A Design Guide for Information and Technology Equipment

Prepared by:
Innovative Environmental Solutions
Leah Burnett Jung, Principal

For:
American Plastics Council
Information Technology Industry Subcommittee

The American Plastics Council (APC) is a joint initiative with The Society of the Plastics Industry, Inc. The APC is working with industry to facilitate the recovery and reuse of plastics from durable goods and packaging materials. The mission of APC's Information Technology Industry Subcommittee (formerly the Computer and Business Equipment Group) is to address life cycle issues related to the use of plastics in information technology equipment and to develop programs for the environmentally sound management of these post-consumer plastics. The APC is currently funding an experimental electronic equipment recycling facility as well as research on plastics identification and materials separation.

Table of Contents

Figures and Tables

Executive Summary

Computer and business equipment designs are now being modified to more fully incorporate environmental considerations. Past designs focused primarily on traditional design parameters, with environmental criteria considered later. Now, however, environmental stewardship concerns are pushing environmental considerations to the forefront of design.

Environmental design criteria can embody numerous Design for the Environment (DFE) principles. Some of the more pertinent standards minimize material use and waste, facilitate material identification and separation, enhance product recycling, promote efficiency, and balance economics. Environmental design criteria, like traditional design parameters, can involve complex tradeoffs. For example, a fastener which facilitates product disassembly and recycling may require more labor to install. Environmentally preferable design criteria have been and are continuing to be identified, but tradeoffs between these goals must be evaluated by individual product manufacturers.

In many cases, DFE principles can be integrated with other design goals. The use of fewer materials, optimized design, and appropriate fasteners meet DFE as well as traditional design criteria. Encouraging plastic processors to utilize the most efficient and effective processing methods not only benefits the environment but provides financial advantages as well. As plastic recycling technology evolves, additional DFE design criteria will be identified, reducing total product costs. Incorporation of environmental designs during the early stages of product development is becoming critical for reducing long-term product management costs. Cost efficiency, long-term liability, consumer desires, and worldwide environmental initiatives necessitate immediate integration of DFE principles into product designs.

1.0

Introduction

This guide contains a synopsis of basic environmental design considerations applicable to computer, business, and other information technology equipment. This covers a variety of products including data processing equipment such as computers, calculators and computer-aided design (CAD) systems, and communication equipment such as telephones, fax machines, and pagers. The guide is structured for use by mechanical designers but also provides insight on designing for environmental management to employees whose activities affect design. Because the concept of design for the environment (DFE) is still new and no universal formula exists for its implementation, integration of DFE criteria into particular designs will be product and company specific.

Design engineers are typically faced with complex product design decisions that require tradeoffs between competing design goals. Designing environmental features into a product may sometimes seem to be at odds with certain traditional design criteria, but in many cases DFE criteria can be integrated with other design goals. For example, design for maintenance and servicing, design for assembly, and design for disassembly are often compatible with DFE since one of the primary DFE focuses is designing a product to be recycled at the end of its life. Cost effective recycling usually requires efficient dismantling of the product for separation of dissimilar materials.

The goal of reducing costs in product design—design for profitability—is also often compatible with DFE, particularly when DFE criteria are included early in the design process. DFE designs generally call for simplicity and reduced material variability and material use. These factors typically translate into cost savings. DFE principles typically follow preferred environmental management strategies by reducing material requirements, material variability and part counts, reusing products and parts whenever feasible, and recycling materials at the end of their life.

It is advantageous to include DFE criteria in current product design if products are to be managed efficiently in the future. Products designed and sold in today’s market will potentially need to meet end-of-life product management standards applicable many years in the future. A listing of current international environmental standards related to information technology equipment is contained in Appendix C. Environmental initiatives affecting product design are shown in Appendix D. Appendix E provides a list of references (e.g., organizations and publications) where additional information may be obtained.

Design Guidelines

2.1 Use of the Design Guidelines

The American Plastics Council (APC) recognizes that designing environmentally conscious information technology equipment requires blending environmental considerations with traditional design criteria while minimizing costs. The design information that follows provides generic recommendations from plastic resin manufacturer and original equipment manufacturer (OEM) representatives serving on APC's Information Technology Industry Subcommittee.

This document is intended primarily as an aid for mechanical designers of information technology equipment. The design guidelines contain some processing and manufacturing principles that may be outside the domain of design engineers, but provide useful information to those who have input into design-related processing and manufacturing decisions. The guidelines are general in nature and are intended as supplemental information for use in conjunction with standard design practices. OEM design engineers may wish to tailor these principles to actual information technology equipment designs and to the end-of-life disposition methods utilized by their companies.

Design, disassembly and recycling technologies are constantly evolving; this guide addresses design and processing methods as they exist today. Design engineers are encouraged to keep abreast of developments in environmentally conscious materials, environmental standards, and environmental design and processing methods. Design criteria should then be modified accordingly.

The design principles in this document apply specifically to information technology equipment and do not directly apply to packaging. However, product designers should, wherever feasible, use environmentally responsible packaging for transporting products and product parts internally as well as externally.

2.2 Recycling Information Technology Equipment

Summary: Discarded information technology equipment contains valuable materials worth recovering. Automated recovery technology is available but it requires identification and separation of differing materials. Certain product designs can facilitate material recovery and recycling.

2.2.1 General

Information technology equipment is currently being recycled to recover parts, integrated circuits, copper and precious metals. Because of product and material variability, manual disassembly processes are typically used to recover these components. Disassembly generates plastic housings and parts that contain a variety of materials which include labels, metal fasteners, foam and mixed plastics. These items must be separated from the plastic to render the plastic recyclable. Separation can be done manually with tools such as scrapers, screwdrivers, pliers, saws and hammers, but the labor is often too costly to justify.

2.2.2 Automated Separation

Mechanized separation processes have been developed to make post-consumer plastic recycling more economically viable. A process developed with funding from the American Plastics Council is shown in Figure 1. After identifying and batching plastic parts by type, this process relies on breaking plastic parts into similar size pieces (“size reduction”). Metal contaminants are removed magnetically while light materials such as paper labels and foam are separated from the plastic with air (“air classification”). Remaining materials (e.g., different recyclable plastics) are separated by their differing specific gravities. Traditional hydroseparation techniques are most commonly applied.

2.2.3 Current Challenges

Issues that have not yet been fully addressed by current equipment recycling technology include:

- complete plastic identification, particularly for darkly pigmented plastics;
- ways to remove paints, metallic coatings, well-adhered labels or foam insulation from recyclable plastic;

- separation of rubber and other elastomers from plastics with similar densities;
- separation of metal foils from recyclable plastic (foils do not separate out relative to their density); and
- identification and removal of potentially hazardous materials (e.g., small batteries, mercury relays, beryllium copper or lead-based solder).

