial applications.

[f] References 5, 16.

[g] Bonded urethane scraps usually are held together by an adhesive called "polyol," which contains toluene diisocyanate (TDI)

[h] Most common in residential applications (includes homes, hotels, and motels).

[i] Most common in commercial applications. SBR latex is the most common binder used in the formulation of carpet adhesives.

about 125.[17] To some degree, the decline in the number of carpet mills over the past decade may have been induced by a decrease in the profit margin of the industry, which has been influenced by several factors, including: (1) increases in the face weight of finished carpet,[17] (2) sharp rises in the cost of raw materials,[17] and (3) no corresponding increases in carpet wholesale prices to compensate for the increases in production cost.[17]

Nylon is the most versatile and popular of the synthetic fibers used for carpet yarns, and it accounts for approximately 75% of all face fiber used in carpet construction.[2,4,7,10] Polypropylene (an olefin derivative) is the second most common fiber and accounts for 16% of yarn used to produce carpet, and is followed by polyester at 9%.[13] In the United States, wool face fibers are used in only 1% or less of the carpet produced annually (see Table 4-1).[13]

The Current Industrial Reports present all carpet sales, production, and usage data in terms of the method of carpet construction.[2] Various construction methods, including tufting, weaving, knitting, braiding and others, can be used to make carpet from any type of face fiber.

The most prevalent method of carpet construction is tufting. Tufted carpet is constructed by inserting yarn into a backing material, such as woven polypropylene or jute. The resulting loops of pile are anchored to the backing by coating the backs of the loops with a layer of latex, which is called the backcoat. Often, a secondary backing material (usually woven polypropylene or jute) is adhered to the primary backing with another coat of latex (Figure 4-2). The secondary backing adds dimensional stability to the carpet.

In some tufted carpet, however, no secondary backing material is applied. Rather, a heavier or thicker coat of SBR latex is applied to the outside of the primary backing and allowed to dry. This thicker backcoat then serves as the only form of secondary backing. This type of construction is known as a "unitary" backing (Figure 4-3). Unitary-backed carpet is usually used in commercial, direct glue-down applications.

Another type of carpet - woven carpet - is constructed by weaving the surface yarns and backing material together. Woven carpets include velvet, Wilton, and Axminster weaves. It is the particular configuration of the weave that results in the variety of types. Woven carpet is the most dimensionally stable of all constructions and has the best wear qualities. Because of its wear qualities, woven carpet is often preferred for heavy traffic areas.[11]

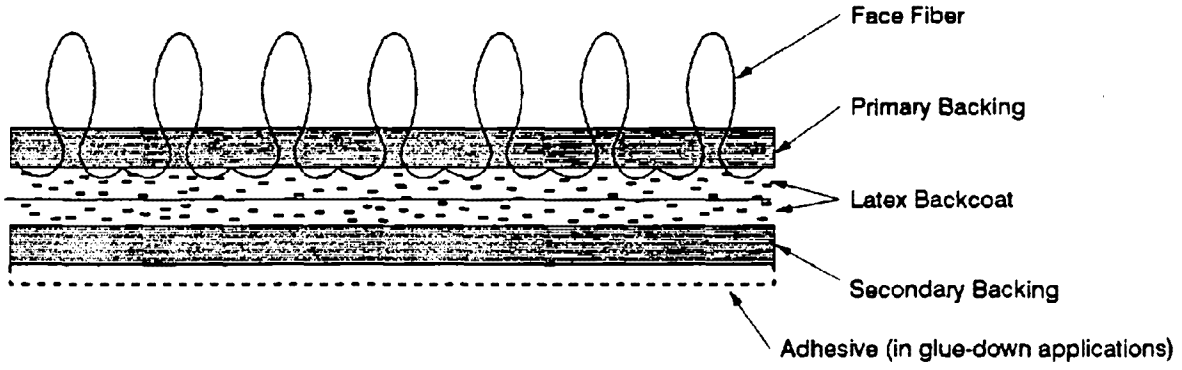

Figure 4-2. Structural Components of Tufted Carpet with Primary and Secondary Backings

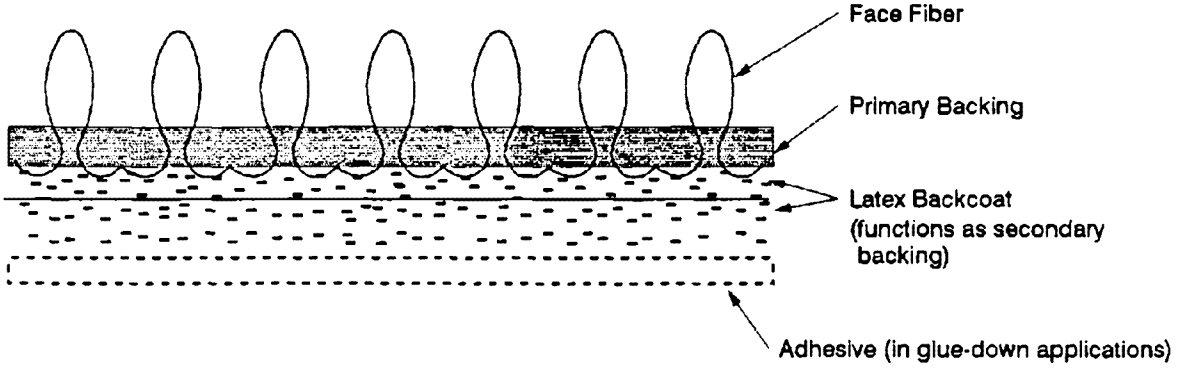

Figure 4-3. Structural Components of Tufted Carpet with Unitary Backing

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The remainder of the carpet market is comprised of a variety of carpet types, all of which vary in their methods of construction. These types include knitted, needle-punched, felt, braided, and hooked carpet.

Different carpet constructions and installation techniques may have different potentials for indoor air emissions. For example, tufted carpet requires the use of latex backcoating to secure the fibers to the primary backing and to laminate the secondary backing to the primary. Backcoating is not required to secure the face fibers to the backing material in other types of carpet. Therefore, the use of latex backcoating on tufted carpet may increase its indoor air emission potential as compared to the potentials of carpets that do not require backcoating. The emission potential of carpet is further influenced by the method of installation. For example, carpet used in commercial applications is often glued down. The use of adhesives to affix carpet to subflooring increases its potential to emit. These examples indicate that potential indoor air emissions increase as greater amounts of latex and adhesive are used in carpet construction and installation.

There are large differences in the sales and usage of the different types of carpet. Thus, some types of carpet are more prevalent in indoor environments. Table 4-2 presents carpet consumption data from 1989, as well as values for the various construction types in that year. Tufted carpet, by far, holds the largest share of the carpet market. Tufted carpet has comprised 90% or more of the market since 1974.[11] Consumption of tufted carpet in 1989 was 1.2327 billion square yards, or 94% of all carpet used in the United States.[2] Consumption of woven carpet in 1989 was 23.8 million square yards, or approximately 2% of all carpet shipments in the United States.[2] Consumption of all other carpet types in 1989 was 61.2 million square yards, or 5% of all carpet used in the United States. Clearly, tufted carpet has a greater potential to affect indoor air environments than other types of carpet, merely due to its preference among consumers and prevalence of use.

4.2 Major Constituents of Concern

Data on the major chemical constituents of the components in carpet systems were obtained from the literature and, to a lesser extent, from communications with industry representatives. The first step to identifying the chemical constituents of carpet systems is to develop an understanding of the manufacturing process of each component. Literature that proved useful in this step included a variety of EPA reports on Industrial Process Profiles and Source Assessments.[7,18-20] In addition to these reports, numerous papers provided a basic understanding of carpet backcoating technology and fiber dyeing and finishing treatments.[14,21-35]

Table 4-2

1989 Consumption of Carpet and Rugs

SIC	Description	Consumption	
		Quantity (millions sq yd)	Value (millions $)
	All carpets and rugs	1,317.8	8,431.1
22731	Woven carpets and rugs	23.8	299.0
22732	Tufted carpets and rugs	1,232.7	7,932.8
22733	Other carpets and rugs	61.2	199.3

Source: Reference 2.

The chemical constituents identified for carpet components from available studies do not represent complete lists of constituents. Difficulties encountered in attempting to identify the chemical constituents include a large volume of literature to evaluate and the presence of outdated data--many of the references that identified chemical constituents are 10 or more years old. Few references provided information on specific formulations for chemical treatments or product manufacture and the formulations of dyes, fiber treatments, and adhesives likely have changed since these references were published. Further, many formulations are guarded trade secrets and manufacturers are hesitant to release specific, up-to-date information due to market competition.

It is likely that more specific chemical constituent information is available in U.S. patents.[10,34] If patent numbers can be obtained, the specific formulation of a product can be located in the patent. Searching patents without a patent number, however, can be laborious and time-consuming.[36]

As the carpet industry evolves, new materials may be introduced into the manufacturing of any carpet component and this would influence potential emissions. For example, one new development in the carpet industry is the use of a bulked continuous filament yarn, called polybutylene terephthalate (PBT). A manufacturing process for PBT yarn was recently patented.[35] As a yarn, PBT is highly versatile and has properties that are similar to those of nylon. The developers of PBT yarn will have to compete with nylon as a carpet fiber, as well as a fiber for the apparel industry.[35]

The PBT polymer is manufactured by using either dimethyl terephthalate and butanediol (BD), or by using pure terephthalic acid with BD in an esterification reaction. During this process, BD engages in

a side reaction that generates tetrahydrofuran (THF). Most of the THF can be recovered and sold as a relatively pure byproduct,[35] but residual THF may remain in the fiber and become a potential source of indoor air contamination. However, PBT can be dyed at atmospheric pressure, which enables dyeing without the use of chemicals commonly used as dye carriers (e.g., biphenyl, chlorobenzenes, and methyl and dimethyl phthalates) for other face fibers. Residuals of these chemicals also may remain in the finished carpet fibers and could contribute to indoor air contamination. Therefore, the decreased use of toxic substances during the manufacturing of PBT might result in decreased indoor air emissions from the finished carpet products.

4.3 Emissions Information

Most carpet emissions data obtained come from environmental chamber studies using gas chromatography/mass spectrometry analysis. Headspace studies are the second most common source of emissions data. Most of the emissions studies have involved tests on carpet combined with the associated components of carpet systems; carpet systems subjected to emission tests have sometimes included the adhesives used in glue-down applications, as well as the underlayment.

Typical chamber test parameters specify temperature at 25°C, relative humidity at 48 to 52%, and one air change per hour. The time frame for test periods has been the most variable parameter, encompassing from 1 hour to several weeks; however, this has provided insight into the potential of carpet as a short-term and long-term emission source.

One encumbering aspect of the published literature on carpet emissions is the lack of specificity or description of the materials that have been tested. For instance, some publications fail to identify the type of face fiber, the type of primary and secondary backing, the type of adhesive, or the type of cushion. Sometimes carpet samples are merely referred to as "carpet" with no other qualifier.[37,38] This lack of specificity and detail makes it difficult to determine the relative contributions of the components of the carpet systems.

One fairly specific emission study involved tests of a carpet tile applied to a concrete underlayment with an adhesive.[32] The carpet tiles used in this study had been in an office building for 2 years. They were made of an unspecified face fiber and finishing treatment, but were PVC-backed and installed on a concrete underlayment using an unspecified adhesive. It was known that the PVC backings of these carpet tiles contained plasticizers composed of 2-ethylhexyl phthalate (DOP) and di-heptyl nonyl phthalate (Santicizer 790). The plasticizer formulation also contained an alkaline component of calcium oxide.

The carpet tiles (called the Oregon sample) were tested with and without adhesive on concrete underlayment using a headspace apparatus. A second control sample was a "similar" carpet tile that had been installed in a different location, but which had produced no complaints after 6 years. Whether the control carpet had been installed using an adhesive on concrete was not revealed in the study. The plasticizers in the backings of the control samples were di-nonyl phthalate, diisohexyl phthalate, and DOP. The results of the headspace analysis indicated that the use of the adhesive increased the off-gassing of alcohols by 20% in the Oregon sample and 180% in the control sample. The release of the alcohols was a result of the hydrolysis of the plasticizers in the carpet backings. Evidently, this hydrolysis was facilitated by the adhesive and perhaps, to a lesser degree, by the alkalinity of the concrete. Two of the alcohols emitted in this study, 2-ethyl-l-hexanol and *n*-hexanol, were also prevalent in four buildings studied by the EPA.

Several papers have been published on whole-building or whole-room studies.[39-43] Although carpet is potentially a contributor to the concentrations of emissions found in these studies, the contribution from carpet cannot be separated from the other products and furnishings found in rooms or houses, such as wall coverings, paints, and furniture.

Other studies have indicated that the compound 4-phenylcyclohexene (4-PCH) is responsible for new carpet odor.[5,44] Styrene and butadiene are components of SBR latex, which is the most common binding component used in latex carpet backing and multipurpose carpet adhesives. The compound 4-PCH is produced during polymerization of SBR latex in a Diels-Alder reaction between styrene and butadiene. The production of 4-PCH can take place even after a carpet is installed. The human toxicity, if any, of 4-PCH has not been established.[38,45]

Further influence on indoor air emissions from the components of carpet systems can be deduced from the available information. In glue-down applications, there is a potential for higher emissions, as compared to tufted carpets applied by the stretched-in method, due to the use of SBR latex backings and SBR-formulated adhesives in the glued-down applications. Another carpet system component, bonded polyurethane (used for cushions), may increase potentially harmful emissions, due to the use of toluene diisocyanate (TDI) - a component of the adhesive most commonly used to bond the cushion material together (Table 4-1).

An endeavor that has produced much useful information is a cooperative movement between the EPA and the Carpet and Rug Institute called the Carpet Policy Dialogue.[4,5,9] The Carpet Policy Dialogue is EPA's forum to encourage voluntary industry actions to reduce total VOC emissions from carpet, carpet cushions, and carpet adhesives. The Dialogue includes representatives from industry,

public interest groups, labor, other government agencies, and the scientific community. The goal of the Dialogue is to develop guidelines for systematic and standardized small chamber tests on a number of carpet systems to evaluate VOC emission rates. When the testing is completed, the results of the tests will be published and made available to the public.[5]

4.4 Data Tables

The following data tables summarize information identified in the literature relating to the carpet product category. Only VOCs are presented in these data tables; components such as nonvolatile inert ingredients, fillers, and inorganics that may be constituents of a product are not included. Each VOC is identified as a constituent or an emission. In many cases, compounds were identified in the literature as constituents, but had not specifically been identified through emissions testing. In addition, a few compounds were identified as being emitted from a product, but not listed as a constituent. In these cases, emissions may be the result of a chemical reaction within the product.

Emission rates are presented for those compounds that were identified in the literature as being emitted. These rates are presented as ranges where multiple emission rates were identified.

Chemicals that are hazardous air pollutants (as defined in the Clean Air Act as amended in November, 1990), carcinogens, or which have a threshold limit value established are designated by an "H", "C", or "T", respectively, in the column following the chemical.

Full reference citations for all information presented in the tables are included at the end of the section. The appendix at the end of this section presents additional information, where available, concerning test conditions for literature cited.

The tables include active and volatile inert carpet product constituent data and emissions data that were obtained from references, contacts, and label inventories.

ORGANIZATION OF DATA TABLES

SYNTHETIC FIBER CARPET

Nylon Face Fiber 4-13

Nylon and Olefin Blend Face Fiber 4-20

Polypropylene Face Fiber 4-22

Acrylic Face Fiber 4-24

NATURAL FIBER CARPET

Wool Face Fiber 4-25

UNSPECIFIED FACE FIBER 4-26

BACKINGS

Primary 4-30

Secondary 4-31

CARPET CUSHION 4-32

CARPET TILES 4-34

APPENDIX TO DATA TABLES 4-38

Chapter	Carpet	Product	Face Fiber, Nylon
SIC	2273	SIC	22732-11
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Nylon carpet with stain guard								
Aliphatic Sulfonic Acids			X					10
Benzaldehyde		100-52-7	X					10
Bisphenol		80-05-7	X					10
Chlorosulphonic Acid			X					10
Cresol	H,T	1319-77-3	X					10
Cyclohexane Sulfonic Acid			X					10
Cyclopentane Sulfonic Acid			X					10
Dihydroxydiphenylsulfone			X					10
Formaldehyde	C,H,T	50-00-0	X					10
Furfuraldehyde	T	98-01-1	X					10
Monothiobisphenols			X					10
Naphthol		90-15-3	X					10
Oligomeric Thiophenols			X					10
Phenol	H,T	108-95-2	X					10
Polymeric Alcohol Sulfonic Acids			X					10
Resorcinol	T	108-46-3	X					10

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Carpet	Product	Face Fiber, Nylon
SIC	2273	SIC	22732-11
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Formaldehyde	C,H,T	50-00-0		0.01			ppm*	49
SUBPRODUCT: Polypropylene primary backing; urethane secondary backing; "low VOC" adhesive								
1,2,4-Trimethylbenzene		95-63-6		NQ			ug/m2-hr	48
2,6-Di-tert-butyl-4-methylphenol	T	128-37-0		NQ				48
Methylisopropylcyclohexane				NQ			ug/m2-hr	48
Octamethyl Cyclotetrasiloxane		556-67-2		NQ			ug/m2-hr	48
Vinylmethylbenzene				NQ			ug/m2-hr	48
Total Volatile Organic Compounds				241	111	411	ug/m2-hr	48
SUBPRODUCT: Polypropylene primary backing; urethane secondary backing; "low VOC" adhesive; seam sealant								
Total Volatile Organic Compounds				188	171	214	ug/m3*	48
SUBPRODUCT: Nylon carpet with polypropylene primary backing, urethane secondary backing								
1,2-Dichlorobenzene	T	95-50-1		NQ				48
2,6-Di-tert-butyl-4-methylphenol	T	128-37-0		NQ				48
Total Volatile Organic Compounds				41	6	98	ug/m2-hr	48
SUBPRODUCT: SBR latex backcoating								
4-Phenylcyclohexene				107	64	150	ug/m2-hr	47
Total Volatile Organic Compounds				193	71	315	ug/m2-hr	47
SUBPRODUCT: Neoprene cushion								
Formaldehyde	C,H,T	50-00-0		90.25	50	159	ug/m2-hr	50
Formaldehyde	C,H,T	50-00-0		0.076	0.055	0.097	ppm*	50

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.
*This value is the concentration of the compound in the air tested.

Chapter	Carpet	Product	Face Fiber, Nylon
SIC	2273	SIC	22732-11
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Nylon carpet with polypropylene primary and secondary backings; SBR latex backcoating; static control treatment								
4-Ethenylcyclohexene				0.07			ppb*	56
4-Phenylcyclohexene				1.91	0.14	3.1	ppb*	56
C5 Aldehydes				0.94	0.28	1.6	ppb*	56
C6 Aldehydes				2.56	0.51	4.6	ppb*	56
C7 Aldehydes				3.8	1.0	6.6	ppb*	56
C8 Aldehydes				1.73	0.55	2.9	ppb*	56
C9 Aldehydes				3.5	2.2	4.8	ppb*	56
C10 Aldehydes				0.29	0.14	0.44	ppb*	56
Styrene	H,T	100-42-5		0.28	0.21	0.35	ppb*	56
Total Volatile Organic Compounds				46	22	84	ugC/m3**	56

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.
**During thermal desorption, approximately 8 percent of each VOC sample were separated and analyzed without GC by a flame ionization detector. This produces a measure of total C over a boiling-point range encompassing approximately C3-C14 hydrocarbons. The results were reported as a mass of carbon.

