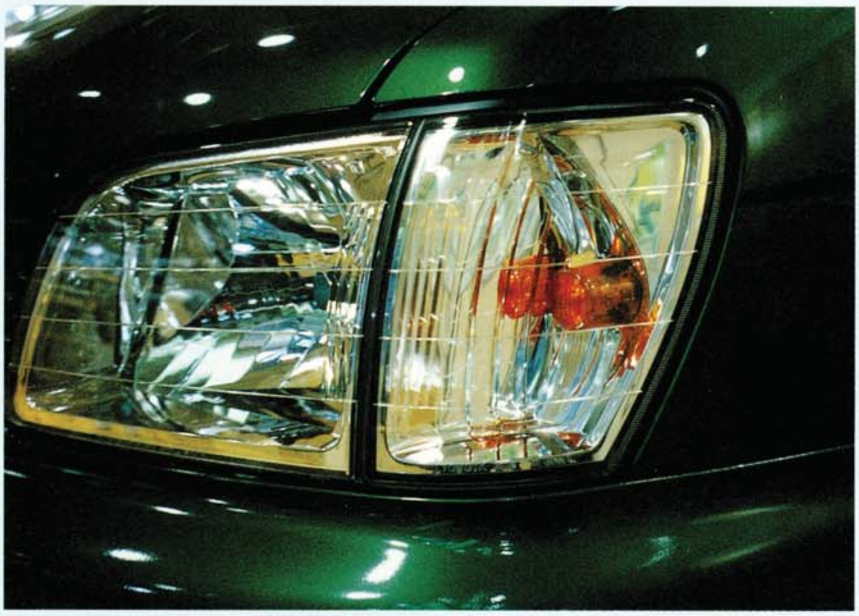
A Booklet on Engineering Plastics

(1999 Edition)

JEPTEC

Japan Engineering Plastics Technical Committee

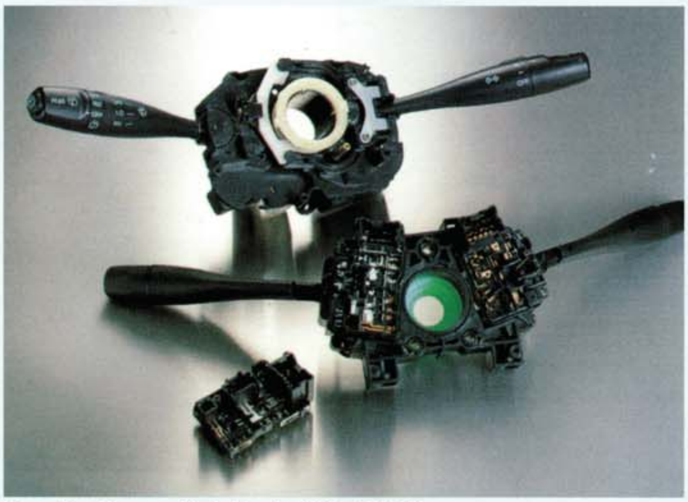


Amber cap of turn signal lamp (PAR)

Alternator brush holder (GF-PPS)

Pedal module (GF-PA6, GF-PA66)

Bumper facia (PPE/PA alloy)



Combination switch body (MD-PA66)

Air intake manifold (GF-PA6)

HOUSEHOLD APPLIANCES, INFORMATION APPLIANCES

Microwave oven: Door cover (PET)

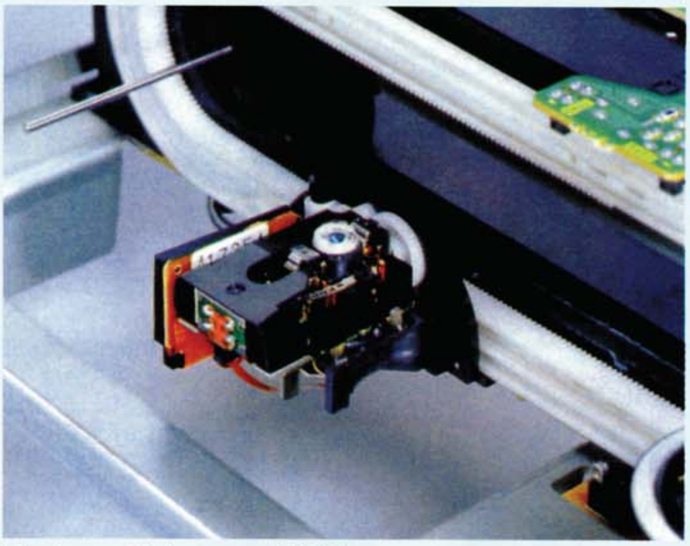
TV set: Polarization yoke (Modified-PPE)

Portable socket outlet:
Body and around the contacts (PBT)

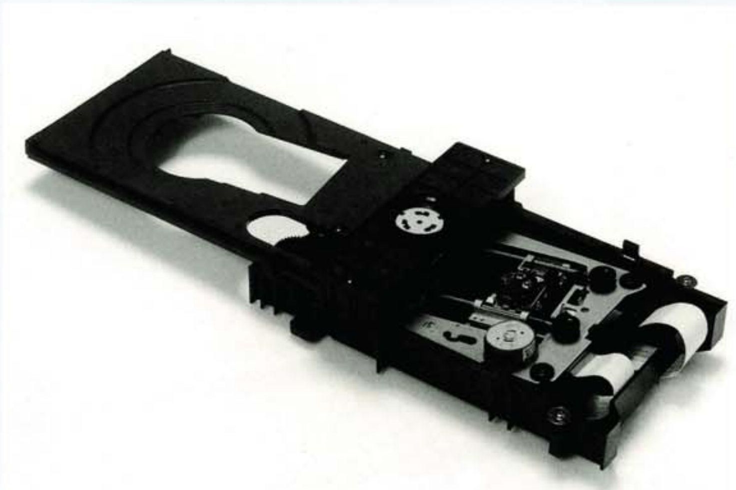
Mobile-phone housing (PC)

Portable CD-player housing (PC)

CD player: Gear (POM)



LD player: Pickup gear (POM)

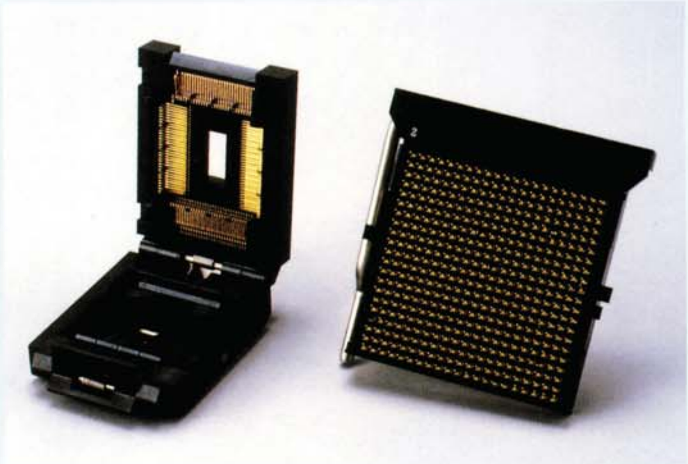


DVD-player chassis (Modified-PPE)

Connectors (PBT)

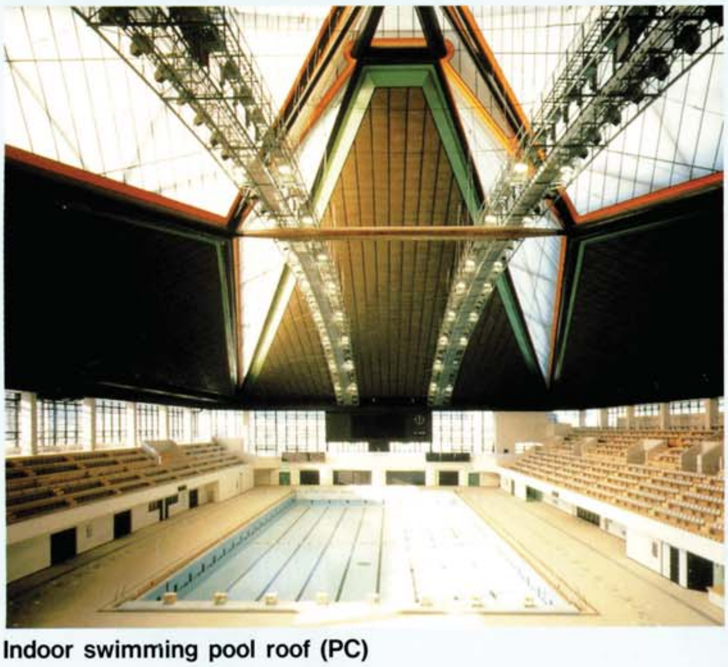
ELECTRONIC EQUIPMENT AND PARTS


IC-wafer carrier (PEEK)


Socket for testing IC (PES)

Connector on a PC-card (LCP)

OTHER APPLICATIONS


Indoor swimming pool roof (PC)


Traverse of chair (GF reinforced PBT)


Dialyzer housing (PC)

A Booklet on Engineering Plastics

(1999 Edition)

JEPTEC

—編集・執事—

古田　淳一郎

横内　満

山口　泰彦

渡辺　哲二

御旅屋　瑛一

木庭　道夫

Preface

This booklet is based on the third edition of ENPURA NO HON, the Japanese-language version, which the members of Japan Engineering Plastics Technical Committee (formerly, Japan Engineering Plastics Association) compiled and issued in 1998. This booklet is aimed for presenting the fundamental ideas of the types, properties, selection and designing, and the general view of the markets of Engineering Plastics. It is thereby intended to give information to potential customers, salespersons, newcomers, and other people who have interest in the Engineering Plastics but usually would not dare to read the Japanese version. The English-version editors attempted to update, modify, expand or abridge the texts in the original Japanese version so that non-Japanese readers may remain interested in what are addressed in this booklet.

In the era of ever-progressing technologies and developing industries, readers are cautioned to note that so many changes in materials and products occurring every moment could affect the credibility of the information given in this booklet.

The technical data reported in this booklet are representative values obtained under suitable test conditions and do not necessarily apply under different conditions. These data do not imply the minimum criteria for the materials' specifications.

Editorial staff

CONTENTS

1 INTRODUCTION

1.1 Classification

Table1-1 shows a systematic arrangement of plastic materials. The plastics consist of two major categories: THERMOPLASTICS and THERMOSETS. When heated, the thermoplastics melt and flow, therefore become moldable; the thermosets cross-link and solidify, therefore must be shaped as desired prior to heating.

The thermoplastics comprise two groups: GENERAL-PURPOSE(or COMMODITY) PLASTICS and ENGINEERING PLASTICS. The engineering plastics are distinguishable from the general-purpose plastics in respect that the engineering plastics have the continuous-use-temperature ratings (cf. UL746B in Chapter10) at 100℃ or above, the tensile strength at 49.0MPa(500kgf/cm^2) or higher, and the flexural strength at 2.4GPa(24,000kgf/cm^2) or greater.

There are two classes in the engineering plastics: GENERAL-PURPOSE ENGINEERING PLASTICS and SPECIALTY(or SUPER) ENGINEERING PLASTICS. The specialty engineering plastics have the distinctive continuous-use-temperature ratings at as high as 150℃ or above.

In terms of morphology, some engineering plastics are semi-crystalline and others are amorphous; see Chapter 2.

Some heat-resistant thermosets call themselves engineering plastics in a broader sense; actually, some specialty engineering plastics are cross-linkable.

This booklet for the most part deals with the thermoplastic engineering plastics.

1.2 Definition

The term ENGINEERING PLASTICS, as used in this booklet, means the high-performance plastics that are suitable for making structural components or machine parts, and for use mainly in industrial applications; and that have the continuous-use-temperature ratings at 100℃ or above.

1.3 Brief history

The term "engineering plastics" first came out in 1960 when DuPont in the U.S.A. released a polyacetal homopolymer(POM) with the appeal that the material would be usable as a substitute for some metals.

Around that time, polyamide(PA), which was mainly for use in fibers, began to have its share of use in the engineering-plastics-type applications.

Since then, many engineering plastics came on the market: polyacetal copolymer, polycarbonate(PC), modified polyphenylene ether(Modified-PPE), and, in 1970, polybutylene terephthalate(PBT).

1.4 General-purpose engineering plastics

Polyamide(PA)

The term "Polyamide" includes several variants with different chemical structures. The following are only general comments on what is called "Polyamide".

Polyamide is a semi-crystalline plastic that has a high melting point and excellent mechanical properties, particularly a high impact strength. Also superb in friction/wear properties, chemical resistance (except to strong acids and phenol), oil/grease resistance, and gas-barrier characteristic.

Polyamide absorbs moisture leading to loss of dimensional stability and mechanical strength, and to gain of flexibility and impact strength. Take into account the effect of water absorption when designing and molding polyamide articles.

Major applications are in injection molded articles for use in such areas as automotive/vehicle components, electric/electronic appliances, and machine parts. Polyamide is also useful as extruded products such as films and monofilaments.

- THERMOPLASTICS
  - GENERAL-PURPOSE PLASTICS
    - PE, PVC, PP, PS, ABS, AS
    - PMMA, PVA, PVDC, PBD, PET, etc.
  - **ENGINEERING PLASTICS**
    - **GENERAL-PURPOSE ENGINEERING PLASTICS**
      - Polyamide(PA) s
      - Polyacetal(POM) s
      - Polycarbonate(PC) a
      - Modified polyphenylene ether(Modified-PPE) a
      - Polybutylene terephthalate(PBT) s
      - Glassfiber-reinforced polyethylene terephthalate(GF-PET) s
      - Ultra-high molecular weight polyethylene(UHPE) s
    - **SPECIALTY ENGINEERING PLASTICS**
      - Polysulfone(PSU) a
      - Polyethersulfone(PES) a
      - Polyphenylene sulfide(PPS) s,c
      - Polyarylate(PAR) a
      - Polyamideimide(PAI) a
      - Polyetherimide(PEI) a
      - Polyetheretherketone(PEEK) s
      - Polyimide(PI) a,c
      - Liquid-crystal polymer(LCP) s
      - Fluoroplastics(FR) s
- THERMOSETS
  - Phenol, Urea, Melamine
  - Alkyd, Unsaturated polyester
  - Epoxide, Diallylphthalate
  - Polyurethane, Silicone, etc.

s: Semi-crystalline plastic a: Amorphous plastic c: Cross-linkable plastic

Table1-1 Classification of Plastic Materials

Polyacetal(POM)

A semi-crystalline plastic with a good combination of mechanical properties. Particularly excellent in fatigue endurance. Outstanding in friction/wear properties, chemical resistance, creep resistance, and dimensional stability. Exhibits a low absorption of water.

POM neat resin is a difficult material to be formulated for a hard-burning characteristic since it has a significant number of oxygen atoms in the molecule. But, POM has a successful formulation for an improved weatherability.

Major uses are in electric/electronic industries and automotive manufacture. Those are very active industrial sectors in Japan. Particularly, the demand for engineering plastics in the electric/electronic industries is expanding to keep pace with the increasing output of consumer-electronics such as VTR, and office equipment such as copying machines.

Polycarbonate(PC)

An amorphous plastic; the only transparent material among the general-purpose engineering plastics. PC exhibits a small mold-shrinkage and a good dimensional precision on molded articles, as well as a good dimensional stability due to its small absorption of water. Possesses a high mechanical strength, a distinctively high impact strength, a low creep, and very good electrical properties. Somewhat vulnerable to chemicals and susceptible to stress cracking.

PC contains ester bonds in the molecule, accordingly degrades through hydrolysis when heated in the presence of more than a critical amount of water. Therefore, drying of the material is necessary to remove moisture before molding or other processing.

Electric/electronic applications provide the largest demand for PC, followed by machine/apparatus parts such as for cameras. The market for discs(CD/MD) is growing where PC makes the most of its optical properties. The consumption in automotive/vehicle components is on the rise. In addition, a considerable portion of PC consumption is for use in extruded sheets.

Modified polyphenylene ether(Modified-PPE)

An amorphous plastic generally used in the form of PPE-plus-styrenic polymer alloy. Retains physical properties (stiffness, impact strength, and fatigue endurance) over a wide range of temperature. The distinctive properties are the lowest specific gravity and the smallest water absorption of all general-purpose engineering plastics. Good in electrical properties. Resistant to hot water. The small mold-shrinkage of this material results in a good dimensional stability and precision of the molded articles. A number of heat resistant variants are available on the market. Modified-PPE is almost immune to acids or alkalis, but vulnerable to aromatic or halogenated hydrocarbons.

The electric/electronic and OA(Office Automation) applications are the largest uses, with the automotive components in second position. A new large-volume demand for Modified-PPE has emerged from OA equipment housings: the housings of copying machines, word processors, facsimiles, and personal computers.

Polybutylene terephthalate(PBT)

PBT is the newest entrant to general-purpose engineering plastics. A strong, stiff, heat resistant semi-crystalline plastic that holds its physical properties in an aging atmosphere at a high temperature. Also retains its electrical properties over a broad range of temperature. Exhibits a small absorption of water. Has weatherability and chemical resistance. All considered, well balanced in properties.

PBT carries ester bonds in the molecule, therefore needs to be dried before processing to prevent hydrolysis.

This material can be formulated easily for a hard-burning characteristic, therefore suitable for electronic applications.

Electric/electronic sectors account for the majority of PBT consumption; automotive applications come in second. Those two markets add up to over 80 percent of total PBT consumption.

Glassfiber-reinforced polyethylene terephthalate(GF-PET)

New markets for PET are emerging in addition to the conventional markets in fiber and film applications. One of the new markets is in biaxially oriented blow bottles, and the other is in the injection-molded articles for engineering applications.

Until the recent past, the poor moldability of GF-PET had long kept this material from a sizable demand in spite of its attractive properties. But the recently developed quick-crystallizing PET has presented GF-PET an immensely improved moldability, which generated the new market opportunities. Today, GF-PET applications are rapidly broadening to take advantage of the electrical properties, heat resistance, chemical resistance, and weatherability of the material.

The PET-based material should be dried before processing to prevent hydrolysis from arising at the ester bonds in the molecule.

Main uses are in electric/electronic parts and automotive/vehicle applications.

1.5 Specialty engineering plastics

Specialty engineering plastics take only a limited share of the plastics market because of their relatively high costs. However, the prominent properties of the material are valuable in the area where applications call for the very high heat resistance or other high-performance properties that are unobtainable with general-purpose engineering plastics.

Polyphenylene sulfide(PPS)

A semi-crystalline plastic with an outstanding heat resistance: the continuous-use-temperature rating at around 240℃. Has a very high mechanical strength. Other highlight properties include stiffness, flame retardancy, chemical resistance, electrical properties, and dimensional stability.

The markets for PPS are surging so high today that this plastic is paving the way for the position of a large-consumption engineering plastic, like a general-purpose engineering plastic, of the next generation.

Major outlets are the parts for electric/electronic equipment, household appliances, automobiles, and machines such as chemical pumps.

Polyarylate(PAR)

An amorphous and transparent plastic featuring a high resistance to heat (Tg at 195℃), resistance and barrier to UV-light (passes the tests on SAE standards), and impact strength. Excellent in creep recovery after an applied pressure.