2.2.4 Implications for Design

When using multiple materials in a product design, designers should try to ensure that all materials can be easily liberated from the primary plastic. It is preferable for product materials to have densities that differ by at least 0.05 specific gravity units per material. To facilitate recycling, plastic resins should be clearly identified without the use of dissimilar material labels. Paints, metallic coatings, dark pigments and elastomers may complicate recycling of plastic parts, and the design process should address ways to minimize such complications.

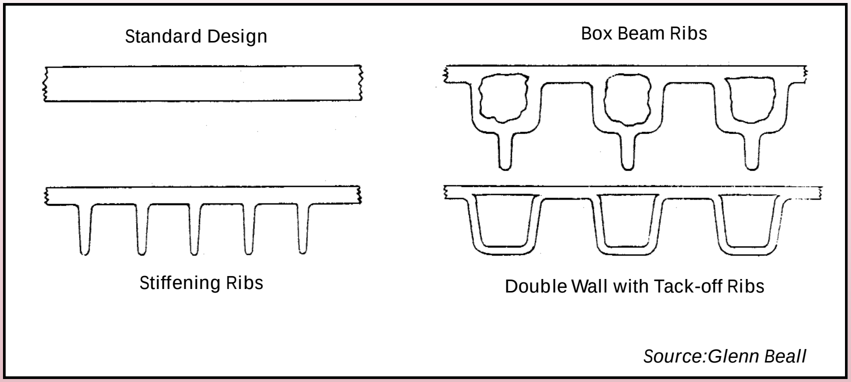
Figure 1: Automated Material Separation (APC Project M-133)

Source: Mike Biddle and Associates

2.3 Material Selection

Summary: Careful selection of product materials helps facilitate part separation and sorting at the end of the product's life, increasing the feasibility of product recycling. The type of resin selected can also enhance recyclability.

Figure 2: Designs Requiring Less Material



2.3.1 Less is Better

Using fewer materials to make new products reduces both the use of natural resources and the amount of material that needs to be recycled or disposed of at the end of the product's life. Whenever possible, only the minimum amount of material should be used. Designers can use engineering principles to utilize reduced amounts of material. For example, stiffening ribs, a double wall with tack-off ribs, or gas-assisted injection molded box beam ribs can be used to increase plastic stiffness instead of increasing the amount of plastic used (see Figure 2). Upgrading to a stronger plastic to achieve stiffness will also usually require less plastic than using a larger amount of a weaker plastic to achieve the required strength.

While meeting product requirements, the number of different plastic and non-plastic materials used in a product should be minimized. Using only one to two materials for major mechanical parts is preferable. Reduction in the variety of materials used generally facilitates efficient disassembly of the product and enhances product recyclability.

Frequent changes in materials used in a product, or in product upgrades, should be minimized unless parts are clearly and accurately marked for material identification. Multiple recyclers will likely be processing the product material and they need to be aware of material selection changes. Changing materials without accurately marking the changed parts could result in contamination of recycled resin.

2.3.2 Resin Compatibility

If more than one type of plastic is to be used within a product, recyclability will be enhanced if the plastics are compatible for recycling together. If incompatible resins are to be used, designers should ensure that the materials can be physically separated. It may also be helpful to select resins that have different specific gravities; many recyclers separate materials by differences in specific gravity.

To avoid unnecessarily using incompatible resins, material selection options should be discussed with your suppliers. Suppliers should also be consulted about recyclability when the use of composite materials is planned. Additionally, suppliers can help ensure use of materials which meet OEM and regulatory specifications.

2.3.3 Recyclable Materials

Designers can facilitate recycling by selecting materials that can be used in internal “closed loop” recycling processes. Plastic parts and enclosures should be designed to be recycled into the same part or into a different part within the same product whenever feasible. This approach helps provide an outlet for the plastic at the end of its life. Preferences can also be shown for materials that are readily recyclable externally. Because recycling markets and technology are changing rapidly, it is advisable for designers to periodically investigate recycling opportunities.

2.3.4 Contaminants

Whenever possible, designers should select resins and design techniques to avoid using materials that may become contaminants in the plastic recycling process. Such materials include: labels, adhesives, coatings, finishes and metal fasteners. Examples of preferable design strategies are contained in the sections that follow.

2.3.5 Hazardous/Toxic Additives

Engineering plastics contain vital additives such as colorants, fire retardants, stabilizers, plasticizers, reinforcement materials, and fillers. The use of additives formulated with hazardous, toxic or banned materials should be avoided in information technology equipment. Hazardous and toxic materials not only pose environmental, health and liability concerns but may also be regulated by multiple agencies. Designers should check with material suppliers for Material Safety Data Sheet (MSDS) information which will provide toxicological data and regulatory classifications for the particular material. OEM environmental, regulatory and/or purchasing departments may be additional sources of useful information.

2.3.6 Total Cost

Resins selected for information technology applications should satisfy both functional and processability requirements. Concurrently, the total manufacturing cost associated with resin use should be considered over the resin cost alone. For example, plastics may offer significant manufacturing, assembly and disassembly cost reductions over other materials because of their multi-function capability. Plastics capability for part consolidation decreases material costs and may reduce use of natural resources. Total life cycle costs also include the cost of future product disposition. Designers should consider the potential costs associated with managing their product when it is returned at some point in the future.

2.4 Use of Recycled Plastic

Summary: Using recycled material creates outlets for recycled material, providing opportunities for recycling different products and making recycling more economically feasible. The use of recycled material also may conserve the use of natural resources and extends the life of the plastic.

2.4.1 General

When selecting materials for business equipment applications, companies should consider using recycled plastic. To facilitate stable markets for recycled materials, as high a percentage of recycled resin as possible should be selected. Requirements of regulatory and certification agencies should also be considered. Companies can also "close the recycling loop" by reusing plastic recycled from their own products and by not unnecessarily restricting the use of recycled material.[1]

Recycled resins may not be considered for appearance parts because of color-matching issues. Currently, recycled resins have been found suitable for interior or non-appearance applications such as:

- new "accent" pieces on enclosures;
- partitions, card guides, frames, and bases, or EMI shielding shrouds or laminates; and
- middle layers of multi-layer parts.