Chapter	Carpet	Product	Face Fiber, Nylon
SIC	2273	SIC	22732-11
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Nylon carpet with polypropylene primary and secondary backings; SBR latex backcoating; static control treatment								
4-Ethenylcyclohexene				ND	0.5	7.6	ug/m2-hr	6
4-Phenylcyclohexene				ND	46.1	87.4	ug/m2-hr	6
C2 Alkylbenzenes				ND	3.8	6.9		6
Styrene	H,T	100-42-5		ND	1.8	36.7	ug/m2-hr	6
Total Volatile Organic Compounds				ND	36.2	222.6	ug/m2-hr	6

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Carpet	Product	Face Fiber, Nylon
SIC	2273	SIC	22732-11
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Nylon carpet with polypropylene primary backing; polyvinyl chloride secondary backing; scotchguard and antimicrobial treatments								
1,2-Propanediol				ND	152.7	757.5	ug/m2-hr	6
2,2,4-Trimethylpentane				ND	18.5	67.7	ug/m2-hr	6
2-Ethyl-1-hexanol		104-76-7		ND	20.6	58.6	ug/m2-hr	6
Acetaldehyde	H,T	75-07-0		ND	4.6	26.7	ug/m2-hr	6
Formaldehyde	C,H,T	50-00-0		ND	18.2	57.2	ug/m2-hr	6
Methyl Acetate				ND	0.6	1	ug/m2-hr	6
Total Volatile Organic Compounds				ND	143.6	625.5	ug/m2-hr	6
Vinyl Acetate	H,T	108-05-4		ND	82.8	894.5	ug/m2-hr	6

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Carpet	Product	Face Fiber, Nylon
SIC	2273	SIC	22732-11
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Nylon carpet; polypropylene primary backing; polyurethane secondary backing								
4-Ethenylcyclohexene				4.6	1	8.2	ppm*	56
Acetaldehyde	H,T	75-07-0		1.4			ppm*	56
Formaldehyde	C,H,T	50-00-0		0.8	0.5	1.3	ppm*	56
C5 Aldehyde				0.23	0.09	0.54	ppm*	56
C6 Aldehyde				0.79	0.2	1.5	ppm*	56
C7 Aldehyde				0.96	0.3	1.7	ppm*	56
C8 Aldehyde				0.51	0.25	0.86	ppm*	56
C9 Aldehyde				0.81	0.33	1.4	ppm*	56
C10 Aldehyde				0.15	0.03	0.3	ppm*	56
Total Volatile Organic Compounds				15.8	9.1	30	ugC/m3**	56

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.
**During thermal desorption, approximately 8 percent of each VOC sample were separated and analyzed without GC by a flame ionization detector. This produces a measure of total C over a boiling-point range encompassing approximately C3-C14 hydrocarbons. The results were reported as a mass of carbon.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Carpet	Product	Face Fiber, Nylon
SIC	2273	SIC	22732-11
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Nylon carpet; polypropylene primary backing; polyurethane secondary backing								
1,2-Dichlorobenzene	T	95-50-1		ND	1.5	11.2	ug/m2-hr	6
1-Butanol	T	71-36-3		ND	4.6	28.5	ug/m2-hr	6
2,6-Di-tert-butyl-4-methylphenol	T	128-37-0		ND	164.9	234.5	ug/m2-hr	6
Dipropylene Glycol Methyl Ether	T	34590-94-8		ND	14.3	27.1	ug/m2-hr	6
Total Volatile Organic Compounds				ND	20	108.3	ug/m2-hr	6
SUBPRODUCT: Nylon carpet with SBR latex secondary backing								
4-Phenylcyclohexene				113	32	320	ug/m2-hr	6
Styrene				10	2	28	ug/m2-hr	6
SUBPRODUCT: Nylon carpet, polypropylene primary and secondary backings; stain and soil resistance treatment								
Total Volatile Organic Compounds				425	71	779	ug/m2-hr	9
SUBPRODUCT: Nylon carpet; jute primary backing								
1-Methylnapthalene				NQ				51
2-Methylnaphthalene				NQ				51
3-Phenylcyclohexene				NQ				51
Aliphatic Hydrocarbons				NQ				51
Alkylbenzenes	H,T	75-07-0		NQ				51
Decane		124-18-5		NQ				51
Dichlorobenzene				NQ				51
Naphthalene				NQ				51
Nonanol				NQ				51
Styrene	H,T	100-42-5		NQ				51

T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Carpet	Product	Face Fiber, Nylon and Olefin Blend
SIC	2273		
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: 75%/25% olefin/nylon carpet; polypropylene primary and secondary backings; SBR latex backcoating								
4-Ethenylcyclohexene				0.19	0.09	0.27	ppm*	56
4-Phenylcyclohexene				2.5	1.3	3.9	ppm*	56
Acetaldehyde	H,T	75-07-0		1.8	0.2	3.6	ppm*	56
C5 Aldehydes				0.64	0.11	0.94	ppm*	56
C6 Aldehydes				1.3	0.1	2	ppm*	56
C7 Aldehydes				2.26	0.19	3.4	ppm*	56
C8 Aldehydes				0.52	0.06	0.8	ppm*	56
C9 Aldehydes				3.12	0.76	4.5	ppm*	56
C10 Aldehydes				0.12	0.09	0.14	ppm*	56
Formaldehyde	C,H,T	50-00-0		1.82	0.98	2.8	ppm*	56
Styrene	H,T	100-42-5		1.05	0.61	1.6	ppm*	56
Total Volatile Organic Compounds				49	28	70	ugC/m3**	56

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.
**During thermal desorption, approximately 8 percent of each VOC sample were separated and analyzed without GC by a flame ionization detector. This produces a measure of total C over a boiling-point range encompassing approximately C3-C14 hydrocarbons. The results were reported as a mass of carbon.

Chapter	Carpet	Product	Face Fiber, Nylon and Olefin Blend
SIC	2273		
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: 75%/25% olefin/nylon carpet; polypropylene primary and secondary backings; SBR latex backcoating								
4-Ethenylcyclohexene				ND	2.6	24.2	ug/m2-hr	6
4-Phenylcyclohexene				ND	48.3	81.9	ug/m2-hr	6
Alkylbenzenes	H,T	75-07-0		ND	2.9	12.4	ug/m2-hr	6
Styrene				ND	15.5	260	ug/m2-hr	6
Total Volatile Organic Compounds				ND	79.8	399	ug/m2-hr	6

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Carpet	Product	Face Fiber, Polypropylene
SIC	2273	SIC	22732-19
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
1,2,3-Trimethylbenzene		95-63-6		ND	0.027	0.13	ug/m2-hr	53
1,2,4-Trimethylbenzene		95-63-6		ND	0.063	1.2	ug/m2-hr	53
1,3,5-Trimethylbenzene		108-67-8		1.5			ug/m2-hr	53
Benzene	C,H,T	71-43-2		0.92			ug/m2-hr	53
Cyclohexylbenzene				NQ				53
Ethylbenzene	H,T	100-41-4		0.05			ug/m2-hr	53
Isopropylbenzene	T	98-82-8		0.17			ug/m2-hr	53
m-Ethyltoluene				2.1			ug/m2-hr	53
m,p-Xylene	H,T			0.41			ug/m2-hr	53
n-Decane		124-18-5		ND	0.23	11	ug/m2-hr	53
n-Dodecane		112-40-3		ND	4	6.4	ug/m2-hr	53
n-Propylbenzene		103-65-1		0.49			ug/m2-hr	53
n-Undecane		1120-21-4		ND	7.1	12	ug/m2-hr	53
o-Ethyltoluene		611-14-3		1.1			ug/m2-hr	53
o-Xylene	H,T	95-47-6		ND	0.37	0.83	ug/m2-hr	53
p-Dichlorobenzene		106-46-7		0.18			ug/m2-hr	53
Styrene	H,T	100-42-5		0.1			ug/m2-hr	53

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ND - No data.
NQ - Detected but not quantified.

Chapter	Carpet	Product	Face Fiber, Polypropylene
SIC	2273	SIC	22732-19
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Foam backing with self-stick adhesive								
Aliphatic Hydrocarbons				NQ				51
Alkylbenzene	H,T	75-07-0		NQ				51
Trimethylcyclohexane				NQ				51

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Carpet	Product	Face Fiber, Acrylic
SIC	2273	SIC	22732-19
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Foam backing, type unspecified								
1-Methylnaphthalene		90-12-0		NQ				51
2-Methylnaphthalene		91-57-6		NQ				51
Aliphatic Hydrocarbons				NQ				51
Biphenyl	T	92-52-4		NQ				51
Naphthalene	H,T	91-20-3		NQ				51
Phenol	H,T	108-95-2		NQ				51

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T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

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Chapter	Carpet	Product	Face Fiber, Wool
SIC	2273	SIC	22732-19
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Camphechlor			X					8
Chlorphenylid			X					8
Cyfluthrin			X					8
Dieldrin		60-57-1	X					8
Dioxins	C		X					8
Furans		110-00-9	X					8
Lindane	H,T	58-89-9	X					8
Organophosphates			X					8
Permethrin		52645-53-1	X					8
Synthetic Pyrethroids			X					8
Toxaphene	H,T	8001-35-2	X					8

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T - Threshold Limit Value has been established for this chemical.
ND - No data.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Carpet	Product	Face Fiber, Unspecified
SIC	2273	SIC	
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
1,1,1-Trichloroethane	H,T	71-55-6		NQ				46
1,1-Biphenol-4-amine				NQ				46
1,2,4-Benzene Tricarboxylic Acid				NQ				37
1,2-Dichloroethane		107-06-2		NQ				37
2-Methylbenzothiazole				NQ				46
2-Propanone	T	67-64-1		NQ				37
Acetic Acid	T	64-19-7		NQ				37
Aliphatic Hydrocarbons				NQ				51
Benzene	C,H,T	71-43-2		NQ				37,46
Benzylbutylphthalate				NQ				46
Butyl Acetate	T	123-86-4		NQ				37
Butylcyclohexylphthalate				NQ				46
Chloroform	C,H,T	67-66-3		NQ				37
Decane		124-18-5		NQ				37
Ethanol	T	64-17-5		NQ				46
Ethyl Acetate	T	141-78-6		NQ				46
Ethylbenzene	H,T	100-41-4		NQ				46
Heptadecane		629-78-7		NQ				37
Hexadecane		544-76-3		NQ				46

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T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Carpet	Product	Face Fiber, Unspecified
SIC	2273	SIC	
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Hexadecanoic Acid		57-10-3		NQ				37
Methylene Chloride	C,H,T	75-09-2		NQ				46
n-Methylacetamide		79-16-3		NQ				37
n-Nonane				NQ				51
n-Octane				NQ				51
Octadecane		593-45-3		NQ				46
Octane	T	111-65-9		NQ				37
Phenol	H,T	108-95-2		NQ				46
Propylcyclohexane				NQ				37
p-Dichlorobenzene		106-46-7		NQ				46
Tetrachloroethane	H,T	79-34-5		NQ				37
Toluene	H,T	108-88-3		NQ				37,46
Trichloroethane	H,T	79-01-6		NQ				46
Xylene	H,T	1330-20-7		NQ				37

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H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Carpet	Product	Face Fiber, Unspecified
SIC	2273	SIC	2273
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: SBR latex back, SBR foam cushion								
4-Phenylcyclohexene				NQ				44
4-Vinylcyclohexene		100-40-3		NQ				44
Aliphatic Hydrocarbons				NQ				44
Diethylamine	T	109-89-7		NQ				44
Formaldehyde	C,H,T	50-00-0		NQ				44
Styrene	H,T	100-42-5		NQ				44
Toluene	H,T	108-88-3		NQ				44
Xylene	H,T	1330-20-7		NQ				44
SUBPRODUCT: Backing, type unspecified								
Aliphatic Hydrocarbons				NQ				51
n-Nonane	T	111-84-2		NQ				51
n-Octane	T	111-65-9		NQ				51
SUBPRODUCT: Cushion, type unspecified; particleboard underlayment								
Total Volatile Organic Compounds				0.549			ug/m2-hr	12
SUBPRODUCT: Cushion, type unspecified; concrete underlayment								
Total Volatile Organic Compounds				ND	136	776	ug/m2-hr	12

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ND - No data.
NQ - Detected but not quantified.

Chapter	Carpet	Product	Face Fiber, Unspecified
SIC	2273	SIC	
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Foam backing, type unspecified								
Formaldehyde	C,H,T	50-00-0		24.67	0	65	ug/m2-day	52
SUBPRODUCT: Glued to plywood								
1,1,1-Trichloroethane	H,T	71-55-6		22	19.4	24.6	ug/m3*	55
1,2-Dichloroethane		107-06-2		15	14	16	ug/m3*	55
Ethylbenzene	H,T	100-41-4		6.4	3.2	9.6	ug/m3*	55
n-Decane		124-18-5		46	33	59	ug/m3*	55
n-Undecane		1120-21-4		42	30	54	ug/m3*	55
o-Xylene				8.5	6.2	10.8	ug/m3*	55
p-Dichlorobenzene		106-46-7		3.5	2.3	4.7	ug/m3*	55
p-Xylene		106-42-3		13	10.9	15.1	ug/m3*	55
Styrene	H,T	100-42-5		8.4	7.2	9.6	ug/m3*	55
SUBPRODUCT: SBR latex backcoating; multi-purpose latex adhesive; concrete underlayment								
Total Volatile Organic Compounds				ND	88300	153000	ug/m2-hr	12
SUBPRODUCT: SBR latex backcoating; multi-purpose latex adhesive; cushion, type unspecified; concrete underlayment								
Total Volatile Organic Compounds				145000			ug/m2-hr	12
SUBPRODUCT: SBR latex backcoating; "low VOC" latex adhesive; concrete underlayment								
Total Volatile Organic Compounds				783			ug/m2-hr	12

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ND - No data.
*This value is the concentration of the compound in the air tested.

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Chapter	Carpet	Product	Primary Backing Latex
SIC	2273		
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Butadiene	H,T	106-99-0	X					54
Styrene	H,T	100-42-5	X					54

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Carpet	Product	Secondary Backing Latex
SIC	2273		
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Butadiene	H,T	106-99-0	X					54
Styrene	H,T	100-42-5	X					54

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Carpet	Product	Carpet Cushion
SIC	2273		
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Flat rubber cushion								
Total Volatile Organic Compounds				5735	3360	8110	ug/m2-hr	9
SUBPRODUCT: Hair and jute cushion								
Total Volatile Organic Compounds				126	12	240	ug/m2-hr	9
SUBPRODUCT: Polyurethane rebond cushion								
Total Volatile Organic Compounds				91	59	123	ug/m2-hr	9

ND - No data.

INDOOR AIR CATALOG - Floor Coverings

Chapter	Carpet	Product	Carpet Cushion, Unspecified
SIC	2273		
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Total Volatile Organic Compounds				ND	59	8110	ug/m2-hr	12

ND - No data.

Chapter	Carpet	Product	Carpet Tiles
SIC	2273	SIC	23990-95
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: PVC backing plasticizer								
2-Ethylhexyl Phthalate		117-81-7	X					32
Diisohexyl Phthalate			X					32
Di-Heptyl Nonyl Phthalate			X					32
Di-Nonyl Phthalate		84-76-4	X					32

ND - No data.

Chapter	Carpet	Product	Carpet Tiles
SIC	2273	SIC	23990-95
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Nylon carpet; polypropylene primary backing; polyvinyl chloride secondary backing; scotchguard and antimicrobial treatments								
Acetaldehyde	H,T	75-07-0		4.6			ppb*	56
Butylated Hydroxytoluene				0.37	0.06	0.67	ppb*	56
C5 Aldehydes				0.26	0.23	0.28	ppb*	56
C6 Aldehydes				0.80	0.78	0.81	ppb*	56
C7 Aldehydes				1.16	0.92	1.4	ppb*	56
C8 Aldehydes				0.11	0.1	0.12	ppb*	56
C9 Aldehydes				1.35	1.2	1.5	ppb*	56
C10 Aldehydes				0.09			ppb*	56
Formaldehyde	C,H,T	50-00-0		6.4	4.6	8.1	ppb*	56
Total Volatile Organic Compounds				62.5	62	63	ugC/m3**	56
Vinyl Acetate	H,T	108-05-4		5.6	4.8	6.3	ppb*	56

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T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.
**During thermal desorption, approximately 8 percent of each VOC sample were separated and analyzed without GC by a flame ionization detector. This produces a measure of total C over a boiling-point range encompassing approximately C3-C14 hydrocarbons. The results were reported as a mass of carbon.

Chapter	Carpet	Product	Carpet Tiles
SIC	2273	SIC	23990-95
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Nylon carpet; polypropylene primary backing; polyvinyl chloride secondary backing; scotchguard and antimicrobial treatments								
Acetaldehyde	H,T	75-07-0		0.89	0.67	1.1	ppb*	56
Butylated Hydroxytoluene				0.62	0.56	0.67	ppb*	56
C9 Aldehydes				0.33			ppb*	56
Formaldehyde	C,H,T	50-00-0		5.5	4.6	6.3	ppb*	56
Total Volatile Organic Compounds				51	35	66	ugC/m3**	56
Vinyl Acetate	H,T	108-05-4		7.8	5.7	9.9	ppb*	56

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INDOOR AIR CATALOG - Floor Coverings

Chapter	Carpet	Product	Carpet Tiles
SIC	2273	SIC	23990-95
Usage/Sales	1.35E+09 sq. yd.	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Carpet tiles with PVC backing, latex adhesive, concrete underlayment								
Total Alcohols				180	20	361	ug/10 g carpet	32

ND - No data.

Carpet

6 Reference: Hodgson, A. T. et al., 1992
Test Method: Chamber Study; Test House
Sampling Method: Tenax Tubes
Analysis Method: GC/MS

	Value	Min	Max	Units
RH		45.7	50.7	%
Temp		22.6	23.3	° C
ACH		0.97	1.01	
Testing Duration		24	1248	hr

Comment: Chamber Study: new carpet aged 2–3 weeks before chamber study. Test House: new carpet direct from manufacturer installed in house.

9 Reference: IT Environmental Programs
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS

	Value	Min	Max	Units
RH	50			%
Temp	25			° C
ACH	1.0			
Testing Duration		1	144	hr

Comment: New carpet direct from mill.

12 Reference: Black, M., et. al., 1991
Test Method: Chamber Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH		48	52	%
Temp		24.8	25.2	° C
ACH		0.95	1.05	
Testing Duration		24	144	hr

Comment:

32 Reference: McLaughlin and Aigner, 1990
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS

	Value	Min	Max	Units
RH	50			%
Temp	37			° C
ACH				
Testing Duration		2	18	wk

Comment:

37 Reference: Black and Bayer, 1986
Test Method: Chamber Study
Sampling Method:
Analysis Method: Thermal Desorption/GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration	4			hr

Comment:

44 Reference: Schroder, 1990
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp	95			° C
ACH				
Testing Duration				

Comment: Emissions measured under reduced atmospheric pressure 10E−02 Torr. Emissions measurements not reported.

46 Reference: Bayer, C., et. al., 1988
Test Method: Headspace Study; Chamber Study
Sampling Method:
Analysis Method: Thermal Desorption/GC/MS; Direct GC Analysis

	Value	Min	Max	Units
RH		45	55	%
Temp		23	27	° C
ACH	1			
Testing Duration		1	24	hr

Comment: Headspace study: Sample taken after 1 hr. No RH, temperature or ACH were specified.
Chamber study: Sample taken after 24 hrs. RH, temperature, and ACH in table are for this method.

47 Reference: Black, M., 1990
Test Method: Chamber Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH	50			%
Temp		24.8	25.2	° C
ACH		0.95	1.05	
Testing Duration	24			hr

Comment: Sampling and analytical methods are unspecified.

48 Reference: Davidson, J., et. al., 1991
Test Method: Chamber Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH		48	52	%
Temp		24.8	25.2	° C
ACH		0.95	1.05	
Testing Duration		1	140	hr

Comment:

49 Reference: Godish and Kanyer, 1982
Test Method: Chamber Study
Sampling Method: H_2O Bubbler
Analysis Method: Modified Pararosaniline Method

	Value	Min	Max	Units
RH		48	56	%
Temp		20	22	° C
ACH	1			
Testing Duration	24			hr

Comment: Chamber air purified through filter.
Sample collected through bubbler into distilled H_2O.
Distilled H_2O analyzed by modified pararosaniline method.

50 Reference: Matthews, T., 1984
Test Method: Test House, Floor Chamber
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH		48	52	%
Temp		22	24	° C
ACH		0.2	3	
Testing Duration			96	day

Comment: Timeframe is 0 to 96 days for both test methods.

51 Reference: Miksch, R., et. al., 1982.
Test Method: Headspace Study
Sampling Method: Tenax Cartridges
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration				

Comment:

52 Reference: Pickrell, et. al., 1982
Test Method: Headspace Study
Sampling Method:
Analysis Method: Pararosaniline Reservoir Analysis

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration				

Comment:

53 Reference: Sheldon, L. et al., 1988
Test Method: Chamber Study; Headspace
Sampling Method: Tenax Tubes
Analysis Method: GC/MS

	Value	Min	Max	Units
RH		0	48	%
Temp		25	34	° C
ACH		0.5	11	
Testing Duration		3	25	wk

Comment: Chamber Study: Emission values are measured. Timeframe is 14–25 weeks. Headspace: Emission values are calculated. Timeframe is 3–6 weeks.

55 Reference: Wallace, L., et. al., 1987
Test Method: Chamber Study
Sampling Method: Tenax Tubes
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration	12			hr

Comment: Emission rates are calculated from emission concentrations.

56 Reference: Weschler, C. J. et al., 1992
Test Method: Chamber Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH		45	55	%
Temp		22.9	23.5	°C
ACH	1.0			
Testing Duration		167	247	hr

Comment: Samples were taken at 167 hours prior to O_3 fumigation, at 194 hours when O_3 was present, at 217 hours after O_3 depletion, and at 245 hours after refumigation with O_3.

GLOSSARY

ACRYLICS - In the carpet industry, this refers to acrylic and modacrylic fibers. Acrylic fiber is a polymer composed of at least 85% by weight of acrylonitrile units. Modacrylic fiber is a polymer composed of less than 85% but at least 35% by weight of acrylonitrile units. Acrylics come only in staple form and are noted for their high durability, stain-resistance, and wool-like appearance.

AXMINSTER - One of the basic weaves used in making carpets. The pile tufts in this weave are mechanically inserted and bound to the back in a manner similar to the hand-knotting of Oriental rugs, making possible almost unlimited combinations of colors and patterns. *See weaving.*

BACKING - Material that forms the back of the carpet, regardless of the type of construction. (1) Primary back: In a tufted carpet, the material to which surface yarns are attached. May be made of jute, kraftcord, or woven or nonwoven synthetics. (2) Secondary back: Also called "double backing." Any material (jute, woven or nonwoven synthetics, scrim, foam, or cushion) laminated to the primary back.

BCF - Bulked continuous filament nylon. The highly bulked fibers have a trilobular or triskelion cross section, which gives them greater covering power than round, cross-section fibers possess.

BONDED URETHANE CUSHION - A carpet cushion made from trim generated from urethane foam product manufacture that has been granulated and bonded to form a porous foam material that is fabricated into foam sheets.

CARPET CUSHION - A term used to describe any kind of material placed under carpet to provide softness when it is walked on. Not only does carpet cushion provide a softer feel underfoot, it usually provides added acoustical benefits and longer wear life for the carpet. In some cases the carpet cushion is attached to the carpet when it is manufactured. Also referred to as "lining," padding," or "underlay," although "carpet cushion" is the preferred term.

CARPET - The general designation for fabric used as a floor covering. It is occasionally used incorrectly in the plural as "carpets" or "carpeting." The preferred usage today is "carpet" in both the singular and plural form. It may be used as an adjective, as in "carpeted floors."

CONTINUOUS FILAMENT - Continuous strand of synthetic fiber extruded in yarn form without the need for spinning, which all natural fibers require.

KNITTING - A method of fabricating a carpet in one operation, as in weaving. Surface and backing yarns are looped together with a stitching yarn on machines with three sets of needles.

NEEDLEPUNCHING - Layers or batts of loose fiber are needled into a core, or scrim, fabric to form a felted or flat-textured material.

NYLON - A synthetic material, of synthetic polyamides derivable from coal, air, and water, which is adapted for fashioning into filaments of extreme toughness, strength, and elasticity.

OLEFINS - Any long chain synthetic polymer composed of at least 85% by weight of ethylene, propylene, or other olefin units.

POLYESTER - A manufactured fiber in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85% by weight of an ester of a dihydric alcohol and terephthalic acid ($p\text{-}HOOC\text{-}C_6H_4\text{-}COOH$).

GLOSSARY

POLYPROPYLENE - High-molecular weight paraffin fiber made by the polymerization of propylene (FTC Classification Olefin).

PRIMARY BACKING - The material on which the carpet is constructed. The material to which the visible secondary backing is anchored. Usually jute or polypropylene.

