CHAPTER 6

ADHESIVES APPLICATIONS

6.1 BACKGROUND

1,1,1-Trichloroethane is used as an adhesive solvent because it is non-flammable, dries rapidly, does not contribute to local air pollution, and performs well in many applications, particularly foam bonding. The use of 1,1,1-trichloroethane in these applications has diminished somewhat, although some 40-50 thousand tonnes of the chemical are used annually in the U.S., Western Europe, and Japan (Chem Systems, 1989). As CFC-113 is not used in adhesives it is not discussed further in this section.

A partial list of applications where 1,1,1-trichloroethane adhesives are used includes:

- packaging;
- non-rigid bonding;
- construction;
- tapes;
- rigid bonding;
- transportation; and
- consumer adhesives.

This section provides a summary of 1,1,1-trichloroethane use in adhesives. Section 6.2 discusses the physical properties of 1,1,1-trichloroethane that make it attractive for adhesives use and gives examples of its use. Section 6.3 discusses a number of alternatives for reducing or replacing 1,1,1-trichloroethane in adhesives, and Section 6.4 compares the costs of these alternatives. Section 6.5 discusses the environmental and energy considerations of alternatives. Section 6.6 presents potential global reduction of 1,1,1-trichloroethane in the adhesives industry. Finally, Section 6.7 discusses the suitability of alternatives for developing countries and small quantity users.

6.2 1,1,1-TRICHLOROETHANE USE IN ADHESIVES APPLICATIONS

1,1,1-Trichloroethane has several physical characteristics that provide desirable performance properties for adhesive applications. It has been used for many years in contact bond adhesives because it offers similar performance characteristics to the flammable solvent-based adhesives it replaced and yet is not flammable. In particular, it has found wide use in bonding decorative laminates to substrates such as particleboard and plywood (Dawnkaski 1991). In general, 1,1,1-trichloroethane has been used when:

- a solvent-based adhesive is desired for rapid drying time and high film strength, and either flammability is a consideration or the use of volatile organic compounds (VOCs) is restricted; and
- bonding certain substrates, such as foam, plastic, or wood.

Table VI-1 presents physical properties of 1,1,1-trichloroethane and selected conventional solvents used in adhesives. Of particular note is that 1,1,1-trichloroethane (and methylene chloride) has no flash point.[1] The other conventional solvents listed in the table have low flash points, low explosion limits, and are considered to be flammable solvents.

1,1,1-Trichloroethane also displays low water affinity. Only 0.05 grams of 1,1,1-trichloroethane can be dissolved in 100 grams of water at 25°C. It is, therefore, used as a coalescent in some water-based adhesive systems. 1,1,1-Trichloroethane evaporates faster than other solvents used in adhesive formulations, which allows increased throughput in applications where drying time contributes to the overall process yield (e.g., in pressure-sensitive

---

[1] Flash point temperature is the lowest temperature at which vapours above a volatile combustible substance ignite in air when exposed to flame.

Table VI-1. PHYSICAL PROPERTIES OF COMMON ADHESIVE SOLVENTS

Solvent	Flash Point Open Cup (°C)	Flammable Limit in Air 25°C (Volume %)		Water Soluble in 100g Solvent (g)	Kg/ Liter 20°C
		Upper	Lower		
1,1,1-Trichloroethane	NF[a]	12.5	7.5	0.05	1.314
Methylene Chloride	NF	22.0	14.0	0.17	1.316
Toluene	7.22	7.0	1.3	0.05	0.870
n-Hexane	-27.8	6.9	1.25	0.01	0.678
Methyl Ethyl Ketone	-5.6	11.5	1.81	11.80	0.804
Ethyl Acetate	-2.2	11.0	2.25	3.3	0.900

[a] NF = No Flash Point.

Source: Dow 1984.

tape manufacturing). The density of chlorinated solvents, such as 1,1,1-trichloroethane, is greater than that of conventional solvents used in adhesives, and the solids/viscosity relationship of adhesives diluted with chlorinated solvents is different from those diluted with conventional solvents. When selecting solvent alternatives, these differences are taken into account with regard to application cylinders, machine speeds, and so on.

1,1,1-Trichloroethane has a mid-range solvency when compared to conventional adhesive solvents. The chemical is an active solvent for alkyl, acrylic, chlorinated rubbers and many phenolic resins and a diluent for nitrocellulose, vinyl, and epoxy resins (Dow 1984). 1,1,1-Trichloroethane can be mixed with other solvents to adapt its solubility strength to the needs of a specific resin system. This task is usually performed by the adhesive formulator who customises solvent blends to meet specific solubility needs.