2.4.2 Verification of Physical Properties

When using recycled plastic, companies should ensure that the material meets safety and performance criteria. Resin suppliers can usually provide this information, but in some cases, a material sample may need to be sent to an analytical lab for verification. Some recycled materials are available that have undergone considerable testing. Companies should ask their resin suppliers for resins that meet their needs.

2.5 Basic Part Design Concepts

Summary: Properly designed parts can not only enhance the performance of information technology equipment but also positively impact the disassembly and recycling of the finished product.

2.5.1 Optimize Design/Avoid Over Design

Rather than over-designing products and parts, designs should meet optimum needs. Simplified designs are not only less costly but also easier to disassemble and recycle. To optimize designs, finite element analysis or computer-aided mold flow and/or mold cool analysis can be used. Designers should also define realistic requirements for stiffness and strength. Designers can consult with resin suppliers, molders, mold makers and other suppliers for recommendations and input on optimizing designs.

2.5.2 Lifetime Extension

Extending the life of a product delays its replacement and conserves natural resources. To accomplish this, products and parts can be designed to last longer or to be reused after appropriate servicing. For example, business equipment housings can be designed to be cleaned and/or repaired and then reused for the next model upgrade. (See additional information under "Design for Reuse" in the Fastening and Joining section 2.6.12.) The life of plastic enclosures, particularly portable product enclosures, can be extended by selecting a plastic material that can best accommodate repetitive reprocessing..

Products, parts and components can also be designed to be upgraded as technology changes, extending the technological life of the product and preventing premature discard of the product material. To facilitate removal, upgradable parts should be designed as sub-assemblies. Additionally, the life of the plastic resin used in a part can be extended through recycling.

2.5.3 Design for Disassembly

Part designs that make disassembly of products cumbersome result in increased labor costs at the end of the product's life. Increased costs decrease the economic feasibility of recycling or reusing product material.

Designers can facilitate recycling and reuse of products and parts by choosing assembly procedures that result in efficient product disassembly and separation of differing materials. However, tradeoffs between designing for disassembly and designing for maintenance and servicing should be evaluated when applicable.

Minimizing the variability in type of fasteners used in a product (e.g., screws, clips, nuts) speeds disassembly and reduces the number of different tools required. When molded into a product, breakaway joints and panels can also speed disassembly.

The need for disassembly of a product can be reduced by lowering the number of separate parts required in a design. For example, multiple parts can be designed into one part. This will reduce the number of fasteners used and thus reduce the amount of time required for disassembly, sorting and recycling. Disassembly may even be eliminated by joining parts made of the same material through alternative joining methods that do not require the use of hinges, fasteners, inserts and other attachment devices (see the Fastening and Joining section 2.6 for more information).

2.5.4 Wall Thickness

When designing part wall thicknesses, keep in mind that thinning the walls conserves natural resources but may result in tradeoffs of strength,stiffness, toughness, warpage and ease of mold filling. Optimizing wall thicknesses according to cost/function tradeoffs is preferred over thinning walls. Additionally, design engineers should ensure that national and international safety requirements and standards are met. If a product is not designed with a uniform wall thickness, the thick sections should be cored out.

2.5.5 Stiffness (Ribs/Bosses/Gussets)

When plastic parts are designed with thin walls, part stiffness can be reinforced by using one of several environmentally preferred design features. Increasing stiffness using such features allows conservation of plastic material. Design features include:

- narrow ribs used to stiffen a flat surface area; a larger number of narrow ribs is preferable to a smaller number of large and heavy ribs;

- bosses (protruding studs or pads used to reinforce holes or for mounting an assembly); and/or
- gussets (supporting members used to provide added strength to features such as bosses or walls).

2.6 Fastening and Joining

Summary: The selection of fastening and joining methods can significantly affect the cost of recycling a product and the recyclability of product material. Careful and consistent choices can decrease the time, cost and amount of scrap associated with product disassembly. Generally, fasteners and joined parts should be accessible and easily removed and sorted.

2.6.1 General

The reuse of a resin depends primarily on the purity of the resin or resin blend in the application and on the availability of a market for the recovered material. The cost effectiveness of plastics recycling decreases when different plastics or plastic and non-plastic materials are joined together. To facilitate product recycling, designers should avoid the intimate attachment of plastic and non-plastic parts, as well as the attachment of parts made from different plastic materials.

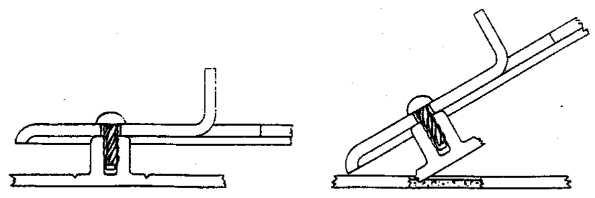
Designers should also ensure that fasteners between two different types of plastic or between a plastic and non-plastic part can be accessed for removal during product disassembly. For example, avoid using insert molding or recessed attachments (e.g., pegs, screws, etc.) in these applications. Additionally, plastic parts should be joined in a way that leaves no dissimilar material in the recyclable stream (e.g., no adhesives or metal from fasteners). One method is to use plastic fasteners made of the same type of plastic as the parts to be fastened, or which are compatible for recycling with the plastic product.

2.6.2 Metal Fasteners

Metal fasteners must usually be removed before product parts can be recycled. Any metal fasteners not removed prior to product shredding can damage equipment teeth or blades. When liberated from products and parts, ferrous fasteners can usually be magnetically separated from plastic and other product materials. However, many fasteners are not designed for easy removal, so additional effort is required to separate them from other product materials. Naturally, this increases recycling costs.

Therefore, when metal fasteners are to be used in a product, carbon or magnetic stainless steel should be preferred over non-magnetic stainless steel, aluminum or brass. When metal hinges are used in plastic products, break points can be provided on parts for easy hinge removal with limited loss of plastic material. Because of the difficulty in their removal prior to recycling, metal rivets should be avoided in product designs.