PRIME URETHANE CUSHION - A carpet cushion made from virgin polyether urethane foam slab stacks.

RESIN - A synthetic or natural substance that is thermoplastic, flammable, nonconductive of electricity and dissolves in certain specific organic solvents, but not water.

RUG - A term used to designate soft floor coverings laid on the floor but not fastened to it. As a rule, a rug does not cover the entire floor.

TUFTED CARPET - Carpet or rug fabric that is not woven in the usual manner, but formed by the insertion of thousands of needles that punch tufts through a fabric backing on the principle of the sewing machine.

VELVET CARPET - A woven carpet made on a cam loom very similar to the Wilton loom, except that there is no Jacquard motion to control when each individual yarn rises to the surface. Today most velvet carpet produced is a level loop fabric in tweed or plain colors. Some cut pile plush or splush fabrics are also produced.

VOC - Any organic compound which participates in atmospheric photochemical reactions.*

WEAVING - Surface and backing yarns are interlaced, or woven together, in one operation. Several types of looms are employed. *See Axminster, Wilton, Velvet.*

WILTON - Named after a town in England. This carpet weaving process employs a Jacquard pattern making mechanism, operating on the same principle as player piano rolls, with punched pattern cards determining the pile height and color selection; most often used for patterns and multilevel textures.

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* U.S. Environmental Protection Agency. Code of Federal Regulations. Title 56, Part 52, p. 11390.

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5.0 ADHESIVES

5.1 Description of Product Category

The industry-accepted definition for adhesives includes any substances capable of holding materials together by surface attachment.[1] These substances can include paints, finishes, coatings, grouts, sealants, caulks, cements, and concretes in certain applications. For the purpose of this Catalog, however, adhesives includes only materials in a distinct container whose primary function is to adhere a building material to an indoor surface or substrate in a home or office building. This category does not include adhesives that are an integral part of a building material, such as the adhesives used to bind plywood particles together or the adhesives that are an integral part of carpet backing. In this Catalog, paints and sealants and caulks are not considered adhesives and are discussed in separate sections.

5.1.1 Product Classification

Every adhesive has a natural or synthetic resin base that determines how the adhesive is formulated. For instance, some resins are water-dispersible, while others require an organic solvent to dissolve them. Adhesives also come in different polymer forms, including solids, liquids, and emulsions. Based on formulation, each synthetic resin type is classified as a general polymer type. Resins that are classified as a certain polymer type have similar emissions potential because they are formulated in similar ways. A classification scheme of adhesives by general polymer types is shown in Figure 5-1.

The natural-based materials, excluding natural rubber, are divided by resin type into natural vegetable-based adhesives, natural animal-based adhesives, and other natural-based adhesives. Natural vegetable adhesives include starches and dextrins; and natural animal adhesives include casein. The third category includes oleoresinous and bituminous (asphaltic) adhesives. The division of these natural adhesives parallels their Standard Industrial Classification (SIC) codes, which also categorizes natural adhesives by their resin base. The emissions potential for most natural adhesives is low and, therefore, they were not grouped by polymer type, which differentiates the emission potential of adhesives. Starches, dextrins, and casein resins are all water soluble and, therefore, do not require large quantities of organic solvents to formulate. Asphaltics are available in emulsion form (water-based) or in hot-pour forms, which set as they cool and are virtually 100% solids. Oleoresinous adhesives can be formulated with small amounts of organic solvent because they dry by oxidation and not by solvent release.

The synthetic polymers and natural rubber-based adhesives are first grouped by polymer type including solid polymers and solid rubbers, emulsions, liquid polymers, hot melts, and pressure-

I. NATURAL-BASED ADHESIVES
- A. Natural vegetable-based adhesives
  - 1. Starches
  - 2. Dextrins
- B. Natural animal-based adhesives
  - 1. Casein
- C. Other natural adhesives
  - 1. Oleoresinous
  - 2. Bituminous (asphaltics)

II. SYNTHETIC-BASED ADHESIVES
- A. Solid polymer/solid rubber
  - 1. Styrene butadiene rubber (SBR)
  - 2. Neoprene rubber
  - 3. Nitrile rubber
  - 4. Butyl rubber
  - 5. Natural rubber[a]
  - 6. Polyvinyl chloride (PVC)
  - 7. Polyurethane (PUR)
- B. Liquid polymer
  - 1. Epoxy
  - 2. Polyurethane (PUR)
  - 3. Phenolics (resorcinol)
  - 4. Polyvinyl alcohol (PVOH)
  - 5. Amino (urea formaldehyde/melamine formaldehyde)
  - 6. Nitrile
  - 7. Silicone
- C. Emulsions
  - 1. Latex acrylics
  - 2. Polyvinyl acetate (PVAC)
  - 3. Styrene butadiene latex
  - 4. Neoprene latex
  - 5. Natural rubber latex[a]
- D. Hot melts
  - 1. Ethylene vinyl acetate
- E. Pressure-sensitive
  - 1. Natural rubber
  - 2. Styrene butadiene rubber
- F. Latex acrylics

[a] Natural rubber adhesives are included with synthetics because they are formulated in a similar way.

Figure 5-1. Classification of Adhesives by Polymer Type

sensitives. Of these groups, the solid polymers and solid rubbers have the greatest potential to emit indoor air contaminants because they are formulated with the largest amount of organic solvent, which is released when they dry. Liquid polymers and water-based emulsions tend to have less emissions because neither of these types of polymers dry by release of organic solvent. Usually a base resin may fit into more than one of these categories. The SIC codes group different synthetic resin and polymer types into one code. Because resin and polymer type are the basis for emissions potential, no overlap between SIC code and emission potential existed, and SIC codes were not used to help classify synthetic adhesives.

The solid polymer and solid rubber adhesives category includes all of the solid resins that are dispersed or dissolved in organic solvents. Resins in this category include natural rubber, synthetic rubbers, and solid synthetic resins (organosols). Because they are in solid form, these polymers require large amounts of solvent to alter the viscosity of the solid until the adhesive becomes spreadable. This type of adhesive dries primarily by solvent evaporation and basically converts back to the base polymer from which it was formulated. Fillers and other additives, which may or may not be volatile, can also be required in the formulation. Organosols may require heat to flash off the solvent.

The emulsions category includes those resins and polymers that are dispersed in water. Adhesives in the emulsions category dry by water evaporation but may also release small quantities of volatile fillers or additives.

The liquid polymer category includes those adhesives that dry by methods other than organic solvent or water evaporation. They are thermosetting adhesives, which primarily cure or "dry" by exposure to air or water, by application of heat and pressure, or with the help of a curing agent. Some type of reaction or crosslinking occurs, which may produce volatile by-products. Liquid polymers require little or no solvent to adjust the viscosity of the adhesive. However, they often require fillers or additives to improve the properties of the base polymer, and these materials may or may not be volatile. If the polymer itself is not liquid, it is dissolved or dispersed in a solvent that may or may not be volatile.

Hot melts and pressure-sensitive adhesives have low emission potential. Hot melts are thermoplastic polymers that soften and become tacky when heated and return to the original solid form when cooled. The heat must be sufficiently high to make the material spreadable. Hot melt pressure-sensitive adhesives are included in the hot melt category. Pressure-sensitives remain permanently tacky and do not cure or dry. These adhesives require pressure and not heat for application. Some pressure-sensitive adhesives use organic solvent-based systems and have the potential to emit extremely small quantities of solvent. Pressure-sensitives can also be emulsion-based.

The polymer types are generalities. Many resin combinations and copolymer systems can be used to formulate adhesives, creating instances when a resin type does not clearly fit into one of the categories. Also, emission potential varies from product to product. Therefore, the emissions from a particular adhesive may be higher or lower than predicted by the adhesive's polymer type.

5.1.2 Product Major Uses

There are five major end uses defined for adhesives including: flooring, insulation, walls, and miscellaneous and general uses. Miscellaneous uses are those end uses that did not fit into the flooring, insulation, or walls categories (e.g., kitchen cabinets). The general uses group lists adhesives used for specific substrate types, such as adhesives used for wood or metal. Different types of adhesives used for each of the five areas of application are shown in Tables 5-1 through 5-5, respectively. The data list specific end uses of each adhesive based on general polymer type and specific resin base. For example, all of the liquid polymer epoxy resin adhesives used for flooring are listed in Table 5-2. This table contains the most common adhesives used for typical residential applications.

5.1.3 Sales and Production

Overall adhesive consumption for all applications has grown by 250% from 1975 to 1990, but consumption of adhesives based on synthetic polymers has grown by over 600% in the same time period.[2] Synthetic adhesives provide improved adhesion to various substrates, can be applied at faster speeds, and exhibit superior properties compared to natural adhesives.[2] Synthetic adhesives are replacing natural adhesives in many applications because it is possible to formulate synthetic adhesives that have specific final properties. Many synthetic adhesives are now "tailor made" for particular end uses. This overall increase in consumption equates to an increase in adhesive use of approximately 50% by volume.[2] The use of certain adhesive types has grown more rapidly than others, however. Consumption of all types of acrylic adhesives has grown by 175% in the last 12 years, and most of this growth has been in the construction and pressure-sensitive market.[2] Polyvinyl acetate polymers and copolymer adhesives, ethylene-vinyl acetate hot melts, and polyurethane adhesives have also exhibited rapid increases in usage.[2]

Table 5-6 shows the breakdown of the adhesives market in 1990 and the predicted use of adhesive products in 1995. Total adhesives demand is expected to increase from 9,850 million pounds to 11,050 million pounds during that period.[3] It is predicted that polyurethane adhesives and acrylic adhesives will show the largest percent increase in demand (26.2% and 23.1% respectively).[3] Phenolics should show the largest increase in use by pound.[3]

Table 5-1

Adhesives End Use and Polymer Type (Walls)

MAJOR CATEGORY	SOLID POLYMER/SOLID RUBBER					EMULSIONS			HOT MELTS	LIQUID POLYMER	NATURAL	
	SBR	NEOPRENE RUBBER	NITRILE RUBBER	PUR	NATURAL RUBBER	LATEX ACRYLICS	PVAC	NEOPRENE LATEX	ETHYLENE/ VINYL ACETATE	EPOXY	DEXTRINS	STARCH
TYPE: WALLPAPER - INSTALLED ON ANY SURFACE						X					X	X
TYPE: GYPSUM WALLBOARD - INSTALLED ON B,S,M,CCB	X	X										
- INSTALLED ON P,PC	X*	X*				X			X			
- INSTALLED ON GB,W,PW, HB,PB	X*	X*				X	X		X			
TYPE: PLYWOOD AND PANELING - INSTALLED ON METAL	X*	X*				X			X			
- INSTALLED ON B,S,PC,CCB	X*	X				X	X		X			
- INSTALLED ON GB,P,HB,PB, PW,W	X*	X				X	X*		X			
TYPE: TILEBOARD/WALL TILE - INSTALLED ON B,S,C,CCB	X				X							
- INSTALLED ON GB,P,W,PW, HB,PB	X*				X							
- INSTALLED ON METAL	X*	X			X							

Table 5-1

(Continued)

MAJOR CATEGORY	SOLID POLYMER/SOLID RUBBER					EMULSIONS			HOT MELTS	LIQUID POLYMER	NATURAL	
	SBR	NEOPRENE RUBBER	NITRILE RUBBER	PUR	NATURAL RUBBER	LATEX ACRYLICS	PVAC	NEOPRENE LATEX	ETHYLENE/ VINYL ACETATE	EPOXY	DEXTRINS	STARCH
TYPE: HARDBOARD PANEL												
- INSTALLED ON M,,S,CCB	X	X										
- INSTALLED ON PC	X*	X*				X			X			
- INSTALLED ON GB,P,HB,PB, W,PW	X*	X*				X	X		X			
TYPE: SANDWICH PANELS												
- INSTALLED ON ANY SURFACE		X		X			X			X		
TYPE: PLASTIC LAMINATES												
- INSTALLED ON M,B,S,PC, CCB	X	X	X					X		X		
- INSTALLED ON HB,P,GB	X	X*	X*					X		X		
- INSTALLED ON PB,PW,W	X	X*	X*				X*	X		X		

* MOST COMMONLY USED ADHESIVE

SURFACE ABBREVIATIONS:

S - STONE
B - BRICK
CCB - CONCRETE CINDER BLOCK
PC - POURED CONCRETE
P - PLASTER
HB - HARDBOARD
GB - GYPSUM BOARD
W - WOOD
PW - PLYWOOD
PB - PARTICLE BOARD
M - METAL

Table 5-2

Adhesives End Use and Polymer Type (Flooring)

MAJOR CATEGORY	SOLID POLYMER/SOLID RUBBER						HOT MELTS	PRESSURE SENSITIVE	EMULSIONS			NATURAL		LIQUID POLYMER
	SBR	NEOPRENE RUBBER	NITRILE RUBBER	PUR	BUTYL RUBBER	NATURAL RUBBER	ETHYLENE/ VINYL ACETATE	NATURAL RUBBER	LATEX ACRYLICS	PVAC	SBR	ASPHALT	STARCH	EPOXY
TYPE: CARPET - INSTALLED ON ANY SURFACE	X*	X	X				X		X					
TYPE: CARPET TILE - INSTALLED ON ANY SURFACE			X						X					
TYPE: VINYL TILE - INSTALLED ON ANY SURFACE	X				X	X	X	X	X		X	X		X
TYPE: VINYL SHEET - INSTALLED ON ANY SURFACE	X				X	X	X		X		X		X	X
TYPE: WOOD FLOORING - INSTALLED ON B,S,PC,CCB	X*	X		X										X
- INSTALLED ON GB,P,W, HB,PB,M,PW	X*	X		X										
TYPE: SUBFLOORING - INSTALLED ON GB,P,W, PB,HB,PW	X*	X*					X			X				
TYPE: WOOD PARQUET - INSTALLED ON B,S,CCB,P	X*	X*		X					X					
- INSTALLED ON PC,P,HB, PB,PW	X*	X		X					X	X*				
- INSTALLED ON METAL SURFACES	X*	X*	X	X					X					X

Table 5-2

(Continued)

ADHESIVES
USAGE CATEGORY: FLOORING

MAJOR CATEGORY	SOLID POLYMER/SOLID RUBBER						HOT MELTS	PRESSURE SENSITIVE	EMULSIONS			NATURAL		LIQUID POLYMER
	SBR	NEOPRENE RUBBER	NITRILE RUBBER	PUR	BUTYL RUBBER	NATURAL RUBBER	ETHYLENE/ VINYL ACETATE	NATURAL RUBBER	LATEX ACRYLICS	PVAC	SBR	ASPHALT	STARCH	EPOXY
TYPE: SLATE TILES														
- INSTALLED ON B,S,M,CCB	X*													X
- INSTALLED ON PC	X*								X					X
- INSTALLED ON GB,P,HB, PW,W,PB	X*								X					X
TYPE: ASPHALT TILES														
- INSTALLED ON ANY SURFACE	X											X		
TYPE: CERAMIC TILE														
- INSTALLED ON B,S,M,CCB	X*					X				X				X
- INSTALLED ON PC	X*					X				X				X
- INSTALLED ON GB,P,HB, PB,PW,W	X*					X			X	X				X
TYPE: QUARRY TILE														
- INSTALLED ON B,S,CCB	X*													X
- INSTALLED ON PC	X*								X					X
- INSTALLED ON GB,P,HB, W,PW,PB	X*								X					X
TYPE: MARBLE														
- INSTALLED ON ANY SURFACE EXCEPT METALS	X*	X*		X										
- INSTALLED ON METAL SURFACES	X*	X*		X										X

* MOST COMMONLY USED ADHESIVE

SURFACE ABBREVIATIONS:

S - STONE
B - BRICK
CCB - CONCRETE CINDER BLOCK
PC - POURED CONCRETE
P - PLASTER
HB - HARDBOARD
GB - GYPSUM BOARD
W - WOOD
PW - PLYWOOD
PB - PARTICLE BOARD
M - METAL

Table 5-3

Adhesives End Use and Polymer Type (Insulation)

MAJOR CATEGORY	SOLID POLYMER/SOLID RUB			HOT MELTS	EMULSIONS		LIQUID POLYMER	
	SBR	NEOPRENE RUBBER	PUR	ETHYLENE/ VINYL ACETATE	LATEX ACRYLICS	PVAC	EPOXY	NITRILE
TYPE: CELLULOSE INSULATION								
- INSTALLED ON ANY SURFACE						X		
TYPE: POLYSTYRENE FOAM								
- INSTALLED ON ANY SURFACE EXCEPT METALS	X			X	X	X		X
- INSTALLED ON METAL SURFACES	X			X	X			X
TYPE: POLYURETHANE FOAM								
- INSTALLED ON ANY SURFACE EXCEPT METALS	X	X		X	X	X		X
- INSTALLED ON METAL SURFACES	X*	X*			X			X

* MOST COMMONLY USED ADHESIVE

Table 5-4

Adhesives End Use and Polymer Type (Miscellaneous)

MAJOR CATEGORY	SOLID POLYMER/SOLID RUBBER				HOT MELTS	EMULSIONS		NATURAL ANIMAL	LIQUID POLYMER	
	SBR	NEOPRENE RUBBER	NITRILE RUBBER	PUR	ETHYLENE/ VINYL ACETATE	LATEX ACRYLICS	PVAC	CASEIN	EPOXY	UREA-FORMALDEHYDE
TYPE: CEILING TILE - INSTALLED ON ANY SURFACE						X				
TYPE: FURRING STRIPS - INSTALLED ON M,B,S, PC,CCB	X	X								
- INSTALLED ON GB,P,HB, PB,PW,W	X*	X*			X	X				
TYPE: DECORATIVE BRICK - INSTALLED ON B,S,PC,CCB	X	X*	X							
- INSTALLED ON METAL	X	X	X	X						
- INSTALLED ON GB,P,HB,PB, PW,W	X*	X*			X	X				
TYPE: COVE BASE - INSTALLED ON ANY SURFACE EXCEPT METAL	X	X*				X				
- INSTALLED ON METAL	X	X*				X				

Table 5-4

(Continued)

MAJOR CATEGORY	SOLID POLYMER/SOLID RUBBER				HOT MELTS	EMULSIONS		NATURAL ANIMAL	LIQUID POLYMER	
	SBR	NEOPRENE RUBBER	NITRILE RUBBER	PUR	ETHYLENE/ VINYL ACETATE	LATEX ACRYLICS	PVAC	CASEIN	EPOXY	UREA-FORMALDEHYDE
TYPE: PLASTIC TUB & SHOWERS										
- INSTALLED ON M,B,S,PC, CCB	X									
- INSTALLED ON GB,P,HB,W, PW,PB	X*				X	X				
TYPE: KITCHEN CABINETS										
- INSTALLED ON ANY SURFACE	X	X*								
TYPE: WOOD DOORS										
- INSTALLED ON WOOD							X	X		X
TYPE: METAL DOORS										
- INSTALLED ON METAL		X							X	

* MOST COMMONLY USED ADHESIVE

SURFACE ABBREVIATIONS:

S - STONE
B - BRICK
CCB - CONCRETE CINDER BLOCK
PC - POURED CONCRETE
P - PLASTER
HB - HARDBOARD
GB - GYPSUM BOARD
W - WOOD
PW - PLYWOOD
PB - PARTICLE BOARD
M - METAL

Table 5-5

Adhesives End Use and Polymer Type (General)

MAJOR CATEGORY	SOLID POLYMER/SOLID RUBBER				HOT MELTS	EMULSIONS		LIQUID POLYMER		NATURAL
	SBR	NEOPRENE RUBBER	NITRILE RUBBER	PUR	ETHYLENE/ VINYL ACETATE	LATEX ACRYLICS	PVAC	EPOXY	RESORCINOL	CASEIN
TYPE: WOOD/PLYWOOD										
- INSTALLED ON B,S	X*	X*		X						
- INSTALLED ON CCB	X*	X*		X		X		X		
- INSTALLED ON PC	X*	X*		X	X	X	X	X		
- INSTALLED ON GB,P	X*	X		X	X	X	X*			
- INSTALLED ON HB	X*	X		X	X*	X	X*		X*	X*
- INSTALLED ON M	X*	X*		X				X		
- INSTALLED ON PB,PW,W	X*	X		X	X*	X	X*		X*	X*
TYPE: METAL										
- INSTALLED ON B,S,CCB	X*	X*		X						
- INSTALLED ON PC	X*	X*		X				X		
- INSTALLED ON M	X	X	X	X				X		
- INSTALLED ON GB,P,W, PW,PB,HB	X*	X*		X		X	X			
TYPE: CHALKBOARD/CORK										
- INSTALLED ON B,S,CCB	X*	X								
- INSTALLED ON PC,P,GB, HB,M,PW,W,PB	X*	X			X	X				

* MOST COMMONLY USED ADHESIVE

SURFACE ABBREVIATIONS:

S - STONE
B - BRICK
CCB - CONCRETE CINDER BLOCK
PC - POURED CONCRETE
P - PLASTER
HB - HARDBOARD
GB - GYPSUM BOARD
W - WOOD
PW - PLYWOOD
PB - PARTICLE BOARD
M - METAL

Table 5-6

Adhesives Demand - Total Market
1990 - 1995 (in Millions of Pounds)

Product Type	1990 Adhesive Demand	1990 Percent of Total	1995 Adhesive Demand	1995 Percent of Total	Percent Increase 1990 to 1995
Synthetic	5,845	59.3%	6,760	61.2%	15.7%
Phenolics	1,480	15.0%	1,675	15.2%	13.2%
Vinyl	1,023	10.4%	1,180	10.7%	15.3%
Synthetic Rubber	925	9.4%	1,070	9.7%	15.7%
Hot Melts	878	8.9%	1,035	9.4%	17.9%
Amino	869	8.8%	960	8.7%	10.5%
Acrylic Adhesives	325	3.3%	400	3.6%	23.1%
Polyurethane Adhesives	103	1.0%	130	1.2%	26.2%
Epoxy Adhesives	49	0.5%	60	0.5%	22.4%
Polyester Adhesives	37	0.4%	50	0.5%	35.1%
Other Synthetic Adhesives	156	1.6%	200	1.8%	28.2%
Natural	4,005	40.7%	4,290	38.8%	7.1%
TOTAL	9,850	100.0%	11,050	100.0%	12.2%

One literature reference states that one of the largest uses for adhesives is in the construction industry, and, more importantly, the bulk of the volume of adhesives used in this industry are thermoplastic, water-based adhesives.[2] Adhesive technology is leaning away from solvent-based systems and toward water-based, high-solids systems and hot melts.[3] The environmental focus is prompting the development of recyclable or biodegradable adhesive systems.[3] Tables 5-1 through 5-5 show that solid styrene butadiene rubber adhesives are the most commonly used adhesive in many applications. In most cases, however, a lower-emitting adhesive could be substituted.