Rather than a PAR single material, the alloys or composites are more useful and widely employed as materials of the parts in automotive-lamp (heat resistant high-flow grades), precision-machine (precision-moldable filled grades), electronic equipment (chemically resistant alloys with amides), and other uses.

Fluoroplastics(FR)

FR is a general name given to a family of more than ten different plastics, viz. PTFE, PFA, PFEP, ETFE, PVDF and other variants, each containing fluorine atoms and possessing distinctive characteristics. FR as a whole is a material of versatility and high performance: high/low-temperature endurance, chemical resistance, weatherability, non-sticking surface, a low coefficient of friction, and electrical performance under a high frequency. Generally, the higher the fluorine content, the higher is the functional performance.

Current main outlets are the applications that exploit the property advantages of FR such as electric/electronic properties, chemical resistance, non-sticking surface, and friction/wear properties. The FR use-fields are expanding the horizons.

Polysulfone(PSU)

An amorphous, amber-color transparent plastic with a high heat resistance: the continuous-use-temperature rating at around 160℃. Resists hydrolysis; stable to hot water, acids, and alkalis at a high temperature. Good in creep resistance, low-temperature endurance, and electrical properties.

Mainly for use in electric/electronic appliances, medical equipment, precision machines, food-processing devices, and automotive components.

Polyethersulfone(PES)

An amorphous, amber-color transparent plastic with a high heat resistance: the continuous-use-temperature rating at around 180℃. Exhibits the highest creep resistance of all thermoplastics up to 180℃. Resistant to hydrolysis and chemicals; the resistance to stress cracking is the highest of all amorphous plastics. Flame retardant. Dimensionally stable.

Major applications are in electric/electronic appliances, hot-water-handling devices, medical equipment, and automotive components.

Polyetheretherketone(PEEK)

A semi-crystalline plastic having unprecedented property features. Especially, has the highest-level heat resistance among the competing thermoplastics: continuous-use-temperature rating at around 240℃, and DTUL(Deflection Temperature Under Load) at 300℃ on a 30%-glass-filled grade. Highly flame retardant; if burnt, barely generates smoke or corrosive gasses. Stable in exposure to hot water (continuously usable in 200℃ steam), chemicals, and radioactive rays.

PEEK is useful mainly for electric wire covering and injection molding.

Liquid-crystal polymer(LCP)

In a molten state, LCP exhibits liquid-crystallinity. In a solid state, it exhibits a high stiffness and a high strength, as well as dimensional precision and dimensional stability on molded articles.

LCPs are divided into the types I, II, and III, corresponding to different levels of heat resistance. In terms of molecular structure, LCPs are either wholly-aromatic polymers or partially-aromatic polymers. The wholly-aromatic polymers feature a high strength; the partially-aromatic polymers boast a thin-wall flowability in molding.

Mainly used as materials to make electric/electronic components and friction/wear parts.

Polyetherimide(PEI)

An amorphous, amber-color transparent plastic which has in its molecules both ether bonds and imide bonds; the former provides processability, the latter imparts heat resistance and mechanical strength. Features a good heat resistance with the continuous-use-temperature rating at 170℃, as well as mechanical properties, hard-burning characteristic, electrical properties, and a low emission of smoke if burnt.

Major applications are the parts in machinery, electric/electronic appliances, automobiles and aircraft.

Polyamideimide(PAI)

An amorphous plastic having in its molecules both amide bonds and imide bonds; the former offers processability and toughness, the latter imparts heat resistance and mechanical strength. Highlight properties are heat resistance, fatigue endurance, hard-burning characteristic, friction/wear properties, electrical properties, chemical resistance, and resistance to stress cracking.

Mainly for use in the parts in electric/electronic appliances, automotive components, industrial machines, and office automation equipment.

Polyimide(PI)

A thermosetting plastic with the highest heat resistance of all organic polymers on the market. Has an exceptionally high heat resistance with the continuous-use-temperature rating at 250℃ or above, as well as mechanical strength, hard-burning characteristic, and dimensional stability.

Many manufacturers have developed a variety of polyimides with different chemical structures.

Mainly used for making the parts of machines, electric/electronic appliances, automotive components, and other equipment.

1.6 Development of new materials

The following are some topics on the recent developments of new engineering plastics. The new materials are to meet the diverse needs and the demanding requirements in the markets.

1 New Plastics

The plastics industry has recently developed such new engineering plastics as PCT, PEN, PBN, thermoplastic PI and new LCPs, which are aimed for performing higher functions. More new plastics will emerge in the future.

2 Alloys

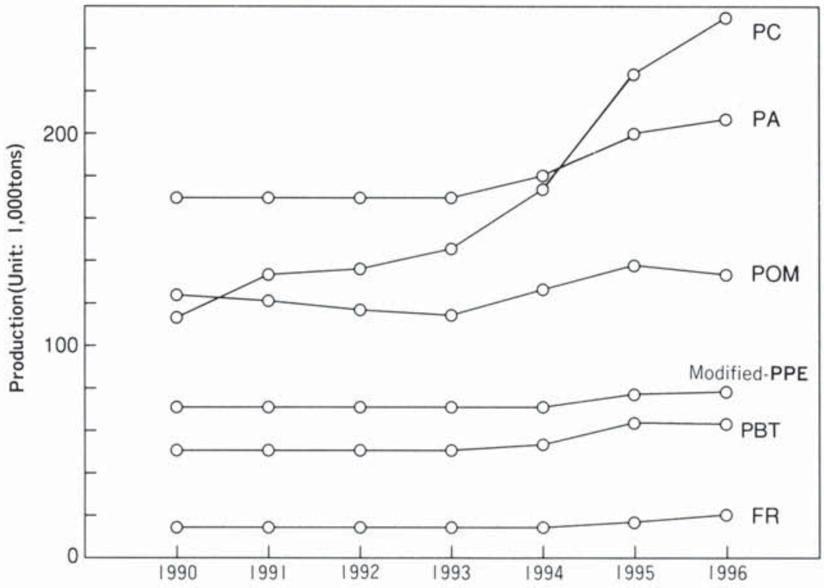
Many of the plastic applications in recent years demand the difficult combinations of properties that are unobtainable with a single polymer: for example, a heat-resistance to go with moldability, and an impact-strength while maintaining stiffness. Alloying of conventional polymers is a practical technique to develop the new plastic material that has a specific combination of properties to live up to a particular quality requirement. Table1-2 shows some of the major alloys.

Table1-2 Major Alloys

Combination of polymers	Featured properties	Main uses
PA/modified-polyolefins	Improved low-temperature impact strength of PA	Automotive components, sports goods
PPE/PA	Stiffness, Heat resistance, Chemical resistance	Automotive exterior components
PC/Polyesters (PBT,PET)	Impact strength, Chemical resistance	Automotive exterior components
POM/ Polyurethane	Friction/wear properties, Impact strength, Low mechanical noise	Gears, Hinges
PBT/PPE	Stiffness, Heat resistance, Dimensional precision/ stability	Automotive outer panel
PPS/ Elastomers	Chemical resistance, Heat resistance, Resilience	Electronic parts
Engineering-plastics/PTFE	Friction/wear properties	Bearings, Friction/wear parts

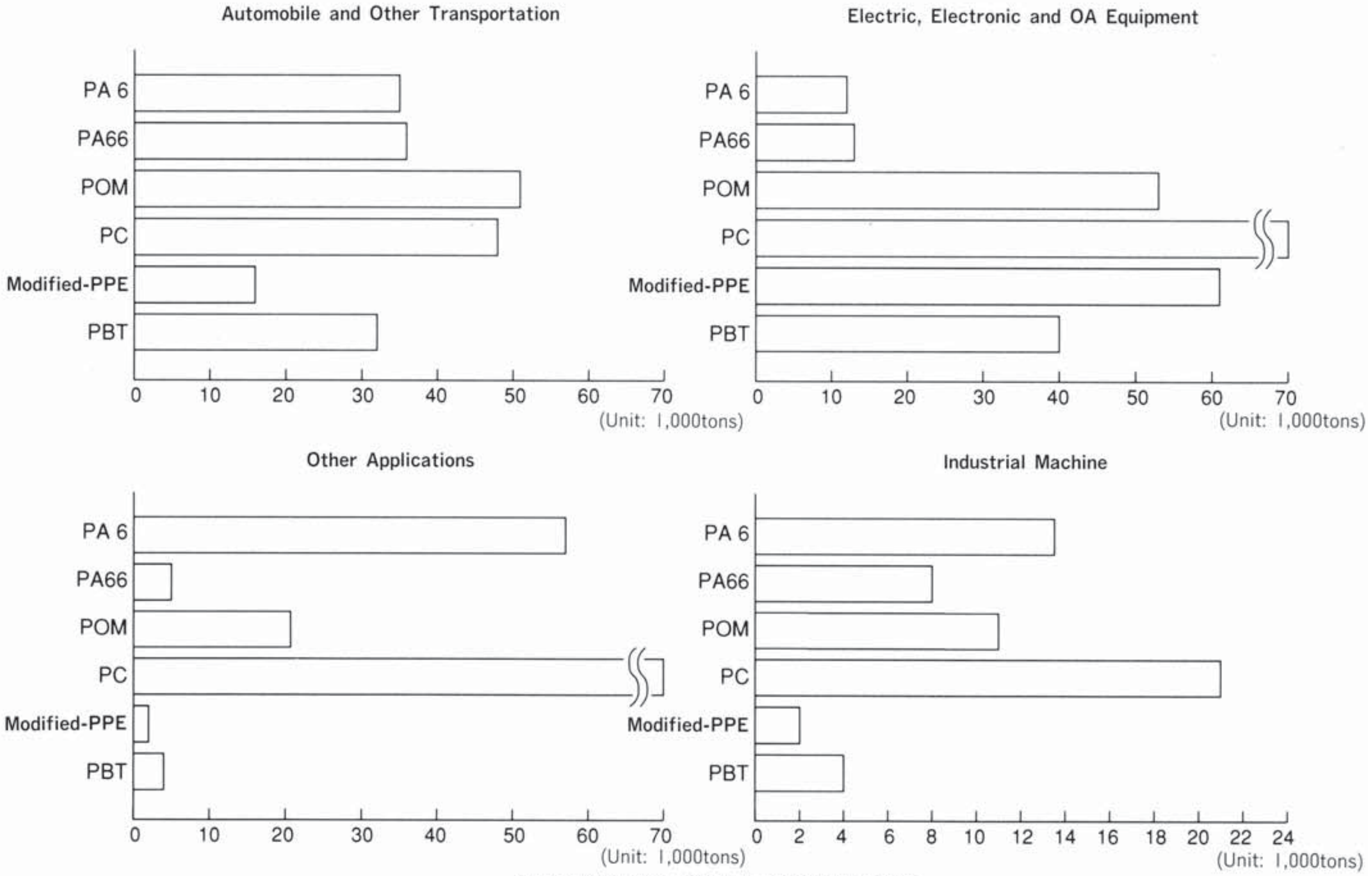
1.7 Market demand in Japan

Some excerpts are cited below from published statistical data.



Source: Research and Statistics Department, MITI

Figure1-1 Production of Engineering Plastics



Source: Chemical Economy Research Institute

Figure1-2 Demand for Engineering Plastics by Use (1996)

2 AMORPHOUS PLASTICS AND SEMI-CRYSTALLINE PLASTICS

Figure2-1 illustrates the molecular structures of different types of plastics. Plastics are the collections of long chain-like polymers, which are in either random or ordered arrangement. The random arrangement forms an AMORPHOUS domain; the ordered arrangement forms a CRYSTALLINE domain. AMORPHOUS PLASTICS include only the amorphous domains; SEMI-CRYSTALLINE PLASTICS include both the crystalline and the amorphous domains. Note that the crystalline domains are present only in segments in the semi-crystalline plastics. CRYSTALLINITY is the ratio of the crystalline domains to the total domains in a semi-crystalline plastic.

Some substance exhibits anisotropic properties in a liquid state over a certain range of temperature. Such a substance comprises oriented molecules in the liquid, and is referred to as LIQUID CRYSTAL. A polymeric liquid-crystal substance is called LIQUID-CRYSTAL POLYMER.

2.1 Influence of temperature on movement of molecules

The above-explained arrangements of polymers, crystalline or amorphous, are susceptible to the change in temperature. Figure2-2 shows a modulus-vs.-temperature relationship to explain how plastics respond to varied temperatures.

The modulus of either the semi-crystalline or the amorphous plastic decreases as the temperature rises past Tg, which is called the GLASS TRANSITION POINT (or the GLASS TRANSITION TEMPERATURE) of the plastic. In the range of temperature above Tg, the molecules in the amorphous domains move vigorously. Accordingly, the modulus of the amorphous plastic decreases sharply. The modulus of the semi-crystalline plastic declines to a less extent due to the restricted movement of molecules in the crystalline domains. In the range of temperature exceeding Tm, the crystalline domains disappear and the plastics melt and flow.

When a semi-crystalline plastic is once heated to melt and then cooled, the plastic crystallizes in the manner that depends on the rate of cooling. In case that the resulting crystal is what is called a spherulite, the larger the rate of cooling, the smaller is the size of the resultant spherulites.

One of the property advantages of engineering plastics is heat resistance. To have a high heat resistance, the amorphous plastic should have a high Tg at which the material turns into a rubbery low-modulus state; the semi-crystalline plastic should have a high Tm at which the crystalline domains melt and disappear.

2.2 Properties

The following is a list of representative engineering plastics as divided into the semi-crystalline and the amorphous plastics.

Semi-crystalline Plastics

- Polyamide(PA)
- Polyacetal(POM)
- Polyethylene terephthalate(PET)
- Polybutylene terephthalate(PBT)
- Polyphenylene sulfide(PPS)
- Polyetheretherketone(PEEK)
- Liquid-crystal polymer(LCP)
- Polytetrafluoroethylene(PTFE)

Amorphous Plastics

- Polycarbonate(PC)
- Polyphenylene ether(PPE)
- Polyarylate(PAR)
- Polysulfone(PSU)
- Polyethersulfone(PES)
- Polyetherimide(PEI)
- Polyamideimide(PAI)
- Polyimide(PI)

In general, the semi-crystalline plastics feature hardness and stiffness; the amorphous plastics boast transparency and impact strength. The semi-crystalline plastics, as compared with the amorphous, offer more effective reinforcement to enhance strength and stiffness with glassfibers and/or other fillers.

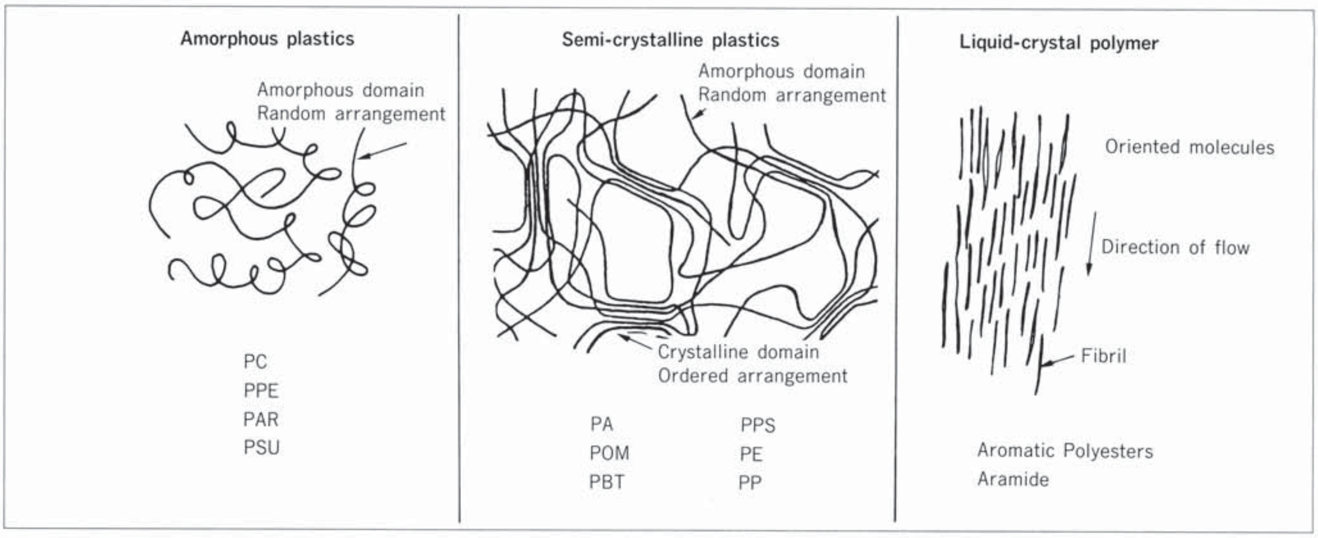


Figure2-1 Molecular Structures of Plastics

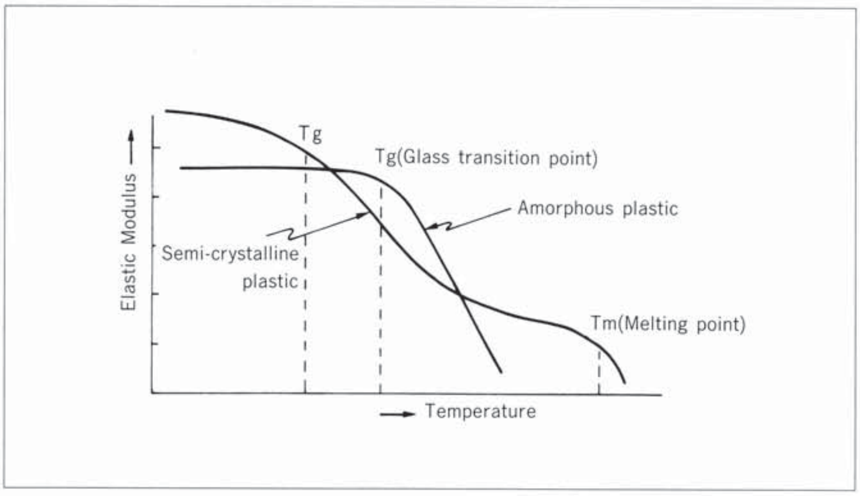


Figure2-2 Influence of Temperature on Plastics

Amorphous Plastics	Semi-crystalline Plastics
Only Tg exists Properties Impact strength: good Transparency: good Anisotropy in properties:small Mold shrinkage:small	Both Tg and Tm exist Empirical equations Symmetric polymer:Tg = 1/2Tm Asymmetric polymer:Tg = 2/3Tm Properties Flowability:good Chemical resistance: good Reinforcement: effective (strength, modulus, heat resistance)

Table2-1 Properties of the Amorphous and the Semi-crystalline Plastics

3 THERMAL PROPERTIES

The degree of heat resistance is an inborn property of a plastic material, and is the criterion to distinguish engineering plastics from general-purpose plastics; the engineering plastics are continuously usable at 100℃ or above.

In many cases, heat resistance is the essential property for selecting a material to make a projected product.