Figure 3: Break-off of Metal Inserts

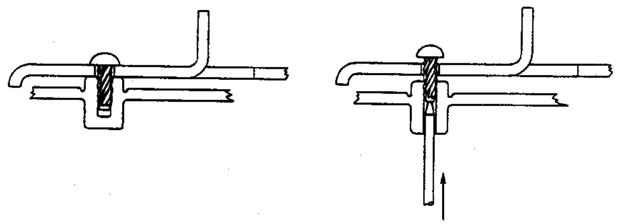


Source:Glenn Beall

2.6.3 Metal Inserts

If metal inserts are to be used in a product, thread-forming inserts are preferable over molded-in, heat or ultrasonically inserted metal fittings. Preferred alternatives to threaded metal inserts include bolts and self-tapping screws. Designers should avoid using irregularly shaped sheet metal inserts, typically used for electrical components with molded-in conductors. The use of metal inserts with concentric ring undercuts or deep locking undercuts should also be avoided. Unless installed on breakable bosses, molded-in metal inserts can be difficult to remove at the end of a product's life. If molded metal inserts are used, a weak area in the plastic should be included to facilitate break-off of the insert[2] in

Figure 4: Through Hole on Metal Drive Pin



Source:Glenn Beall

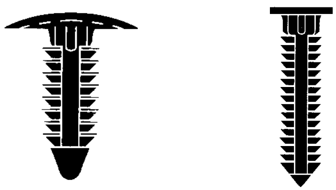
preparation for product recycling (see Figure 3). When using metal drive pins, a through hole should be provided for easy pin removal (see Figure 4).

2.6.4 Plastic Fasteners

A variety of plastic fasteners are available for use in business equipment. Because of their flexibility, plastic fasteners permit simple, efficient designs. When made of the same type of plastic as the parts they are joining, plastic fasteners may not have to be removed prior to recycling. This elimination of a processing step reduces time, cost and potential contamination of the recyclable material.

Specialized types of plastic fasteners include blind plastic rivets and ratchet fasteners. Blind plastic rivets are available in a number of types of thermoplastics. Plastic ratchet fasteners can be used to join solid or compressible components of varying thicknesses. Plastic ratchet fasteners are composed of a shaft with a smooth head and flexible annular ribs (see Figure 5). When pressed into a hole, the fastener's ribs compress and then pop out on the other side. Considering the number of plastic fasteners available, designers should consult with suppliers to determine which type of fasteners will best meet their needs.

Figure 5: Plastic Ratchet Fasteners

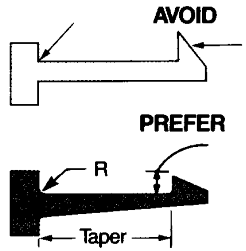


Source:TR W Fasteners

2.6.5 Snap Fits

Snap fits are useful for fastening and joining plastic parts. Snap fits are molded into parts, reducing the need for separate fasteners and the potential for contamination of recyclable materials from the use of dissimilar materials (e.g., metal inserts, adhesives and other fasteners). If designed for disassembly (e.g., with the tines easily accessible), snap fits may allow rapid and efficient separation of materials. Tapered snap fit designs are more likely to withstand repeated disassembly and assembly, facilitating product servicing (see Figure 6).

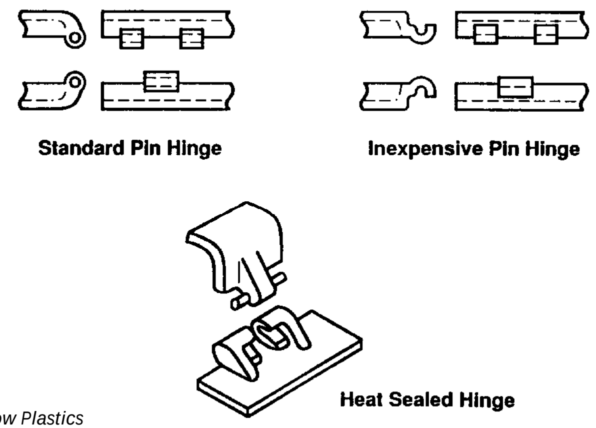
Figure 6: Snap Fits



Source:Bayer Corporation

Designers should use molded-in snap fits instead of screws or fasteners only where EMI shielding concerns are minimal (snap fits may not provide enough pressure on connected parts to ensure adequate conductive continuity in products requiring shielding). Plastic parts can be designed to allow the use of snap fits if necessary.

Figure 7: Molded-in Hinges



Source:Dow Plastics

2.6.6 Integral (Molded-in) Hinges

Several designs may be used to make integral or molded-in plastic hinges (see Figure 7). Integral strap hinges use a molded-in strip of plastic to connect plastic parts. Molded ball-and-socket or ball-grip designs are usually assembled through snap fits. Knuckle-and-pin designs may use hooks and/or eyes to form the knuckles that serve as the hinge pivot on an axial pin. Certain types of integral hinges have been shown to flex up to one million times without failure. If an integral hinge is to be attached, then bonding, ultrasonic welding or plastic rivets should be utilized. Any plastic rivets used should be of a material similar to the parent parts to facilitate recycling.

2.6.7 Adhesives

Adhesives (e.g., glues, epoxies) usually introduce a dissimilar, contaminating material to potentially recyclable parts. This may impact the quality and reusability of the recycled material for new applications unless the adhesive can be removed easily or is thermally stable and compatible with the plastic to which it adheres. Designers should either look for adhesives that do not already affect recyclability or consider alternative fastening options.

2.6.8 Welding and Bonding

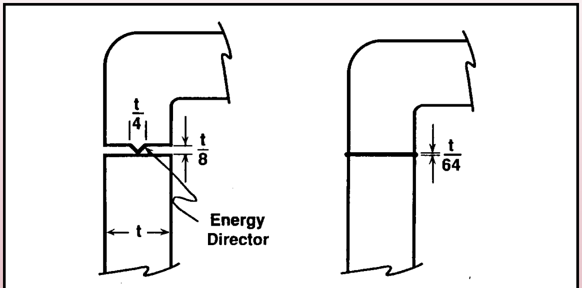
Several types of welding and bonding methods are available for joining plastic parts. Designers should consider the energy requirements associated with thermal-intensive joining methods.

When two parts to be attached are made from the same type of thermoplastic material, ultrasonic welding is an environmentally acceptable method. Ultrasonic welding melts plastics together using ultrasonic energy, forming a strong bond (see Figure 8).When one of the two parts is made from a different type of material, however, the parts will usually have to be separated before being recycled. Separation of materials bonded ultrasonically is very difficult and will most likely render part recycling infeasible.

Focused Infrared Welding creates pressure-tight welds without distorting the plastic being melted. With Focused Infrared Welding, only the mating surfaces are heated and the temperature of the two parts can be controlled, permitting attachment of thin-walled parts to thick-walled parts without plastic distortion.

Solvent bonding is a useful way to bond similar thermoplastic materials. However, the smallest amount of organic solvent needed should be used in order to reduce environmental impact.When solvent-bonded parts are molded from the same plastic material, they are treated as a single part for recycling because the solvent bond adds no contamination to the recyclable stream.