5.2 Major Constituents of Concern

A typical adhesive requires several additives to modify the properties of the base polymer. These may include tackifiers, plasticizers or oils, solvents, fillers, curing agents, stabilizers, antifoams, or thickeners. The major constituents of concern are any volatile organic solvents used to formulate an adhesive, along with the plasticizers, which are typically VOCs. Some of the more common organic solvents used are listed in Table 5-7. Tackifiers and thickeners are usually some type of modifying resin different from the base resin, and fillers are solid materials such as clay, silica, and calcium carbonate. These materials are typically not volatile. The use of stabilizers, antifoams, and curing agents varies with each adhesive and, consequently, these components may or may not be a concern. Stabilizers are important for polymers that are sensitive to such things as ultraviolet light, heat, bacteria, and moisture because they keep the base polymer from breaking down.

For solid polymers and solid rubbers, organic solvents are used in large quantities to dissolve the polymer. Typical solvents include ketones, alcohols, esters, hydrocarbons, and chlorinated compounds. Each polymer is soluble in particular types of solvents. For instance, butyl rubber is soluble in hydrocarbon and chlorinated solvents but not in common alcohols, esters, or ketones.[2] Any other additives must be dispersible or soluble in the organic solvent used in the formulation.

With emulsions, the major volatile component is water. However, small amounts of volatile plasticizers or organic solvents are often used to optimize the properties of the adhesive. Any other additives must be soluble or dispersible in water. Table 5-7 also lists the water miscibility of various organic solvents.

Similarly, the constituents of concern in liquid polymers and natural adhesives are the volatile solvents and additives used in the formulation. In the past, pressure-sensitive adhesives were formulated from solvent-based rubber systems. However, technological developments have led to the development of latex-based and hot melt pressure-sensitive adhesives to decrease the dependency on solvents.[2]

Table 5-7

Typical Organic Solvents and Their Water Miscibility

Solvents	Water Miscible	Water Immiscible
Alcohols		
Ethanol	X	
Isopropanol	X	
Methanol	X	
Chlorinated Compounds		
Ethylene dichloride		X
Methylene chloride		X
Perchlorethylene		X
1,1,1-Trichlorethane		X
Trichloroethylene		X
Esters		
Ethyl acetate		X
Methyl acetate		X
n-Butyl acetate		X
Glycols, Ethers, and Oxides		
Diethylene glycol diethyl ether	X	
Diethylene glycol monobutyl ether	X	
Diethylene glycol monoethyl ether	X	
Diethylene glycol monomethyl ether	X	
Dioxane	X	
Ethylene glycol monoethyl ether	X	
Ethylene glycol monobutyl ether	X	
Lower glycol ethers		
Hydrocarbons		
Mineral spirits		X
Naphtha		X
Toluene		X
Xylene		X
Ketones		
Acetone	X	
Cyclohexanone		X
Diacetone alcohol	X	
Isophorone		X
Methyl ethyl ketone	X	
Methyl isobutyl ketone	X	
Miscellaneous		
Tetrahydrofuran		X

5.3 Emissions Information

Limited emissions data are available on adhesives, and the data that are available are extremely general. For example, emissions for a flooring adhesive or a water-based adhesive are reported. Additional descriptive information is needed that can be applied to specific types of adhesives so that emissions from specific products such as styrene butadiene rubber and neoprene rubber can be compared.

General conclusions about emissions can be drawn based on an adhesive formulation, however. For instance, it can be assumed that almost all of the solvent used with solid polymers and solid resins will be off-gassed because that is how the adhesive dries. By studying a specific polymer in this category, it is reasonable to assume that the typical solvents used with this polymer have emissions potential. Concentration profiles have also been developed comparing the effects of such variables as temperature, relative humidity, and air exchange rates on emission rates. This information, used in conjunction with information that identifies chemicals that are potentially off-gassed, could provide relatively complete emissions information.

Estimating emission potential for adhesives that cure by chemical reaction is slightly more complicated than for those adhesives that dry simply by water or solvent evaporation. Numerous volatile by-products can be produced. For instance, certain phenolics are cured with hexamethylene tetramine (HMTA), which breaks down into formaldehyde and ammonia in the presence of heat and moisture. This type of off-gassing could occur years after the adhesive is applied. Another concern is the breakdown of the base polymer itself. For instance, an ultraviolet-sensitive resin could break down upon prolonged exposure to sunlight.

A study by the National Aeronautics and Space Administration (NASA) tested numerous adhesives considered for use in the space shuttle. The testing was done in a chamber at a temperature of 120°F, and the pressure was maintained below atmospheric. The off-gas was analyzed for all possible chemical constituents, not just specific chemicals or chemical types. Therefore, the study provides a complete list of chemicals with emission potential from each particular adhesive. The applicability of these data is questionable, however, because the test conditions are not representative of the type of conditions typically found in homes or office buildings. It is also possible that many of the products tested are specialty adhesives used primarily in the aerospace industry. Although this database cannot be used to provide quantitative emissions data on adhesives, it can provide qualitative data on the chemicals potentially emitted from a wide variety of adhesives.

5.4 Data Tables

The following data tables summarize information identified in the literature relating to the adhesives product category. Only VOCs are presented in these data tables; components such as nonvolatile inert ingredients, fillers, and inorganics that may be constituents of a product are not included. Each VOC is identified as a constituent or an emission. In many cases, compounds were identified in the literature as constituents, but had not specifically been identified through emissions testing. In addition, a few compounds were identified as being emitted from a product, but not listed as a constituent. In these cases, emissions may be the result of a chemical reaction within the product.

Emission rates are presented for those compounds that were identified in the literature as being emitted. These rates are presented as ranges where multiple emission rates were identified.

Chemicals that are hazardous air pollutants (as defined in the Clean Air Act as amended in November, 1990), carcinogens, or which have a threshold limit value established are designated by an "H", "C", or "T", respectively, in the column following the chemical.

Full reference citations for all information presented in the tables are included at the end of the section. The appendix at the end of this section presents additional information, where available, concerning test conditions for literature cited.

The tables list typical constituents and any available emissions data for the different types of adhesives, and are based on the organization scheme presented in Figure 5-1. A brief review of the tables reveals obvious gaps in the available emissions data.

The different sections in the data tables represent the natural resin types and the synthetic polymer types. The product headings represent a specific resin type, and the subproduct headings parallel the five major end uses described in Section 5.1.2. The subproduct represents a typical use for an adhesive formulated with the constituents listed.

In some instances, emissions are reported for compounds not listed as constituents. There are several explanations for this discrepancy, including:

- The emitted compounds are listed in more generic or specific terms than the constituent compound (i.e., benzene or aromatic hydrocarbon).
- The emissions data were obtained from a different source than the constituent data.

- Crosslinking or some type of reaction produced a volatile by-product that is not a constituent (i.e., the curing agent used with some phenolic resins, HMTA, breaks down into ammonia and formaldehyde upon exposure to heat and moisture[1]).

ORGANIZATION OF DATA TABLES

NATURAL-BASED ADHESIVES

Natural Vegetable-Based Adhesives 5-20

Natural Animal-Based Adhesives 5-22

SYNTHETIC-BASED ADHESIVES

Solid Polymer/Solid Rubber 5-23

Liquid Polymers 5-28

Emulsions 5-32

Hot Melts 5-37

Pressure Sensitive Adhesives 5-38

APPENDIX TO DATA TABLES 5-39

INDOOR AIR CATALOG - Adhesives

Chapter	Natural Based Vegetable Glue	Product	Asphaltic
SIC	28913	SIC	28913-80
Usage/Sales	$1.95E+07	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
C10 Cyclohexane	T	110-87-7		NQ				7
C10-C11 Branched Alkanes				NQ				7
n-Decane		124-18-5		NQ				7
n-Undecane		1120-21-4		NQ				7
SUBPRODUCT: Flooring								
Asphalt		8052-42-4	X					4
Petroleum Solvent			X					4

T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Natural Based Vegetable Glue	Product	Starch
SIC	28913	SIC	28913-55
Usage/Sales	ND	Usage/Sales	$3.16E+07

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Walls								
Ammonium Ricinoleate			X					8
Anionic Polyacrylamide			X					2
Carboxymethyl Cellulose		9004-32-4	X					2
Formaldehyde	C,H,T	50-00-0	X					8
Hydroxyethyl Cellulose			X					2
Parachloro-meta Cresol		59-50-7	X					2
Polyacrylamide		9003-05-8	X					2

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Natural Based Animal Glue	Product	Casein Glue
SIC	28913	SIC	28913-50
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: General								
Casein		9005-46-3	X					2,4
Mineral Oil		8020-83-5	X					2
Sodium o-Phenylphenate			X					4

ND - No data.

INDOOR AIR CATALOG - Adhesives

Chapter	Solid Polymer/ Solid Rubber	Product	NP
SIC	28914		
Usage/Sales	ND	Usage/Sales	9.25E+08 lbs

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Alcohol				NQ				7
Alcohol-diols				NQ				6
Aldehydes				NQ				6
Aliphatic Hydrocarbons				NQ				6
Aromatic Hydrocarbons				NQ				6
Cyclohexane				NQ				7
Esters				NQ				6
Halogenated Hydrocarbons				NQ				6
Ketones				NQ				6
Methyl Cyclopentane				NQ				7
Saturated Cyclic Hydrocarbons				NQ				6
Styrene	H,T	100-42-5		NQ				7
Toluene	H,T	108-88-3		36.86	0.59	62	ug/g-hr	7
Total Volatile Organic Compounds				1079	507	1650	ug/cm2-hr	6

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.
NQ - Detected but not quantified.

Chapter	Solid Polymer/ Solid Rubber	Product	Natural Rubber
SIC	28914	SIC	28914
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Walls								
Coumarone-Indene Resin			X					8
Mineral Spirits			X					8
Natural Rubber			X					8

ND - No data.

Chapter	Solid Polymer/ Solid Rubber	Product	Neoprene Rubber
SIC	28914	SIC	28914
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
1,1,1-Trichloroethane	H,T	71-55-6		NQ				5
1,1,2-Trichloro-1,2,2-trifluoromethane				NQ				5
1,4-Dioxane	C,T	123-91-1		NQ				5
2-Butanone	H,T	78-93-3		NQ				5
2-Methyl-2-propanol	T	75-65-0		NQ				5
2-Propanol	T	67-63-0		NQ				5
2-Propanone	T	67-64-1		NQ				5
Butenes		25167-67-3		NQ				5
Ethanol	T	64-17-5		NQ				5
Methanol	H,T	67-56-1		NQ				5
Nitromethane	T	75-52-5		NQ				5
Propanol	T	71-23-8		NQ				5
SUBPRODUCT: General, insulation, miscellaneous, walls								
Neoprene Rubber			X					8
Toluene	H,T	108-88-3	X					8

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Solid Polymer/ Solid Rubber	Product	Nitrile Rubber
SIC	28914	SIC	28914
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Flooring								
Nitrile Rubber			X					2
Piccanol A600E			X					2
Polyvinyl Chloride Latex		9002-86-2	X					2
Sodium Polyacrylate			X					2
Toluene	H,T	108-88-3	X					2

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Solid Polymer/ Solid Rubber	Product	Styrene Butadiene Rubber
SIC	28914	SIC	28914
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Flooring								
Petroleum Hydrocarbon			X					2
Styrene Butadiene Rubber			X					2

ND - No data.

Chapter	Liquid Polymer	Product	Silicone
SIC	28914	SIC	28914
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2-Butanone	H,T	78-93-3		NQ				5
2-Methyl-2-propanol	T	75-65-0		NQ				5
2-Propanol	T	67-63-0		NQ				5
C10 Saturated and Unsaturated Aliphatic Hydrocarbons				NQ				5
Hexamethylcyclotrisiloxane				NQ				5
Methylbenzene	T	108-88-3		NQ				5
Octamethyl Cyclotetrasiloxane		556-67-2		NQ				5

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Liquid Polymer	Product	Nitrile Rubber
SIC	28914	SIC	28914
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Insulation								
Nitrile Rubber			X					2
Polyacrylate Resin			X					2

ND - No data.

INDOOR AIR CATALOG - Adhesives

Chapter	Liquid Polymer	Product	Epoxy Resin
SIC	28914	SIC	28914-11
Usage/Sales	ND	Usage/Sales	4.90E+07 lbs

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Flooring								
Diethylenetriamine		111-40-0	X					4
DMP			X					8
Epoxy Resin			X					4,8
Lancast A			X					8
Polyamide Amino Resin			X					4
Versamid 115			X					8
SUBPRODUCT: General, insulation, miscellaneous, walls								
DMP			X					8
Epoxy Resin			X					8
Lancast A			X					8
Versamid 115			X					8

ND - No data.

INDOOR AIR CATALOG - Adhesives

Chapter	Liquid Polymer	Product	Epoxy Resin
SIC	28914	SIC	28914-11
Usage/Sales	ND	Usage/Sales	4.90E+07 lbs

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2-Butanone	H,T	78-93-3		NQ				5
2-Methoxy Ethanol		109-86-4		NQ				5
2-Propanone	T	67-64-1		NQ				5
4-Methyl-2-pentanone	T	108-10-1		NQ				5
Acetaldehyde	H,T	75-07-0		NQ				5
Acetonitrile	H,T	75-05-8		NQ				5
Ammonia		7664-41-7		NQ				5
Benzene	C,H,T	71-43-2		NQ				5
Butane	T	106-97-8		NQ				5
Butenes		25167-67-3		NQ				5
C5 Ketones				NQ				5
C5 Saturated Aliphatic Hydrocarbons				NQ				5
C6 Ketones				NQ				5
C6 Saturated Aliphatic Hydrocarbons				NQ				5
C8 Saturated Aliphatic Hydrocarbons				NQ				5
Methanol	H,T	67-56-1		NQ				5
Methylbenzene	T	108-88-3		NQ				5
Nitromethane	T	75-52-5		NQ				5
Propane		74-98-6		NQ				5
Trichloroethene	H,T	79-01-6		NQ				5
Xylene	H,T	1330-20-7		NQ				5

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

INDOOR AIR CATALOG - Adhesives

Chapter	Emulsions	Product	NP
SIC	28914		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2-Methylnonane				NQ				9
Alcohol-diols				NQ				6
Aldehydes				NQ				6
Aliphatic Hydrocarbons				NQ				6
Aromatic Hydrocarbons				NQ				6
C8, C9 Branched Alkanes				NQ				7
C8, C9 Cyclohexanes	T	110-87-7		NQ				7
Decane		124-18-5		NQ				9
Dimethyl Benzene	H,T	1330-20-7		NQ				9
Dimethyl Octane				NQ				9
Esters				NQ				6
Halogenated Hydrocarbons				NQ				6
Ketones				NQ				6
Methyl Cyclohexane	T	108-87-2		NQ				7
Nonane	T	111-84-2		NQ				9
n-Nonane	T	111-84-2		NQ				7
n-Octane	T	111-65-9		NQ				7
Saturated Cyclic Hydrocarbons				NQ				6
Undecane		1120-21-4		NQ				9
Total Alkanes				695	610	780	ug/g-hr	7
Total Volatile Organic Compounds				105	<1	210	ug/cm2-hr	6

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.
NQ - Detected but not quantified.

Chapter	Emulsions	Product	Natural Rubber
SIC	28914	SIC	28914
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
C10 Cyclohexane	T	110-87-7		NQ				7
C10, C11 Branched Alkanes				NQ				7
n-Decane		124-18-5		NQ				7
n-Nonane	T	111-84-2		NQ				7
n-Undecane		1120-21-4		NQ				7
Toluene	H,T	108-88-3		NQ				7
SUBPRODUCT: Flooring								
Casein		9005-46-3	X					2
Courmarone Resin			X					2
Hydrocarbon Resin (60% solution in toluene)		108-88-3	X					2
Natural Rubber Latex			X					2
Process Oil			X					2
Solvent			X					2
Terpene Phenolic Resin			X					2
Thiourea	C	62-56-6	X					2
Zinc Diethyldithiocarbamate Dispersion		14324-55-1	X					2

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Emulsions	Product	Neoprene Latex
SIC	28914	SIC	28914
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Walls								
Basin Ester			X					2
Neoprene Latex		126-99-8	X					2
Polyterpene Resin			X					2
Terpene Phenolic Resin			X					2

ND - No data.

Chapter	Emulsions	Product	Polyvinyl Acetate Resin
SIC	28914	SIC	28914-43
Usage/Sales	ND	Usage/Sales	1.023E+09 lbs

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Flooring, general								
Butyl Acetate	T	123-86-4	X					8
Dibutyl Phthalate	H,T	84-74-2	X					8
Ethyl Acetate	T	141-78-6	X					8
Gelvatol 20-30			X					8
Polyvinyl Acetate Latex		9003-20-7	X					8
Santicizer 160			X					8

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Emulsions	Product	Styrene Butadiene Latex
SIC	28914	SIC	28914
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Total Volatile Organic Compounds				10.58	3.95	17.2	mg/m2-hr	10
SUBPRODUCT: Flooring								
2,3-Methylene bis(4-Methyl-6-tertiary-butylphenol)			X					4
Casein		9005-46-3	X					4
Cunilate 2778-I			X					4
Dioctyl Phthalate	T	117-81-7	X					2
Methanol	H,T	67-56-1	X					2
Mineral Spirits			X					2
Rosin Gum Emulsion			X					4
Sodium o-Phenylphenate			X					4
Sodium Pentachlorophenate		131-52-2	X					4
Sodium Polyacrylate Hydrocarbon Resin			X					2
Styrene Butadiene Latex			X					2,4
Total Volatile Organic Compounds				95	90	99	mg/m2-hr	10

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

INDOOR AIR CATALOG - Adhesives

Chapter	Hot Melt	Product	Ethylene Vinyl Acetate
SIC	28914-65	SIC	28914-65
Usage/Sales	8.78E+08 lbs		

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Flooring								
Ethylene Vinyl Acetate			X					2,4
Glycerol Ester of Hydrogenated Rosi			X					4
Styrene Butadiene Styrene			X					2
Sylvator 95			X					2
Thinonylphenyl Phosphite			X					2
White Mineral Oil			X					2

Chapter	Pressure Sensitive	Product	Natural Rubber
SIC	28914-71	SIC	28914-71
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Flooring								
Coumarone-Indene Resin			X					2
Natural Rubber			X					2
Petroleum Oil			X					2
Poly(B-pinene) Resin			X					2
Trimethyldihydroquinoline			X					2

ND - No data.

5 Reference: NASA, 1986
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS/IS

	Value	Min	Max	Units
RH				%
Temp	120			° F
ACH				
Testing Duration	72			hr

Comment: 72±1 hours before sample is taken.

6 Reference: Person, et. al., 1990
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp		20	24	° C
ACH				
Testing Duration	1.5			hr

Comment: Samples taken 90 minutes after being placed in chamber. Sample duration = 10–30 minutes.

7 Reference: Girman, et al., 1986
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS

	Value	Min	Max	Units
RH	40			%
Temp		23	25	° C
ACH	14			
Testing Duration	1			hr

Comment: Sample taken after drying periods of 9 to 14 days.

9 Reference: Tichenor, 1989
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration	30			min

Comment: Sample taken after 30 minutes.

10 Reference: Black, M., et al., 1991
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS

	Value	Min	Max	Units
RH		48	52	%
Temp		24.8	25.2	° C
ACH		0.95	1.05	
Testing Duration	24			hr

Comment: Carpet adhesive. Samples taken after 24 or 144 hours in chamber.

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6.0 SEALANTS AND CAULKS

6.1 Description of Product Category

Sealants and caulks are similar to adhesives in that they must bond to the surfaces they are sealing. The primary purpose of sealants and caulks is to exclude dust, dirt, moisture, and chemicals from joints, gaps, or cavities; in some circumstances, they provide structural support.[1] Sealants and caulks are used in many areas of construction to seal a wide variety of surface types, including glass, concrete, masonry, wood, plastic, and metals.[1]

6.1.1 Product Classification

There are numerous ways to classify sealants, but for the purpose of this Catalog, they are classified according to the type of resin, movement capability, and end use.

Resin Type

The resin type classification divides sealants into natural-based and synthetic-based (Figure 6-1). The natural-based sealants are categorized by resin including natural oil-based and natural bituminous-based sealants. Natural rubber sealants are included with the synthetics because they are formulated in the same way as other synthetic sealants. The synthetic sealant categories are divided by basic polymer types, which include solid rubber and solid polymers, emulsions, liquid polymers, and tapes and foams. These polymer types are then subdivided into resin type. This basic polymer type classification scheme parallels the emissions potential of different types of synthetic sealants and caulks.

Resins are liquid or solid, depending on their chemistry. In order to apply a liquid or solid resin as a sealant, solvents are added. Solid resins require the largest amounts of solvent. Solid polymer and solid rubber sealants have the highest emissions potential because they dry by releasing (emitting) the organic solvents used to adjust their viscosity. Emulsions also dry by solvent release, but the solvent used in these sealants is water. Liquid polymers require only small amounts of solvent to adjust their viscosity and dry by methods other than solvent release. Tapes and foams are virtually 100% solids formulations. Natural-based sealants typically have low emissions potential and are categorized by their natural resin base instead of a polymer base. The resin base classification scheme parallels the SIC system for sealants, which also classifies natural sealants by resin types. The SIC Codes classify synthetic sealants more broadly and include different polymer and resin types under the same code. Because the emissions potential of synthetic sealants are closely related to specific polymer

I. NATURAL-BASED SEALANTS
- A. Natural oil-based sealants
  - 1. Oleoresinous
- B. Natural bituminous-based sealants
  - 1. Asphaltics

II. SYNTHETIC-BASED SEALANTS
- A. Solid rubber/solid polymer
  - 1. Butyl rubber
  - 2. Chlorosulfonated polyethylene (Hypalon)
  - 3. Acrylic rubber
  - 4. Nitrile rubber
  - 5. Neoprene rubber
  - 6. Styrene butadiene rubber
- B. Emulsions
  - 1. Polyvinyl chloride
  - 2. Latex acrylics
  - 3. Polyvinyl acetate
  - 4. Natural rubber latex[a]
  - 5. Styrene butadiene latex
- C. Liquid polymers
  - 1. Polysulfide
  - 2. Polyurethane
  - 3. Silicones
  - 4. Polyisobutylene
  - 5. Epoxy
  - 6. Polybutene
- D. Tapes and foams
  - 1. Butyl (post/preformed tape)
  - 2. Polyvinyl chloride (foam tape)
  - 3. Polyurethane (foam)
  - 4. Polybutene (preformed tape)
  - 5. Polyisobutylene (preformed tape)
  - 6. Thermoplastic rubber

[a] Natural rubber sealants are included with synthetics because they are formulated in a similar way.