3.1 Influence of molecular structure on thermal properties

The conventional thermoplastics were for use at temperatures mostly below 150℃. Lately, a number of new plastics have emerged to meet the rising demands for the materials of much higher heat-resistance. Such materials are needed to make the components around the automotive engine, or the parts in the densely-packed electric/electronic chips.

The high heat-resistant plastics should have a high bonding energy in the molecule; more specifically, a rigid chemical structure including phenylene groups in the main chain of the polymer. The high heat-resistant plastics are:

- Mostly a product of polycondensation, and,
- With para-phenylene structures in the main polymer chain.

Melting point(Tm) and Glass transition point(Tg)

The melting point(Tm) indicates the level of heat resistance of semi-crystalline plastics, while the glass transition point(Tg) indicates that of amorphous plastics.

The polymer of stereo-regularly-arranged molecules is apt to crystallize and form the semi-crystalline plastic having a melting point. The melting point(Tm), melting enthalpy(△H) and melting entropy(△S) are related as follows:

$Tm = \triangle H / \triangle S$.

The △H represents an intermolecular force, and is large where hydrogen-bonds are present. The △S is small where the main-chain structure is symmetrical, cross-linked or stiff.

The polymer that contains twisted phenylene radicals is apt to form an amorphous plastic, which has a glass transition point. At temperatures below Tg, the molecular movements are frozen; hence, the physical properties may change only to a small extent. Above Tg, molecules move vigorously; hence incur conspicuous lowering in stiffness and candid expansion in volume.

3.2 Heat resistance in practical use

Short-term heat resistance

The Tm or Tg is the point at which the polymer's internal phase changes. Obviously, neither Tm nor Tg is a direct indicator to tell the practically usable temperature of the material.

The generally accepted indicator of a practical short-term heat resistance is DTUL(Deflection Temperature Under Load; formerly HDT: Heat Deflection Temperature). The testing procedure is to hold a bar (test specimen) under a 1.82 or 0.45MPa load, and heat it up to reach the temperature, i.e. DTUL, at which the bar starts deflecting. The practically usable temperatures should be lower than DTUL since the plastic actually deflects at that DTUL. The norm is to take somewhere about 10℃ lower than DTUL as the practical maximum temperature for a short-term use.

Long-term continuous-use temperature

The fiber-reinforced, particularly semi-crystalline, plastics may give the appearance of being durable even at Tg because of the restricted molecular movements in the crystalline domains. Therefore, it is worth defining a different measure than DTUL to warrant a long-term continuous use.

UL defines a test method for rating a long-term continuous-use temperature. The method is to expose specimens to varied levels of elevated temperatures for thousands of hours so as to determine the temperature at which the specified properties should come down to half the initial value over the assumed 40,000 hours of time.

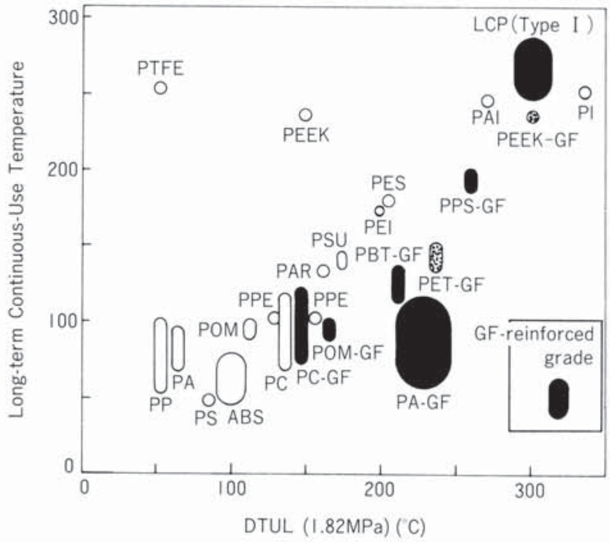


Figure3-1 DTUL vs. Long-term Continuous-Use Temperature

Figure3-1 correlates DTULs with the actually demonstrated long-term continuous-use temperatures. It is noteworthy from the figure that glassfiber reinforcement remarkably improves the DTUL of the semi-crystalline plastics, but only little enhances the long-term continuous-use temperatures from those of the non-reinforced grades; PA is a typical example. PTFE and PEEK have their long-term usable temperatures at as high as 250-260℃ even without reinforcements.

The actual long-term continuous-use temperature can vary depending on the loading mode, use conditions, use environment, and heat dissipating conditions. Therefore, a thorough study of users' requirements is necessary to select a correct material.

Incidentally, the amorphous plastics exhibit only a small rise in DTUL with glassfiber reinforcement.

Soldering-heat resistance

The major method for mounting parts on a circuit board has been direct immersion of the board into a molten-solder bath. More recently, the mainstream method is of re-flow soldering to deal with smaller and thinner parts.

In the direct immersion method, the bath temperature used to be about 260℃; yet, the plastics with 220-230℃ DTUL were usable because the immersion time was only 10seconds or shorter. Nowadays, the process runs at a much higher temperature to shorten the soldering time and to prevent excessive solder remaining on the board; therefore, the plastics with above 260℃ DTUL are necessary.

The re-flow soldering method has emerged to meet the demands for downsizing and mass-production of electric/electronic devices; therefore, now widespread in soldering chip-sized small parts. This method is to preheat the parts for about 1.5 minutes at 150℃, then to heat up for soldering at 220-230℃ or above for about 30seconds. The re-flow temperature is lower than the soldering-bath temperature but the exposure time is longer; besides, the parts are much smaller and thinner. Accordingly, the re-flow method demands higher heat resistant plastics: in most cases, those plastics with 260℃ or higher DTUL are eligible for use in the re-flow method.

Heat resistance that corresponds to use conditions

Engineering plastics are employed in so wide-ranging fields that they encounter diverse use conditions. Therefore, a meticulous study of users' requirements is important for selecting a correct material: the study of not only the heat resistance but also other factors that may count in the actual use conditions. The following paragraphs introduce a few of such factors.

A heat resistance at somewhere around 100℃ is generally sufficient for the parts of electric/electronic appliances that humans normally use by direct touch with hands.

A heat resistance at higher than 180℃ is not necessary for the mechanical parts that contact oil or grease because most of the lubricants degrade around that temperature. In contrast, where the use-temperature is above 180℃, a self-lubricating material is necessary for the friction/wear parts since no oil or grease is usable at that temperature.

A 260℃ level heat resistance is necessary with the parts for soldering as explained in the preceding section.

In the market of plastic materials, the heat resistance levels are generally in good correspondence with the price levels. The higher the heat resistance, the higher should be the price, though some exceptions are seen among recently developed alloys, or in some turmoil markets.

Coefficient of linear thermal expansion

The coefficient of thermal expansion is an important property to define the range of usable temperature of a material. Particularly, when a plastic is used in place of or in combination with a metal, the difference in expansion between the materials can cause dimensional variances leading to a malfunction of the product. A few facts about the thermal expansions of plastics are:

(1) The thermal expansion of plastics is greater than that of metal.

(2) Semi-crystalline plastics have non-isotropic coefficients of linear expansion.

(3) The coefficients of linear expansion of fiber-reinforced plastics in the direction parallel to the fiber orientation are close to those of metals. In the direction perpendicular to the fiber orientation, the coefficients are much closer to those of the base resins.

(4) LCP has a small coefficient of linear expansion.

Specific heat

The specific heats of most plastics are in the range of 0.8-2kJ/kg-K; that of glassfiber is 0.8kJ/kg-K at room temperature; that of carbon fiber is 0.7kJ/kg-K. In terms of the specific heat per unit volume, there are no significant differentials among the specific heats of those materials.

Thermal conductivity

The thermal conductivity of plastics is smaller than that of metal. Actually, some plastics are for use as a heat insulator. See Table3-1 for more information about thermal conductivity and other thermal properties of various plastics.

Other

In the stationary applications such as casings, housings, and heat-insulating boards, stiffness and strength as well as heat resistance are the indexes for selecting a material.

Beware that semi-crystalline plastics sharply lose their strength above the crystallization temperature. The knowledge of strength of the material at the actual use-temperature is a practical key to use engineering plastics correctly. Figures3-2 and 3-3 show how temperature influences the strength or the stiffness of plastics.

	Specific gravity	Specific heat, kJ/kg-K	Thermal conductivity, W/m-K	Coefficient of linear expansion		Glass transition point, ℃	Melting point, ℃
				Non-reinforced, 10^{-5}/K	GF30%-reinforced, 10^{-5}/K		
PA6	1.14	2	0.2～0.2	8～15	2.2～3.0	30～50	219～226
PA66	1.14	2	0.2～0.3	8～10	2.5～3.0	50～65	259～265
POM	1.42	1.5	0.05～0.2	8～12	2～4(GF25%)	−50～−60	163～180
PC	1.20	1.3	0.2～0.3	6～7	2～3	150～156	—
PPE	1.06	—	0.2	6～7	2.5～3.5	140～150	—
PBT	1.31	1.2	0.1～0.2	8～10	2～3	20～25	224～228
PET	1.35	—	0.3	—	3～5	67～71	254～260
PAR	1.21	—	—	5～6	3.6	181～195	—
PSU	1.24	1.1	0.1～0.2	5.5	2～4	181～190	—
PES	1.37	1.1	0.2	5.5	2.3	222～225	—
PEI	1.27	—	0.2	5.6	2.0	210～217	—
PPS	1.34	1.0	0.3	2～4	2～3	85～88	278～285
PEEK	1.30	1.3	0.3	4～5	1.3	143～145	334
LCP(I)	1.3～1.4	—	0.3	−0.5～11	1.5～2.0	—	400～450
Fe	7.4	—	80	1.2	—	—	—
Al	2.7	—	237	2.4	—	—	—

Table3-1 Thermal Properties of Engineering Plastics

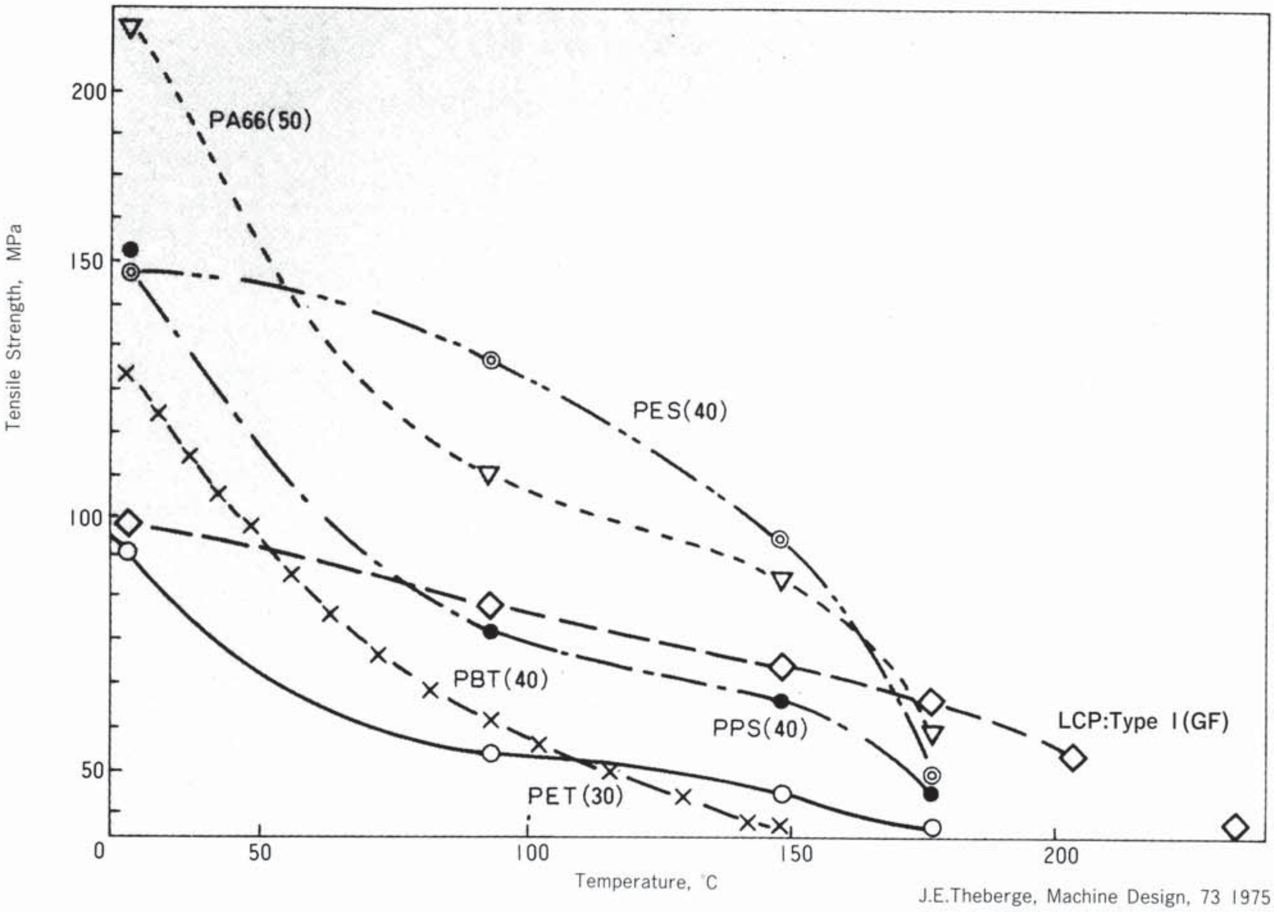


Figure3-2 Tensile Strength vs. Temperature (GF-reinforcement, wt%)

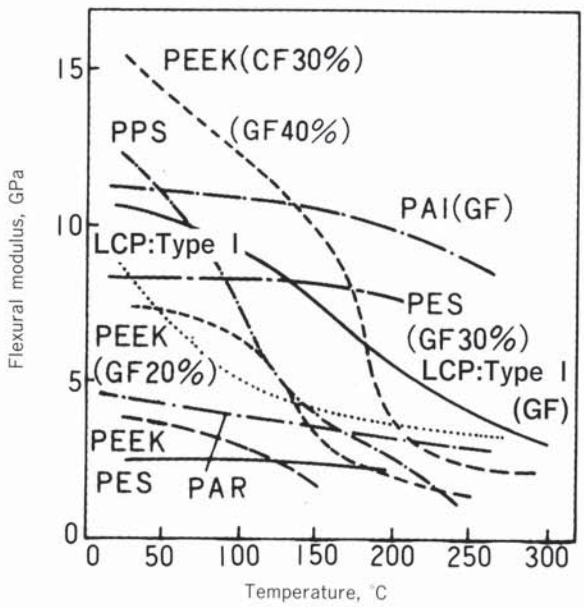


Figure3-3 Flexural Modulus vs. Temperature (Specialty-engineering Plastics)

4 MECHANICAL PROPERTIES

Note that plastics are very sensitive to the environmental temperatures, and that plastics creep under a long-term loading. Plastics differentiate themselves from metals in the mechanical characteristics that come from the inherent nature of the plastics: the viscoelasticity and the glass transition point (Tg).

4.1 Viscoelasticity

At an ambient temperature, a plastic material looks like elastic solid. At an elevated temperature where molecular movements are vigorous, it is readily deformable with a small external force, or even melt-flowable. Also, it deforms while supporting a heavy load for a long time (Creep).

In concept, the plastic material is more understandable as being a very viscous liquid rather than an ordinary elastic solid.

A truly viscous liquid undergoes deformation in response to the external force while contending with the internal friction. A truly elastic solid undergoes deformation in proportion to the external force. A plastic material undergoes deformation in both the viscous-liquid behavior and the elastic-solid behavior; hence, the material is referred to as a visco-elastic substance.

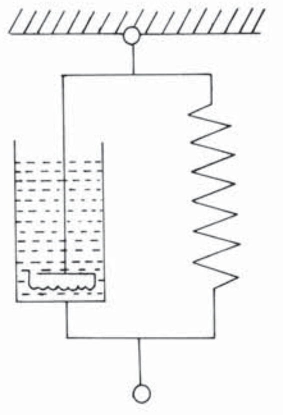


Figure4-1 Voigt-Model

A linked combination of a dashpot(a piston-in-cylinder type shock absorber) and a spring can conveniently explain the visco-elastic behavior: the dashpot and the spring respectively represent viscosity and elasticity. Figure4-1 is called a Voigt-model, where a dashpot on the left and a spring on the right linked in parallel: each element respectively shares the stress on viscosity and the stress on elasticity.

When the lower ring is pulled down, the total mechanism extends downward in a way to maintain an equilibrium in each of the two elements. On the one side, the dashpot continues to go down as long as even a minimal force is applied. On the other side, the spring resists the pull-down force with the recovering force that occurs in proportion to the deformation. Over all, the total deformation, that should have taken place instantaneously if otherwise only the spring was present, is achieved belatedly with the presence of the piston which moves on a viscous flow in the dashpot.

When the pull-down force is removed after a considerable deformation has resulted, the spring immediately starts returning with a strong force, which the piston follows with a reduced returning speed. During the returning process, the spring force declines as the strain decreases.

4.2 Influence of temperature on mechanical properties

Figure4-2 presents the relationship between temperatures and elastic moduli. In view of the moduli, Tg is the uppermost usable temperature of the amorphous plastics, while Tm is that of the semi-crystalline plastics. Practically, however, the uppermost usable temperatures are often taken at somewhere lower than Tg or Tm depending on the required performance and the involved use-conditions such as load, environment, and duration time.

The following clauses summarize how temperature influences the mechanical behavior of amorphous plastics, which change the phases from glass through rubber to liquid as the temperature rises.

(1) At temperatures below Tg, the plastics are stiff, deform in proportion to the applied stress, and recover instantaneously after removal of the stress.

(2) At temperatures past Tg, the elastic modulus declines sharply as the temperature increases. In this region, the plastics are rubbery, where some portions of the polymer chains under stress deform reversibly, while the other portions deform irreversibly. The reversible deformation corresponds to that in the spring on the Voigt-Model in Figure4-1: the deformation recovers on removal of the stress (elastic deformation). The irreversible deformation corresponds to the displacement in the dashpot: the displacement does not revert to the former state after removal of the stress (plastic deformation).

(3) At yet higher temperatures where the plastics flow and further melt, the plastic deformation is predominant. The viscosity decreases further; the elastic modulus comes almost to zero.

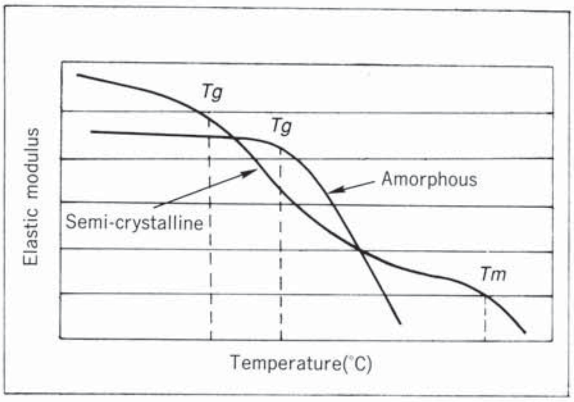


Figure4-2 Temperature vs. Elastic Modulus

The strength of a plastic varies in response to the rate of loading: a high-rate loading leads to an impact test, a medium-rate loading to tensile, flexural, compression, and shearing tests, and a low-rate to a creep test.