Figure 8: Ultrasonic Welding (butt joint)

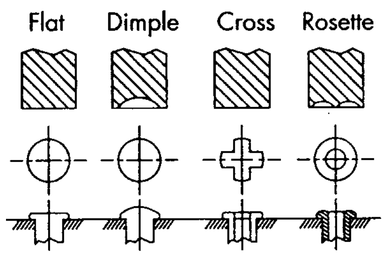


Source:TR W Fasteners

2.6.9 Swaging and Heat or Ultrasonic Staking

Swaging and staking may be good substitutes for fasteners used between plastic parts. Environmentally conscious staking involves using thermal or ultrasonic energy to join two parts made of similar thermoplastic material. The parts are joined by reforming the plastic material and forming a locking head.

Figure 9: Heat Staking Configurations



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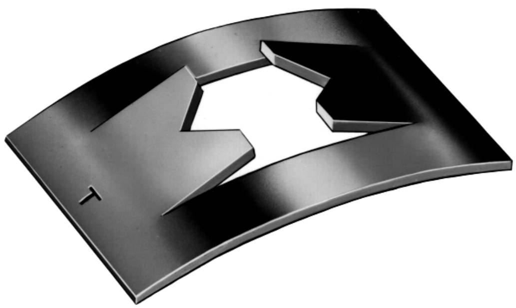
Several locking configurations are available for use (see Figure 9). Because no dissimilar materials are introduced to the plastic parts during joining, the plastic is a good candidate for recycling into new applications.

2.6.10 Spring (Speed) Clips

Spring or speed clips provide a rapid and inexpensive method of fastening parts as long as they are easily accessible. Spring clips are usually snapped over a boss, stud or wall section in the plastic part and can be removed by breaking off the boss or stud or by prying with a special tool. To facilitate recycling of parts fastened with spring clips, the clips should be removed and also recycled when feasible. Figure 10 shows a common spring clip design.

Figure 10: Spring Clip



Source:Eaton Corporation,Engineered Fasteners Division

2.6.11 Metal Nuts, Bolts, Washers and Screws

Metal nuts, bolts, washers and screws, like other metal fasteners, must usually be removed from products prior to recycling. Rapid and efficient removal of these fasteners reduces recycling costs. To reduce separation efforts, integrated washers are recommended. Also, good designs should provide adequate, visible head accessibility and clearance to allow for a removal tool's range of motion.

2.6.12 Design for Reuse

Fasteners must be designed to be removed and replaced on products and parts that are likely to be reused or serviced. Fasteners and joints should also be designed so that they will not be damaged during disassembly and re-assembly. For example, consider designing snap fits so they can be easily disengaged without breaking.

Because of the possibility of breakage, designers may wish to provide redundant features for fasteners and attachments on products designed to be reused or serviced. Specific fastening designs and methods may also protect against breakage. Examples include:

- internal hinges that are integral to the plastic part;
- use of the same type and size of screw heads within a product and product lines; and
- use of metal boss caps instead of threaded metal inserts (the press-on metal caps fit over plastic bosses and are easy to remove for recycling, plus they provide a guide for starting screw threads back into the hollow boss after product servicing and will withstand repetitive screw assembly and removal without stripping)[3].

2.7 Coatings and Finishes

Summary: Unless removed prior to recycling, coatings and finishes can affect the performance of recycled material. The presence of coatings can also affect the appearance and physical properties of products made from recycled material.

2.7.1 Thermal Compatibility

When recycled plastic is remolded, small amounts of paint remaining in the plastic can affect the mechanical performance of the recycled material. When plastic resin is recovered from either decorative or conductive coated parts, the resin may require performance re-evaluation before use in information technology applications.

2.7.2 Decorative

Integral (molded-in) finishes are preferred for decorative appearances because they eliminate the need for paint or coatings. Integral finishes are generally cost-effective in addition to being environmentally sound. Paint and coatings are not only difficult and often costly to remove, but may contribute to the generation of chemical emissions and waste. Residual paint particles can also act as stress concentrators in molded recycled parts, potentially reducing impact, fatigue and toughness characteristics. Integral colorants are thus preferred over exterior coatings whenever feasible. Pre-colored plastics or natural-plus-concentrate are good choices. If decorative coatings are to be applied, water-based coatings are preferred over solvent-based coatings.

Certain types of decorative finishes are easier to maintain and refurbish on serviceable equipment. For example, low-gloss and textured surfaces hide blemishes and may help eliminate the need for painting. If painting is considered as a refurbishing option,parts should be designed so that the painting will require little or no masking. Masking requires OEMs to use additional resources and often adds additional costs when the parts are refurbished.

2.7.3 Functional

Metallic conductive coatings, including EMI and RFI shielding, can be difficult to remove from plastic parts. Such coatings may also contribute to chemical waste and air and water emissions, both during use and during the recycling process. If metallic particles are carried over into the recycled plastic, the plastic's physical properties may be affected, reducing its feasibility for use.

Since vacuum deposition introduces only a small amount of metallic material onto a part, it is preferred over metallic coatings such as copper and nickel-based paint or plating. However, the use of metallic coatings and vacuum deposition should be minimized whenever feasible. Mechanically attached metal shrouds or metallic foil/plastic (flexible) laminates are preferable over other EMI/FRI shielding methods because they are easier to remove. However, the total cost associated with shielding (including the labor costs for attachment and removal) should be considered in determining shielding requirements.

2.8 Material Identification and Marking

Summary: Once molded, engineering plastics become very difficult to identify. Testing the material is time-consuming and not always conclusive. Marking can provide critical information to recycling facilities, identifying not only plastic resins but also additives that may necessitate changes in the recycling process.

2.8.1 Marking for Plastic Identification

At a minimum, plastic enclosures and significant sized parts[4] should be marked according to ISO (the International Organization for Standardization) Standard No. 11469. This marking may be enhanced with the addition of another line that indicates the commercial resin name (followed by the word "resin") or the OEM material code name (see marking examples in Table 1, below). Designers may also wish to mark products with additional information that may facilitate product reuse and recycling. Knowing the grade of a plastic material at a part's end of life can facilitate its reuse in business equipment and its resale to a recycling vendor. Products and parts should be marked for identification with the realization that the OEM may be responsible for managing the materials at the end of the product's life.