Figure 6-1. Classification of Sealants by Resin Type

types, the SIC codes for synthetic-based sealants cannot be related to emissions potential. Therefore, the SIC Codes were not used as a basis for categorizing synthetic sealants.

Each specific synthetic resin type fits into one or more of the basic polymer types. For instance, polysulfide sealants are a specific resin type within the liquid polymer resin type category. The specific resin types are listed in Figure 6-1.

The polymer types are generalities. Many resin combinations and copolymer systems can be used to formulate sealants, creating instances where a resin type does not clearly fit into one of the categories. Also, emission potential varies from product to product. Therefore, the emissions from a particular sealant may be higher or lower than predicted by the sealant's polymer type.

Movement Capability

The sealants are further classified according to movement capability, which represents the percentage of compression or tension that a sealant can withstand. The sealants in this study include low-movement sealants, which are sealants with movement capabilities up to and including 5%. Medium-movement sealants have movement capabilities greater than 5% but less than 25%, and high-movement sealants have movement capabilities greater than 25%. Lower-movement sealants are generally used for interior, static joints where minor or no elastomeric properties are required.[2] Higher-movement sealants are used when greater amounts of elasticity are required. These sealants offer higher performance and versatility and usually have a longer service life. Caulk is a term used to describe sealants with movement capabilities of 10% or less.

6.1.2 Product Major Uses

Information describing a sealant's movement capability, resin type, and typical end uses is summarized in Tables 6-1, 6-2, and 6-3, which list low-, medium-, and high-movement sealants, respectively. Natural-based sealants are typically considered low-movement sealants. Most solid polymers and emulsions exhibit volume shrinkage when their solvent evaporates, which limits their movement capabilities. These sealants are therefore typically medium-movement sealants, as are tapes. Liquid polymers are formulated with less solvent, shrink less, and are therefore used as high-movement sealants.

Table 6-1

Caulks and Sealants Classification Scheme and End Use: Low-Movement Sealants

MAJOR CATEGORY:	NATURAL OIL	NATURAL BITUMINOUS	LIQUID POLYMER
	OLEORESIN	ASPHALTICS	POLYBUTENE
GLAZING/BEDDING COMPOUND	X		
SIDING	X		
INTERIOR DUCTWORK	X		
CONCRETE SEALANT (PIPING/PRECAST PANELS)	X		
ACCOUSTICAL			X
INDUSTRIAL/COMMERCIAL CONSTRUCTION SEALANT			X
RESIDENTIAL CONSTRUCTION SEALANT			X
SEALANT FOR DISSIMILIAR MATERIALS	X		X
EXPANSION AND CONTRACTION JOINTS		X	

Table 6-2

Caulks and Sealants Classification Scheme and End Use: Medium-Movement Sealants

MAJOR CATEGORY:	SOLID POLYMER/SOLID RUBBER				EMULSIONS		TAPES AND FOAMS					
	CHLOROSULFONATED POLYETHYLENE (HYPALON)	NEOPRENE RUBBER	ACRYLIC RUBBER	BUTYL RUBBER	LATEX ACRYLICS	PVAC EMULSIONS	BUTYL POSTFORM TAPES	POLY-ISOBUTYLENE TAPES	POLYBUTENE TAPES	POLYVINYL CHLORIDE TAPES	BUTYL TAPES	POLY-URETHANE FOAM
GENERAL USE SEALANT/CAULK	X	X	X									
GLAZING/BEDDING COMPOUND	X		X	X	X		X	X	X	X	X	
INDUSTRIAL/COMMERCIAL CONSTRUCTION SEALANT	X	X	X	X	X	X	X			X	X	
CONCRETE SEALANT (PIPING/PRECAST PANELS)	X	X	X				X					
PIPE JOINT/ PIPE DUCT			X					X	X		X	
EXPANSION/CONTRACTION JOINTS				X								
ELECTRICAL				X								
SIDING					X			X	X		X	
GLASS INSULATION							X		X			
TUB/TILE CAULK					X							
WITH PAINTS/COATING					X							
GENERAL HOUSEHOLD USE					X	X						
RESIDENTIAL CONSTRUCTION	X			X	X	X						
SEALANT FOR DISSIMILIAR MATERIALS	X	X		X								
ACCOUSTICAL										X		
FLAME RETARDANT												X

Table 6-3

Caulks and Sealants Classification Scheme and End Use: High-Movement Sealants

MAJOR CATEGORY:	LIQUID POLYMERS				SOLID POLYMER/ SOLID RUBBER
	POLYSULFIDE	POLYURETHANE	SILICONE	EPOXY	STYRENE BUTADIENE RUBBER
GENERAL CONSTRUCTION SEALANT	X	X	X		
GLASS INSULATION	X	X	X		
INDUSTRIAL/COMMERCIAL CONSTRUCTION	X	X	X		X
GLAZING	X	X	X	X	
EXPANSION/CONTRACTION JOINTS	X	X	X		
ELECTRICAL		X	X		
GENERAL HOUSEHOLD			X		
TUB/TILE CAULK			X		
RESIDENTIAL CONSTRUCTION	X	X	X		
CONCRETE SEALANT (PRECAST PANELS/PIPING)	X	X		X	
SOLDER				X	

6.1.3 Sales and Production

In the past 40 years, the demand for high performance construction sealants has increased in response to the development of curtainwall construction, which involves the assembly of buildings by attaching precast panels to an erected steel frame.[1] The sealants used in this type of construction, typically synthetic rubber-like or elastomeric sealants, must accommodate for foundation settling, thermal expansion and contraction of different substrates, and various environmental conditions. The construction industry is now the largest user of caulks and sealants.[2]

In 1990, sealant and caulk sales amounted to almost $1.03 billion and are expected to rise to approximately $1.27 billion in 1995.[2] Table 6-4 shows the breakdown of sealant sales in 1990 and expected sales in 1995. Silicone and butyl sealants represented 45% of the market in 1990.[2] Silicone sealants are expected to have the greatest increase in market share from 1990 to 1995, closely followed by polyurethanes.[2] These two types of sealants are expected to represent approximately half of the sealant market by 1995.[2] The use of silicone sealants is expanding because of their versatility and high-performance characteristics.[3] Styrene-butadiene rubber and nitrile rubber sealants are rarely used because both require large amounts of solvent to achieve a satisfactory viscosity.[1] Therefore, they have extremely high shrinkage and low movement capability. Polysulfide use is expected to decrease almost 14% by 1995.[2]

6.2 Major Constituents of Concern

As previously stated, the resin type classification scheme shown in Figure 6-1 groups sealants and caulks according to their emissions potential. Solid polymers and solid rubbers have the greatest emissions potential because they require large amounts of solvent to reduce the solid to a liquid consistency. These sealants dry by solvent evaporation and are thus called solvent-release sealants. Upon solvent evaporation, the sealant basically converts back to the original rubber.[3] A typical formulation for a sealant in this category consists of the base polymer, solvents, and fillers.[4] Each resin type requires certain types of solvents (i.e., polar, nonpolar). Fillers are usually nonvolatile fine powders such as silica or calcium carbonate. Very little crosslinking takes place when these sealants dry,[4] so volatile by-products are of little concern with these resin types.

Emulsions are similar to solvent-release sealants except that they dry by water evaporation. An emulsion is a suspension of polymer particles in water, and emulsion-based sealants are easily formed by adding fillers, plasticizers, and other ingredients directly to the emulsion.[3] Plasticizers used in emulsions can consist of a nonvolatile copolymer or a volatile liquid. Fillers are generally nonvolatile compounds such as calcium carbonate, pigments, or thickening agents.[3]

Table 6-4

U.S. Market for Caulks and Sealants
1990 - 1995

Product Type	1990 Caulks and Sealants Sales (in Millions of $)	1990 Percent of Total	1995 Caulks and Sealants Sales (in Millions of $)	1995 Percent of Total	Percent Increase 1990 to 1995
Silicone	275	26.7%	404	31.8%	46.9%
Butyl	191	18.6%	211	16.6%	10.5%
Acrylic	148	14.4%	180	14.2%	21.6%
Polyurethane	124	12.1%	167	13.1%	34.7%
Polysulfide	88	8.6%	76	6.0%	-13.6%
Oil Based	35	3.4%	35	2.8%	0.0%
Asphaltic	33	3.2%	38	3.0%	15.2%
Other	135	13.1%	159	12.5%	17.8%
TOTAL	1,029	100.0%	1,270	100.0%	23.4%

Source: Reference 3.

Liquid polymers dry by exposure to moisture or air, or with the help of a curing agent. These sealants do not actually "dry" but rather cure or crosslink and react with terminal groups, increasing the molecular weight of the polymer until it becomes more elastic. Two-part sealants are mixed just prior to application to prevent premature curing. Typical constituents include fillers, plasticizers, curing agents, additives, and solvents. The amount and type of each component varies among sealants. Potential volatile components include solvents, plasticizers, additives, and volatile by-products that form when the sealant crosslinks or reacts.

Tapes and foams are usually 100% solids formulations. Postformed tapes are thermoplastic materials that are heated and poured into a joint opening. The material returns to its original state upon cooling and forms a seal. Preformed tapes are either 100% solids-cured systems or noncuring permanently tacky polymers.

Natural sealants dry in various ways and their emissions potential is comparable to that of synthetic sealants, based on their polymer types and curing method. Oleoresinous sealants cure by oxidation and crosslinking and, therefore, have an emissions potential similar to that of liquid polymers. Asphaltics are solvent-diluted, emulsion, or thermoplastic hot pour systems, which are similar to synthetic solid polymer, emulsions, and 100% solids systems.

Most of the specific constituent data were obtained from a study of sealants and caulks done by the Saskatchewan Research Council in Canada.[5,6] This study reports constituent data for sealants based on their resin base, which fits into the classification scheme presented in Figure 6-1 quite well. The constituent data obtained from other sources usually supported those found in the Saskatchewan study, although the level of detail varied. For instance, one reference might list "plasticizer" as a constituent, where another would list a specific plasticizer. Some constituents were listed as trade names when no other information was available.

Each resin type requires certain types of solvents, plasticizers, and other additives to formulate a sealant. For instance, silicone sealants can only use silicone oils and silicone fluids as plasticizers. It is possible to use this information to assess which types of chemicals may off-gas from a particular sealant.

6.3 Emissions Information

Most of the emissions data for sealants were also obtained from the study done by the Saskatchewan Research Council.[5,6] One or two sealants of each resin type were tested in an environmental chamber, and the emissions were recorded in milligrams per gram of sealant. A total of

twenty tests representing different sealant products were performed. Analysis of the chemicals in the off-gas was limited to identifying common solvents used in sealant formulations found in all types of sealants. Therefore, the test results for each sealant usually listed only one or two chemicals and their emission factors. Sampling was done using activated charcoal sampling tubes accompanied by gas chromatography. The test chamber was maintained at approximately 80°F and 50% relative humidity.

In all 20 tests, only four specific chemicals and two general chemical groups were measured. The specific chemicals included toluene, xylene, hexane, and methyl ethyl ketone; the chemicals groups were petroleum and aliphatic hydrocarbons. In most cases, the specific chemicals listed as emissions data matched up with one of the sealant constituents. The chemical groups usually represented one or more of the constituent solvents.

Although these chemicals and chemical groups represent the most typical solvents used with sealants and also have high emissions potential, they are not the only emissions of concern. Each sealant has a unique formulation because the resin base requires particular additives. Along with plasticizers and other volatile ingredients, there are less common solvents used to formulate sealants. Toxic by-products may also form when a resin crosslinks and cures. The Saskatchewan study did not analyze the off-gas emissions for a number of constituents that may present potential indoor air concerns.

6.4 Data Tables

The following data tables summarize information identified in the literature relating to the caulks and sealants product category. Only VOCs are presented in these data tables; components such as nonvolatile inert ingredients, fillers, and inorganics that may be constituents of a product are not included. Each VOC is identified as a constituent or an emission. In many cases, compounds were identified in the literature as constituents, but had not specifically been identified through emissions testing. In addition, a few compounds were identified as being emitted from a product, but not listed as a constituent. In these cases, emissions may be the result of a chemical reaction within the product.

Emission rates are presented for those compounds that were identified in the literature as being emitted. These rates are presented as ranges where multiple emission rates were identified.

Chemicals that are hazardous air pollutants (as defined in the Clean Air Act as amended in November, 1990), carcinogens, or which have a threshold limit value established are designated by an "H", "C", or "T", respectively, in the column following the chemical.

Full reference citations for all information presented in the tables are included at the end of the section. The appendix at the end of this section presents additional information, where available, concerning test conditions for literature cited.

The tables summarize the constituent and emissions data gathered for various sealants. The tables contain a good representation of typical sealant constituents. Unfortunately, the emissions information is not as complete.

In some instances, emissions are reported for compounds not listed as constituents. There are several explanations for this discrepancy, including:

- The emitted compounds are listed in more generic or specific terms than the constituent compound (i.e., benzene or aromatic hydrocarbon).
- The emissions data were obtained from a different source than the constituent data.
- Crosslinking or some type of reaction produced a volatile by-product that is not a constituent (i.e., the curing agent used with some phenolic resins, hexamethylene tetramine, breaks down into ammonia and formaldehyde upon exposure to heat and moisture[1]).

ORGANIZATION OF DATA TABLES

NATURAL-BASED SEALANTS

Natural Oil-Based Sealants 6-13

Natural Bituminous-Based 6-14

SYNTHETIC-BASED SEALANTS

Solid Polymer/Solid Rubber 6-15

Emulsions 6-21

Liquid Polymer 6-24

Tapes and Foams 6-30

APPENDIX TO DATA TABLES 6-35

INDOOR AIR CATALOG - Sealants/Caulks

Chapter	Natural Oil Base	Product	Oleoresinous
SIC	28917-11	SIC	28917-11
Usage/Sales	ND	Usage/Sales	$3.5E+07

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Aliphatic Hydrocarbons				0.39	0.11	0.68	mg/g sealant*	5
Linseed Oil		8001-26-1	X					6
Mineral Spirits			X					6
Polybutene		9003-29-6	X					6
Soya Fatty Acid			X					6
Soybean Oil			X					6
Tall Oil Fatty Acid		8002-26-4	X					6
Vegetable Fatty Acid			X					6

ND - No data.
*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Sealants/Caulks

Chapter	Natural Bituminous Base	Product	Asphaltic
SIC	28917-21	SIC	28917-21
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Asphalt		8052-42-4	X					6
Asphalt Emulsion			X					6
Ester Gum			X					6
Petroleum Hydrocarbons				0.564	0.2	0.93	mg/g sealant*	5
Reclaimed Rubber			X					6

ND - No data.
*This value is the concentration of the compound in the air tested.

Chapter	Solid Polymer/Solid Rubber	Product	Acrylic
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	$1.48E+08

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Acrylic			X					1,6
Dimethyl Formamide	T	68-12-2	X					6
Ethylene Glycol	H,T	107-21-1	X					1,6
Pine Oil			X					1,6
Thixotropic Agent			X					6
Xylene	H,T	1330-20-7	X	1.18	0.33	2.03	mg/g sealant*	1,5

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.

Chapter	Solid Polymer/Solid Rubber	Product	Butyl Rubber
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	$1.91E+08

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Alcohol			X					6
Aliphatic Hydrocarbons				3.41	0.99	5.83	mg/g sealant*	5
Aliphatic Hydrocarbons				NQ				8
Alkyl Benzenes				NQ				8
Butyl Rubber			X					1,6
Cab-O-Sl M5			X					1
Castor Oil			X					6
Ethyl Alcohol		64-17-5	X					1
Isostearic Acid			X					1,6
Methyl Ester			X					1,6
Mineral Spirits			X					1,6
Nonane	T	111-84-2		NQ				8
Octane	T	111-65-9		NQ				8
Octene		25377-83-7		NQ				8
Petroleum Resin			X					1,6
Polybutene		9003-29-6	X					1,6
Polyisobutylene		9003-27-4	X					6
Soya Oil			X					1,6
Vistonex LM-MS			X					1

T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.
*This value is the concentration of the compound in the air tested.

Chapter	Solid Polymer/Solid Rubber	Product	Chlorosulfonated Polyethylene
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2-Mercaptobenzothiazole		149-30-4	X					1,6
Chlorinated Paraffin			X					1,6
Chlorosulfonated Polyethylene			X					1,6
Dibutyl Sebacate			X					6
Hydrogenated Resin			X					6
Isopropyl Alcohol	T	67-63-0	X					1,6
Lead Maleate		816-68-2	X					6
Petroleum Plasticizer			X					1,6
Rosin			X					1
Tetramethyl Thiuram Disulfide	T	137-26-8	X					1,6
Thixotropic Agent			X					1,6
Tribasic Lead Maleate			X					1
Xylene	H,T	1330-20-7	X	1.036	0.22	1.85	mg/g sealant*	1,5,8

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.

Chapter	Solid Polymer/Solid Rubber	Product	Neoprene Rubber
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Butyl Phenol-formaldehyde Resin			X					1,6
Methyl Ethyl Ketone (MEK)	H,T	78-93-3		2.026	0.25	3.8	mg/g sealant*	5
Neoprene Rubber			X					1,6
Petroleum Oil			X					1,6
Toluene	H,T	108-88-3		0.10	0.018	0.19	mg/g sealant*	5
Xylene	H,T	1330-20-7	X	5.38	0.62	14.68	mg/g sealant*	1,5

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.

Chapter	Solid Polymer/Solid Rubber	Product	Nitrile Rubber
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Aliphatic Petroleum Distillates			X					6
Alkylphenolic Resin			X					6
Methyl Ethyl Ketone (MEK)	H,T	78-93-3	X	8.23	0.91	15.55	mg/g sealant*	5
Nitrile Rubber			X					6

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.

Chapter	Solid Polymer/Solid Rubber	Product	Styrene Butadiene Rubber
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Aliphatic Hydrocarbons				3.35	0.7	6.01	mg/g sealant*	5
Aromatic Plasticizer			X					1,6
Hexane	H,T	110-54-3		5.24	1.17	9.32	mg/g sealant*	5
Methyl Ester			X					1,6
Rosin			X					1
Styrene Butadiene Rubber			X					1,6
Toluene	H,T	108-88-3	X	1.53	0.23	2.83	mg/g sealant*	1,5
Xylene	H,T	1330-20-7	X	2.41	0.14	7.47	mg/g sealant*	1,5

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.

Chapter	Emulsions	Product	NP
SIC	2891		
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
1,1,1-Trichloroethane	H,T	71-55-6		4.9			ug/m3-hr	10
2-Butoxyethanol	T	111-76-2		NQ				11
Aciphatic and Aromatic Hydrocarbons				NQ				8
Aliphatic and Oxygenated Aliphatics				126.13	0.25	252	ug/m3-hr	10
Aliphatic and Oxygenated Aliphatic Organics					251		ug/m2-hr	8
Aromatic Hydrocarbons				380			ug/m3-hr	8,10
Benzene	C,H,T	71-43-2		NQ				11
Butanol	T	71-36-3		NQ				11
Butyl Propionate		590-01-2		NQ				11
Halogenated Hydrocarbons				5.2			ug/m3-hr	8,10
Halogenated Organics					5		ug/m2-hr	8
Methyl Ethyl Ketone (MEK)	H,T	78-93-3		NQ				11
Toluene	H,T	108-88-3		NQ				11
Trichloroethylene	H,T	79-01-6		0.3			ug/m3-hr	10
Volatile Aromatic Hydrocarbons					380.9		ug/m2-hr	8

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.
NQ - Detected but not quantified.

INDOOR AIR CATALOG - Sealants/Caulks

Chapter	Emulsions	Product	Acrylic
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Acrylic Latex			X					1,6
Dispersant			X					6
Ethylene Glycol	H,T	107-21-1	X	NQ				6,8
Methylcellulose		9004-67-5	X					6
Mineral Spirits			X					1
Napco NXZ			X					6
Petroleum Aliphatic Solvent			X					6
Petroleum Hydrocarbons				0.114	0.023	0.205	mg/g sealant*	5
Plasticizer			X					6
Polyacrylate Dispersant			X					6
Polyether Alcohol			X					6

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.
*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Sealants/Caulks

Chapter	Emulsions	Product	Polyvinyl Acetate
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Hydroxyethyl Cellulose			X					1,6
Polyvinyl Acetate		9003-20-7	X					6
Propylene Glycol		57-55-6	X					1,6
Vinyl Acetate	H,T	108-05-4	X					1
Xylene	H,T	1330-20-7	X					1,6

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

INDOOR AIR CATALOG - Sealants/Caulks

Chapter	Liquid Polymer	Product	Epoxy Resin
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Epoxy Resin			X					1,7
Lancast A			X					7
Methylenediamine	H	2372-88-5	X					7
Santocel			X					7
Thiokol LP-3			X					1
Toluene	H,T	108-88-3	X					1
Triethylene Tetramine		112-24-3	X					1
Trimethylaminomethyl Phenol			X					1
Triphenyl Phosphate	T	115-86-6	X					7

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Liquid Polymer	Product	Polybutene
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Mineral Spirits			X					6
Petroleum Hydrocarbons				1.29	0.33	2.25	mg/g sealant*	5
Polybutene		9003-29-6	X					6
Soya Fatty Acids			X					6
Tall Oil Fatty Acids		8002-26-4	X					6

ND - No data.
*This value is the concentration of the compound in the air tested.