In the U.S., 1,1,1-trichloroethane is exempt from volatile organic compound (VOC) regulations in most states, which provided an incentive for some adhesive manufacturers and their customers to use the solvent in place of VOC solvents (Dawnkaski 1991). As an example, 1,1,1-trichloroethane has been used as a replacement for organic solvents in the following applications (UNEP 1989):

- manufacture of styrene-butadiene latex adhesives;
- formulation of polyurethane adhesives;
- replacing extremely flammable solvents in pressure-sensitive tapes and labels, and in industrial and consumer adhesives;
- substituting flammable solvents in PVC flooring adhesives; and
- replacing ethyl acetate solvents in laminating adhesives used in packaging.

In general, 1,1,1-trichloroethane is used as active solvent in solvent-borne adhesives and as a diluent in water-borne adhesives. Solvent borne adhesives containing 1,1,1-trichloroethane are primarily contact adhesives and spray adhesives used where good "green bond," or initial bond, is desired, as in the manufacture of foam cushioned furniture or plastic laminated countertops. The primary binders in these adhesives are rubbers of various kinds, including natural rubber, neoprene, chloroprene, and styrene-butadiene rubber. Acrylic binders are also used. Adhesive grades applied by extrusion or spraying have dry solids contents of less than 15 percent, while other grades are between 15 and 30 percent. Table VI-2 shows specific binding substances (i.e., adhesive type) where 1,1,1-trichloroethane is used.

In assembling foam padded furniture, for example, a thin film of adhesive is applied to the two surfaces being joined. When the foam padding is applied to the frame, the adhesive bonds immediately. The adhesive joint must then hold without adhesive or solvent migrating into the foam material and ruining it. In other words, the tack, or "stickiness", of the adhesive must decline quickly. The time between application and the last moment for assembly (when the tack disappears) is called the "open assembly time". The solvent-based rubber adhesives have good properties in these respects, with good green bond and a short open assembly time.

Two paths are available for solvent reduction in adhesives; established technologies and emerging technologies. Established technologies include other solvent-based adhesives, water-based adhesives, hot melt systems, and solvent recovery systems in continuous operations. Emerging technologies include radiation cured adhesives, "high solids" adhesives, powders, and reactive liquids. These technologies are discussed in further detail below.

6.3 ALTERNATIVES FOR REDUCING OR REPLACING 1,1,1-TRICHLOROETHANE USE

6.3.1 Other Solvent-Based Adhesives

The rubber binders used in 1,1,1-trichloroethane adhesives are soluble in other solvents, such as acetone, ethyl acetate, heptane, and toluene. Although there has been a general trend in the U.S. and Western European adhesives industries to replace organic solvent-based adhesives with solvent-

Table VI-2. USES OF 1,1,1-TRICHLOROETHANE

Use Sector	Binding Substance
As Active Solvent in Solvent-Borne Adhesives	Styrene-Butadiene Rubber (SBR) Neoprene Natural Rubber Rubber Cement Other
As a Diluent or Coalescent in Water-Borne Adhesives[a]	

[a] No data is currently available on the specific binding systems that employ 1,1,1-trichloroethane as a diluent and or coalescent.

Source: Based on Skeist 1987.

free types, one alternative is to return to earlier solvent formulations. According to one market survey conducted in the U.S., volatile organic compound (VOC) regulations provided the initial impetus for moving away from solvent-based technologies. However, for some industry sectors, such as tapes, this shift would continue in the absence of regulations because alternative technologies are more competitive on a cost and performance basis (Ellerhorst 1982). The use of solvent-diluted (as opposed to solvent-based) adhesives has also been declining for economic reasons (Kimel 1988).

The use of solvent-based adhesives is costly because they require flame proof equipment and extraction systems (O'Driscoll 1988, Johnson 1991). The premises and apparatus must be designed fire-safe in terms of both sparking and static electricity. In many cases it is necessary to use robots in closed booths, which means large-scale use is required for cost effectiveness.