Table 1: Recommended Marking Examples

Part Consists of:	*Marking:*
PVC	>PVC< commercial grade name "resin" or OEM material code name
ABS-PC alloy or blend	>ABS+PC< commercial grade name "resin" or OEM material code name
Polyethylene Terephthalate (PET)-Polyphenylene Sulfone (PPSU) blend, 20% glass filled	>(PET+PPSU)-GF20< commercial grade name "resin" or OEM material code name

2.8.2 Methods

A number of methods exist for marking information on plastic parts. Generally, marking through tooling is preferable to marking by labels, pad printing, bar coding or laser inscribing. For information on labels, see the section below. Molded-in markings are one of the most environmentally conscious marking methods available since they require no use of other materials or chemicals, thus reducing the likelihood of contaminating the recyclable material.

2.8.3 Labels

Unless labels and their adhesives are completely removed before a product is recycled, they may introduce dissimilar, contaminating materials into the recycling stream. To reduce contamination from surface labels and adhesives, use molded-in labels or print labels on the same type of plastic as the part to be labeled and attach them through methods that leave no contamination[5] (e.g., ultrasonic welding or solvent bonding; see the Fastening and Joining section for more information). When labels are placed on separate molded parts, they can also be snap fitted onto enclosures, allowing easy removal.

2.9 Plastic Processing

Summary: Encourage plastic processors to select processing methods that: are the most efficient; minimize material use and resin scrap; facilitate recycling of the end product; have the least effect on resin performance; and provide the best balance of economics.

2.9.1 General

Some molders show more environmental initiative in managing plastic materials than others. OEMs can encourage molders to use processing methods that produce less plastic scrap and decrease impacts on the plastic's recyclability. For example, OEMs can ask molders to integrate environmental quality controls with other quality criteria to avoid contamination of recyclable plastic. In the interest of expanding applications for recycled material, OEMs should encourage molders to increase the usage of regrind back into a product where feasible.

2.9.2 Implications for Part Recycling

Certain molding processes facilitate and others may inhibit the recycling of plastic material. Coatings provide finishes to molded plastics but these finishes can become contaminants during the recycling process. Alternative processing methods which may decrease the need for coatings and associated pigments include:

- high-pressure thermoforming and counter-pressure structural foam molding, both of which can produce parts with acceptable as-molded surfaces, potentially eliminating the need for coatings; and
- in-mold coating processes that limit pigments to the surface layer of a plastic part.[6]

Unless made of materials compatible with the plastic to be joined, glues and adhesives typically introduce dissimilar, contaminating materials to a potentially recyclable material. An alternative to gluing two similar materials together is to use a two-shot injection molding process, particularly when a specific look and "feel" is desired for the product.

Manufacturers of information technology equipment should also require that molders use only the type of plastic specified. Changes in material selection can cause significant identification difficulties during product recycling.

2.9.3 Heat History/Thermal Degradation

When plastics are recycled into new products, the new round of processing adds to the heat history and potential thermal degradation of the plastic material. The following processing recommendations should reduce the heat history and thermal degradation of plastics, facilitating multiple recycling of plastic material:

- use a properly sized molding machine;
- ensure that plastic is not processed above recommended melt temperatures;
- reduce plastic's exposure to long heating cycles; and
- have molders consider the use of tooling which minimizes regrind. For example, use heated runner systems instead of cold runner molds.

Notes

1. At the time of this publication, Underwriters Laboratories allows the use of 25 percent recycled preconsumer material in business equipment. Preconsumer material, also called "regrind," is material generated from manufacturing operations; it is not material recovered from consumer product use.
2. Break-off of molded metal inserts can be accomplished by embedding the metal insert into a pillar or boss that is molded into the interior of an enclosure part (normally the base).
3. In addition to being easy to disassemble, boss caps also protect the inside diameter and reinforce the open end of the hollow boss. This allows use of a thinner boss wall, which reduces the amount of plastic used and the molding cycle time.
4. In Europe, parts exceeding 25 grams by weight are recommended for marking.
5. For example, labels can be printed on plastic sheets with water-based silk screening, then attached to plastic parts through ultrasonic welding. The use of the same type of plastic for the label and the product allows recycling of the product without label removal. The ink may still be a contaminant but its volume is usually very small.
6. Some injection molding, in-mold coating systems are being developed to produce fully colored parts using a powdered form of the same material as the substrate. Molded parts produced by this technique are reported to be capable of being recycled into high value products.

4.0 Appendices

Appendix A:
American Plastics Council Members

Amoco Corporation
ARCO Chemical Company
BASF Corporation
Bayer Corporation
Chevron Chemical Company
The Dow Chemical Company
DuPont
Eastman Chemical Company
Exxon Chemical Company
FINA, Inc.
GE Plastics
Hoechst Celanese Corporation
Huntsman Chemical Corporation
ICI Americas Inc.
Lyondell Petrochemical Company
Mobil Chemical Company
Monsanto Company
Montell North America, Inc.
NOVA Corporation
Occidental Chemical Corporation
Quantum Chemical Company
Shell Chemical Company
Solvay America, Inc.
Union Carbide Corporation

Appendix B:

Information Technology Industry Subcommittee Members and Information Contributors

Aclo Compounders
Advanstar Communications
Amesbury Group
Apple Computer Co.
ARCO Chemical Co.
Association of Plastics Manufacturers in Europe (Belgium)
AST Research
AT&T
AT&T Bell Laboratories
BASF (UK)
Battenfeld of America, Inc.
Bayer Corp.
Bayer (UK)
Bay Resins
Boothroyd and Dewhurst
Branson Ultrasonics
Cashiers Plastic
Compaq Computer Corp.
Cut Craft
Degussa
Diametric (UK)
Digital Equipment Corp.
Dow Chemical Co.
Dow Plastics
Eastman Chemical Co.
Eastman Kodak Co.
Eaton Corporation, Engineered Fasteners Div.
Eberhard Jaeger GmbH (Germany)
Enthone-OMI
European Centre for Plastics in the Environment (Belgium)
Evode Group (UK)
EWvK (Germany)
GE Plastics - Americas
General Electric Plastics (UK)
General Motors
Georgia Gulf Corp.
GEON
GFO (Germany)
Goodrich, B.F. (UK)
Hewlett-Packard Co.
Hoechst (UK)
Ideal-Jacobs Printing and Engraving Co.
IBM Corp.
Invo Vacuum Coatings (UK)
International Journal of Environmentally Conscious Manufacturing
Kerr-McGee
Leabank Coatings (UK)
Lexmark International
Licefa (Germany)
Michael Biddle & Associates
Micro Plastics
Mobil Chemical Co.
Monsanto Chemical Co.
Motorola
NCR
Northern Telecom
Novatec Plastics