Chapter	Liquid Polymer	Product	Polyisobutylene
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Polyisobutylene		9003-27-4	X					1

ND - No data.

INDOOR AIR CATALOG - Sealants/Caulks

Chapter	Liquid Polymer	Product	Polysulfide
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	$8.8E+07

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Chlorinated Terphenyl			X					6
Dibutyl Phthalate	H,T	84-74-2	X					6
Gamma-aminopropyltriethoxy Silane			X					1,6
Glycolate Esters			X					1
Lithopone		1345-05-7	X					6
Methylan			X					6
Phenolic Resin			X					1,6
Phthalate Plasticizer			X					1
Plasticizer			X					1,6
Polysulfide			X					1,6
Soya Oil			X					1,6
Stearic Acid		57-11-4	X					1,6
Toluene	H,T	108-88-3	X	0.24	0.06	0.42	mg/g sealant*	5

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Sealants/Caulks

Chapter	Liquid Polymer	Product	Polyurethane
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	$1.24E+08

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
1,2,4-Trimethylpiperazine		120-85-4	X					6
Aromatic Hydrocarbons				0.00013			mg/m3-hr	8,10
Dibutyl Tin Di-2-ethylhexoate		2781-10-4	X					6
Mineral Spirits			X					6
Polyethylene Glycol-Isocyanate Prepolymer			X					6
Polypropylene Glycol		25322-69-4	X					6
Propylene Triol			X					6
Stannous Octoate	T		X					6
Toluene	H,T	108-88-3	X					6
Toluene Diisocyanate (TDI)	H,T	584-84-9	X					6
Xylene	H,T	1330-20-7		0.452	0.112	0.792	mg/g sealant*	5

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Sealants/Caulks

Chapter	Liquid Polymer	Product	Silicone
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	$2.75E+08

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2-Butoxyethanol	T	111-76-2		NQ				8
Benzene	C,H,T	71-43-2		NQ				8
Butanol	T	71-36-3		NQ				8
Butyl Propionate		590-01-2		NQ				8
Methyl Ethyl Ketone (MEK)	H,T	78-93-3		NQ				8
Toluene	H,T	108-88-3		NQ				8
Total Organics				26	2	50	mg/m2-hr	8
Xylene	H,T	1330-20-7		0.077	0.0097	0.14	mg/g sealant*	5
Total Volatile Organic Compounds				7.5	<2	13	mg/hr	9

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.
*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Sealants/Caulks

Chapter	Tapes and Foams	Product	Butyl Rubber
SIC	28917	SIC	28917-71
Usage/Sales	ND	Usage/Sales	$1.91E+08

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Alkyl-Phenol Resin			X					1
Butyl Rubber			X					1,6
Naphthenic Rubber Process Oil			X					1
Paraffinic Process Oil			X					1
Poly DNB			X					1
Polybutene		9003-29-6	X					1,6
Polyethylene		9002-88-4	X					1
Polypropylene		9003-07-0	X					1
Solvents			X					1
Terpene Phenolic Resin			X					1
Vistanex MM L-100			X					1

ND - No data.

Chapter	Tapes and Foams	Product	Polybutene
SIC	28917	SIC	28917-71
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Polybutene		9003-29-6	X					1,6
Tall Oil Fatty Acid		8002-26-4	X					1,6

ND - No data.

Chapter	Tapes and Foams	Product	Polyisobutylene
SIC	28917	SIC	28917-71
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Polybutene		9003-29-6	X					1
Polyisobutylene		9003-27-4	X					1
Rosin Ester			X					1

ND - No data.

Chapter	Tapes and Foams	Product	Polyurethane Foam
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2-Propanone	T	67-64-1		NQ				12
C6 Saturated and Unsaturated Aliphatic Hydrocarbons				NQ				12
Dichlorodifluoromethane	T	75-71-8	X					6
Dichlorofluoromethane	T	75-43-4	X					6
Polyether Polyol			X					6
Polymeric Isocyanate			X					6
Trichlorofluoromethane	T	75-69-4	X					6
Xylene	H,T	1330-20-7	X	NQ				12

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NQ - Detected but not quantified.

Chapter	Tapes and Foams	Product	Thermoplastic Rubber
SIC	2891	SIC	2891
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Asphalt		8052-42-4	X					1
Plasticizing Oil			X					1
Polybutene		9003-29-6	X					1
Polystyrene Rubber		9003-53-6	X					1

ND - No data.

5 Reference: Jennings, et al., 1988
Test Method: Chamber Study
Sampling Method: Activated Charcoal
Analysis Method: GC

	Value	Min	Max	Units
RH	50			%
Temp	23			° C
ACH	0.75			
Testing Duration		0.5	48	hr

Comment: Sampling begins 100 minutes after the sample is placed in the chamber.

8 Reference: Baechler, et. al., 1990
Test Method: Chamber Study
Sampling Method:
Analysis Method:

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration		0.5	5	hr

Comment: Samples are either aged 0.5, 1, 5, or 24 hours before vapors are collected.

9 Reference: Levin, 1989
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS or GC/FID

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration	30			min

Comment: Sampling times are either >10 hours or 10–100 hours.

10 Reference: Wallace, et al., 1987
Test Method: Headspace/Chamber Study
Sampling Method: Tenax GC Cartridges
Analysis Method: GC/FID

	Value	Min	Max	Units
RH	48			%
Temp	25			°C
ACH				
Testing Duration				

Comment: New office building.

11 Reference: Tichenor, 1987
Test Method: Headspace/Chamber Study
Sampling Method: Tenax Charcoal
Analysis Method: GC/FID

	Value	Min	Max	Units
RH				%
Temp		23	35	°C
ACH		0.25	2	hr^{-1}
Testing Duration				

Comment: Sample is taken after approximately 30 minutes.

12 Reference: NASA, 1986
Test Method: Chamber Study
Sampling Method:
Analysis Method: GC/MS/IS

	Value	Min	Max	Units
RH				%
Temp	120			°F
ACH				
Testing Duration	72			hr

Comment: 72±1 hours before sample is taken.

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7.0 PESTICIDE PRODUCTS

7.1 Description of Product Category

The term "pesticide" is defined to mean "any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any insects, rodents, nematodes, fungi, or weeds, or any other forms of life declared to be pests... ; and any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant."[1] Based on this definition, this broad category can be divided into the following subcategories: insecticides, repellents, fungicides, rodenticides, and herbicides. All of these subcategories are potential sources of indoor air emissions because the products can be stored or used inside homes. However, the scope of data-gathering for this Catalog was limited to indoor household insecticides, insect repellents, and fungicides used to remove bathroom mold and mildew. These products have the greatest potential to impact indoor air quality because of their extensive use in households and the toxicity of their constituents. Products excluded from this Catalog include agricultural chemicals (fertilizers, insecticides, herbicides, and fungicides used by farmers), commercial exterminants and termiticides (including those applied during building construction), rodenticides, herbicides, plant fungicides, and outdoor pesticides. Although these products were excluded from data-gathering efforts, they are included in the classification scheme.

Information concerning pentachlorophenol (PCP) emissions from treated wood and sealed treated wood will be included in the Wood Products Section in Volume II of this Catalog.

7.1.1 Product Classification

Deciding on an appropriate classification system was difficult because of the variety of pesticide products. At one point, the classification scheme was divided into indoor and outdoor pesticides. However, although outdoor pesticides could be an indoor air concern (because of indoor storage, etc.), including both categories would create a scheme too broad to handle in this Catalog. It was decided, therefore, to focus on indoor pesticides. Classifying according to constituents was also considered, but the scheme was too complex because of the number of active constituents. Therefore, with the available information, it was decided that pesticide products would be classified based on mode of action/specificity and application methods.

The modes of action of common household pesticides may be classified generally as contact poisons, stomach poisons, neurological poisons, growth regulators, or combinations. Some pesticides work on a broad spectrum; that is, they can affect many pests in a variety of situations. Diazinon is one such broad-spectrum insecticide, with the ability to eliminate over 100 different pests. Other pesticides

are more specific and are designed to control only one or two particular types of pests. The pesticide mode of action and specificity (targeted pest) are reflected in the initial division of the product classification presented in Figure 7-1. Insecticides are classified further into products for crawling insects and products for flying insects. It should be noted, however, that some insecticide products can be used for both flying and crawling insects.

Pesticides are sold in various forms, such as liquid concentrates (also called emulsifiable concentrates if oil-based), which must be diluted with water. Others are prediluted in ready-to-use aerosol cans or trigger sprayers. Some pesticides may be mixed with a powder designed to be applied as a dust or with a wettable powder meant to be mixed into a suspension with water. Some are designed as baits, attracting pests and then delivering poison along with the food. Others are in the form of foggers (bombs), "no bug" shelf paper, pest strips, granules, tablets, sticks, pet collars, and pet shampoos. The differences in insecticide application methods vary in the aerosol/nonaerosol divisions.

7.1.2 Product Major Uses

Insecticides are used inside the home to control a variety of crawling and flying insects such as ants, crickets, spiders, cockroaches, fabric pests (moths), pantry pests (moths or beetles whose larvae feed on stored food), flies, and silverfish. Fleas and ticks on pets can be controlled with special shampoos, dips, or collars. Insect repellents are sprayed or spread on the body to repel mosquitoes, ticks, and gnats. Mold and mildew in bathrooms can be controlled by spraying walls and floors with fungicides.

Pesticides are highly complex products made up of essentially two types of ingredients: active and inert. An active ingredient in a pesticide is any ingredient that will prevent, destroy, repel, or mitigate a pest.[2] An inert ingredient is any intentionally added ingredient that lacks active properties; examples include propellants, carriers, and fragrances. It is the active component of the pesticide that determines its subsequent use. For example, in a household insecticide product there may be only one active ingredient that targets one specific insect (such as fleas). Another product may contain an active ingredient that is effective against a group of insects, such as crawling insects. Still another product may contain a combination of active ingredients that will destroy flying as well as crawling insects.

Another factor that affects pesticide product use is the means of application. As mentioned above, pesticides are available in a variety of forms. Some pesticides may be available in only one application form, while others may be offered in several forms. Consumers may prefer one form over another. Table 7-1 contains the most common product forms, active components, their primary indoor uses, and target insects.[1,3,4]

I. Insecticides[a]
   A. Crawling Insects
      1. Aerosols
      2. Nonaerosols
   B. Flying Insects
      1. Aerosols
      2. Nonaerosols

II. Insect repellents (includes attractants for insects, birds, fish, and other animals)[a]

III. Fungicides
   A. Household mildew remover[a]
   B. Fungicides for plants

IV. Rodenticides

V. Herbicides

VI. Household pesticidal preparations, including commercial exterminants and termiticides

VII. Outdoor pesticides

[a] Only these products are discussed in this catalog.

Figure 7-1. Classification of Pesticide Products

7.1.3 Sales and Production

According to a 1976 - 1977 National Household Pesticide Usage Study, 83.7% of households used pesticides.[5] These pesticides included outdoor insecticides and fungicides, and herbicides. However, the use of certain pesticides appears to be decreasing. According to one source, this may be due to the fact that while the insecticide industry has created products that have reduced the insect population, it has failed to create the perception that its products are safe and environmentally sound.[6] Over the last five years, the percentage of households using insecticides has fallen from 59% to 50%.[6] Also, weather can affect insecticide use. For example, a nationwide drought in 1988, which inhibited the growth of insects, was reflected in lower insecticide sales that year. According to another source, the overall growth of the consumer pesticide industry over the past few years can be attributed to price increases and some shift in use from homeowners to professional applicators, as opposed to expanded product volume.[7]

Table 7-1

Pesticide Product Forms, Active Components, Indoor Uses, and Target Insects[1,3,4]

Product Form	Active Components	Indoor Household Uses	Target Insects
EC	Acephate	Primarily an outdoor insecticide, but is also used for indoor cockroach control.	Crawling
B	Amidino hydrazone (Combat®)	Control of ants and cockroaches.	Crawling
D	Boric Acid	Control of cockroaches, ants, and silverfish.	Crawling
B, D, F, G, WP Flea collars	Carbaryl (Sevin®)	Control of insects on plants. Also used for household pests and in flea dusts and flea collars.	Crawling
A, D, EC, G	Diazinon	Control of ants, cockroaches, and other crawling insects.	Crawling
A, RL	Hydroprene (Gencor®)	Control of cockroaches.	Crawling
WP, EC, D, B, G, A	Malathion	Control of most crawling insects.	Crawling
A, RL Fogger	Methoprene (Precor®)	Control of fleas.	Crawling
EC, WP, G, D, A	Methoxychlor	Control of pantry pests.	Crawling
B	N-ethyl perfluorooctane-sulfonamide	Control of ants and cockroaches.	Crawling
EC, A No pest strips	Dichlorvos (DDVP)	Control of flying insects.	Flying
Moth balls, flakes, or nuggets	Paradichlorobenzene	Control of moths.	Flying
A, EC, D, G, RL Flea collars	Chlorpyrifos (Dursban®)	Control of mosquitoes, cockroaches, crickets, ticks, fleas, fabric and pantry pests, and spiders.	Crawling, flying
EC, B, WP, A Fogger, roach tape, shelf paper	Propoxur (Baygon®)	Control of cockroaches, ants, flies, mosquitoes.	Crawling, flying
EC, D, WP, A	Pyrethrins/pyrethroids, (resmethrin, permethrin, tetramethrin, sumithrin)	Control of primarily flying insects; fabric protection (moths); pet sprays and shampoos for fleas.	Crawling, flying
RL	Sodium hypochlorite	Removes bathroom mold and mildew.	Fungicides
A, RL Stick	N,N-diethyl-meta-toluamide (Deet)	Insect repellent.	Repellents

A = Aerosol
B = Bait
D = Dust
EC = Emulsifiable concentrate
F = Flowable
G = Granular
RL = Ready-to-use liquid
WP = Wettable powder

One facet of the pesticide market has shown a significant increase. The increased media coverage of Lyme disease (carried by deer ticks) pushed retail sales of insect repellents up by more than 50% in 1990; sales increased an additional 9.1% in 1990 to reach $57.5 million.[8] Product shipment value of repellents and attractants for various insects and animals was $58 million in 1987.[9]

Sales/usage data for crawling and flying insects and repellents are summarized in Table 7-2.[9] From this information, it appears more insecticides for crawling insects are produced than for flying insects. Household insecticide sales for 1990 and projected sales for 1991 through 1995 can be found in Table 7-3.[6] It should be noted that these numbers likely include professional applicator use. Retail sales of household insecticides grew 5% in 1990 to $393 million, and sales are expected to grow 3.5% per year to $465 million in 1995. Aerosols are the largest segment of the household insecticide market, with a 74.3% share. Liquids account for 12.7% of sales and solids, 13%. It is expected that aerosols and liquids will grow 3% per year through 1995, and solids, 6%.

An additional source of sales data is a database called the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and Toxic Substances Control Act (TSCA) Enforcement System (FATES), initiated as a project by the EPA Office of Enforcement, Pesticide and Toxic Substances Enforcement Division; it contains brand-name, product-specific production numbers for 1988.[10-12] However, this information is classified as confidential business information (CBI), so FIFRA clearance would be necessary to obtain and report these data.

7.2 Major Constituents of Concern

As stated previously, pesticides are highly complex products made up of essentially two types of constituents: active and inert. Because of the proprietary nature of inert ingredients, less information was available for these than for active components. The major active constituents of pesticide products have changed over the years. The first pesticides were inorganic compounds such as sulfur, arsenic, or mercury, which controlled pests but could also be deadly to people. Plant-derived poisons such as rotenone and pyrethrins were discovered in the early nineteenth century. The first of the synthetic organic pesticides were introduced in the 1940s. These compounds, such as dichlorodiphenyl trichloroethane (DDT), were classified as chlorinated hydrocarbons. In the 1950s, the organophosphates were introduced. Organophosphates, such as malathion and diazinon, are derivatives of phosphoric acid that break down into harmless compounds more quickly than do chlorinated hydrocarbons. These were followed in the late 1950s by the carbamates, such as propoxur, which are derivatives of carbamic acid and do not persist for long periods of time. The more recent pesticide compounds are synthetic pyrethrins called pyrethroids, which are more effective and longer lasting than the botanical pyrethrins.[4] Most indoor consumer insecticides used today contain pyrethrins/pyrethroids, carbamates, or

Table 7-2

1987 Sales/Usage Data

Product	Product Shipment Value (in millions of $)
Insecticides (crawling insects)	
Aerosols	155.7
Nonaerosols	86.1
Insecticides (flying insects)	
Aerosols	167.4
Nonaerosols	41.1
Repellents and attractants	58.0

Source: Reference 9.

Table 7-3

Household Insecticide Sales for 1990 and Projected Sales for 1991-1995 (in millions of $)

Year	Aerosol	Liquid	Solid	Total
1995	339.7	58.2	67.5	465.3
1994	329.8	56.5	65.5	451.8
1993	317.1	54.8	60.8	432.7
1992	304.1	52.8	55.9	412.8
1991	297.2	51.7	52.2	401.1
1990	292.5	50.3	51.0	393.8

Source: Reference 6.

organophosphates. The primary chemical found in household mildew removers is sodium hypochlorite, a fungicide. It is often found in combination with sodium carbonate (soda ash), which acts as a disinfectant. Insect repellents are usually composed of a chemical called Deet.

Inert constituents have also changed over the years. Fluorinated hydrocarbons and many of the chlorinated solvents that were once popular in aerosols are no longer used because of their potential toxicity and reactivity.[2]

The FATES database, based on a survey of pesticide formulators, may be a potential source of active constituent information. The database contains priority pollutants found in pesticide formulations.[12] Priority pollutants are 126 EPA-identified toxic pollutants found in industrial wastewater. However, because priority pollutants are chemicals of concern for water pollution, it would be necessary to extrapolate the data (perhaps compare the priority pollutant list to the hazardous air pollutants list) to determine the applicability to indoor air emissions.

7.2.1 Pesticide Formulations

Pesticidal chemicals (active ingredients) are usually manufactured in concentrations of 80 - 99+%.[13] In order to obtain a biologically effective but safe pesticide product, dilution of the technical active ingredient with inert materials and necessary additives is performed by a formulator. Most pesticides are formulated in plants separate from the site where active ingredients are manufactured. The final concentrations of the active component in an aerosol pesticide usually range from about 0.1% to 0.5%.[14] Every time a formulator includes a "new constituent" (active, inert, or additive) in a product, it must first be registered by EPA. This requires the formulator to submit all toxicity data, efficacy data, other test results, and sample labels to EPA. One of the reasons there are so few "new" insecticide constituents is the lengthy EPA scrutiny. It is estimated that it takes approximately five years from the point a new product undergoes initial lab work to when it appears on the shelf.[14]

Active Ingredients

Active ingredients in a pesticide product are identified on the label.[15,16] In fact, most of the constituent data on active ingredients for this Catalog were obtained from product labels. The rest of the information was found in reference materials.[17-24] The constituent data are presented in Section 7.3 of this Catalog.

The number of active constituents in indoor consumer pesticide products is actually quite limited. In fact, about 95% of all indoor insecticides are made from about 10 active components.[14] The same active ingredient may be used in a number of different products. For example, propoxur is contained in wasp foggers, ant and roach aerosols, flying and crawling insect aerosols, and "no-bug" shelf paper. The active ingredients are usually the same among different brands of pesticides. The constituent data on active ingredients included in this Catalog are, therefore, quite complete.

One of the trends for future pesticide products is reformulating conventional products, for example, substituting water bases for petroleum bases and adding scents. Most liquid and aerosol insecticide products are now water-based, except for ant and roach sprays, which are still mainly oil-based.[14] Water-based ant and roach insecticides are available on the market; however, without petroleum distillates and solvents (which provide a quicker killing response), these water-based products are not as popular with consumers.[14] Various technologies, including recombinant DNA methods, bioprocessing, and cell biology innovations, will result in new "natural" pesticides. Viruses, bacteria/fungi, synthetic hormones (pheromones), regulatory/messenger-control chemicals, and other microorganisms will eventually be used for alternative insecticides.[22,25,26]

Substances that have recently been developed and that destroy target insects without harming humans or other animals are called insect growth regulators (IGRs).[22] These chemicals, such as methoprene and hydroprene, are very effective against the egg/larval and immature stages of insects such as fleas and roaches. Their low volatility and low toxicity are advantages from an indoor air standpoint; however, because of their slow-acting property, IGRs are not suitable for destroying flying insects.

The discovery or rejection of specific active ingredients for pesticide products depends on continuing research. For example, the active ingredient in one roach bait, hydramethylnon, was first investigated as a possible treatment for malaria.[23] Just recently, EPA urged women of childbearing age to avoid using an insect repellent linked to birth defects in test animals.[24] This suspect chemical, 2-ethyl-1,3-hexanediol, is found in one repellent currently in use; another manufacturer who previously used the chemical is recalling existing stocks.

Inert Ingredients and Additives

Only a small percentage of a concentrated pesticide product is actually active ingredient (often measured in parts per million). The rest, sometimes 99% or greater, are inert ingredients. The inert constituents are not all identified individually on pesticide product labels but are usually grouped under the term "inerts." The term "inert" ingredients does not necessarily mean the chemicals are innocuous,

only that they lack the property of the active components. In the case of insecticides, the inerts lack the ability to kill insects. Inert ingredients may be carrying agents, solvents, adjuvants, emulsifiers, wetting agents, diluents, surfactants, stabilizers, or conditioning agents.[18]

There are approximately 1,200 inert ingredients in pesticide formulations.[2] However, identifying inert components in specific pesticide products is difficult because of the proprietary nature of that information. Many factors, such as trial and error techniques, are involved in the development and optimization of a successful formulation. Therefore, the composition of a formulation is usually considered confidential. In some cases, the formulator may not be aware of the identity of all the inert ingredients, especially perfumes.[14] This is because the formulator obtains a number of inert ingredients from different suppliers who market them as "proprietary inerts," although they are disclosed to EPA in the CSF and are included in the health and safety testing of a product prior to acceptance for registration.[2]

Hydrocarbon blends used as solvents in ant and roach aerosols are usually nonaromatic compounds. The blends may have specific names but the exact percentage of each hydrocarbon may not be known by the formulators, only by the supplier.[14] Hydrocarbon blends used as propellants in flying insect aerosols usually contain hydrocarbons such as butane and propane.