4.3 Creep phenomenon

CREEP PHENOMENON is a progressive change in the geometry of a substance supporting a constant load over an extended time.

The creep can appear in metals in some occasions, but it occurs more frequently in plastics even at an ambient temperature. Figure4-3 schematically explains how a tensile creep develops. Figure4-4 is a creep curve: a graphical expression of the change in strain as the time elapses. Immediately after loading the test specimen, the curve exhibits an instantaneous elongation inversely proportional to the elastic modulus (Hooke's law). Then, the shorter segments in the polymer chains gradually move to creep at a small rate. Constant loading continues on the specimen until the polymer chains have fully stretched out (the first-stage creep). After that, the strain remains almost constant for a certain amount of time (the second-stage creep). In the later stage, massive sliding occurs between the polymer chains,

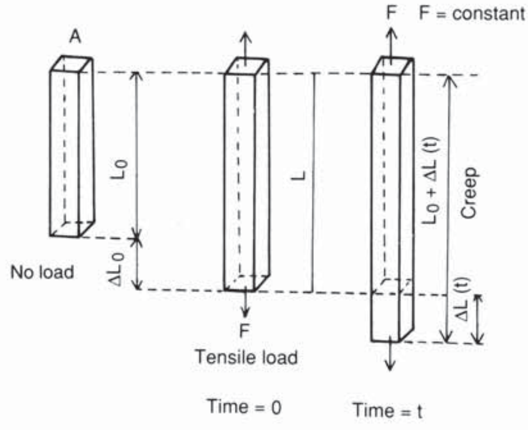


Figure4-3 Tensile Creep

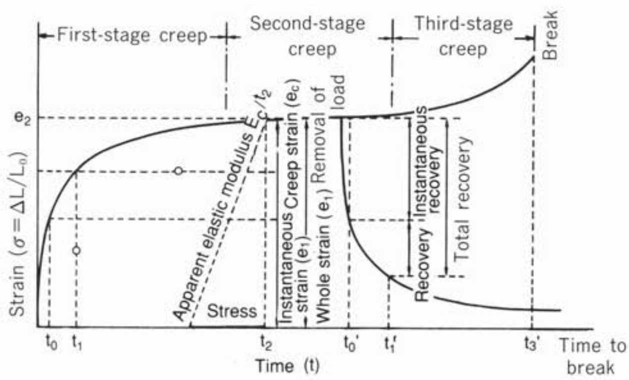


Figure4-4 Creep Curve

which immensely strains the material leading to a break (the third-stage creep).

The creep phenomenon hardly occurs in the material that contains glassfibers or inorganic-particle fillers for reinforcement, or that has three dimensional network structures or very stiff phenylene radicals in the polymer as the thermosets. In contrast, the creep easily takes place with a small stress at an elevated temperature where molecules move vigorously, hence, polymer chains can slide with ease.

If the load is removed, see the point in Figure4-4, a portion of the strain recovers instantaneously, while the rest of the strain recovers slowly over a length of time, yet leaving some permanent strain.

Neither the creep strain nor the recovery of it completes instantaneously, but takes place in a delayed manner; hence, the creep deformation is termed as DELAYED ELASTIC DEFORMATION.

4.4 Tensile properties

The tensile properties are the most fundamental and important attributes of plastics. In the tensile test, a medium-rate loading on a specimen results in a stress-strain curve, which exhibits the maximum stress, stress at break, stress at yield, elongation at break, and the tensile modulus. Any stress-strain curve appears as one of the following three types. (Figure4-5)

(a) The plastics that show a relatively small, no more than several percent, elongation at break. The typical of this type are amorphous plastics in glassy state and glassfiber-reinforced plastics.

(b) The plastics that have both stiffness and

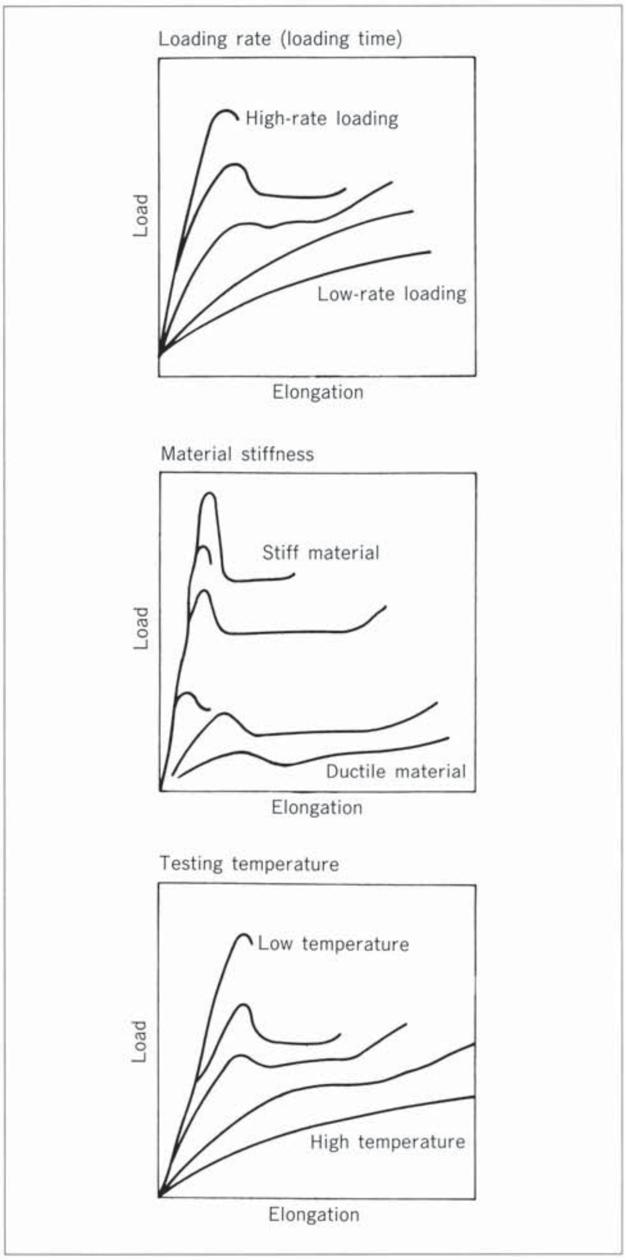


Figure4-6 Stress-Strain Curves under Different Conditions

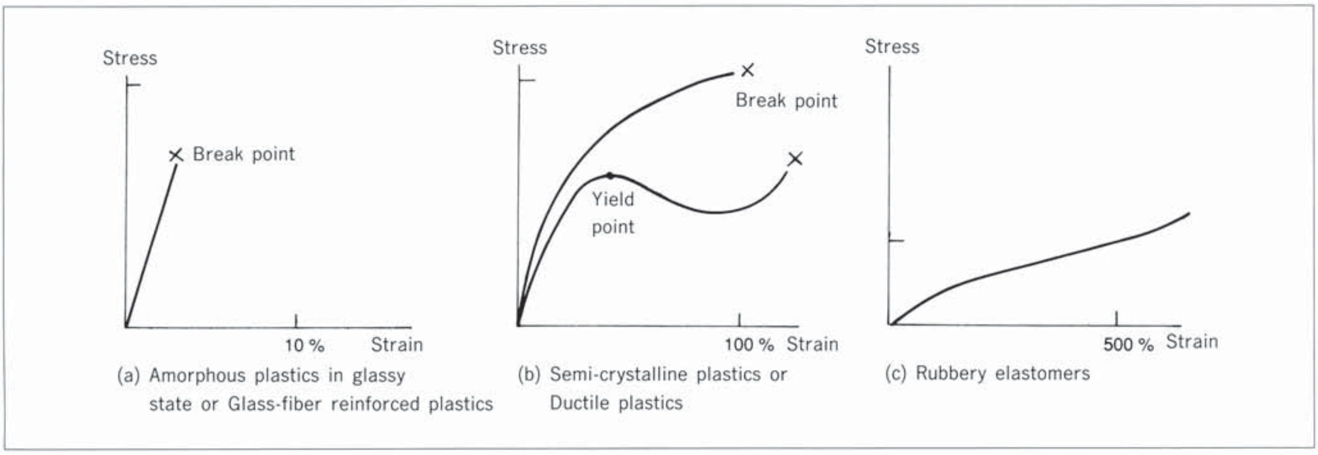


Figure4-5 Tensile Test: Stress-Strain Curve

ductility. Most plastics belong to this category. The upper curve shows an elongation with plastic deformation leading to break (e.g. POM). The lower curve has a yield point, after which the stress once decreases and picks up again exhibiting a strain-hardening before break.

(c) The rubbery polymers that show reversible deformation (e.g. elastomers).

The gradient at the initial section of the stress-strain curve is the tensile modulus. However, since many plastics do not give a real straight line on that section, see (b), usual design practices assume the initial small section of the curve as a straight line to define an apparent Young's modulus; or else adopt the flexural modulus of the material if so permitted by the use conditions.

Figure4-6 summarizes how the loading rate, the material stiffness, and the testing temperature influence the s-s curves. The s-s curve takes the shape more like the type (b) than the type (a) in Figure4-5 when the loading rate is low (i.e. the loading time is long), the material is ductile, or the testing temperature is high.

4.5 Flexural properties

The relationship between the flexural stress and the strain can be expressed in a stress-strain curve that appears similar to Figure4-6 on tensile properties.

Figure4-7 is the typical test method to determine flexural properties.

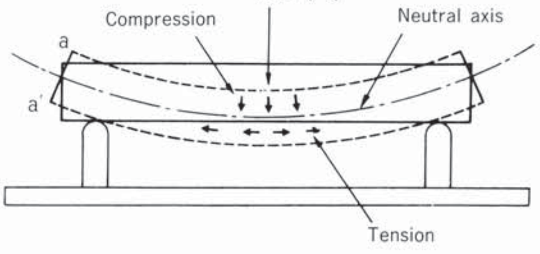


Figure4-7 Flexural Test Method

4.6 Fatigue

Repeated loading on a material will end up with a failure of the material. The load at failure in the repeated loading is much smaller than that in a single static loading. Such phenomenon is termed as FATIGUE and such failure is called FATIGUE FAILURE. The fatigue is not unique to plastics but a common presence among almost all materials.

Engineering plastics are widely employed to make gears, springs and other parts that must endure repeated loading. It is therefore a norm to consider fatigue endurance in designing parts.

Testing for fatigue endurance is to give a material repeated stresses to reach a failure. A graphed relationship between the stress amplitude S as the ordinate and the logarithm of cycles-to-failure N as the abscissa results in an S-N curve. Figure4-8 shows such S-N curves as measured on various plastics.

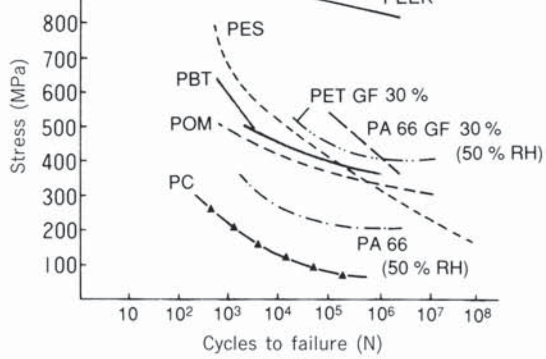


Figure4-8 Fatigue of various plastics: S-N Curve

Among the general-purpose engineering plastics, the semi-crystalline plastics, particularly POM, show excellent fatigue endurance. Among the specialty engineering plastics, PEEK outranks other materials.

For example, take a POM gear that is required to survive beyond one million rotations. As is obvious from the graph, the stress at the root of tooth must be retained smaller than 34MPa, which is about one-third the static flexural strength of POM, 96MPa.

It should be noted that the cyclic frequency of loading, the ambient temperature and other environmental conditions have great influences over the fatigue of plastics.

There are two types of tests to determine fatigue endurance: the Constant-Amplitude-of-Deflection Test (typically the ASTM A-method), and the Constant-Amplitude-of-Force Test (typically the ASTM B-method).

Figure4-9 explains how the A-method equipment works. The eccentric crank gives the specimen constant cyclic deflections, which generate the cyclic stresses in the specimen as described in Figure4-10. The cycles-to-failure are determined under a preset

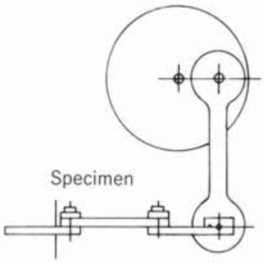


Figure4-9 Explanation of Constant-Amplitude-of-Deflection Test

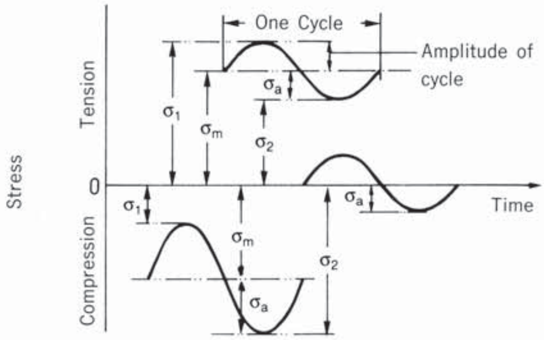


Figure4-10 Stress-Time Curves for Different Values of Mean Stress

condition of testing. The normal setting is to generate the cycles of tensions and compressions of an equal absolute value ($\sigma m=0$); a biased setting ($|\sigma m|=\sigma a$) may be used if so desired. In some cases, the mean stress (σm) is set as desired. The A-method has an inherent problem: the modulus of the specimen may decrease as the test progresses resulting in a reduction of effective stress, which may not render the test specimen a complete failure to finish the test.

The B-method has been devised to solve said problem in the A-method. The B-method, however, is not popular with plastics because the test material may incur increase in strain under a constant stress.

In terms of the modes of applying strains or stresses, there are methods of tension-compression mode, rotational flexural mode, plane flexural mode, and torsional mode.

Some other fatigue-testing machines are Ono-type rotational flexural fatigue-testing machine and a hydraulic-servo-type fatigue-testing machine.

4.7 Impact strength

The impact test uses the highest-rate, or the quickest, loading among all mechanical tests. Beware that many substances appear very weak to a quick impact even if strong to a slow deformation. Every plastic shows such a spread in strength, and the degree of the spread is characteristic of the material. The general-purpose engineering plastics such as PA, POM and PC are superior in impact strength to die-cast metals such as aluminum.

A variety of test methods are available with different impact speeds and directions with-or-without notches. Selection of a test method is therefore important so that the material be evaluated in the conditions that simulate the end-use environment as closely as possible.

The representative impact-test machines are Izod impact tester, Charpy impact tester, Tensile impact tester, and High-rate impact tester.

Izod has long dominated the testing of plastics. But it is somewhat risky to fully trust in the Izod data, since this method can more reflect the effect of notches or sharp corners than it represents the inherent toughness of the tested material. Figure4-13 shows the geometry of a notch in a test specimen as defined in ASTM. Impact strength is very sensitive to the radius of the notch. Table4-1 shows that the impact strength of POM is significantly lower when notches are present; the same applies also to PA or PC.

Because of those arguments on the Izod method, ISO has decided to employ the Charpy method as its standard for testing impact strength.

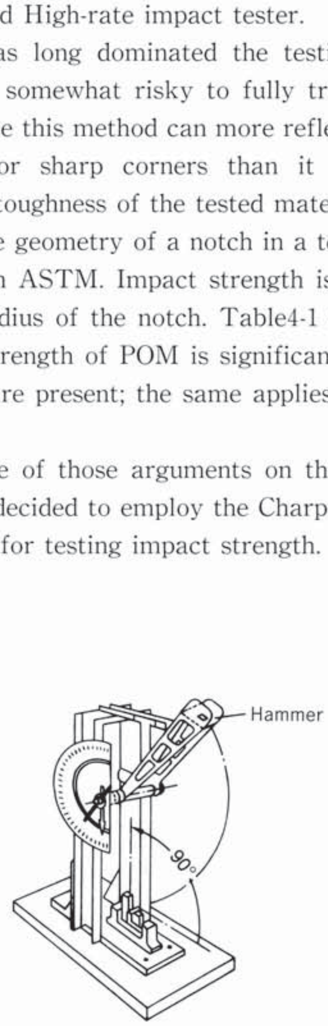


Figure4-11 Cantilever Beam (Izod-Type) Impact Machine

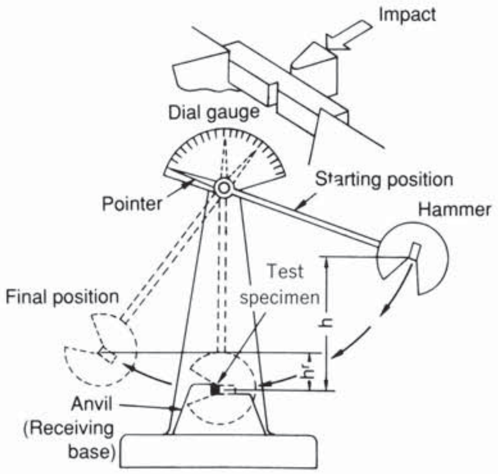


Figure4-12 Charpy Testing Machine

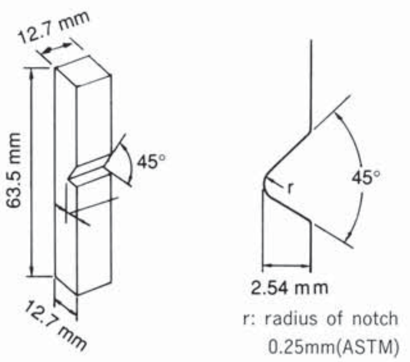


Figure4-13 Notch in Specimen

Table4-1 Impact Strength of POM (J/m)

Material \ Notch	Yes	No	No/Yes ratio
Homopolymer 500	75	1270	17.1
Copolymer M90	64	1120	17.5

Table4-2 Impact Strength by Two Different Test Methods

Material \ Test method	Izod Impact (J/m)	Tensile Impact (kJ/m²)
PC	500	840
ABS(High impact grade)	160-320	157
PA66	107	126
PA66(High impact grade)	133	1261
POM(Homopolymer)	75	207
POM(Copolymer)	64	147
Zinc(Die cast)	—	168
Aluminum(Die cast)	—	83

4.8 Friction/wear properties

The fundamental machine-elements such as levers, wheels, axles, wedges, and screws unexceptionally involve friction-and-wear, which is influential over the life of machinery. Accordingly, the friction-and-wear has long been an important subject of study evolving into the discipline called tribology today.

Automobiles, electric/electronic appliances and other industrial machines are all assemblies of parts contacting each other, which inevitably incur friction and wear. Correct understanding of friction/wear properties of engineering plastics is particularly important because the material is frequently employed in the parts for those assemblies.

Many of the semi-crystalline plastic parts for friction/wear uses have the following characteristics.