Obex
OKW (Germany)
Palnut Co.
Panasonic
Penn Engineering
Phoenix Fiberglass
Pitney Bowes
Premix Inc.
Rochester Institute of Technology
Rostone Corporation
Rover Group (UK)
Schaeffer (Germany)
Shell Chemical Company
Siemens-Nixdorf (Germany)
Sun Microsystems
Trend Plastics
TRW Fasteners
Underwriters Laboratories, Inc.
Unisys Corp.
University of Rhode Island
Utz (Germany)
Wez (Germany)
Xerox Corp.
Zenith Data Systems
Zehrco Plastics

Appendix C:Environmental Standards

INDUSTRY STANDARDS:

Country	*Standard*	*Topic*
Germany	VDI[1] 2243	Design for Recycling™
International	ISO[2] 14,000 Series	Environmental Management Standards (in preparation)
International	ISO[2] 1043^	Plastic acronyms and abbreviations
International	ISO[2] 11469	Marking
United States	UL[3] 746D	Polymeric Materials — Fabricated Parts

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[1] Association of German Engineers
[2] International Organization for Standardization
[3] Underwriters Laboratories, Inc.
^ ISO 1043 is referenced in ISO 11469

ENVIRONMENTAL CERTIFICATION PROGRAMS (released or proposed):

Country	**Program**	**Type**
Canada	Environmental Choice	Gov't
European Community	Ecolabel	Gov't
France	NT-Environment	Gov't
Germany	Blue Angel	Gov't
India	EcoMark	Gov't
International	Flipper Seal of Approval	Private
Japan	EcoMark	Gov't
Korea	EcoMark	Gov't
Nordic Council	White Swan	Gov't
Singapore	Green Label	Gov't
United States	Green Cross	Private
United States	Green Seal	Private

Appendix D:Environmental Initiatives Affecting Product Design

Terminology	Definition	Driver(s)
Design for the Environment (DFE)	incorporate environmental considerations into product design to minimize impacts on the environment	environmental stewardship
Environmentally Conscious Manufacturing (ECM)or Green Manufacturing	incorporating pollution prevention and toxics use reduction into product manufacturing	environmental stewardship
Extended Product or Producer Responsibility (Manufacturer's Responsibility or Responsible entity)	product manufacturers are responsible for taking back their products at the products' end of life and managing them according to defined environmental criteria	a desire to shift product disposal costs from government to industry
Life Cycle Assessment (LCA)	quantified assessment of the environmental impacts associated with all phases of a product's life, often from extraction of base minerals through the product's end of life	reduce pollution and associated environmental management costs
Pollution Prevention	prevent pollution by reducing pollution sources (e.g., through design),as opposed to addressing pollution after it is generated	reduce pollution and associated environmental management costs
Product Life Cycle Management (PLCM)	managing the environmental impacts associated with all phases of a product's life, from inception to disposal	environmental stewardship
Product Takeback	the collection of products by manufacturers at the product's end of life; see "Extended Product or Producer Responsibility," above	a desire to shift product disposal costs from government to industry
Toxics Use Reduction	reduce the amount, toxicity and number of toxic chemicals used in manufacturing	reduce toxic emissions

Appendix E: Resources
Organizations

American Electronics Association
1225 I Street NW, Suite 950
Washington, DC 20005
Tel: (202) 682-4451

American Plastics Council
1275 K Street NW, Suite 400
Washington, DC 20005
Contact: Dr. Michael Fisher
Tel: (202) 371-5319
Fax: (202) 371-5679

American Plastics Council
4101-A Pioneer Drive
Walled Lake, MI 48390
Contact:Al Maten
Tel: (810) 360-8106
Fax: (810) 360-2759

American Society of Mechanical Engineers
1828 L. Street NW, Suite 906
Washington, DC 20036
Tel: (202) 785-3756

Association of Plastics Manufacturers in Europe
Avenue E. van Nieuwenhuyse 4
B-1160 Brussels
Belgium
Tel: (32) 2-6753297
Fax: (32) 2-6753935

Blue Angel
c/o RAL Deutsches Institut fur
Gutesicherung und Kennzeichnung
Bornheimer Strasse
D-5300 Bonn 1
Germany
Tel: (49) 228 726 140

Commission of the European Communities
DG XI
200 Rue de la Loi
B-1049 Brussels
Belgium
Tel: (32) 2-2357180
Fax: (32) 2-2351745

Duales System Deutschland (DSD)
Rochusstrasse 2-6
5300 Bonn 1
Germany
Tel: (49) 228 97 92 0
Fax: (49) 228 97 92 190

Electronic Industries Association
2500 Wilson Boulevard
Arlington, VA 22201-3834
Tel: (703) 907-7581
Fax: (703) 907-7501

Entwicklungsgesellschaft fur die Wiederverwertung von Kunststoffen mbH (EWvK)
Rheingausse 190
65203 Wiesbaden
Germany
Contact: Mr. Michael Rohr
Tel: (49) 611 962 7305
Fax: (49) 611 962 7308

Environment Canada
Solid Waste Management Division
Office of Waste Management
Ottawa, Ontario K1A OH3
Canada
Tel: (819) 953-1100
Fax: (819) 997-3068

Industry Council for Electronic Equipment Recycling (ICER)
6 Bath Place
Rivington Street
London EC2A 3JE
Tel: (44) 71-729 4766
Fax: (44) 71-457 5045

Institute of Electrical & Electronic Engineers
445 Hoes Lane
Piscataway, NJ 08855
Tel: (800) 678-IEEE
Tel: (908) 981-0060
World Wide Web Home Page:
HTTP://www.ieee.org/

Institute of Scrap Recycling Industries, Inc.
1325 G Street NW, Suite 1000
Washington, DC 20005-3104
Tel: (202) 466-4050

International Organization for Standardization
1 Rue De Varembe
Case Postale 56
Ch-1211 Geneva 20 Switzerland
Tel: 22 7490111

Environmental Industries Association
4301 Connecticut Avenue
Suite 300
Washington, DC 20008
Tel: (202) 244-4700

Society of Plastics Engineers
14 Fairfield Drive
Brookfield, CT 06804-0403
Tel: (203) 775-0471

Underwriters Laboratories, Inc.
12 Laboratory Drive
P.O. Box 13995
Research Triangle Park, NC
27709-3995
Tel: (919) 549-1505

The Society of the Plastics Industry, Inc.
1275 K Street NW, Suite 400
Washington, DC 20005
Tel: (202) 371-5200

U.S. Environmental Protection Agency (EPA)
401 M Street SW (OS-301)
Washington, DC 20460
Tel: (202) 260-4489