6.3.2 Water-Based Adhesives

Water-based adhesives use water, in lieu of organic solvents, as the primary solvent. A water-based adhesive can be a solution, a latex, or an emulsion. Solutions are made from materials that are soluble in neutral or alkaline water; most natural adhesives are water solutions. Latexes are stable dispersions of solid polymeric material in an essentially aqueous medium (Landrock 1985), while emulsions are stable dispersions of immiscible liquids. Emulsions usually appear milky white in the liquid state but dry to a clear film. In industry, the terms latex and emulsion are generally synonymous. Latex adhesives are more likely to replace solvent-based adhesives than solution adhesives because their synthetic binders provide more versatility and higher performance (Landrock 1985). Latexes, however, require more extensive formulation because they are produced from polymers not originally designed for use as adhesives.

The binding substances that are candidates for water-borne adhesives include: natural substances, including natural rubber; synthetic elastomers such as styrene butadiene rubber, neoprene, and isoprene; vinyl resins such as polyvinyl acetate (PVAc) and polyvinyl chloride (PVC); acrylics; and epoxies (Landrock 1985). Some of these binding substances require additional formulation and additives like emulsifiers, surfactants, or additional resins. Water-based binding substances use the traditional methods for adhesive application. These include brush, spray, roll coat, curtain, flow, and knife coat (Landrock 1985).

Recent literature on water-based adhesives suggests that there is still much debate about the overall effectiveness of water-based adhesives for many end uses. In general, water-based adhesives show good durability, water resistance, and adhesion to a wide variety of substrates, especially in the area of nonporous to porous bonding (Chao and Hernisch 1986). Problems still exist in the bonding of non-porous to non-porous substrates because water is difficult to evaporate from such substrates. In addition water-based adhesives are not suitable for non-structural bonding of rubbers and many plastics.

Water-based adhesives can bond moist surfaces better than solvent-based adhesives. One inherent advantage of water emulsions is that viscosity is independent of molecular weight of the resin (Fries 1984). The higher initial molecular weight polymer provides greater internal cohesive strength to the freshly made bond. This initial, green bond is important to avoid uneven bond stress and blisters in laminating applications (Fries 1981 and Fries 1984). Poor initial bond strength has been a criticism of low molecular weight water-borne adhesives. Unlike solvent-borne and hot melt adhesives, there are no restrictions on the initial molecular weight of the resin for water emulsions.

The direct replacement of solvents by water is not feasible in all sectors. Selecting water as the vehicle in adhesives demands totally new concepts in raw materials and formulation as discussed above. Water-based adhesives often require special handling in manufacturing, storage, and application. They must be kept from freezing during shipment and storage (Landrock 1985, Dawnkaski 1991). Problems with corrosion require that all storage and transfer pipes be corrosion-resistant. Some manufacturers, however, maintain that corrosion is not a factor if additives which prevent corrosion are included in the formulation, and one set of laboratory tests found water-borne adhesives not to be more prone to corrosion than solvent-borne adhesives (Manino 1981). The problem has not been resolved conclusively; more research and development is needed in this area (Johnson 1991). Another problem with storing water-based adhesives is that agitation is needed to maintain consistency of the dispersed materials in the adhesive solution. Yet agitation can cause foaming, and anti-foaming agents compromise adhesive bond performance.

Water-based adhesives reportedly have other performance disadvantages when compared with solvent-based adhesives. During application, water-based adhesives do not "wet" surfaces as well as their solvent-based counterparts due to water's inherent polarity and high surface tension (Dawnkaski 1991). Minor contamination of the surface (e.g., oil, mould release, fingerprints) can lead to bonding problems.[2] Water-based adhesives do not have the versatility of application provided by solvent-based adhesives (Johnson 1991). Although polar substrates, such as natural rubber, bond well with water-borne adhesives, nonpolar elastomer substrates, such as ethylene propylene

---

[2] A solvent-based primer can boost performance by ensuring a clean substrate for the water-based adhesive. A primer uses less than half as much solvent as solvent-borne adhesives. 1,1,1-Trichloroethane has been used as a primer to degrease many substrates (Landrock 1985).

copolymers, are difficult to bond (Manino 1981). Silicones and fluoroelastomers provide a greater challenge, and water-borne adhesives still cannot compete with solvent-borne systems in these areas (Manino 1981). Finally, spray application of water-based adhesives can be especially difficult due to the ease with which water- carried adhesives are atomized. Spray application results in a fine mist that can travel to all areas of a shop, coating persons and objects with a thin coating of adhesive (Dawnkaski 1991).