1 Self lubricating
2 Absorbs or damps vibrations: suitable for the parts that support fluctuating loads
3 Light in weight
4 Chemically stable

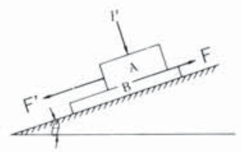
4.8.1 Static friction and Dynamic friction

When two contacting solids displace themselves relatively to each other, a resistance to the displacement arises in the contacting plane. Such resistance that arises at the beginning of the displacement is called a STATIC FRICTIONAL RESISTANCE, and that arises during the displacing movement, i.e. during the uniform sliding, is termed as a DYNAMIC, or a KINETIC, FRICTIONAL RESISTANCE.

Consider a slider on an inclined plane as shown in Figure4-14. While gradually increasing the inclination angle(θ), the slider starts moving down the slope at one point of the angle; the resistance at that point is the static frictional resistance. The ratio (μ) of the static frictional resistance (F) to the force (P) normal to the inclined plane is termed as the COEFFICIENT OF FRICTION; those are related with the frictional angle(θ) in the following equation.

$$\mu = F/P = \tan\theta$$

Figure4-15 shows experimental data arranged in the descending order of the coefficients of static friction between two pieces of the same plastic;



P: Force normal to the inclined plane
F': Force to cause the displacement (sliding) between A and B
F: Force to contend with F' in the friction surface
(frictional resistance)

Figure4-14 Static Friction

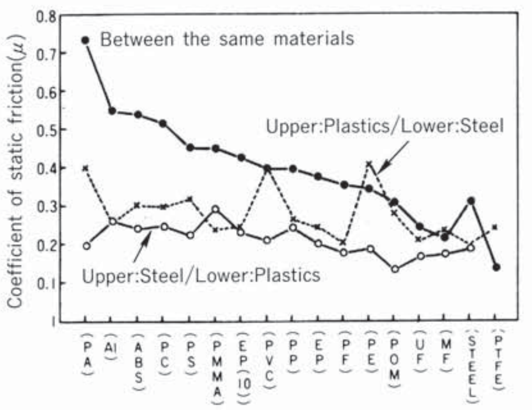


Figure4-15 Coefficient of Static Friction of Plastics

along with the data between the plastics and steel. It is noteworthy from those data that a plastic material shows the different coefficients on the different partner materials or frictional mode.

The dynamic frictional resistance appears while the materials are sliding or rotating. The influential factors over the dynamic frictional resistance include the hardness and surface roughness of the partner material, pressure across the frictional surfaces, friction rate (i.e. sliding speed), type of lubrication and the lubricant, temperature, and humidity. Figure4-16 exhibits the coefficients of dynamic friction between two pieces of the same material.

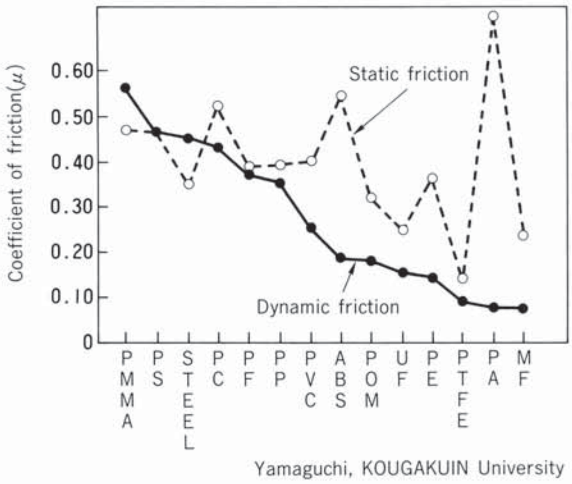


Figure4-16 Coefficient of Dynamic Friction of Plastics

4.8.2 Coefficient of friction of engineering plastics

4.8.2.1 Coefficient of friction of various materials

The conditions of contact between the two materials strongly affect the coefficient of friction. Some of such conditions are geometry, loads, lubrication and surface cleanliness.

PTFE exhibits the smallest coefficient of friction of all solids. Even when molten, PTFE forms a stagnant liquid layer, which serves as a hydrodynamic lubricant.

The frictional coefficients of semi-crystalline plastics are lower than those of amorphous plastics. Table4-3 lists the coefficients of friction of some semi-crystalline general-purpose engineering plastics.

4.8.2.2 Effect of lubricant

No metallic parts can work under friction without lubrication. In contrast, semi-crystalline engineering plastic parts are usable in many cases without lubrication (i.e. under dry friction); given a dash of lubricant during assembling, the friction/wear prop-

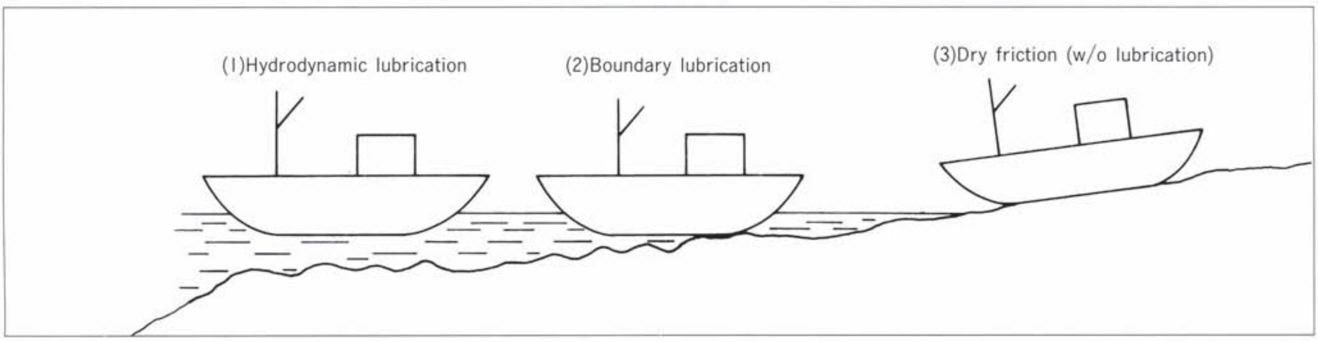


Figure4-17 Lubrication

erties improve remarkably.

In choosing a lubricant, be alert that some lubricants for metals may contain highly alkaline chemicals or extreme-pressure-lubricant additives that are harmful to plastics.

4.8.2.3 Lubricating additive to plastics

Molybdenum disulfide, graphite, FR, and silicone are the popular additives to improve friction/wear properties of either semi-crystalline or amorphous plastics.

	Static	Dynamic
POM/Steel	0.20	0.35
POM/POM	0.30	0.40
POM/PA66		
Maximum	0.46	0.19
Minimum	0.31	0.11
PA66/Steel		
Maximum	0.074	0.43
Minimum	0.31	0.17
GF-PET/GF-PET		
Maximum	—	0.27
Minimum	—	0.17
GF-PET/Steel		
Maximum	—	0.20
Minimum	—	0.17

Test conditions: Not lubricated, Temperature 23°C, Pressure 2.1MPa, Velocity 3m/minute
Test methods: Thrust-washer method for POM
ASTM D1894 for GF-PET

Table4-3 Coefficients of Friction of Semi-crystalline General-purpose Engineering Plastics

4.8.3 Limit PV-Value

While two materials are in a frictional contact, increase in the contact pressure and/or the sliding velocity should finally melt the materials with frictional heat and lead to a catastrophic wear. The mathematical product (PxV) of the pressure P(MPa) and the velocity V(cm/sec) at that critical point is called a LIMIT PV-VALUE, which is a widespread index for defining the conditions to use friction/wear parts. A material to make a friction/wear part should have the Limit PV-Value that meets the required P and V values in the end-use conditions of the product. The Limit PV-Value is dependent on the coefficient of friction; therefore affected by the variables that determine the coefficient.

Figure4-19 is a diagram to show the relations between contact pressures(P) and velocities(V) to come up with the Limit PV-Values of POM neat resin and its reinforced variants. It follows from this chart that the carbonfiber greatly enhances the Limit PV-Value while the glassfiber has little effect.

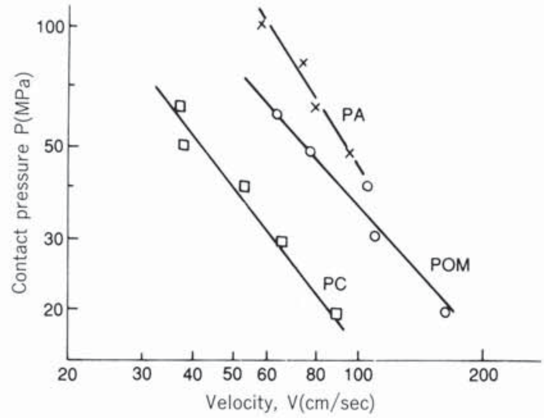


Figure4-18 Limit PV-Values of Thermoplastics (At ambient temperature)

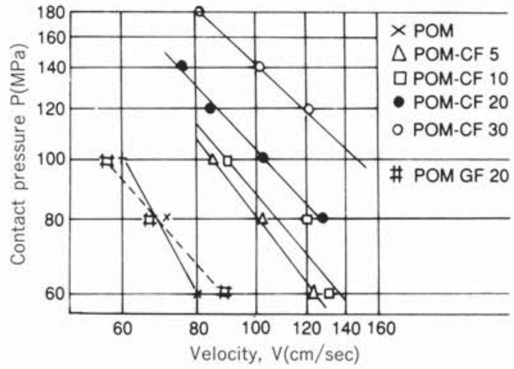


Figure4-19 Limit PV-Values of POM and CF-POM (At ambient temperature)

4.8.4 Frictional wear

Frictional wear is an extremely complicated phenomenon. Any solid is microscopically rough on the surface as shown in Figure4-20; the two rough surfaces attract each other by "cohesion" at the points of contact. If the surfaces slide on each other, the cohesion tears off to cause COHESIVE WEAR, or ATTRITION.

Another mode of wear is ABRASION in which hard particles come in between the sliding articles and grind the surfaces. Such particles may be dusts, the debris that scaled off the surfaces after fatigue, or the particles that the oxidation or corrosion of the metallic partner produced. The frictional wear of the plastic surface depends significantly on the surface roughness of the metallic partner as shown in Figure4-21.

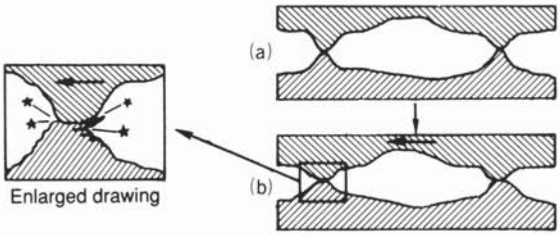


Figure4-20 Surface Roughness and Cohesion

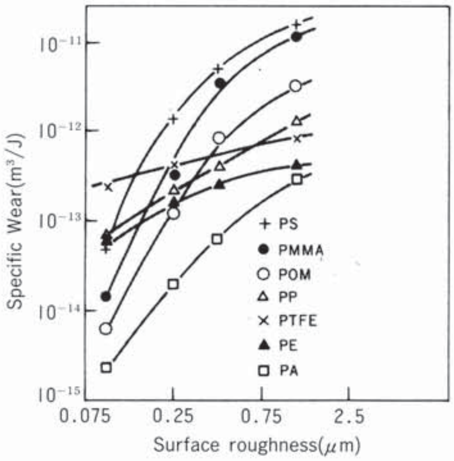


Figure4-21 Specific Wear of Plastics on Steel of Different Surface Roughness

The following are the necessary considerations in designing and using the bearing that incorporates plastic parts.

1 Remove debris as quickly as possible.

2 Minimize generation and maximize removal of frictional heat: use a material of a low coefficient of friction; use lubrication; design a thin-walled product; and employ the dimensional tolerance so that the shaft can fit the hole not too loose, not too tight.

3 Choose a metallic partner that has a hard surface and a low surface roughness.

4.9 Hardness

HARDNESS is the degree of resistance to the deformation as caused by the localized, or concentrated, stress that is applied externally on the substance for a short time.

Thermoplastics are no matches for metals in hardness. Presumably, most plastics will show about 40 on the Vickers scale.

There are three categories of hardness: scratch hardness, rebound hardness and indentation hardness. Introduced in the following are the typical methods for determining the hardness of plastic materials.

4.9.1 Rockwell hardness (H_R)

A Rockwell hardness tester employs the steelball indenters and the loading conditions as shown in Table4-4. The scale is chosen on the type of the plastic to be tested. The method specifies no geometry of a specimen. The testing procedure to obtain a Rockwell hardness (H_R) is: pressing the selected ball against the specimen under the Minor Load to obtain the depth h_0 of indentation; then applying the Major Load for the specified length of time; reverting the load to the Minor Load to know the depth from which h_0 is subtracted to obtain the differential h(mm); the h(mm) determines the H_R.

Reporting of the measured H_R must include the symbol of the scale that identifies the used steel ball and the loading conditions: for example, M115 or R90.

This testing machine features the indicator that gives a direct reading of hardness without a need of calculation. Hence, an easy and time-saving measurement is possible. This method is applicable to wide-ranging materials from soft polyethylene to rigid melamine.

4.9.2 Durometer hardness (H_D)

Also referred to as Shore Durometer hardness. ASTM D2240-97 defines the method, which is based on the penetration of a specific type of indenter, type A or type D. The type D is applicable to the measurement on relatively soft engineering plastics such as PTFE or PA12.

The testing procedure is to press the indenter with a spring action against the surface of the specimen, and read the depth of penetration on the scale directly connected to the indenter. The smaller the penetration, the harder is the material. The testing apparatus is compact and handy to use, but has a risk of giving errors.

Table4-4 Rockwell Hardness Scales (ASTM D785)

Scale	Steelball indenter (Diameter, mm.)	Minor load (N)	Major load (N)	Applicable Plastics
R	12.70	98	588	PE, PA, PBT
M	6.35	98	588	Thermosets, POM, PC, PBT, PET, PPS

5 CHEMICAL RESISTANCE

Rusting or corrosion is a weak point of metal. Rusting arises from a long-term exposure to oxidation in the air, and is much accelerated in the presence of acids or alkalis.

Plastics do not rust, but may degrade if exposed to such chemicals as follows.

- Acids, alkalis
- Organic solvents
- Hydrocarbons
- Polar solvents: alcohols, ketones
- Detergents: trichloroethylene, chlorine-containing solvents
- Gasoline, grease, oil
- Steam
- Hot water

5.1 Acids, Alkalis

Most plastics are resistant to acids, but dissolve or decompose if attacked by a highly concentrated acid. The FRs such as PTFE, PFA, PFEP are inert to most chemicals. PEEK is inert to all chemicals but a concentrated sulfuric acid at a high temperature. Polyesters withstand acids but suffer hydrolysis in alkalis. PA is somewhat weak to acids and alkalis. Amorphous plastics are generally resistant to acids and alkalis.

Alkalis and hydrofluoric acid attack glass; accordingly, glassfiber-reinforced semi-crystalline plastics are not usable in contact with those chemicals.

5.2 Organic solvents

Plastic's endurance to organic solvents is highly dependent on the molecular structure of the main polymer chains. Most of the heat resistant plastics are the products of polycondensation reaction, whose structures endure non-polar hydrocarbon solvents. However, some amorphous plastics that contain stereo-bulky groups in the molecules, such as PC and Modified-PPE, are vulnerable to hydrocarbons. The amorphous plastics such as PAR, PSU, PES, and PEI yield to polar solvents. The semi-crystalline plastics are generally more resistant to solvents than the amorphous because solvent molecules cannot easily invade the crystalline domains.

Automotive parts demand that the materials be resistant to gasoline or engine-oil. The parts for use in a cleaning process, such as for cleaning semiconductors, must be tested for the resistance to the specific cleaning solvent.

5.3 Steam

It is not recommendable to use PBT, PET, PAR, or LCP in contact with steam or warm water. Hydrolysis will take place on those polyester plastics if exposed to steam. Even in warm water, some extent of hydrolysis will occur. Beware not to use those plastics in the medical equipment that requires steam sterilization.

Amorphous plastics are generally resistant to steam, but the ester bonds in the molecules of PC and PAR are likely to incur hydrolysis.

5.4 Hot water

Such articles as bathroom-shower heads, the parts around hot-water supplying devices (tank, pump, etc) and cooking utensils frequently contact hot water. The plastic materials to replace conventional metals in those applications must not alter their mechanical properties or weights over a long-term contact with hot water.

The hot-water resistant plastics must have a DTUL above 100℃, and fundamentally little affinity with water. The apparent water absorption is not necessarily the correct and sufficient indicator of the affinity with water: the affinity as well depends on the molecular structure.

The plastics that contain hydrophilic bonds such as hydroxyl, ester, amide, or imide groups are considered generally inferior in hot-water resistance. That is because those plastics undergo gradual hydrolysis during a long-time exposure to hot water, which brings about decrease in molecular weight and hence deterioration in mechanical properties.

Those plastics with no hydrophilic bond in the molecule are superior in hot-water resistance. A few of such plastics are FR, PPE, PSU, PES, PPS, and PEEK.

5.5 Environmental stress cracking

Some chemicals that are harmless to plastics in the absence of stress can cause cracking on the surface of a plastic article in the presence of stress. The cracking can bring about a serious decay in the product performance. Such phenomenon, environmental stress cracking, is a synergistic effect of an interaction between the environment and the stress.

The environment is a chemical to which the plastic is exposed. The stress may be present externally, or internally, e.g. a frozen-in stress during molding, or as a combination of both. The environment and the stress can cooperatively accelerate the development of such cracks.

Well-known examples are the cracking on PE in contact with a surface-active agent, and on PA exposed to an aqueous solution of metallic salt such as zinc chloride.

It is important to know how a plastic material behaves in the actual-use conditions with regard to the environmental stress cracking. The following are the representative methods to know the degree of stress cracking.

(1) Environmental Stress-Cracking of Ethylene Plastics:ASTM D1693

Bent specimens of the plastic, each having a controlled imperfection (notch) on one surface, are exposed to the action of a surface-active agent. The proportion of the total number of specimens that crack in a given time is observed. Calculation is made to determine the time that elapsed before five out of ten specimens suffer cracks.

(2) Bergen 1/4 Elliptical Stress-Cracking Jig

Hold the specimen on a 1/4-ellipse jig that has varied curvatures along the surface; immerse the whole in a solution; measure the tensile strain at the end of the resultant crack.

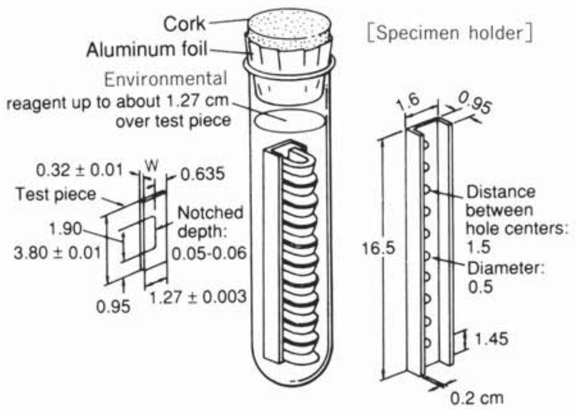


Figure5-1 Environmental Stress-Cracking Test Equipment: ASTM D1693

(3) Constant Tensile Load Creep Rupture Test

Immerse the specimen under the specified stress in the solution; measure the time that elapsed before cracking.