Flying insect aerosols are predominantly water-based.[14] Because of the water content, these formulations are more complicated to develop and produce. This is due to the need for inerts and additional ingredients such as surfactants, perfumes, corrosion inhibitors (to prevent the can from rusting), and their interactions with the water. Preservatives found in liquid sprays prevent bacterial growth in the container.

Synergists in pesticides are not classified as inert components but are added to pesticides to increase the killing efficiency of the active ingredients. With the addition of a synergist, less active ingredients are required in a formulation. The most widely used synergist in consumer insecticides is piperonyl butoxide.[14]

Because of concern that some inert ingredients in pesticide products might cause adverse effects to humans or the environment, EPA developed a regulatory policy for inert ingredients, which was published in the Federal Register in 1987.[2] The EPA divided the approximately 1200 inert ingredients contained in pesticide products into four toxicity categories. Lists 1 and 2 contain inerts of toxicological or potential toxicological concern. Inerts of unknown toxicity or minimal concern are found in Lists 3 and 4. According to one insecticide formulator, List 1 chemicals can be used in pesticides as long as there is a warning on the product label, but most of the constituents (such as chlorinated

solvents) are no longer used in these products at all.[14] The lists contained in the Federal Register notice are a source of inert components but were not included in the Catalog database because it could not be determined which of these inerts were currently in use, and which inerts were found in indoor consumer pesticides. It should be noted that some chemicals, such as the pyrethrins/pyrethroids, are identified in List 1 of the notice as inert ingredients, but are also active ingredients. This is because a chemical may be present in a pesticide formulation to act against some pest, although not necessarily the pest targeted by the formulation. For example, an ingredient normally considered active may be added to a rodent bait to repel flies; the chemical is not active against rodents so it is classified as inert.

Because most inert ingredients are not identified specifically on product labels, the majority of inert constituent data were obtained from references and contacts. The data tables in Section 7.3 do not differentiate between active and inert constituents; however, Table 7-4 provides a summary of the more common inerts and additives found in pesticides, and, if known, their function (emulsifier, propellant, etc.) and product form (aerosol, liquid, etc.).[1,2,4,14-16,18,21,27]

7.3 Emissions Information

A review of the references identified to date revealed that studies pertaining to consumer pesticide products and indoor air targeted active rather than inert pesticide ingredients.[27-49] One study sampled for over 30 different household pesticides (including outdoor and commercial) in homes in two U.S. test locations over three seasons.[3,19] Other studies targeted acephate, diazinon, chlorpyrifos, and dichlorvos. No emissions data were found for fungicides and insect repellents.

The pesticide studies described in the reviewed literature were conducted in test houses in which concentrations of active pesticide components were measured. The pesticide levels were usually found in the microgram-to milligram-per-cubic-meter range.[30]

Table 7-4

Common Inert Constituents and Additives Found in Consumer Pesticides

Inert Ingredient/Additive	Function	Product Form
Sulfated alkylphenoxypoly-(ethyleneoxy)-ethanol sodium or ammonium salts	Adjuvant	--
2-ethyl-1-hexanol	Solvent and adjuvant	--
Sodium salts of fatty acid amide sulfonates	Dispersant and wetting agent	--
Ethane	Carrier	A
–	Corrosion inhibitor	A
Dimethylpoly-siloxane	Defoamer	A
Dichlorodifluoromethane	Propellant	A
Isobutane	Propellant	A
n-Butane	Propellant	A
Carbon dioxide	Propellant	A
Propane	Propellant	A
Dicarboximide	Synergist	A
N-octyl bicycloheptene	Synergist	A
Piperonyl butoxide	Synergist	A, L
Water	Carrier/diluent	A, L
Lignosulfonates	Dispersant	A, L
Tridecyloxpoly (ethyleneoxy) ethanol	Emulsifier	A, L
Alkylated naphthalenes	Solvent	A, L
Toluene	Solvent	A, L
Methyl, ethyl, and isopropyl alcohol	Solvent	A, L
Cyclohexanone	Solvent	A, L
Kerosene	Solvent	A, L
Mineral oil	Solvent	A, L
Xylenes	Solvent	A, L
Petroleum distillates	Solvent	A, L
Polyoxyethylated vegetable oil	Surfactant	A, L
Di-1-*p*-menthene	Sticker-spreader	D
Soda ash	Disinfectant	L

Table 7-4

(Continued)

Inert Ingredient/Additive	Function	Product Form
--	Preservative	L
Paper	Carrier	S
--	Fragrance	S, A, L, D
Kaolin	Carrier/diluent	S, D
Diatomaceous earth	Carrier/diluent	S, D
Gypsum	Conditioner/carrier	S, D
Calcium carbonate	Conditioner/extender	S, D
Magnesium carbonate	Desiccant	S, D
Bentonite	Granular carrier	S, D
--	Base (used to neutralize acidic formulations)	S, L, A

A = Aerosol
S = Solid
L = Liquid
D = Dust
-- = Not available

One study measured the concentration of a pesticide over a two-week period after baseboard spraying.[43] Another study tested the distribution of a pesticide throughout a house over a 35-day period after application.[47] The indoor and outdoor concentrations of a pesticide in a test house were measured and compared in another study.[45] Still other studies measured the pesticide concentrations from pest control strips over various periods of time.[36,40,44] One of the most comprehensive and recent studies using test homes to measure concentrations of active ingredients was the Nonoccupational Pesticide Exposure Study from 1990.[3,19,48] This study examined levels of 32 pesticides in hundreds of homes in two cities over a period of one year or more. The EPA determined that emissions were low enough so that "the non-cancer risks were generally low, and the cancer risks were in a range the Agency generally considers negligible with the possible exception of heptachlor and aldrin," two pesticides no longer in use.[3]

Air samples for most of the test houses were collected using portable air pumps to draw air through a polyurethane foam (PUF) plug. Pesticide concentrations were determined by analyzing the PUF plugs by GC or GC/MS. No reference studies were located that measured pesticide product

emissions using test chambers. One reason for this may be that a majority of household pesticides are in aerosol form and chamber testing is not appropriate for products such as aerosol sprays.[49] Sampling from aerosols and controlling sample quantity can be quite difficult.

Quantifying "typical" emissions for pesticide products is difficult because emissions vary depending on the product's active ingredients, formulation, application method, and user conditions. However, most consumer pesticides exhibit high initial concentrations after application, with concentrations declining over time. Consumer pesticides eventually degrade to form nontoxic materials such as carbon dioxide and water.[14] The rate of decline is partially due to the type and volatility of the active constituent found in the product. Generally it can be said that pyrethrins/pyrethroids degrade fastest, then carbamates, and then organophosphates. One study revealed that diazinon (an organophosphate) concentrations peaked within 24 hours, decreased with time, but were still measurable 35 days after application.[31] A study of dichlorvos pest strips, which continually emit the insecticide, showed a decline from 60 $\mu g/m^3$ one hour after installation to 10 $\mu g/m^3$ after 56 days.[30] These plastic resin strips are very volatile, and it is suggested that the strips not be used where food, people, or pets may contact the vapors for long uninterrupted periods.[4]

Comparing vapor pressures of active pesticide constituents in consumer products may not be a reliable means of determining volatility because the active ingredients combined with water, emulsifiers, and other inert ingredients will have a joint vapor pressure that may or may not be similar to that of the active constituent alone. Therefore, the combination of ingredients in a formulation affect volatility and subsequent emissions.

The application form of pesticide products is the major determinant of indoor air emissions. Using an aerosol for flying insects produces an initially high pesticide concentration, which dissipates to negligible amounts within 24 hours.[14] Crawling insect aerosols and liquid sprays will also produce a high concentration initially but small amounts of the active component may linger for as long as 60 days. The DDVP pest strips are the most volatile of the pesticide products. Studies have shown initially high pesticide concentrations, with detection levels after 30 to 50 days.[30] These strips are not nearly as popular as in past years, and one of the major insecticide manufacturers no longer produces them.[14] Baits volatilize very slowly over long periods of time. The active ingredients in dusts are bound to the solid materials in the formulation, and are not volatile.[14]

Another variable that affects pesticide product emissions is the user environment. Studies revealed that airborne emissions are directly proportional to air flow.[33] Homes having the poorest ventilation have the highest levels of air contamination.[30] The size of a room, the number of windows and doors, whether the windows are open or closed, and whether there is air conditioning or heating all

influence the concentration of pesticides after application. The season of the year and the geographical location of a home can also affect pesticide indoor emissions. It has been shown that the higher the temperature, the higher the pesticide concentration in a home because an increase in temperature causes an increase in volatility.[3,14] Humidity affects pesticide emissions and product efficiency.[3] For example, boric acid powder is an effective roach insecticide in dryer sections of the United States. However, the powder cakes up under humid conditions and loses its efficiency; therefore, this product is not as popular in more humid areas.[14] Lastly, the consumer greatly influences pesticide emissions in a home. One person may spray an aerosol insecticide for 3 seconds to kill a fly, while another may spray for 10 seconds. This variable is difficult to test or control.

7.4 Data Tables

The following data tables summarize information identified in the literature relating to the pesticide product category. Only VOCs are presented in these data tables; components such as nonvolatile inert ingredients, fillers, and inorganics that may be constituents of a product are not included. Each VOC is identified as a constituent or an emission. In many cases, compounds were identified in the literature as constituents, but had not specifically been identified through emissions testing. In addition, a few compounds were identified as being emitted from a product, but not listed as a constituent. In these cases, emissions may be the result of a chemical reaction within the product.

Emission rates are presented for those compounds that were identified in the literature as being emitted. These rates are presented as ranges where multiple emission rates were identified.

Chemicals that are hazardous air pollutants (as defined in the Clean Air Act as amended in November, 1990), carcinogens, or which have a threshold limit value established are designated by an "H", "C", or "T", respectively, in the column following the chemical.

Full reference citations for all information presented in the tables are included at the end of the section. The appendix at the end of this section presents additional information, where available, concerning test conditions for literature cited.

The tables include active and volatile inert pesticide product constituent data and emissions data that were obtained from references, contacts, and label inventories.

ORGANIZATION OF DATA TABLES

INSECTICIDES

General Insecticides 7-16

Crawling Insecticides -- Aerosol 7-22

Crawling Insecticides -- Nonaerosol 7-24

Flying Insecticides -- Aerosol 7-25

Flying Insecticides -- Nonaerosol 7-26

INSECT REPELLENTS 7-27

APPENDIX TO DATA TABLES 7-28

Chapter	Insecticides	Product	NP
SIC	2879	SIC	
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
1,1,1-Trichloroethane	H,T	71-55-6		82			ug/m3*	41
2,3,4,5-bis(2-Butylene)tetra-hydro-2-furaldehyde			X					21
2-Ethyl-1-hexanol		104-76-7	X					1
4,4'-DDD		72-54-8	X					19
4,4'-DDE	H		X	0.55	0.2	0.9	ng/m3*	3,19
4,4'-DDT	T	50-29-3	X	0.67	0	1	ng/m3*	3,19,42
Aldrin	T	309-00-2	X	17.43	0	31.3	ng/m3*	3,19,42
Alkylated Naphthalenes			X					1
Alpha-BHC			X	1.07	0	2	ng/m3*	3,19,42
Bendiocarb			X	42.95	0.2	85.7	ng/m3*	3,19

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.
*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Pesticides

Chapter	Insecticides	Product	NP
SIC	2879	SIC	
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Carbaryl (SEVIN)	H,T	63-25-2	X	34.05	0	68.1	ng/m3*	3,19,21
Chlordane	H,T	57-74-9	X	121.07	0	324	ng/m3*	3,19,42,48
Chlorothalonil				97			ng/m3*	42
Chlorpyrifos (DURSBAN)	T	2921-88-2	X	21600	0.2	15000	ng/m3*	3,15,16,19, 42,45,48
Cyclohexanone	T	108-94-1	X					1
Dichlorvos (DDVP)	H,T	62-73-7	X					21

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.
*This value is the concentration of the compound in the air tested.

Chapter	Insecticides	Product	NP
SIC	2879	SIC	
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Diazinon	T	333-41-5	X	102.91	0	420.7	ng/m3*	16,19,42, 47,48
Dichlorvos (DDVP)	H,T	62-73-7	X	76.25	1.5	148	ng/m3*	3,19,21
Dicofol			X	5.5	0	11	ng/m3*	3,19
Dieldrin	C,T	60-57-1	X	7.85	1	14.7	ng/m3*	3,19,42
Dimethyl Polysiloxane			X					1
Di-1-p-menthene			X					1
Allethrin		584-79-2	X					15,16
Ethylbenzene	H,T	100-41-4		NQ				41

C - This chemical is a known carcinogen.
H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.
NQ - Detected but not quantified.
*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Pesticides

Chapter	Insecticides	Product	NP
SIC	2879	SIC	
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Gamma-BHC (lindane)	T	58-89-9	X	9.57	0.5	20.2	ng/m3*	3,19,42
Glycol Ether	H		X					21
Heptachlor	H,T	76-44-8	X	58.19	0	163.4	ng/m3*	3,19,42,48
Heptachlor Epoxide			X	0.6	0	1	ng/m3*	3,19,42
Hexachlorobenzene	H	118-74-1		0.65	0	1.3	ng/m3*	3
Isopropyl Alcohol	T	67-63-0	X					1,14
Malathion	T	121-75-5	X	10.4	0	20.8	ng/m3*	3,19,21

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.
*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Pesticides

Chapter	Insecticides	Product	NP
SIC	2879	SIC	
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Methoxychlor	H,T	72-43-5		0.15	0	0.3	ng/m3*	3
Methanol	H,T	67-56-1	X					1
Mineral Oil		8020-83-5	X					21
n-Decane		124-18-5		NQ				41
Chlordane	H,T	57-74-9	X	3.25	0	6.5	ng/m3*	3,19
o-Phenylphenol		90-43-7		44.67	14	80	ng/m3*	19,42
Pentachlorophenol	H,T	87-86-5		19			ng/m3*	42
Piperonyl Butoxide Technical		51-03-6	X					1
Propoxur (BAYGON)	H,T	114-26-1	X	264.3	0	528.5	ng/m3*	3,19,42,48

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.
NQ - Detected but not quantified.
*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Pesticides

Chapter	Insecticides	Product	NP
SIC	2879	SIC	
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Resmethrin			X	0.05	0	0.1	ng/m3*	3,19
Ronnell	T	299-84-3	X	3.73	0	11	ng/m3*	3,19,42
Sumithrin			X					16
Tetrachloroethylene	H,T	127-18-4		NQ				41
Tetramethrin			X					16
Toluene	H,T	108-88-3	X					1
Permethrin		52645-53-1		0.55	0	1.1	ng/m3*	3
Trichloroethylene	H,T	79-01-6		NQ				41
Tridecyloxpoly(ethyleneoxy)-ethanol			X					1
Xylene	H,T	1330-20-7	X	NQ				1,41

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.
NQ - Detected but not quantified.
*This value is the concentration of the compound in the air tested.

Chapter	Insecticides	Product	Crawling
SIC	2879	SIC	2879
Usage/Sales	$1.557E+08	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Aerosol								
1,1,1-Trichloroethane	H,T	71-55-6	X					21
2-Hydroxyethyl-n-octyl Sulfide			X					16
Acephate		30560-19-1		46.97	0.01	194.13	ug/100 cm2*	43
Aromatic Petroleum Hydrocarbons			X					16
Cyanomethyl 4-Chloroalpha-benzeneacetate			X					16
Cyfluthrin			X					15
Propoxur (BAYGON)	H,T	114-26-1	X					14
Hydramethylnon			X					23
Hydrocarbon Propellant			X					21
Isobutane		75-28-5	X					21
Pyrethrins		8003-34-7	X					14
Piperonyl Butoxide Technical		51-03-6	X					14
Dicarboximide (MGK-264)			X					14
n-Octyl Bicycloheptene			X					14
Tetramethrin			X					14
Sumithrin			X					14

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.

T - Threshold Limit Value has been established for this chemical.

ND - No data.

*This value is the concentration of the compound in the air tested.

INDOOR AIR CATALOG - Pesticides

Chapter	Insecticides	Product	Crawling
SIC	2879	SIC	2879
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
Naphtha		8030-30-6	X					21
n-Butane	T	106-97-8	X					21
n-Octyl Bicycloheptene Dicarboximide			X					16
Permethrin		52645-53-1	X					15
Piperonyl Butoxide Technical		51-03-6	X					15,16
Propane		74-98-6	X					18
Pyrethrins		8003-34-7	X					15,16
Resmethrin			X					16
Sumithrin			X					16
Tetramethrin			X					15,16,21
Methoprene		40596-69-8	X					15
Propoxur (BAYGON)	H,T	114-26-1	X					14
Total Volatile Organic Compounds			X					17

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

INDOOR AIR CATALOG - Pesticides

Chapter	Insecticides	Product	Crawling
SIC	2879	SIC	2879
Usage/Sales	$8.61E+07	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Non-Aerosol								
Methoxychlor	H,T	72-43-5	X					1
Chlorpyrifos (DURSBAN)	T	2921-88-2	X					16
Hydramethylnon			X					23
n-Ethyl Perfluorooctane Sulfonamide			X					15
n-Octyl Bicycloheptene Dicarboximide			X					15,21
Propoxur (BAYGON)	H,T	114-26-1	X					15
Methoprene		40596-69-8	X					1
Pyrethrins		8003-34-7	X					15,21
Piperonyl Butoxide Technical		51-03-6	X					15,21
Xylene	H,T	1330-20-7	X					16
Amidino Hydrazone			X					15
Acephate		30560-19-1	X					15
Carbaryl (SEVIN)	H,T	63-25-2	X					15
Diazinon	T	333-41-5	X					1
Hydroprene (GENCOR)			X					1
Malathion	T	121-75-5	X					1

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

Chapter	Insecticides	Product	Flying
SIC	2879	SIC	2879
Usage/Sales	ND	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Aerosol								
2-Phenyl Methylcarbamate			X					16
Chlorpyrifos (DURSBAN)	T	2921-88-2	X					15
d-trans Allethrin			X					15
Fluoromethane	T	593-53-3	X					18
1,1,1-Trichloroethane	H,T	71-55-6	X					15
Isobutane		75-28-5	X					21
Naled	T	300-76-5	X					21
Naphtha		8030-30-6	X					21
n-Butane	T	106-97-8	X					14,21
o-Isopropoxyphenyl Methylcarbamate	T	114-26-1	X					15
Propane		74-98-6	X					14,18
Tetramethrin			X					15
Sumithrin			X					14
Piperonyl Butoxide Technical		51-03-6	X					14
Resmethrin			X					14

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.

INDOOR AIR CATALOG - Pesticides

Chapter	Insecticides	Product	Flying
SIC	2879	SIC	2879
Usage/Sales	$4.11E+07	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
SUBPRODUCT: Non-Aerosol								
Camphor	T	76-22-2	X					20
Carbaryl (SEVIN)	H,T	63-25-2	X					16
Chlorpyrifos (DURSBAN)	T	2921-88-2		<0.25			ug/m3*	44
Diazinon	T	333-41-5		<1.4			ug/m3*	44
Dichlorvos (DDVP)	H,T	62-73-7		125	0.01	0.24	ug/l*	40
Dichlorvos (DDVP)	H,T	62-73-7		35	10	60	ug/m3*	30
Naphthalene	H,T	91-20-3	X					20,21
Paradichlorobenzene	H,T	106-46-7	X					15,20
Propoxur (BAYGON)	H,T	114-26-1		<0.8			ug/m3*	44

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
*This value is the concentration of the compound in the air tested.

Chapter	Insect Repellents	Product	NP
SIC	28799	SIC	
Usage/Sales	$5.75E+07 containers	Usage/Sales	ND

Chemical/Compound	Notes	CAS#	Constituent	Emissions Data				Ref
				Average	Min	Max	Units	
2,3,4,5-bis(2-Butylene)tetra-hydro-2-formaldehyde			X					21
2,3,4,5-bis(2-Butylene)tetra-hydro-2-furaldehyde			X					1
2-Ethyl-1,3-hexanediol		94-96-2	X					1,21
Benzyl Benzoate		120-51-4	X					1
Dibutyl Phthalate	H,T	84-72-2	X					1
Dimethyl Carbate		5826-73-3	X					1
Dimethyl Phthalate	T	131-11-3	X					1
Di-n-butyl Succinate			X					1
Ethyl Hexanediol		94-96-2	X					1
n,n-Diethyl-m-toluamide		134-62-3	X					15
n-Butylacetanilide			X					1
n-Octyl Bicycloheptene Dicarboximide			X					21
Total Volatile Organic Compounds			X					17

H - Hazardous Air Pollutant as defined in the Clean Air Act as amended, November, 1990.
T - Threshold Limit Value has been established for this chemical.
ND - No data.
NP - No product.

Pesticides

3 Reference: Immerman and Schaum, 1990
Test Method: Test House
Sampling Method: Polyurethane foam (PUF) personal sampler pump
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration				

Comment: Tested for 30 target compounds in 2 U.S. test locations over 3 seasons. Most comprehensive study to date.

19 Reference: Bond and Lewis, 1990
Test Method: Test House
Sampling Method: PUF personal sampler pump
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration				

Comment: Tested for detectable limits of target pesticides in 2 locations. Sampled for 24 hours.

30 Reference: Lee, 1976
Test Method: Test House
Sampling Method: Methods not given
Analysis Method: Methods not given

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration	1			hr

Comment: Tested emissions from pest control strips (Vapona); concentrations measured after 1 hour and after 56 days from installation.

40 Reference: Elgar and Steer, 1972
Test Method: Test House
Sampling Method: Bubbler
Analysis Method: Cholinesterase inhibition test

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration			120	day

Comment: Sampled for dichlorvos from pest strips. 3000 air samples taken. 97.2% of results were ≤0.1 μg/l.

41 Reference: Wallace et al., 1989
Test Method: Headspace Study
Sampling Method: Tenax cartridges
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration				

Comment: Concentration data. Three–day sampling period.

42 Reference: Fortmann and Sheldon, 1991
Test Method: Test House
Sampling Method: PUF personal sampler pump
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration				

Comment: 9–home study; 23 of 31 target pesticides were detected in air, dust, and soil.