6.3.3 Hot Melt Adhesives

The Committee D-14 of the American Society for Testing and Materials (ASTM) defines a hot melt adhesive as one that is applied in a molten state and forms a bond upon cooling to a solid state (Fullhart and Mottershead 1980). Hot melts are primarily 100 percent solids thermoplastic bonding materials that achieve a solid state and resultant strength upon cooling. The major applications of hot melt adhesives are bookbinding, packaging, textiles, and product assembly, including construction glazing and automotive door panel and carpet installation (Fullhart and Mottershead 1980). Application methods include melt-reservoir and pressure-feed systems (Landrock 1985). The binding substances that provide the foundation for hot melt adhesives are ethylene vinyl acetate (EVAc) and other polyolefin resins; polyamide (or nylon) and polyester resins; polyester/amide resin alloys; and thermoplastic elastomers (Landrock 1985). Foamable hot melts (e.g., polyethylene) form a superior bond with metals, plastics and paper (Landrock 1985).

Although earlier hot melt pressure sensitive adhesives (PSAs) had unacceptable colour retention and UV resistance, present hot melt PSAs are clear and UV resistant (Maletsky and Villa 1984). Hot melt PSAs now compete with water-based acrylics in outdoor applications (Maletsky and Villa 1984). They have been used on paper labels for indoor applications since 1978.

Hot melts are, however, limited in several key performance characteristics. They have poor specific adhesion to a number of substrates, creep under load over time and at high temperatures, have limited strength, and limited heat resistance (Landrock 1985). A specific hot melt acrylic used for pressure-sensitive applications has poor tack for many applications (Lipiec 1982). Room temperature shear resistance and elevated temperature shear resistance are also deficient in hot melt acrylic PSAs (Lipiec 1982).

6.3.4 Radiation Cured Adhesives

Radiation curing is a production technique for drying and curing adhesives through the use of radiant energy such as ultraviolet (UV), infrared (IR) electron beam (EB), gamma, and x-rays. In essence, radiant energy becomes chemical energy in the forming of the adhesive bond. The binding agents that can be cured with radiant energy are acrylics, epoxies, urethanes, anaerobic adhesives, and polyester resins (Adhesives Age 1988). Pressure-sensitive or 100 percent non-volatile formulations of adhesives are applied by conventional techniques between one or two plastic films and then cured by exposure to radiant energy (Chemical Week 1987). Application areas include electronics, communications, consumer products, transportation, packaging, and medical and dental uses (Bluestein 1982). Radiation cured adhesives are especially well adapted for the electronics and communications industries for encapsulating applications with end use requirements of resistance to environment, electricity, and aging. Pressure-sensitive tapes are another major application of radiation cured adhesives. High growth is anticipated for UV and EB curing adhesives. It is not evident whether UV methods are particularly suited to bonding opaque substrates.

6.3.5 High Solids Adhesives

One way to lower volatile organic compound (VOC) emissions when using solvent-based adhesives is to increase the percent solids in the formulation.

In the specific example of polyester urethane laminating adhesives, high solids/low solvent adhesives are an alternative to solvent-borne adhesive systems. Using the existing technology for polyesters and polyester urethane systems, high solids have been very successful in laminating uses (Bentley 1983). One manufacturer supplies a 68.5 percent solids polyester urethane laminating adhesive which meets VOC regulations by lowering the amount of solvent used (Wood 1984). High solids adhesives have good performance characteristics, including initial bond strength, comparable to that of 30 percent solids adhesives in medium and high demand applications and can be applied using existing equipment at normal line speeds with minor modifications (Wood 1984).

In other application areas, high solids adhesives have not been as successful. For bonding rubber assemblies, high solids adhesive films are too thick, which results in limited versatility and generally poor performance (Manino 1981). In general, high solids adhesives cost more and perform worse than their solvent-borne counterparts at lower solids levels. However, this technology is still being developed; wider application may be possible in the near future.

6.3.6 <u>Powders</u>

One-part epoxies, urethanes, and natural resins are often supplied as powders that require heat to cure (Frisch and Xiao 1988). Powders are only used for non-pressure-sensitive applications. They are generally applied in three ways: by sifting the powder onto pre-heated substrates, by dipping a preheated substrate into the powder, and by melting the powder into a paste or liquid and applying it by conventional means (Landrock 1985). One advantage of the powder form is that no mixing or metering is necessary; however, to maximise shelf life, powders must be refrigerated (Landrock 1985). No data are currently available comparing performance and cost with solvent-borne adhesives.