(4) C-Type Environmental Stress Degradation Method

As Figure5-2 shows, load the specimen on both ends of its C-shape; immerse the middle part of the C-shape in a solution; observe generation of cracks.

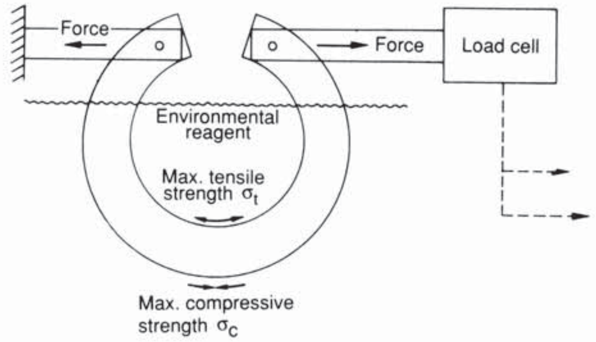


Figure5-2 C-Type Method Testing Apparatus

The molecular weight, crystallinity, and thermal history of the material influence the extent of environmental stress cracking. Table5-1 presents what engineering plastic in contact with what chemical is how susceptible to environmental stress cracking.

L: Little cracking
D: Depending on conditions
P: Pronounced cracking

Chemicals \ Plastics	PC	PPE	PA66	PBT	POM
Inorganic acids	D～L	L	P～D	D	P
Inorganic alkalis	P～D	L	D	P	D～L
Inorganic salts	L	L	D	L	L
Alcohols	P～D	P～D	L	D	L
Ketones	P	P	L	L	L
Esters	P	P	L	L	L
Chlorinated solvents	P	P	L	L	L
Aromatic solvents	P	P	L	L	L
Gasoline	P	P	L	L	L
Kerosene	P～D	P	L	L	L
Lube-oil	D～L	L	L	L	L
Grease	L	P～L	L	L	L

Table5-1 Environmental Stress Cracking of Engineering Plastics

5.6 Others

The chemical resistance of plastics depends significantly on the molecular structure. Where the polycondensation bonds are polarized in the polymer, the plastic readily suffers solvation with a polar solvent. Where the bonds are bulky, the plastic swells because a solvent easily invades the polymer. Both PA and PI contain nitrogen atoms, hence they are apt to absorb water. That may raise a problem when those plastics are exposed to inorganic salts: for example, some automobile parts may contact zinc chloride or calcium chloride as contained in an antifreezing agent.

The nominal-term chemical resistance, or the result of standard tests, is not the almighty index for selecting a plastic material that is durable in a chemical-contacting use. The real-term chemical resistance of the material is determined by the actual-use conditions. For example, absorption of a chemical vapor may give rise to blisters, or absorption of a monomer may cause searing. Also, there are many other influential variables worth considering: the applied load, geometry, molding conditions, degree of reinforcement with fibers, effect of annealing over crystallinity, and so on.

6 ELECTRICAL PROPERTIES

6.1 Insulation

Plastics for use in electrical/electronic parts benefit mainly from their insulation properties. Actually, most plastics are highly insulative to electricity.

The insulation property, i.e. the barrier to electric current, comprises two categories: one is VOLUME RESISTANCE to represent insulation across the thickness, and the other is SURFACE RESISTANCE to represent insulation parallel to the surface.

An engineering plastic generally has a volume resistance above $10^{14}\Omega$-cm. The plastics that absorb water exhibit decreasing insulation as the absorbed water increases. Reinforcing materials and stabilizing agents are influential on the insulation property.

6.2 Dielectric Breakdown Voltage

Plastics lose insulating capability under an extremely high voltage load. That is, the plastics retains its insulative property up to a certain voltage per unit thickness, kV/mm, called a DIELECTRIC BREAKDOWN VOLTAGE.

The dielectric breakdown voltage of an engineering plastic is normally somewhere between 10 and 50kV/mm at 20℃. A material with no polar group in the molecule generally exhibits a high dielectric breakdown voltage. This property decays as the material absorbs water.

6.3 Dielectric constant

When an insulator is loaded with electric voltage, electric charges develop within the material (dielectric effect). The degree of such effect is expressed as DIELECTRIC CONSTANT (ε).

If an insulator is loaded with a high-frequency alternating voltage, thermal energy develops within the material (conversion of AC loss to thermal energy). The amount of such energy is proportional to ε x tanδ, where tanδ is termed as DISSIPATION FACTOR, which is inherent in every plastic.

A small ε and a small tanδ are the keys to select a material for use in the electric equipment that handles a high voltage or an above 1 MHz frequency.

The dielectric characteristics, particularly tanδ, have significant relations with the molecular structure of the material. In general, the smaller the dipole moment (or polarity) of the material, the smaller is the tanδ. Some of the plastics that have a

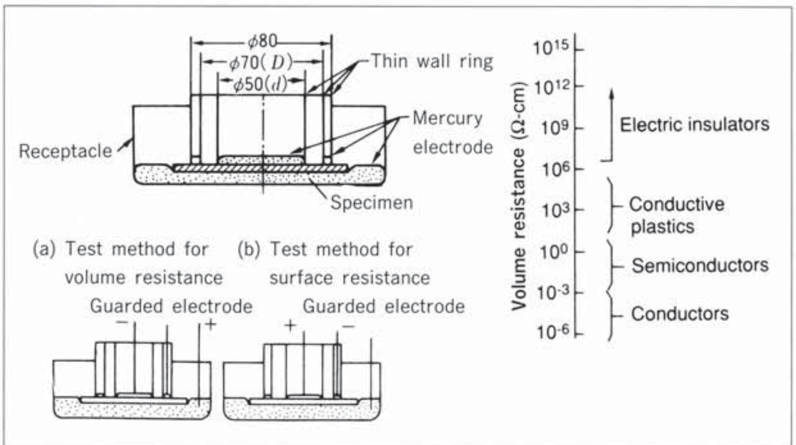


Figure6-1 Electrode System for Measuring Volume and Surface Resistances

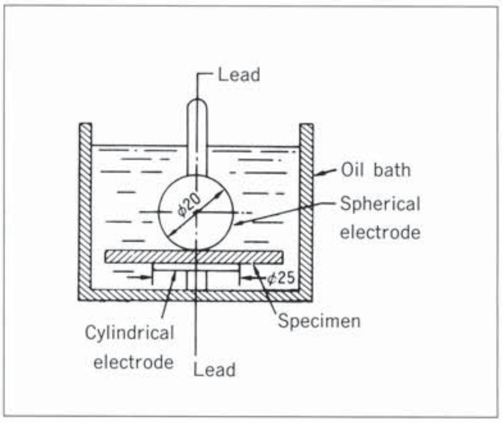


Figure6-2 Test Method for Dielectric Breakdown Voltage

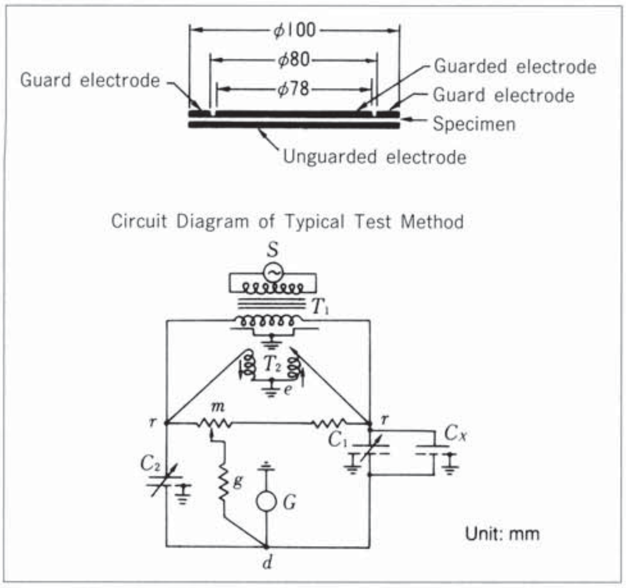


Figure6-3 Electrode System of the Test Method for AC Loss characteristics and Permittivity (Dielectric Constant)

small dissipation factor are PTFE, PPE, and PPS.

6.4 Arc resistance

If an arc, or a corona discharge, takes place on the surface of a plastic, it can accelerate degradation of the material, even with a plastic of high dielectric breakdown voltage. The arc resistance is accordingly an important factor in selecting a material for use in a high voltage insulation. The mechanisms of the degradation by arc, and their relations with the molecular structures, are yet to be known thoroughly. Empirically, the arc resistance is low with the polymers that contain easily carbonizable chemical groups such as benzene rings.

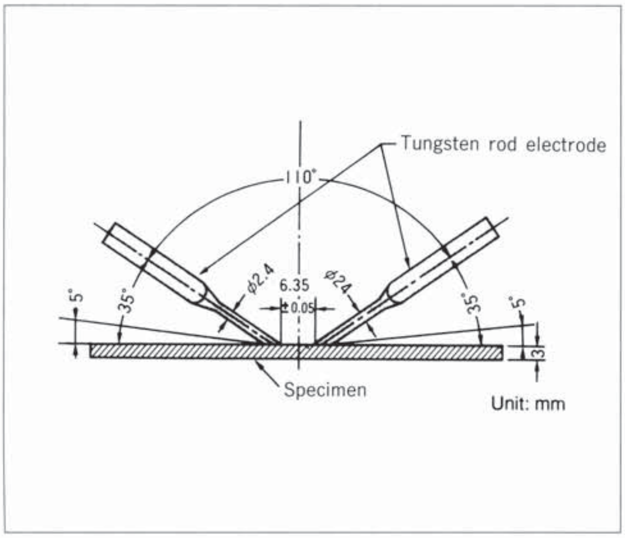


Figure6-4 Electrode Assembly of Test Method for Arc Resistance and Specimen

N: Non-reinforced GF: Glassfiber reinforced

		Dielectric constant (60Hz)	Dissipation factor (60Hz)	Volume resistivity (Ω-cm)	Dielectric breakdown voltage (kV/mm)	Arc resistance (sec)
PA-6	N	3.6	0.01	10^{14}	19	120～134
	GF	4.3	0.01	10^{14}	20	90
POM Homopolymer	N	3.7	0.005	10^{15}	20	220
	GF	3.8	0.005	10^{14}	20	168
POM Copolymer	N	3.7	0.001	10^{14}	20	240
	GF	3.9	0.003	10^{14}	23	130～136
PBT	N	3.3	0.002	$10^{15\sim16}$	17	125～190
	GF	3.2～3.8	0.002	10^{16}	21	120～130
PC	N	3～3.2	0.006～0.009	10^{16}	16～18	120
	GF	3.2～3.9	0.001～0.003	$10^{14\sim16}$	21	120～130
PPE	N	2.6	0.0004	10^{17}	22	75
	GF	2.9	0.0009	10^{17}	22	100
PAR	N	2.7	0.0008	10^{16}	16	125～129
	GF	3.5	0.002	10^{16}	23	83
PTFE	N	2.1	0.0002	10^{18}	20	300
PSU	N	3.1	0.0008	10^{16}	17	122
	GF	3.6	0.0019	10^{17}	19	115
PES	N	3.1	0.0008	10^{16}	17	122
	GF	3.6	0.0019	10^{17}	19	115
PEI	N	3.15	0.0013	10^{19}	33	128
	GF			10^{17}	30	85
PPS	N	3.6	0.0004	10^{16}	23	
	GF	3.8	0.0004	10^{16}	18	34～45
POB	N	3.2	0.01	10^{16}	14	124
	GF	4.8	0.009	10^{15}	17	136
PEEK	N	3.2～3.4	0.003	10^{16}	17	
	GF		0.001	10^{16}	15	
PAI	N	3.5	0.001	10^{18}	24	125
	GF			10^{18}	33	

Table6-1 Electrical Properties of Engineering Plastics

7 FLAMMABILITY

Plastics, with their excellent physical and chemical properties, enjoy expanding consumption in wide-ranging industrial fields such as automotive parts, household electrical appliances, electric/electronic equipment, electric wires, building materials, and a substantial number of other uses. In many of those fields, the burning characteristic is under a strict control in view of product safety because plastics are fundamentally flammable organic compounds.

The well-known international standards relevant to the burning characteristics of plastics are: IEC standards, ISO Standards, UL standards(the U.S.A.), FMVSS-302(the U.S. automobiles), and CSA standards(Canada); in Japan, the Electrical Appliance and Material Control Law and the Fire Service Law(the Government Ordinance therefrom for controlling dangerous objects).

IEC Standards	International standards to manage safety of electric/electronic products
ISO Standards	International standards on terminology and test methods relating to academic disciplines and industries
UL Standards	The most important standards to manage safety of electric/electronic products in the U.S.A. and affiliated countries
FMVSS-302	Standards on flammability of interior components of the U.S. automobiles
CSA standards	The most important standards to manage safety of electric/electronic products in Canada
Electrical Appliance and Material Control Law	A law to manage safety of electric/electronic products in Japan

Table7-1 Standards on Flammability of Plastics

Definition of burning

The burning of a plastic article in general is the sequence of such processes as: (1)the radiation from the thermal source (fire) heats the surface of the article, (2)the heat conducts into the bulk of the article, (3)the plastic material decomposes and generates volatile matters, (4)the volatile matters diffuse and spread through the bulk of the article, then, (5)reach the surface and diffuse into the gas phase, which maintains burning.

Any technology to inhibit burning consists in how to cut such a burning cycle.

Indexes of hard-burning characteristics

The general concept of hard-burning is the difficulty in starting the cycle (ignition) or the difficulty in repeating the cycle (continuation of burning).

A well known index for ignition is LOI (Limited Oxygen Index): a burner heats a test specimen in a mixed gas of varied oxygen/nitrogen ratios to determine the minimum oxygen content at which the specimen can ignite and maintain flaming. The LOIs

Plastics	LOI	Plastics	LOI
PE	18[1]	PA66	29[2]
PP	18[1]	PC	27[1]
PS	18[1]	POM	15[1]
PVC	47[1]	LCP	35～50[3]
PA6	29[2]		

1) Hard-burning Technology for Plastics, Taisei-sha Co, Ltd.
2) Plastics Data Handbook
3) FLAMMABILITY HANDBOOK FOR PLASTICS (Fourth Edition, TECHNOMIC PUBLISHING CO. INC.)

Table7-2 LOI of Engineering Plastics

of some engineering plastics are listed in Table7-2. The higher the LOI, the harder is the material to burn, more particularly to ignite. Since a higher-than-21% oxygen content does not come naturally on the earth, the LOI includes some abnormal burning conditions as well.

A newly proposed and a little complex index of hard-burning characteristics comprises quantitative expressions of three different elements of burning: ignition, heating characteristic (ease of spreading fire), and emission of smoke. The emission of smoke is particularly to the fore these days in view of a fire safety.

The cone calorimeter is a device to test a material for said three elements of burning in the new index. The testing is a procession of such procedures as: the cone-shaped heater fitted on top of the device heats the specimen at a constant rate, then the pilot burner ignites the specimen; the flue gas is introduced into the chimney equipped with a thermocouple to measure the temperature; also, the quantity of the smoke is measured. The elements of burning are the time(S) that elapsed before the ignition, the maximum rate of heat output(kW/m^3), and the quantity of the smoke(m^3/kg) generated per 1kg of the burned material.

Such quantitative and universal index may gain a greater significance in the future. Most hopefully, the correlations will become clear between aforementioned incumbent standards and the above-said quantitative and physical index of hard-burning.

Technology to impart hard-burning characteristics to plastics

The first method to cut the burning cycle is to restrict decomposition (generation of volatile matters) of the plastic. If the first method is not attainable, the second method is to curb diffusion of the volatile matters through the bulk of the material.

The first method includes: (1)formation of a carbonized skin to hinder heat conduction (formation of a heat-barrier layer to increase an apparent specific heat); (2)addition of the agent that generates radical catchers most efficiently at the temperature where the volatile matters evolve (efficient catching of radicals in the gas phase to cut the chain of decomposition reactions); (3)addition or in-situ generation of a heat absorbing substance to cool down the material (e.g. generation of steam from the released crystallization water).

The second method includes: (4)introduction of cross-linking or intermolecular physical entanglement to increase viscosity; (5)formation of a skin to curb diffusion of the volatile matters.

The brominated aromatic flame-retardants are effective mainly in (2), accompanied by some effects in (1) and (5). Widely used flame-retardant auxiliary agents, such as antimony trioxide, help promote efficient generation of the radical catchers in (2).

The flame retardants that contain nitrogen, phosphorus, sulfur, or boron turn into strong acids during burning and serve as dehydration agents (carbonization promoters) to produce char, and thereby effective in (1) and (5). The phosphorus-containing agent is said to be particularly effective because the resultant viscous film of polyphosphoric acid stays long within the solid phase; and also effective in (2). Increase in molecular weight or introduction of cross-linking brings increase in viscosity in (4), but also brings decrease in industrial productivity in want of flowability. One of the industrially demonstrated techniques is addition of a special grade PTFE. Stirring the special grade PTFE under a high-rate shearing force at a temperature above its melting point results in fibrillated trunk polymers and derived branches; this builds a kind of high-degree network fibril structure. Such structure will be effective to prevent the flamed material from dripping rather than to curb diffusion of the volatile matters.

The bromine-containing compounds are the mainstream flame-retardants today. Varieties of new developments are emerging to avoid use of bromine in a long-range perspective to the protection of the global environment: for example, use of metal (Mg, Al) hydroxides to realize (3), and use of silicon containing compounds to form a glass layer on the burning surface to induce (1) and (5).

8 WEATHERABILITY

WEATHRABILITY means the durability to outdoor exposure: the resistance against the property-degradation as arising from exposure to sunlight, raindrops, wind, snowflakes, and other weather conditions. The weatherability is a particularly important characteristic of engineering plastics because they are exposed to weathering in many applications.

The weatherability is observed as deterioration in mechanical strength, surface gloss, color, and appearance (cracks, etc); and as changes in geometry and weight. Such deterioration and changes are obviously caused by UV light, temperature, humidity, load or stress, and gases such as ozone, NO2, or SO2. The most influential of all is UV light.

The weatherability depends on the molecular structure of the material. Plastics are the organic compounds with relatively small bond energies between atomic groups. The material with smaller bond energy is more vulnerable to degradation as caused by a short wave length, i.e. high energy, UV light.

Varieties of techniques are in use to improve the weatherability of plastics. The typical of them is addition of a UV absorber, coloring agent, filler, or plasticizer to a plastic.

The outdoor exposure weathering test takes time and is difficult to follow standardized testing conditions. The accelerated artificial weathering test is a quantitative simulation of the outdoor exposure test.

The established standards for weatherability are in JIS, ASTM, and ISO.

(1) Outdoor exposure weathering test methods

An ordinary setup is to fix the testing specimens on a facing-south rack at a specified angle and height to let them bathe in the sunlight with or without a glass covering. The daylight method is to let the specimens stand outdoors around the clock; the sunlight method is to expose the specimens only during daytime. The locality and the seasonal climate are greatly influential over the outdoors testing conditions. Therefore, a long-term testing and/or testing at plurality of locations are necessary to obtain reliable results. Also, use of control specimens is important in order to compare the data from different tests. (ISO 877:94)

(2) Accelerated artificial weathering test methods

The outdoor exposure test is useful to know the natural degradation of the material directly, but it takes a long time. The accelerated artificial weathering test was therefore devised. This test is to observe the degradation of the material exposed to the artificial environment that simulates the natural weather as closely as possible.