43 Reference: Wright et al., 1989
Test Method: Test House
Sampling Method: PUF personal sampler pump
Analysis Method: Analysis of variance (ANOVA)

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration				

Comment: Acephate present after baseboard spraying. Concentrations determined immediately after spraying, and after 1-week and 2-week intervals.

44 Reference: Jackson and Lewis, 1981
Test Method: Test House
Sampling Method: High volume air sampler
Analysis Method: GC

	Value	Min	Max	Units
RH	50	30	70	%
Temp	21	20	22	° C
ACH				
Testing Duration				

Comment: Tested concentration from pest control strips over 30-day period; target pesticides were propoxur, diazinon, and chlorpyrifos. Sampled for 2-hour periods.

45 Reference: Anderson and Hites, 1988
Test Method: Test House
Sampling Method: PUF personal sampler pump
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp				° C
ACH				
Testing Duration				

Comment: Sampled 12 homes for chlorpyrifos concentration.

47 Reference: Leidy et al., 1984
Test Method: Test House
Sampling Method: PUF personal sampler pump
Analysis Method: GC

	Value	Min	Max	Units
RH				%
Temp				°C
ACH				
Testing Duration				

Comment: Tested distribution of diazinon concentrations throughout test house rooms over 35–day period.

48 Reference: Lewis et al., 1986
Test Method: Test House
Sampling Method: PUF personal sampler pump
Analysis Method: GC/MS

	Value	Min	Max	Units
RH				%
Temp				°C
ACH				
Testing Duration				

Comment: Sampled 9 homes for various pesticides. Sampled for 24 hours.

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APPENDIX A

Summary of Emission Rates by Compound and Material

Comparisons of Emission Rates by Compound and Material

The following tables present information on emissions by chemical for materials included in the Catalog. Only those VOCs for which emissions data were found in the literature are included. The data are sorted by compound, and for each compound, a list of materials that were found to emit that particular compound is presented. The materials are grouped by their product categories (e.g., carpet, wall coverings, insulation). In some studies chemicals were detected as being emitted but not quantified. This type of emissions data is included in the tables as "NQ".

Because the tables are meant to provide a summary of emission rates from different materials, only those compounds that were identified as being emitted from more than one product are included. However, it should not be assumed that because a material does not appear under a specific compound that it does not emit that compound.

Pesticide products are not included in this appendix for two reasons. First, the compounds emitted from pesticides are typically different from those emitted from the other materials presented in the Catalog. Secondly, emissions of pesticides are typically expressed in different units than emissions from other products (e.g., gram of chemical per volume of product dispensed) making comparison of pesticide emission rates with other building materials difficult. Comparison of emissions from pesticides with other consumer products would be a more pertinent exercise, however at this time no other consumer products are included in this report.

Footnotes are included indicating compounds which are carcinogens, compounds which are classified as hazardous air pollutants, and compounds for which Threshold Limit Values have been established.

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Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Acetone*	67-64-1	INSULATION			
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Sheet Vinyl Flooring	NQ	

*A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Aliphatic Hydrocarbons		FLOOR COVERINGS			
		Carpet	Face Fiber, Acrylic	NQ	
		Carpet	Face Fiber, Nylon	NQ	
		Carpet	Face Fiber, Polypropylene	NQ	
		Carpet	Face Fiber, Unspecified	NQ	
		Carpet	Face Fiber, Unspecified	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Other Resilient Floor Coverings	6	$\mu g/m^2$-hr
		Resilient Floor Coverings	Sheet Vinyl Flooring	NQ	
		Resilient Floor Coverings	Vinyl Tile	NQ	
		ADHESIVES			
		Emulsions	No Product	NQ	
		Solid Polymer/Solid Rubber	No Product	NQ	
		SEALANTS/CAULKS			
		Solid Polymer/Solid Rubber	Butyl Rubber	3.41	
		Solid Polymer/Solid Rubber	Styrene Butadiene Rubber	3.35	mg/g sealant*
		Natural Oil Base	Oleoresinous	0.39	mg/g sealant*
		Solid Polymer/Solid Rubber	No Product	NQ	

*This value is the concentration of the compound in the air tested.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Alkylbenzene		FLOOR COVERINGS			
		Carpet	Face Fiber, Nylon	NQ	
		Carpet	Face Fiber, Polypropylene	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Vinyl Tile	NQ	

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Aromatic Hydrocarbons		INSULATION			
		Fibrous – Mineral Fibers	Fiberglass – Batts, Blankets, Rolls	0.15	$\mu g/m^2$–hr
		Fibrous – Mineral Fibers	Fiberglass – Batts, Blankets, Rolls	0.08	$\mu g/m^2$–hr
		FLOOR COVERINGS			
		Resilient Floor Coverings	Other Resilient Floor Coverings	35	$\mu g/m^2$–hr
		ADHESIVES			
		Emulsions	No Product	NQ	
		Solid Polymer/Solid Rubber	No Product	NQ	
		SEALANTS/CAULKS			
		Emulsions	No Product	380	$\mu g/m^3$–hr
		Liquid Polymer	Polyurethane	130	$\mu g/m^3$–hr

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Benzaldehyde	100-52-7	INSULATION			
		Fibrous-Mineral Fibers	Fiberglass	NQ	
		Fibrous-Mineral Fibers	Mineral Wool	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Sheet Vinyl Flooring	NQ	
		Resilient Floor Coverings	Vinyl Tile	NQ	

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Benzene*	71-43-2	FLOOR COVERINGS			
		Carpet	Face Fiber, Polypropylene	0.92	$\mu g/m^2$-hr
		Carpet	Face Fiber, Unspecified	NQ	
		INSULATION			
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	NQ	
		ADHESIVES			
		Liquid Polymer	Epoxy Resin	NQ	
		SEALANTS/CAULKS			
		Emulsions	No Product	NQ	

*Benzene is a carcinogen; and it is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Butanol*	71-36-3	FLOOR COVERINGS			
		Resilient Floor Coverings	Vinyl Tile	NQ	
		SEALANTS/CAULKS			
		Emulsions	No Product	NQ	
		Liquid Polymer	Silicone	NQ	

*A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
i-Butanol*	78-92-2	INSULATION			
		Fibrous-Mineral Fibers	Fiberglass	NQ	
		Fibrous-Mineral Fibers	Mineral Wool	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Other Resilient Floor Coverings	NQ	

*i-Butanol is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
2-Butanone*	78-93-3	FLOOR COVERINGS			
		Resilient Floor Coverings	Vinyl Tile	NQ	
		ADHESIVES			
		Liquid Polymer	Epoxy Resin	NQ	
		Liquid Polymer	Silicone	NQ	
		Solid Polymer/Solid Rubber	Neoprene Rubber	NQ	

*2-Butanone is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
2-Butoxyethanol*	111-76-2	INSULATION			
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	NQ	
		SEALANTS/CAULKS			
		Liquid Polymer	Silicone	NQ	

*A threshold limit value has been established for this chemical.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Butenes	25167-67-3	ADHESIVES			
		Liquid Polymer	Epoxy Resin	NQ	
		Solid Polymer/Solid Rubber	Neoprene Rubber	NQ	

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Butyl Acetate*	123-86-4	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Other Resilient Floor Coverings	NQ	
		Resilient Floor Coverings	Sheet Vinyl Flooring	NQ	

*A threshold limit value has been established for this chemical.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
C10 Cyclohexane*	110-87-7	ADHESIVES			
		Emulsions	Natural Rubber	NQ	
		Other Natural Based Adhesives	Asphaltic	NQ	

*A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Decane	124-18-5	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		Carpet	Face Fiber, Nylon	NQ	
		ADHESIVES			
		Emulsions	No Product	NQ	

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
n-Decane	124-18-5	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	46.00	$\mu g/m^3$ *
		Carpet	Face Fiber, Polypropylene	5.62	$\mu g/m^2$-hr
		WALLCOVERINGS			
		Wallpaper (glued to sheetrock)	No Product	11.4	$\mu g/m^2$-hr
		ADHESIVES			
		Emulsions	Natural Rubber	NQ	
		Other Natural Based Adhesives	Asphaltic	NQ	

*This value is the concentration of the compound in the air tested.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
p-Dichlorobenzene	106-46-7	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	3.50	$\mu g/m^3$ *
		Carpet	Face Fiber, Polypropylene	0.18	$\mu g/m^2$-hr
		Carpet	Face Fiber, Unspecified	NQ	
		INSULATION			
		Foam-Rigid	Polystyrene	0.59	$\mu g/m^2$-hr
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	NQ	

*This value is the concentration of the compound in the air tested.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Ethanol*	64-17-5	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		ADHESIVES			
		Solid Polymer/Solid Rubber	Neoprene Rubber	NQ	

*A threshold limit value has been established for this chemical.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Ethyl Acetate*	141-78-6	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Other Resilient Floor Coverings	NQ	

*A threshold limit value has been established for this chemical.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Ethylbenzene*	100-41-4	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	6.40	$\mu g/m^3$ **
		Carpet	Face Fiber, Polypropylene	0.05	$\mu g/m^2$-hr
		Carpet	Face Fiber, Unspecified	NQ	
		INSULATION			
		Foam-Rigid	Polystyrene	12.5	$\mu g/m^2$-hr
		FLOOR COVERINGS			
		Resilient Floor Coverings	Sheet Vinyl Flooring	65	$\mu g/m^2$-hr

*Ethylbenzene is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

**This value is the concentration of the compound in the air tested.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
m-Ethyltoluene		FLOOR COVERINGS			
		Carpet	Face Fiber, Polypropylene	2.1	$\mu g/m^2$-hr
		INSULATION			
		Foam-Rigid	Polystyrene	0.59	$\mu g/m^2$-hr
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	0.03	$\mu g/m^2$-hr

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Formaldehyde*	50-00-0	FLOOR COVERINGS			
		Carpet	Face Fiber, Nylon	90.25	$\mu g/m^2$-hr
		Carpet	Face Fiber, Unspecified	1.03	$\mu g/m^2$-hr
		Carpet	Face Fiber, Nylon	NQ	
		Carpet	Face Fiber, Unspecified	NQ	
		INSULATION			
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	47.5	$\mu g/m^2$-hr
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	30.0	$\mu g/m^2$-hr
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	29.0	$\mu g/m^2$-hr
		Mineral Fibers	Fiberglass-Rigid	19.4	$\mu g/m^2$-hr
		Fibrous-Mineral Fibers	Fiberglass	14.0	$\mu g/m^2$-hr
		Mineral Fibers	Fiberglass-Rigid	NQ	
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	NQ	
		WALLCOVERINGS			
		Wallpaper	Vinyl Coated	15	$\mu g/m^2$-hr
		FLOOR COVERINGS			
		Resilient Floor Coverings	Sheet Vinyl Flooring	30	$\mu g/m^2$-hr
		Resilient Floor Coverings	No Product	<240	$\mu g/m^3$ **
		Resilient Floor Coverings	Other Resilient Floor Coverings	NQ	

*Formaldehyde is a carcinogen; and it is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

**This value is the concentration of the compound in the air tested.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Halogenated Hydrocarbons		FLOOR COVERINGS			
		Resilient Floor Coverings	Other Resilient Floor Coverings	4	$\mu g/m^2$-hr
		ADHESIVES			
		Emulsions	No Product	NQ	
		Solid Polymer/Solid Rubber	No Product	NQ	
		SEALANTS/CAULKS			
		Emulsions	No Product	5.2	$\mu g/m^2$-hr

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Hexane*	110-54-3	INSULATION			
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	NQ	
		SEALANTS/CAULKS			
		Solid Polymer/Solid Rubber	Styrene Butadiene Rubber	5.24	mg/g sealant**

*Hexane is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

**This value is the concentration of the compound in the air tested.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Isopropylbenzene*	98-82-8	FLOOR COVERINGS			
		Carpet	Face Fiber, Polypropylene	0.17	$\mu g/m^2$-hr
		INSULATION			
		Foam-Rigid	Polystyrene	1.55	$\mu g/m^2$-hr

*A threshold limit value has been established for this chemical.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Methanol*	67-56-1	ADHESIVES			
		Liquid Polymer	Epoxy Resin	NQ	
		Solid Polymer/Solid Rubber	Neoprene Rubber	NQ	

*Methanol is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Methylbenzene*	108-88-3	ADHESIVES			
		Liquid Polymer	Epoxy Resin	NQ	
		Liquid Polymer	Silicone	NQ	

*A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Methylene Chloride*	75-09-2	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		INSULATION			
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	NQ	

*Methylene chloride is a carcinogen; and it is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990.

A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Methyl Ethyl Ketone (MEK)*	78-93-3	FLOOR COVERINGS			
		Resilient Floor Coverings	Sheet Vinyl Flooring	NQ	
		SEALANTS/CAULKS			
		Solid Polymer/Solid Rubber	Nitrile Rubber	8.230	mg/g sealant**
		Solid Polymer/Solid Rubber	Neoprene Rubber	2.026	mg/g sealant**
		Liquid Polymer	Silicone	NQ	

*Methyl ethyl ketone is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

**This value is the concentration of the compound in the air tested.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
2-Methylnaphthalene	91-57-6	FLOOR COVERINGS			
		Carpet	Face Fiber, Acrylic	NQ	
		Carpet	Face Fiber, Nylon	NQ	
		INSULATION			
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	NQ	

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
2-Methyl-2-propanol*	75-65-0	ADHESIVES			
		Liquid Polymer	Silicone	NQ	
		Solid Polymer/Solid Rubber	Neoprene Rubber	NQ	

*A threshold limit value has been established for this chemical.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Naphthalene*	91-20-3	FLOOR COVERINGS			
		Carpet	Face Fiber, Acrylic	NQ	
		Carpet	Face Fiber, Nylon	NQ	

*Naphthalene is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Nitromethane*	75-52-5	ADHESIVES			
		Liquid Polymer	Epoxy Resin	NQ	
		Solid Polymer/Solid Rubber	Neoprene Rubber	NQ	

*A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Nonane*	111-84-2	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		Carpet	Face Fiber, Unspecified	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Vinyl Tile	NQ	
		ADHESIVES			
		Emulsions	No Product	380	μg/g-hr
		Emulsions	Natural Rubber	NQ	
		Emulsions	No Product	NQ	
		SEALANTS/CAULKS			
		Solid Polymer/Solid Rubber	No Product	NQ	
		Solid Polymer/Solid Rubber	Butyl Rubber	NQ	

*A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Octane*	111-65-9	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		Carpet	Face Fiber, Unspecified	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Vinyl Tile	NQ	
		Resilient Floor Coverings	Vinyl Tile	NQ	
		ADHESIVES			
		Emulsions	No Product	380	μg/g-hr
		SEALANTS/CAULKS			
		Solid Polymer/Solid Rubber	No Product	NQ	
		Solid Polymer/Solid Rubber	Butyl Rubber	NQ	

*A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Phenol*	108-95-2	FLOOR COVERINGS			
		Carpet	Face Fiber, Acrylic	NQ	
		Carpet	Face Fiber, Unspecified	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Vinyl Tile	NQ	

*Phenol is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
4-Phenylcyclohexene		FLOOR COVERINGS			
(4-PCH)		Carpet	Face Fiber, Nylon	193	$\mu g/m^2$-hr
		Carpet	Face Fiber, Unspecified	NQ	

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
2-Propanol*	67-63-0	ADHESIVES			
		Liquid Polymer	Silicone	NQ	
		Solid Polymer/Solid Rubber	Neoprene Rubber	NQ	

*A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
2-Propanone*	67-64-1	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		ADHESIVES			
		Liquid Polymer	Epoxy Resin	NQ	
		Solid Polymer/Solid Rubber	Neoprene Rubber	NQ	
		SEALANTS/CAULKS			
		Tapes and Foams	Polyurethane Foam	NQ	

*A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Styrene*	100-42-5	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	8.4	$\mu g/m^3$ **
		Carpet	Face Fiber, Polypropylene	0.1	$\mu g/m^2$-hr
		Carpet	Face Fiber, Nylon	NQ	
		Carpet	Face Fiber, Unspecified	NQ	
		INSULATION			
		Foam-Rigid	Polystyrene	5.55	$\mu g/m^2$-hr
		ADHESIVES			
		Solid Polymer/Solid Rubber	No Product	NQ	

*Styrene is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

**This value is the concentration of the compound in the air tested.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Tetrachloroethane*	79-34-5	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		INSULATION			
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	NQ	

*Tetrachloroethane is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Toluene*	108-88-3	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		Carpet	Face Fiber, Unspecified	NQ	
		INSULATION			
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	NQ	
		WALLCOVERINGS			
		Wallpaper	Vinyl Coated	21.67	$\mu g/m^2$-hr
		FLOOR COVERINGS			
		Resilient Floor Coverings	Sheet Vinyl Flooring	65	$\mu g/m^2$-hr
		Resilient Floor Coverings	Other Resilient Floor Coverings	NQ	
		Resilient Floor Coverings	Sheet Vinyl Flooring	NQ	
		Resilient Floor Coverings	Vinyl Tile	NQ	
		Resilient Floor Coverings	Vinyl Tile	NQ	
		Resilient Floor Coverings	Vinyl Tile	NQ	
		ADHESIVES			
		Solid Polymer/Solid Rubber	No Product	36.86	$\mu g/g$-hr
		Emulsions	Natural Rubber	NQ	
		SEALANTS/CAULKS			
		Solid Polymer/Solid Rubber	Styrene Butadiene Rubber	1.53	mg/g sealant**
		Liquid Polymer	Polysulfide	0.24	mg/g sealant**
		Solid Polymer/Solid Rubber	Neoprene Rubber	0.10	mg/g sealant**
		Liquid Polymer	Silicone	NQ	

*Toluene is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

**This value is the concentration of the compound in the air tested.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
1,1,1-Trichloroethane*	71-55-6	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	22	$\mu g/m^3$ **
		Carpet	Face Fiber, Unspecified	NQ	
		WALLCOVERINGS			
		Wallpaper (glued to sheetrock)	No Product	5	$\mu g/m^2$-hr
		SEALANTS/CAULKS			
		Emulsions	No Product	4.9	$\mu g/m^3$-hr
		ADHESIVES			
		Solid Polymer/Solid Rubber	Neoprene Rubber	NQ	

*1,1,1-Trichloroethane is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

**This value is the concentration of the compound in the air tested.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Trichloroethene*	79-01-6	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Vinyl Tile	NQ	
		ADHESIVES			
		Liquid Polymer	Epoxy Resin	NQ	

*Trichloroethene is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Trichloroethylene*	79-01-6	FLOOR COVERINGS			
		Resilient Floor Coverings	Sheet Vinyl Flooring	NQ	
		Resilient Floor Coverings	Vinyl Tile	NQ	
		SEALANTS/CAULKS			
		Emulsions	No Product	0.3	$\mu g/m^3$-hr

*Trichloroethylene is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
1,2,3-Trimethylbenzene	95-63-6	FLOOR COVERINGS			
		Carpet	Face Fiber, Polypropylene	0.079	$\mu g/m^2$-hr
		INSULATION			
		Foam-Rigid	Polystyrene	0.08	$\mu g/m^2$-hr
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	0.04	$\mu g/m^2$-hr
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	0.03	$\mu g/m^2$-hr

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
1,2,4-Trimethylbenzene	95-63-6	FLOOR COVERINGS			
		Carpet	Face Fiber, Polypropylene	0.632	$\mu g/m^2$-hr
		Carpet	Face Fiber, Nylon	NQ	
		INSULATION			
		Foam-Rigid	Polystyrene	0.31	$\mu g/m^2$-hr
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	0.08	$\mu g/m^2$-hr
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	0.03	$\mu g/m^2$-hr
		FLOOR COVERINGS			
		Resilient Floor Coverings	Other Resilient Floor Coverings	NQ	

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
n-Undecane	1120-21-4	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	42	$\mu g/m^3$ *
		Carpet	Face Fiber, Polypropylene	9.55	$\mu g/m^2$-hr
		INSULATION			
		Foam-Rigid	Polystyrene	0.19	$\mu g/m^2$-hr
		Fibrous-Mineral Fibers	Fiberglass-Batts, Blankets, Rolls	0.13	$\mu g/m^2$-hr
		WALLCOVERINGS			
		Wallpaper (glued to sheetrock)	No Product	18	$\mu g/m^2$-hr
		ADHESIVES			
		Emulsions	Natural Rubber	NQ	
		Other Natural Based Adhesives	Asphaltic	NQ	

*This value is the concentration of the compound in the air tested.

NQ - Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
Xylene*	1330-20-7	FLOOR COVERINGS			
		Carpet	Face Fiber, Unspecified	NQ	
		Carpet	Face Fiber, Unspecified	NQ	
		FLOOR COVERINGS			
		Resilient Floor Coverings	Vinyl Tile	NQ	
		ADHESIVES			
		Liquid Polymer	Epoxy Resin	NQ	
		SEALANTS/CAULKS			
		Solid Polymer/Solid Rubber	Neoprene Rubber	5.380	mg/g sealant**
		Solid Polymer/Solid Rubber	Styrene Butadiene Rubber	2.410	mg/g sealant**
		Solid Polymer/Solid Rubber	Acrylic	1.180	mg/g sealant**
		Solid Polymer/Solid Rubber	Chlorosulfonated Polyethylene	1.036	mg/g sealant**
		Liquid Polymer	Polyurethane	0.452	mg/g sealant**
		Liquid Polymer	Silicone	0.077	mg/g sealant**
		Tapes and Foams	Polyurethane Foam	NQ	

*Xylene is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

**This value is the concentration of the compound in the air tested.

NQ – Detected but not quantified.

Chemical	CAS	Chapter	Product	Average Emission Rate	Units
o-Xylene*	95-47-6	FLOOR COVERINGS			
		Carpet	Face Fiber, Polypropylene	0.6	$\mu g/m^2$-hr
		INSULATION			
		Foam-Rigid	Polystyrene	0.36	$\mu g/m^2$-hr
		WALLCOVERINGS			
		Wallpaper (glued to sheetrock)	No Product	0.4	$\mu g/m^2$-hr

*o-Xylene is a hazardous air pollutant as defined in the Clean Air Act as amended, November, 1990. A threshold limit value has been established for this chemical.

NQ – Detected but not quantified.