6.3.7 Non-Volatile Solids and Liquids and Reactive Liquids

Moisture cure adhesives and reactive liquids can be applied as 100 percent non-volatile solid and liquid systems. These adhesives are composed entirely of binding substances, modifiers, and fillers (i.e., they have no carrier or solvent). Moisture cure adhesives cure upon exposure to the humidity in the ambient air; this type of adhesive might not work well in dry climates. Moisture cure adhesives are available in 100 percent non-volatile liquids and solids, hot melts, solvent-borne formulations, and other technologies (Frisch and Xiao 1988).

The 100 percent non-volatile moisture cure systems are of interest because they offer another alternative to the solvent-based systems. The two primary binding substances used in moisture cure adhesives are isocyanates and polyurethanes (D'Autilio 1983). They are available as single and multiple component adhesives. The two-part system physically separates the binding agent from the curing agent during storage. Although the adhesive requires metering and mixing to cure, the two-part system has a longer shelf life. The two-component system also achieves higher performance. A two-component solvent-free isocyanate adhesive that does not require moisture to cure nor precise metering has appeared on the market. A thin coat of one component is applied to one part and a thin coat of the other to the second part. The two are brought together and form a rapid and strong bond in a few seconds. As the bond does not require oxygen to form (i.e., is anaerobic), isocyanate adhesives are useful for joining metallic and other non-porous parts. Tests have shown, however, that the electrical properties of the adhesive exclude it from electronics applications, such as bonding surface mounted components to substrates prior to wave soldering.

Reactive liquids are two-component adhesives that contain no solvents. In use, one solution consisting of an elastomer colloidally dispersed in a monomer is cured by a second solution through a free radical chemical polymerisation, thereby creating the bond (Prane 1980). The binding substances for reactive liquid adhesive systems include epoxies, urethanes, polyesters, silicones, polysulphides, acrylics, modified phenolics, and resin compounds (Prane 1980). Reactive liquids are used for high performance structural applications. Application methods are similar to those used in contact adhesives, namely, brush, roller, or spray (Prane 1980). No information is currently available on the relative performance attributes of this emerging technology.

6.4 COSTS OF ALTERNATIVES

Substitution costs for the established alternative technologies are in most cases driven by the raw material costs and capital investments required to implement these technologies (ICF 1989). Research and development resources are also required to develop and test alternative technologies - water-based adhesives, hot melt adhesives, and solvent recovery - for specific adhesive systems. The cost of switching to an alternative solvent is highly dependent on whether or not the solvent is a VOC since VOC emission and worker safety regulations may require installing expensive ventilation and vapour recovery equipment.

Converting to water-based solvents allows adhesives users to reduce their inventory requirements. With minor modification the same equipment used with solvent-based adhesives can be used with water-based formulations, so conversion costs are small (Manino 1981). Water-based adhesives also clean easily during manufacturing and can be stored in less costly plastic or phenolic-coated containers, resulting in additional cost savings (Manino 1981).

Although hot melt adhesives are more expensive per unit of formulated weight, in many applications their use leads to reduced overall costs. The conversion to a hot melt system requires installing new, expensive equipment. The capital costs of conversions are therefore high but the automated equipment saves space and energy, lowers manufacturing costs, and increases productivity (Lipiec 1982). Hot melts can be applied faster and more efficiently than water-borne adhesives because there is no delay for evaporation (Kimel 1988). Since hot melt formulations contain 100 percent solids, the storing and shipping costs attributed to the solvent portion of solvent or water based adhesives are also eliminated (Lipiec 1982).

Prior to curing, radiation cured adhesives have a longer shelf life than most adhesives (Bluestein 1982). Their use leads to production of a more reliable product, lower rejection rates and labour costs, and reduced cleanup and inspection times (Moreau 1988). Radiation cured adhesives are an option for new production facilities due to the simpler, space-saving equipment (Bluestein 1982). Among the radiation curable technologies, UV and EB curing have separate applications. UV curing is more cost effective for smaller applications, whereas EB curing is better adapted for large scale operations.

Radiation cured adhesives have some disadvantages. Existing equipment cannot be used for this type of adhesive without the addition of a cure unit (Bluestein 1982). In addition, the applications are limited for radiation cured adhesives.

As mentioned above, high solids adhesives typically cost more and perform worse than their solvent-borne counterparts at lower solids levels. This technology is being developed; wider application may be possible in the near future. Uncured powdered adhesives must be refrigerated to obtain maximum shelf life, which adds slightly to their cost (Landrock 1985). No data are currently available comparing their performance and cost with those of solvent-borne adhesives.