Fade-o-meter is apt to control the light, temperature, and humidity in the testing chamber. Weather-o-meter can provide different conditions of light, temperature and imitated meteorological precipitation.

Whatever the method, the source of light is critically influential. Generally used are a fluorescent lamp, mercury-vapor lamp, UV carbon-arc lamp, sunshine carbon-arc lamp, and xenon-arc lamp. Use of the xenon-arc lamp is becoming popular among the test standards: ISO 4892-2:94, JIS K 7350-2:95.

9 OPTICAL PROPERTIES

The optical properties of plastics are:

(1) Light transmission (or absorption)

(2) Haze

(3) Refractive index

(4) Birefringence

The wavelength of light and the ambient temperature have influence over those properties.

For a material to be transparent, the light must pass all the way straight through the material with a minimal absorption, refraction, and diffused reflection. Accordingly, the material that contains crystal domains, morphologically heterogeneous alloys, or reinforcing fillers has an impaired transparency.

The engineering plastics already feature such property advantages as mechanical strength, heat resistance and chemical resistance. Therefore, addition of transparency to the property list can make an industrial material that has all the merits shared by different natural materials such as metal, glass, ceramic, and wood.

Many of the lately developed devices, e.g. compact discs and magneto-optical discs, benefit from the optical properties of plastics, which will greatly help expand the market and enhance the importance of transparent plastics.

10 STANDARDS AND CERTIFICATIONS

10.1 Plastic materials

10.1.1 ISO International Standard

ISO introduces itself: "The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from some 130 countries, one from each country. ISO is a non-governmental organization established in 1947. The mission of ISO is to promote the development of standardization and related activities in the world with a view to facilitating the international exchange of goods and services, and to developing cooperation in the spheres of intellectual, scientific, technological and economic activity. ISO's work ends up with international agreements which are published as International Standards." (http://www.iso.ch/)

Japan joined ISO in 1952, being represented by JISC (Japanese Industrial Standard Committee) under the Ministry of International Trade and Industry.

The ISO standards have grown in importance particularly since January 1995 when WTO-TBT (World Trade Organization-Agreement on Technical Barriers to Trade) took effect. That is because the Agreement urges the WTO member countries to make their respective national standards conform to ISO standards so as to lower the technical barriers that may hinder smooth international trading.

The task of ISO is to set standards for all technical fields except electrical and electronic engineering that is the responsibility of IEC (International Electrotechnical Commission). ISO carries out its technical work in a hierarchy of TCs(technical committees), SCs(subcommittees) and WGs(working groups). Among the TCs, TC61 is in charge of plastic materials; see Table10-1.

The ISO/IEC Directives stipulate the procedure to set ISO standards. The core of the work of defining ISO standards is the consensus that calls for a ballot by the member bodies at every stage in the procedure.

0 PWI : Preliminary Work Item
1 NP : New work item Proposal
2 WD : Working Draft
3 CD : Committee Draft
4 DIS : Draft International Standards
5 FDIS : Final Draft International Standards
6 IS : International Standards
7 Periodical Review

ISO reviews its all International Standards at least once every five years, at which time it withdraws those standards that have been scarcely harmonized with the members' individual national standards.

10.1.2 Japanese Industrial Standard

JIS (Japanese Industrial Standard) had its legal ground, Industrial Standardization Law, in 1949. JISC prepares a JIS proposal and the government approves it as a Japanese national standard. JIS has long contributed to various aspects of Japan's economic development after the Second World War.

In recent years, Japan has confronted pressures from overseas demanding to lower trading barriers through so-called "deregulation". In the circumstances, Japan took such actions as follows: implemented a three-year plan (1995-1997) to align JIS with ISO standards; joined WTO-TBT in January 1995; amended the Industrial Standardization Law in March 1997 so as to meet the new situation. The amendment of the law was to re-construct JIS by localizing the international standards and to introduce the certification schemes on the international assessment criteria. The three-year plan resulted in issuance of a series of new JISs based on the translated ISO standards.

ISO/TC 61 -PLASTICS

Convener: E. Lewiecki

WG 1	ANSI	Cigarette Lighters

Chairman: D. Price

SC 1	BSI	Terminology
WG 1	ANSI	Terms and Definitions
WG 3	DIN	Symbols

Chairman: A. Morales

SC 2	AENOR	Mechanical Properties
WG 1	DIN	Static Properties
WG 2	ANSI	Surface Properties
WG 3	BSI	Impact Properties
WG 4	ANSI	Dynamic Properties
WG 5	BSI	Temperature Dependent mechanical properties
WG 6	UNI	Preparation of test specimen by machining
WG 7	ANSI	Fracture and Fatigue Properties
WG 8	BSI	Forms of data presentation

Chairman: P. Briggs

SC 4	BSI	Burning Behaviour
WG 1	ANSI	Ignitability and flame spread
WG 2	NNI	Smoke Opacity and corrosivity
WG 3	AFNOR	Heat release
WG 4	BSI	Guidance on fire testing
WG 5	DIN	Intermediate-scale fire testing

Chairman: S.H. Eldin

SC 5	SNV	Physical-Chemical properties
WG 1	SCC	Optical Properties
WG 4	-	Permeability and absorption
WG 5	DIN	Viscosity
WG 8	AFNOR	Thermal analysis
WG 9	BSI	Melt rheology
WG 10	NNI	Chromatography
WG 12	NNI	Ash
WG 13	-	Reference materials
WG 16	-	Electrical properties
WG 17	ANSI	Density
WG 18	ANSI	Extractable matter
WG 19	-	Determination of melting point of semi-crystalline polymers
WG 21	IBN	Applic. Of statistical methods
WG 22	JISC	Biodegradability

Chairman: P. Trubiroha

SC 6	DIN	Ageing, chemical and environmental resistance
WG1	ANSI	Resistance to biological attack
WG 2	DIN	Exposure to light
WG 3	UNI	Various exposures
WG 7	ANSI	Basic standards

Chairman: R. MacFarlane

SC 9	ANSI	Thermoplastic Material
WG 6	BSI	Polyolegins
WG 7	ANSI	Styrene polymers
WG 8	ANSI	Polyamides
WG 14	DIN	Polymer dispersions
WG 15	DIN	Polycarbonate
WG 16	BSI	Cellulose ester
WG 17	ANSI	Thermoplastic polyesters
WG 18	ANSI	Preparation of test specimens
WG 19	UNI	Polymethyl methacrylate materials
WG 20	DIN	Polyvinyl chloride
WG 21	ANSI	Polyoxymethylene
WG 22	AFNOR	PTFE raw materials and products
WG 23	BSI	Polymers and copolymers of vinyl chloride
WG 24	JISC	Polyphenylene ethers
WG 25	NNI	Polycetones

Chairman: D. Keeler

SC 10	SCC	Cellular plastics
WG 10	ANSI	Joint TC 163/SC 3-TC 61/ SC 10 WG - Plastics insulation products
WG 11	SCC	Physical and mechanical properties
WG 12	DIN	Endurance properties
WG 13	ANSI	Material and product specifications

Chairman: T. Goto

SC 11	JISC	Products
WG 2	AFNOR	Decorative laminates
WG 3	BSI	Plastic films and sheets
WG 5	SNV	Polymeric adhesives
WG 6	UNI	Polymethyl methacrylate sheets
WG 7	DIN	Polycarbonate sheets
WG 8	JISC	Unplasticized polyvinyl chloride sheets

Chairman: T. Steiner

SC 12	ANSI	Thermosetting materials
WG 1	AFNOR	Thermoset moulding compounds
WG2	DIN	Phenolic resins
WG 5	AFNOR	Polyesters, epoxies, polyurethanes and other resins
WG 10	DIN	Standards for designing with thermosets

Chairman: R. Guillermin

SC 13	AFNOR	Composites and reinforcement fibres
WG 11	BSI	General standards
WG 12	IBN	General methods of test for reinforcements
WG 13	AFNOR	Glass fibres
WG 14	JISC	Carbon fibres
WG 15	AENOR	Prepregs and moulding compounds
WG 16	AFNOR	Composite materials

Table10-1 ISO/TC61 - Plastics (1998)

ISO	Title	ASTM	JIS
10350:93	Acquistion and presentation of comparable single-point data	D5935-96	K7140:95
3167:93	Multipurpose test specimens	D5936-96	K7139:96
527-1:93	Determination of tensile properties—Part 1:General principles	D5938-96	K9161:94
527-2:93	Determination of tensile properties—Part 2:Test conditions for moulding and extrusion properties	D5937-96	K7162:94
294-1:96	Injection moulding of test specimens of thermoplastic materials—Part 1: General principles, and moulding of multipurpose and bar test specimens	D5939-96	
294-3:96	Injection moulding of test specimens of thermoplastic materials—Part 3:Small plates	D5940-96	
180:93	Determination of Izod impact strength	D5941-96	
179:93	Determination of Charpy impact strength	D5942-96	K7111:96
178:93	Determination of flexural strength	D5943-96	K7171:96
75-1:93	Determination of temperature of deflection under load—Part 1:General test method	D5944-96	K7191-1:96
75-2:93	Determination of temperature of deflection under load—Part 2:Plastics and ebonite	D5945-96	K7191-2:96

Table10-2 ISO-Standard Items Corresponding to ASTM and JIS Items

ISO	JIS	Title
10350:93	K7140:95	Plastics—Acquisition and presentation of comparable single-point data
3167:93	K7139:96	Multipurpose test specimens
11403-1:94	K7141:96	Plastics—Acquisition and presentation of comparable multipoint data—Part 1:Mechanical properties
11403-2:94	K7141:96	Plastics—Acquisition and presentation of comparable multipoint data—Part 2:Thermal and processing properties
294-1:96	(K7152)	Plastics—Injection moulding of test specimens of thermoplastic materials—Part 1:General principles, and moulding of multipurpose and bar test specimens

Table10-3 ISO and JIS Items as Employed in CAMPUS

10.1.3 European standards

CEN (Comite Europeen de Normalisation: European Committee for Standardization), was organized in 1961. It worked out ENs (European Standards) to lift technical barriers in international trades in Europe. CEN, on the one hand, has been working in close connection with the European-based ISO but, on the other hand, has a trait to create the standards of rather nationalized, localized or closed characters.

The following are other standards in Europe.

DIN : Deutsches Institut fuer Normung e.V.

BSI : British Standards Institution

NF : Normes Francaise

SIS : Standerdiserings kommissionen i Sverige

10.1.4 American standards

In ASTM (American Society for Testing and Materials), D20 Committee takes care of the standards for plastic materials. The Committee, under its core policy of internationalization, is promoting adoption of ISO standards into ASTM standards on a solid support by SPI (The Society of Plastic Industry Inc.). In 1996, ASTM adopted eleven items of ISO standards as fundamental test methods. See Table10-2.

ANSI (American National Standards Institute) authorizes American national standards. ANSI examines every private-sector standard before it is issued as a national standard.

SAE (Society of Automotive Engineers) issues the standards for automotive industry. The standards include the items on plastic materials; those items are being modified to accommodate ISO standards.

10.1.5 CAMPUS

CAMPUS (Computer Aided Material Preselection by Uniform Standards) is a database with which plastics users can make a first-step selection of materials. Plastics suppliers test the properties of their products on ISO standards, then put the data into floppy disks and deliver them, free of charge, to the plastics users. The users may process the data on their computers and select the materials.

Table10-3 summarizes the ISO-standard items, along with its JIS counterparts, as employed in CAMPUS. The ISO standards present so detailed specifications of the equipment, apparatus, procedures, and conditions in every step of testing a plastic material that the obtained data are highly reproducible and reliable. Accordingly, the data enable the users to study information provided by different suppliers on different grades of plastics.

A German non-profit company, CWFG (Chemie Wirtschaftsfoerderungs Gesellschaft mbH), owns the right of CAMPUS business, on which a user can make a contract to introduce CAMPUS. As of 1999, thirty-three European, thirteen American, one Australian, and several Japanese companies are the CAMPUS contractors.

The Japanese office of CAMPUS is JCC (Japan CAMPUS Committee) consisting of nineteen member companies. JCC has been collaborating closely with the members of Arbeitskreis Meeting (six companies from Europe and the U.S.A.), and succeeded in introducing the Japanese language into the CAMPUS Ver.4 for WINDOWS® in addition to English and German.

Arbeitskreis Meeting is working so closely with ISO that CAMPUS data are to evolve into a new version on a revision in ISO standards.

10.2 Electrical applications

Many countries have regulations and/or standards, voluntary or compulsory, to ensure electric/electronic product safety. To introduce a few of them: Electrical Appliance and Material Control Law in Japan, UL Standards by Underwriters Laboratories Inc. in the U.S.A., and CSA Standards by Canadian Standards Association in Canada.

On the urges by WTO-TBT for international unification of safety standards, many of the national safety regulations or standards are being modified worldwide to be in line with IEC (International Electrotechnical Commission) Standards.

10.2.1 Electrical Appliance and Material Control Law(Dentori-ho)

In Japan, electrical appliances can be divided into those to which the rules and regulations of Electrical Appliance and Material Control Law (Dentori-ho) apply and those that are not covered by Dentori-ho. The two types of appliances are controlled under different electrical safety systems.

Those appliances covered by Dentori-ho (Denki-

Youhin) are divided into Category A and B products under the Dentori-ho Rules and they are required to comply with the technical requirements set out by MITI (Ministry of International Trade and Industry). Category A products are required to be recognized by designated testing laboratories, at the same time with the registration of the manufacturing companies, but in terms of deregulation, they are gradually transferred to Category B. In fiscal year 1995, 117 items were transferred from Category A to Category B, and at present there are 165 Category A items and 333 Category B items. For Category B products, notification of commencement of business must be submitted and technical requirements of Dentori must be met (Self-check is acceptable.) before distribution.

The technical requirements of Dentori consist of Ministry Act No.1, which regulates Japan's own safety standards and Act No.2, which is based on IEC standards (including deviations). Now harmonization of Dentori technical requirements with international standards is being promoted; the promotion systems of JIS standards and IEC standards have been unified. Since 1996, JIS standards have been taking in IEC requirements (IEC-J).

As for products not covered by Dentori, voluntary requirements have been set up by related organizations to secure product safety.

In terms of deregulation, transfer from national certification to third-party certification has been desired. A third-party certification system was inaugurated by SCEA (Steering Council of Safety Certification for Electric and Electronic Appliances and Parts of Japan) in 1995. It covers non-Dentori products as well as Dentori products.

Presently, revisions to Electrical Appliance and Material Control Law are under deliberation at Diet and expected to be passed soon.

10.2.2 Optional Registration System for Components and Materials Used in Electrical Appliances

Optional Registration System for Components and Materials Used in Electrical Appliances was inaugurated in 1990, but registration systems of components and materials existed before that. In 1977, verification test on temperature index of insulation material was systematized; in 1985, ball pressure test on thermoplastic was systematized.

When horizontal burning test on synthetic resin material used as enclosure was systematized in 1990, components were added in the system, and CMJ (Certification Management Council for Electrical and Electronic Components and Materials of Japan), was established and Optional Registration System for Components and Materials in Japan was inaugurated. Testing in type approval for final electric and electronic products can be waived the test for components and materials registered under this Optional Registration System.

In the third-party certification system of SCEA, inaugurated in 1995, registration data from this Optional Registration System is to be utilized.

The following are the materials registration items under this system.

1 Verification test on temperature index of insulating materials
2 Ball pressure test on thermoplastic
3 Horizontal burning test on synthetic resin material used as enclosure
4 Vertical burning test on synthetic resin material
5 Vertical burning test on printed circuit board
6 Flammability test on equipment wire

In Optional Registration System for Components and Materials Used in Electrical Appliances, the registration institute of materials is JET (Japan Electrical Safety & Environment Technology Laboratories, formerly Japan Electrical Testing Laboratories), and the verification institutes are JET and JQA (Japan Quality Assurance Organization).

Every year, a component and material list book with a green cover is issued by CMJ.

10.2.3 IEC Standards

IEC (International Electrotechnical Commission) is a non-governmental organization with its headquarters in Switzerland. IEC is aimed to promote international cooperation in the tasks on all problems and issues relevant to standardization of electrotechnical matters, and thus intended to encourage international communication.

The Japanese government approved IEC standards in 1983 under the Electrical Appliance and Material Control Law. At present, the law, JIS and the technical standards are being aligned with IEC standards.

The IEC Technical Committees for plastics are

TC15 (Insulating materials) and TC89 (Fire hazard testing) . They discuss the methods for long- and short-term durability test and burning test on insulating materials.

The IEC standards for testing plastic materials include the burning tests with a flame, IEC60707, IEC60695-11-4, IEC60695-11-10, IEC60695-2-2; without a flame, IEC60695-2-1 (Glow-wire test); the comparative and the proof tracking indices, IEC60112; and the thermal endurance properties of electrical insulating materials, IEC60216.

The standards for electrical end-use products include IEC60065 (Audio, video and similar electronic apparatus), IEC60335-1 (Household and similar electrical appliances), and IEC60950 (Information technology equipment). Those standards incorporate the requirements on material quality.

Most of the European nations have already harmonized their respective national standards with IEC standards. European testing laboratories do not employ the plastic-material-registration system; they directly test the end-use products for electrical-safety approval.

In Japan, an access to the IEC-standard tests is open through JET, JQA, or several other institutions.

10.2.4 UL Standards

UL (Underwriters Laboratories Inc.) is a non-governmental not-for-profit organization in the U.S. A. UL sets the standards and implements the tests mainly for the safety of electrical end-use products, parts and materials.

UL standards are the voluntary criteria that have no legal binding force. However, since many of the state- or local-governments require the electrical products to conform to the UL standards, the standards are almost mandatory for the products. The U.S. federal government has not settled any electrical safety standards by itself; instead, it has transferred to the state governments the competence of addressing the safety matters.

UL standards include three different areas to cover: end-use products, the parts of the end-use products, and the materials of the parts. The major standards on plastic materials are UL94 and UL746.

UL has a registration system for plastic materials, in which the end-use products made of UL94- or UL746-registered plastics are exempt from some of the tests for registration of the end-use products.

UL94 addresses the flammability tests of plastic materials, and the flammability classifications on the test results: cf. Table10-4.

UL746A covers the short-term property evaluations, as listed below, for defining the performance of polymeric materials. This standard explains test procedures, and recommendations of performance-level categories.

1 Dielectric Breakdown Voltage and Strength
2 Hot Wire Ignition(HWI)
3 Comparative Tracking Index(CTI)
4 ASTM D495 Arc Resistance(D495)
5 High-Current Arc Ignition(HAI)
6 High-Voltage Arc-Tracking Rate(HVTR)
7 Deflection Temperature Under Load
8 Mechanical Properties Tests

UL746B elaborates on the long-term thermal-aging test of plastics. The test determines the Relative Thermal Index (the continuous-use-temperature rating) of the material by measuring the time to reach 50-percent retention of its unaged values of mechanical strength and dielectric strength. The UL test is different from its counterpart in IEC60216 in respect that the UL method determines RTI(Relative Thermal Index) by relating the data on the candidate material to those on the control material of a known index.