The Vinyl Environmental Resource Center
One Cascade Plaza, 19th Floor
Akron, OH 44308
Tel: (216) 376-6500
Fax: (216) 376-9379

Publications / Other Information Resources

"Completing the Cycle: Product Design for Recycling"
Environmental Product Design
17 Gateland Lane
Shadwell, Leeds LS17 8HR
England
Tel: (44) 532 737309
Fax: (44) 532 370117

"Design for Recycling"
GE Plastics
General Electric Company
One Plastics Avenue
Pittsfield, MA 01201
Tel: (413) 448-7110

"Designing Business Machines for Disassembly and Recycling"
J.R. Kirby and I.L. Wadehra
Proceedings of the 1993 IEEE International Symposium on Electronics and the Environment
May 1993, p. 32-36
Institute of Electrical & Electronic Engineers
(800) 678-IEEE

"Designing Green:A Guide"
Dow Plastics
Dow Chemical Company
2040 Dow Center
Midland, MI 48674
Tel: (800) 441-4369

"EMI/RFI Shielding Guide"
GE Plastics
General Electric Company
One Plastics Avenue
Pittsfield, MA 01201
Tel: (413) 448-7110

"Environmental Consciousness: A Strategic Competitiveness Issue for the Electronic and Computer Industry"
Microelectronics and Computer Technology Corporation
P.O. Box 200195
Austin,TX 78720-0195
Tel: (512) 331-6200

"Environmental Considerations in Product Design and Processing"
GE Plastics
General Electric Company
One Plastics Avenue
Pittsfield, MA 01201
Tel: (413) 448-7110
Fax: (413) 448-7493

"European Environmental Bulletin"
(Published quarterly by Hunton & Williams)
American Electronics Association
1225 I. Street, NW, Suite 950
Washington, DC 20005
Tel: (202) 682-9110

"Green Products by Design"
OTA-E-541
Office of Technology Assessment
Washington, DC
Contact: U.S. Government Printing Office
Tel: (202) 512-1800

International Environmental Network
Latham and Watkins
1001 Pennsylvania Avenue, NW
Suite 1300
Washington, DC 20004
Contact: Judith King Boyle
Tel: (202) 637-2200

International Journal of Environmentally Conscious Manufacturing
ECM Press
P. O. Box 20959
Albuquerque, NM 87154-0959
Contact: Dr. Mo Jamshidi
Tel: (505) 277-5538
ISO 14,000 Standards (Environmental Management Standards)
Contact: Ms. Rose Tomasello
American Society of Testing and Materials
Tel: (215) 299-5487

"Konstruieren recyclinggrechter technischer Produkte"
VDI 2243, 1993
(in German)

"Life-Cycle Assessment: Inventory Guidelines and Principles"
EPA/600/R-92/245
U.S. EPA
Washington, DC 20460
Contact: U.S. Government Printing Office
Tel: (202) 512-1800

"Life Cycle Design Guidance Manual"
EPA/600/R-92/226
Risk Reduction Laboratory
U.S. EPA
Cincinnati, OH 45268
Contact: U.S. Government Printing Office
Tel: (202) 512-1800

Plastics Design Forum
Advanstar Communications, Inc.
7500 Old Oak Boulevard.
Cleveland, Ohio 44130
Tel: (216) 243-8100

"Plastic Snap-fit Joints"
Miles, Inc.
Mobay Road
Pittsburgh, PA 15205-9741
Tel: (412) 777-2000

Proceedings of the 1994 IEEE International Symposium on Electronics and the Environment
Order # CB-33860
Institute of Electrical and Electronics Engineers
445 Hoes Lane
Piscataway, NJ 08855
Tel: 800-678-IEEE

Proceedings of the 1993 IEEE International Symposium on Electronics and the Environment
Order # CH-32094
Institute of Electrical and Electronics Engineers
445 Hoes Lane
Piscataway, NJ 08855
Tel: 800-678-IEEE

Proceedings of the 22nd Annual Structural Plastics Conference (1994)
Order # BB119
The Society of the Plastics Industry, Inc.
1275 K Street, NW, Suite 400
Washington, DC 20005
Tel: (202) 371-5200

Proceedings of the 21st Annual Structural Plastics Conference (1993)
Order # BB118
The Society of the Plastics Industry, Inc.
1275 K Street, NW, Suite 400
Washington, DC 20005
Tel: (202) 371-5200

"Recyclability of Metallized Plastics for Business Machine Applications"
S. Ching, J.R. Kirby, D. Pitts and I. Wadehra
Engineering Center for Environmentally Conscious Products, IBM
Research Triangle Park, NC
(919) 543-4937

"Recycled Plastic Product Source Book"
American Plastics Council
1275 K Street, Suite 400
Washington, DC 20005
Tel: (202) 371-5319

"Recycled Products Guide"
Recycline
Box 577
Ogdensburg, NY 13699
Tel: (800) 267-0707

"A Technical Framework for Life-Cycle Assessment"
Society of Environmental Toxicology and Chemistry (SETAC)
1010 North 12th Avenue
Pensacola, FL 32501
Tel: (904) 469-1500

World Wide Web:
GE Plastics' Home Page:
WWW.GE.COM
Tel: (800) 845-0600 or
Contact: Joyce Ruppert, GE,
Tel: (413) 448-4961

Acknowledgments

Much of the information in this document was provided by representatives from member companies in the American Plastics Council's Information Technology Industry Subcommittee. Some data was extracted from an APC research study conducted by Dr. Peter Mooney and Glenn Beall. Numerous companies and individuals provided additional information.

It is not feasible to individually acknowledge all the people and institutions who assisted in the development of this publication, but gratitude is extended to all who provided input. Special thanks go to members of the Design Guide team who helped put this guide together:

Sam Bonino	Xerox Corporation
Anne Brinkley	IBM
Patricia Calkins	Xerox Corporation
Dolores Cenci	Unisys Corporation
John Cocup	Dow Plastics
Dr. Werner Glantschnig	AT&T Bell Laboratories
Richard Klein	Eastman Kodak Company
David Lear	Compaq Computer Corporation
John Popek	Unisys Corporation
Phil Richards	GE Plastics
Dr. Inder Wadehra	IBM

Al Maten and Helen Garrett of the American Plastics Council also deserve special recognition for their guidance and support.

Companies and organizations that supplied information for this report are listed in Appendix B. Member companies in the American Plastics Council are listed in Appendix A, and the Information Technology Industry Subcommittee members are listed in Appendix B. Listing does not imply that the company or organization endorses this report.

Leah Burnett Jung, editor

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