6.5 ENVIRONMENTAL AND ENERGY CONSIDERATIONS

There are a number of environmental and energy implications to replacing 1,1,1-trichloroethane-based adhesives with alternatives. Returning to the use of other solvent-based adhesives may affect local air pollution and worker safety unless precautions are taken. VOC solvents contribute to the formation of tropospheric ozone and their use is restricted in many localities; their flammability requires the installation of special equipment to minimize the danger from fire or explosion. These concerns were the incentive to move to the use of 1,1,1-trichloroethane initially.

Water-based adhesives have a number of characteristics that make them attractive substitutes. As they contain no volatile organic solvents, water-based adhesives do not contribute to local smog problems and are non-toxic and nonflammable. They can, however, emit small quantities of hydrocarbons, ammonia, and emulsion-stabilising substances. These pollutants can be removed to some extent using, for example, wet scrubbers.

From the energy perspective, drying ovens used for solvent-based systems generally are adequate to handle water-based adhesives. The argument that more energy is needed to dry water, which has a slower evaporation rate than most solvents, has not been established.

Hot melt adhesives also have several environmental and energy advantages. As no solvents are used in hot melts, they do not contribute to smog formation. In part because no drying oven is needed, hot melt pressure sensitive adhesives require far less energy to process than any other adhesive types (Maletsky and Villa 1981). The percent solids in the formulation directly influences the amount of energy saved; this percentage varies depending on the application. One drawback of hot melts is that the presence of hot equipment may be a danger to workers (Fullhart and Mottershead 1980).

The advantages of radiation cured adhesives are low energy costs and reduced emission of waste effluents and polluting gases and liquids.

Both moisture cure adhesives and reactive liquids achieve compliance with VOC regulations because they contain no solvents. Moisture cure systems also need no driers, and thus save energy (D'Autilio 1983). The application equipment is more compact than that of solvent-based systems, but moisture cure adhesives cannot use existing solvent application equipment (Morphy et al. 1987). There is some concern that the catalysts used with reactive liquid systems are, in some cases, hazardous or toxic substances (Dawnkaski 1991).

6.6 POTENTIAL GLOBAL REDUCTION OF 1,1,1-TRICHLOROETHANE USE IN THE ADHESIVES INDUSTRY

There is limited data on the worldwide market for adhesives; however, information is available on the U.S., European, and Japanese markets. The 1983 adhesive demand in the U.S. and Europe was 4,900 million dry formulated pounds and it grew at an annual rate of 3.9 percent to approximately 5,900 million pounds in 1988 (Broxterman 1988). The U.S. portion of this demand is significantly larger than the European portion, representing about 4,600 million pounds, or 75 to 80 percent of the estimated demand in 1988. The Japanese market is considered roughly equivalent to the European market, together consuming 1,300 million dry pounds of adhesives in 1987 (O'Driscoll 1988). Approximately 40-50 thousand tonnes of 1,1,1-trichloroethane was used in adhesives in these countries in 1985 (ICF 1989). Table VI-3 shows the U.S. and European adhesive demand by segment.

Table VI-3. ESTIMATED U.S. AND EUROPEAN ADHESIVE DEMAND BY SEGMENTS -- 1988

Market Segment	Estimated 1988 Demand U.S. and Western Europe	
	Millions of Dry Formulated Pounds	Percent
Packaging	2,500	42.4%
Non-Rigid Bonding	1,100	18,6
Construction	1,000	16.9
Tapes	500	8.5
Rigid Bonding	400	6.8
Transportation	300	5.1
Consumer	100	1.7
TOTAL	5,900	100.0

Source: Based on Broxterman 1985.

As mentioned above, there has been a worldwide trend away from the use of solvent-based adhesives. The cost savings associated with water-borne and hot melt systems are such that this trend would continue even in the absence of the Montreal Protocol's provisions.

6.7 SUITABILITY OF ALTERNATIVES FOR DEVELOPING COUNTRIES AND SMALL QUANTITY USERS

Most established alternatives to 1,1,1-trichloroethane solvent adhesives can be used in developing countries and by small quantity users. Some systems, hot melts for example, require a larger capital investment for equipment, although the cost per application compares favourably. The cost of converting to an alternative adhesive system may be a hurdle in some situations. It is felt that small users may be a casualty of technological change because they may not be able to safely use alternative technologies.