UL746C is for evaluation of the polymeric materials to be used in specific applications in electrical end products. There are flammability tests using a needle flame, a 3/4-inch flame and a 5-inch flame. The registration items for plastic materials include the data from the tests on (1) metallized parts, and (2) ultraviolet light exposure, water exposure and immersion.

UL746D, often called a "molder program", contains requirements to ensure traceability and performance of parts molded and processed from polymeric materials.

Parts shall not be molded from material that contains more than 25-percent thermoplastic regrind by weight, that has been dry blended by the molder with the same grade of virgin material, unless the results of a separate investigation indicate acceptable performance for the specific part.

Test	Flammability Classification
Horizontal Burning Test	94HB
20mm Vertical Burning Test	94V-0, 94V-1, 94V-2
500w(125mm) Vertical Burning Test	94-5VA, 94-5VB
Thin Material Vertical Burning Test	94VTM-0, 94VTM-1, 94VTM-2
Horizontal Burning Foamed Material Test	94HF-1, 94HF-2, 94HBF

Table10-4 UL94 Test and Flammability Classification

11 PRODUCT SAFETY AND ENVIRONMENTAL PROTECTION

11.1 Product safety

11.1.1 PL law (Product Liability Law, Japan)

Product Liability Law was promulgated as Law No. 85 on July 1, 1994 and has been enforced since July 1, 1995. In the U.S.A., many judicial precedents have been accumulated from the 1960s. There have been instances where Japanese manufacturers were involved. In Europe the PL law has been incorporated into the domestic laws of the member nations of the European Communities by the Council Directive issued in 1985, but the number of judicial precedents are not so many.

In Japan, the PL law has been finally enacted after it was continuously proposed and discussed over 20 years. The substance of this law is closer to that of the EC countries. Before enforcement of the PL law, the product liability had been dealt with in the Civil Code (which makes no specific mention of product liability) since the Meiji era (1868-1912). However, under the Civil Code, a plaintiff had to prove the fault of a defendant on the theory of breach of contract or negligence. Under the PL law, a plaintiff only has the burden of proof as to the defect, damage and relation between defect and damage. There is no provision as to inference of defect and causal relations.

Provisions of PL law

The Provisions of the PL law are mentioned one by one as follows:

Purpose of the law (Article 1)

The purpose of the law is to protect the injured person by setting forth liability of manufacturers for damages to life, personal injury or property.

Definition of terms (Article 2)

"Product"

Product is defined as any movable property that is manufactured or processed. Primary agricultural products and game are not included as products.

"Defect"

Defect is defined as the lack of safety a particular product ordinarily should possess, considering the nature of the product, the use of the product ordinarily expected, the time when the product is delivered and other circumstances relating to the product.

"Manufacturer"

PL law defines "manufacturer, etc." as the person who produces, processes or imports the product as the business or who makes the representation as the manufacturer on the product in such a way as causing other persons to believe himself for manufacturer.

"Product liability" (Article 3)

When the life, body or property of a person is damaged due to a product defect, the manufacturer shall be liable for the damage.

(This doesn't include compensation for the loss of product itself.)

"Exemption from Liability" (Article 4)

The manufacturer shall be exempted from liability when the manufacturer could not recognize defects from the level of science or technical knowledge at the time of delivering the manufactured product (so-called defense of development risks).

The manufacturer shall be exempted from liability where the product is used as a component or raw material of another product and the defect is solely attributable to the design or direction by the manufacturer of another product concerned and there is no fault on the part of the manufacturer.

"Time Limitations" (Article 5)

The first statute of limitation provides that injured person or his legal representative is required to exercise the right within three years from the time he discovered the defect. The second limitation restricts the injured person from bringing suit more than 10 years after the manufacturer delivered the products. (When a toxic substance or others accumulate in the body of a person due to the defect of a product, the period of time shall be calculated from the time damage arose.)

"Damages" (Article 6)

The damages shall be based on the stipulations of this PL law and the Civil Code (the Law No. 89 of 1896). Therefore, as to damages, punitive or exemplary damages are not admitted. There is no deductible of damages and no limitation of liability per accident.

Measures to be taken by enterprises

The enforcement of the PL law makes it more easily possible for the injured person to pursue the claim for compensation to manufacturers when damage occurs. And it will also fill the role of preventing the damage to lives, bodies or properties of persons due to the defects of products.

Manufacturers should start from establishing their in-house system for reviewing the safety of products and preventing damage. Therefore, it is necessary for them to return to the basics and to thoroughly review designs, manufacturing process, descriptions and warnings / cautions on the use of products, and others.

The manufacturers should always prepare themselves to take prompt measures in relieving the injured person and preventing recurrence when damage occurs by any chance. They should utilize information materials issued by official institutions, industrial organizations and insurance companies.

11.1.2 OECD(Organization for Economic Cooperation and Development) Risk Reduction

The OECD Council Act on Co-operative Investigation and Risk Reduction of Existing Chemicals formally established the Risk Management Programme and lays out the guiding principles for all such actions. In particular, the Council:

1. Decided that member countries shall establish or strengthen national programs aimed at the reduction of risks from existing chemicals to the environment and/or the health of the general public or workers;
2. Recommended that member countries collaborate to develop common criteria to determine which chemicals are suitable candidates for concerted risk reduction activities; and
3. Recommended that, where appropriate, member countries undertake concerted activities to reduce the risks of selected chemicals, taking into account the entire life cycle of the chemicals. These activities could encompass both regulatory and non-regulatory measures including: the promotion of the use of cleaner products and technologies; emission inventories; product labeling; use limitations; economic incentives; and the phase-out or banning of chemicals.

Following approval of the Act, OECD began implementation of the Programme by means of a pilot-phase. Five chemicals were selected as part of the pilot phase: lead, mercury, cadmium, methylene chloride, and selected brominated flame retardants. For each of these substances, a status report has been published which describes the current knowledge of the chemical's life cycle (production, use, sources of release, environmental pathways), risk reduction measures in place, and the risk as perceived by member countries. These status reports have been published as monographs and are available to the public.

Now an OECD pilot project for "risk reduction" is under way for five substances, which are lead, mercury, cadmium, methylene chloride, and brominated flame retardants. Meantime, substances which are to be newly included into those subject to risk reduction management are being selected, and also the selection system is being organized.
(http://www.oecd.org/)

11.1.3 MSDS

An MSDS (Material Safety Data Sheet) is what a chemical supplier issues in order to provide information about possible dangers and hazards inherent in the supplied chemical. The MSDS is thus intended to prevent accidents or hazards arising from the supplied material.

The U.S.A. and European countries launched MSDS practice in the 1970s and rooted it as a business norm during the 1980s. The U.S.A. and the U.K. have legally obliged material suppliers to issue an MSDS.

ICCA (International Council of Chemical Associations), organized in 1990, deliberated ways for establishing worldwide MSDS standards. It worked out sixteen items and defined the order of arranging them in an MSDS. ISO (International Organization for Standardization) is elaborating on how to specify what in those sixteen items aiming to make and publish formal standards. ILO (International Labor Organization) adopted C170 Chemicals Convention, 1990, which was mainly intended for providing workers with information about the chemicals at their workplaces, and about appropriate preventive measures so that they can effectively participate in protective programs.

The first model of Japanese MSDS came out in 1985 from Japan Chemical Industry Association; and was revised in 1991. Around 1990, some suppliers set out issuing an MSDS on customer's request. Since 1993, the government has issued several administrative notifications on how to make and use MSDS.

Internationally unified standards are yet to be created for identifying the dangerous/hazardous materials that must be accompanied by an MSDS. For interim purposes, currently effective laws and/or United Nation's Classes/Divisions in Recommendations on the Transport of Dangerous Goods will be helpful. At present, most plastic materials do not fall in the chemical category where an MSDS is mandatory, unless otherwise designated by customers.

A guideline for drawing out an MSDS is available at Japan Engineering Plastics Technical Committee. A Japanese-language guidebook for making an English-language MSDS is issued by Japan Chemical Industry Association.

Unit: 1000ton

Total production of all plastics	14,660
Waste of all plastics	
Industrial waste	4,540
Non-industrial waste	4,550
Total waste	9,090
Handling of the waste	
Recycled	1,030 (11%)
RDF	50 (1%)
Incinerated	4,640 (51%)
Landfill	3,370 (37%)
Total	9,090 (100%)

Table11-1 Production, Waste, and Handling of Waste of All Plastics in Japan (1996)

Unit: 1000ton

Production of engineering plastics *	708
Waste of engineering plastics	190

* Note: Total of PA, POM, Modified-PPE, PC, and PBT

Table11-2 Production and Waste of Engineering Plastics in Japan (1995)

11.2 Recycling

11.2.1 Present status

Table11-1 shows the status of the plastics waste in Japan; Table11-2 is the status particularly of engineering plastics.

Table11-3 shows waste streams of plastics. This table presents ways of handling post consumer plastics: Repeated use of collected parts, Material recycling, Chemical recycling, Reduction agent in blast furnace, Thermal recycling and Final disposal.

Material recycling is the recovery of materials from the waste streams. In Japan, actually recycled engineering plastics are only some portions of copying-machine-toner cartridges. That is because the necessary systems are yet to be developed for an efficient and economical collection of discarded engineering plastics. The difficulty is that engineering plastics, unlike general-purpose plastics, are employed more in functional components, often very firmly joined to the metallic parts that are hard to be taken apart. Lately, a practical material recycling is under study in view of surging use of engineering plastics in the housings of copying machines and computers. To facilitate the material recycling, it may become necessary even to revise the product designs and to consolidate the grades of plastics for the housings.

Chemical recycling includes the recovery of monomers through molecular scission of condensation-polymerized polymers such as polyamides and polyesters. Another chemical recycling exploits various technical developments of late to recover fuel oil through thermal and/or catalytic decomposition of polymers. Several pilot-phase plants are in operation.

Reduction agent in blast furnace is a use of post consumer plastics as a replacement of a portion of the coke that is a chemical reduction agent in a blast furnace to make iron.

Thermal recycling is the recovery of thermal energy, which began by burning trash and garbage in an attempt to use the released heat for generating electric power. The modern thermal recycling is to burn RDF (Refuse-Derived Fuels), which are solid fuels made from waste.

11.2.2 Relevant laws

In Japan, there are two laws relevant to handling plastic wastes. One is the Waste Disposal and Public Cleaning Law (Waste Disposal Law), under The Ministry of Health and Welfare, to curb discharge of wastes, and for appropriate handling of the wastes in sorting, collection, re-use and disposal. The other is the Law for Promotion of Utilization of Recyclable Resources, under The Ministry of International Trade and Industry, to promote utilization of the post consumer plastics as industrial resources.

The Waste Disposal Law took effect in 1971. The law defines the terms of INDUSTRIAL WASTES and MUNICIPAL WASTES, and sets out the regulations on landfill-disposal sites. In 1991, the law was substantially amended to cope with the ever-swelling

Post consumer plastics

- **Repeated use of collected parts** Repeated use of collected industrial parts for the same function. The parts intended for repeated use should be shipped and used in a large volume for the same function; the matured systems are necessary for collecting, quality testing, and using the once-used parts.
- **Material recycling** Plastics collected from waste streams are melted then processed into products.
  - **Mixed-plastic recycling** A mixture of different plastics is melted then processed into products mainly for civil, architectural or agricultural applications.
  - **Single-plastic recycling** A collected and sorted-out lot of each individual plastic is melted then processed into products.
    - **Use as the same parts** The products are the remake of the same parts as collected.
    - **Use in the same area** The products are the different parts, yet for the same use-area as the waste sources.
    - Use in other areas
- **Chemical recycling** Recovery of monomers or fuel oil through thermal/catalytic decomposition of post consumer plastics
  - Recovery of monomers for polymerization into a re-born polymer of the same chemistry
  - Recovery of fuels for use as an energy source
- **Reduction agent in blast furnace** Post consumer plastics replace a portion of coke as a chemical reduction agent to make iron in a blast furnace.
- **Thermal recycling** Burning of post consumer plastics as a fuel to recover heat
  - **RDF(Refuse Derived Fuel)** Shaped into solid bars, chips, etc.
  - **Recovery of Steam/Electricity** Production of steam for heating a local area system, or for generating electricity
- **Final disposal**
  - **Incineration**
  - **Landfill**

Table11-3 Waste Streams of Plastics

volume of the MUNICIPAL WASTES: the amendment included the duties of the government, municipalities and enterprisers; and stipulated the rules on specified wastes. In 1994, the enforcement rules of the law were revised to strengthen the regulations on the landfill-disposal of shredder-dusts. In 1997, further modifications were made on the law to fortify the punishment for controversial illegal dumping of INDUSTRIAL WASTES.

The Law for Promotion of Utilization of Recyclable Resources came into force in 1991. The law specifies the products on which material recycling should be promoted and on which designing should be made with ease of recycling in mind (First-class Specified Product). The law stipulates that cans, PET bottles, and other containers must carry indications to facilitate sorted collection (Second-class Specified Product). Industrial Structure Council has created a guideline aimed to promote recycling. The guideline picks out a wider range of products than those specified in the Law for Promotion of Utilization of Recyclable Resources, and renders each product a guidance such as a design of an easy-to-disassemble structure to facilitate recycling.

In 1997, the Law for Promotion of Sorted Collection and Recycling of Containers and Packing came into effect. The objective of the law is to promote utilization of the ever-increasing refuse of containers and packaging as useful resources; and thereby to reduce the amount of waste from containers and packaging such as cans bottles, paper and plastic. This law makes clear the duties of consumers on sorted generation of wastes, of municipalities on sorted collection, and of designated manufacturers on recycling. Also, designated users, who can use the products of Recycling, have the obligation to use them. The law has been applied to PET bottles since 1997, and will be enforced on other plastics in the year 2000.

More laws will come into force to be abreast of the social awareness of the mounting ecological concern in recent years.

11.3 Environmental protection

11.3.1 ISO 14000-series certifications

11.3.1.1 History

1992 In the preparatory period leading up to the 1992 Earth Summit, The International Organization for Standardization(ISO) and International Electromechanical Commission(IEC) became directly involved. UN Conference on Environment and Development(UNCED) wanted to ensure that business was fully engaged in the process. The Business Council for Sustainable Development(BCSD) was established as a result of these efforts. This council went to the two international standards organizations to see what they were doing in the area of environmental management and to encourage them to become more active.

1993 The first meeting of ISO/TC207 was held at Toronto, Canada. ISO set up a Technical Committee, TC207, on request by BCSD.

1996 Five standards, ISO 14001 to 14005, took effect in September. Their Japanese counterparts became effective in October as part of Japanese Industrial Standard.

1997 The drafts of ISO 14040 to 14043 were completed; those four standards relate to LCA (Life Cycle Assessment).

11.3.1.2 ISO 14000 systems

SC1: EMS(Environmental Management System) ISO 14000-14009

The procedures of implementing an organization's Environmental Management System that may be harmonized with its policy, objectives and targets.

SC2: EA(Environmental Auditing and other related Environmental Investigations) ISO 14010-14019

The procedures of the conduct of EMS audits and guidance on the qualifications of internal or external environmental auditors and lead auditors

SC3: EL(Environmental Labeling) ISO 14020-14029

The principles and methods/procedures for Environmental Declarations and Claims.(Type 1, 2, 3,)

SC4: EPE(Environmental Performance Evaluation) ISO 14031-14039

Provide the guidance on the selection and use of indicators to evaluate an organization's environmental performance.

SC5: LCA(Life Cycle Assessment) ISO 14040-14049

Provide the principles, framework and methodological requirements for the LCA of products and services.

SC6: T&D(Terms and Definitions) ISO 14050-14059

Provide information regarding the terms used in the ISO 14000 series standards.

11.3.1.3 Recent movements

The main task of ISO is shifting from setting the standards for organizations on Environmental Management or Environmental Audit to setting the standards for products on Life Cycle Assessment and Environmental Labeling.

Studies are under way to combine environmental standards with quality standards.

11.3.2 Environmental Label

11.3.2.1 The standards proposed by ISO TC207/SC3

Type 1: The guiding principles and procedures for third-party environmental labeling certification programs.

Type 2: Guidance on the terminology, symbols and testing and verification methodologies an organization should use for self-declaration of the environmental aspects of its products and services.

Type 3: Guidance and procedures on a specialized form of third-party environmental labeling certification using quantified product information labels and preset indices.

11.3.2.2 Environmental Labels in some countries

Japan (Eco-mark)

In 1989, Environment Agency issued a request to Japan Environmental Association for devising an Eco-mark system.

In 1996, the action procedures were revised to incorporate the concept of lifecycle-of-merchandise into the certification standards. Also, the introduction of a scheme for manifestation of the marks enhanced the transparency of the system.

Germany (Blue-angel mark)

Germany was the world's first nation ever to introduce the environmental-label system in as early as 1978. Das Umweltbundesamt (The Federal Environmental Agency) runs the system in collaboration with Deutsches Institut fuer Guetesicherung und Kennzeichnung e.V. (Institute for Quality Assurance and Labeling (RAL)). The assessment criteria include the LCA concepts. The criteria are subject to review every three years as a rule.

About 4300 commercial items hold the certification for the mark as of October 1994. Three to five new items are joining every year.

Germany has prohibited addition of halogenated organic compounds into the plastic materials for use in workstation computers and printers. The same standard will apply to copying-machine materials in the near future. Standards are being prepared for certification of TV-parts.

Sweden (TCO'95)

Sweden created own environmental-label system, which is applicable to electric/electronic components.

This country has prohibited use of specified bromine-containing flame-retardants in the plastic products that weigh 25grams or more.

ISO/Type 3

ISO TC207/SC3 is deliberating on the proposed standard (environmental labeling). The standard requires the indications of consumption of resources and energy, and burden to the environment including atmosphere, water quality, and solid waste. Such indications should cover all stages of production, transportation, use, and disposal.

EU mark

The EU-participating nations adopted the mark in 1992 for urging their industries to make the products as much environment-friendly as possible. The other purpose of the mark is to provide as much information as available about the environmental influences of the products that consumers buy and use.

One hundred and eighty two products have earned the certifications, including such items as washing machines, detergents, paints and paper. EU Committee is discussing the standards for the labels to be placed on personal computers.

Nordic countries

White swan, 1989

France

Normes Francaise, 1992

The Netherlands

The Stichting Milieukeur, 1992

Spain

The AENOR-Medio Ambiente, 1993

12 PRIMARY PROCESSING: MOLDING AND FORMING

12.1 Primary processing methods

Among various methods for processing thermoplastic materials, the primarily important are injection molding, extrusion forming, and blow molding; see Figure12-1. Those methods commonly involve heating and melting the plastic material, then shaping, cooling and solidifying it to put out the product.

The injection molding is particularly suited to an economical mass-production of complicated-shape parts. Coloring can be incorporated in the molding operation. Integral molding of bosses, hinges, snapfit-beams and internal-threads are the normal practices to facilitate downstream assembling processes.

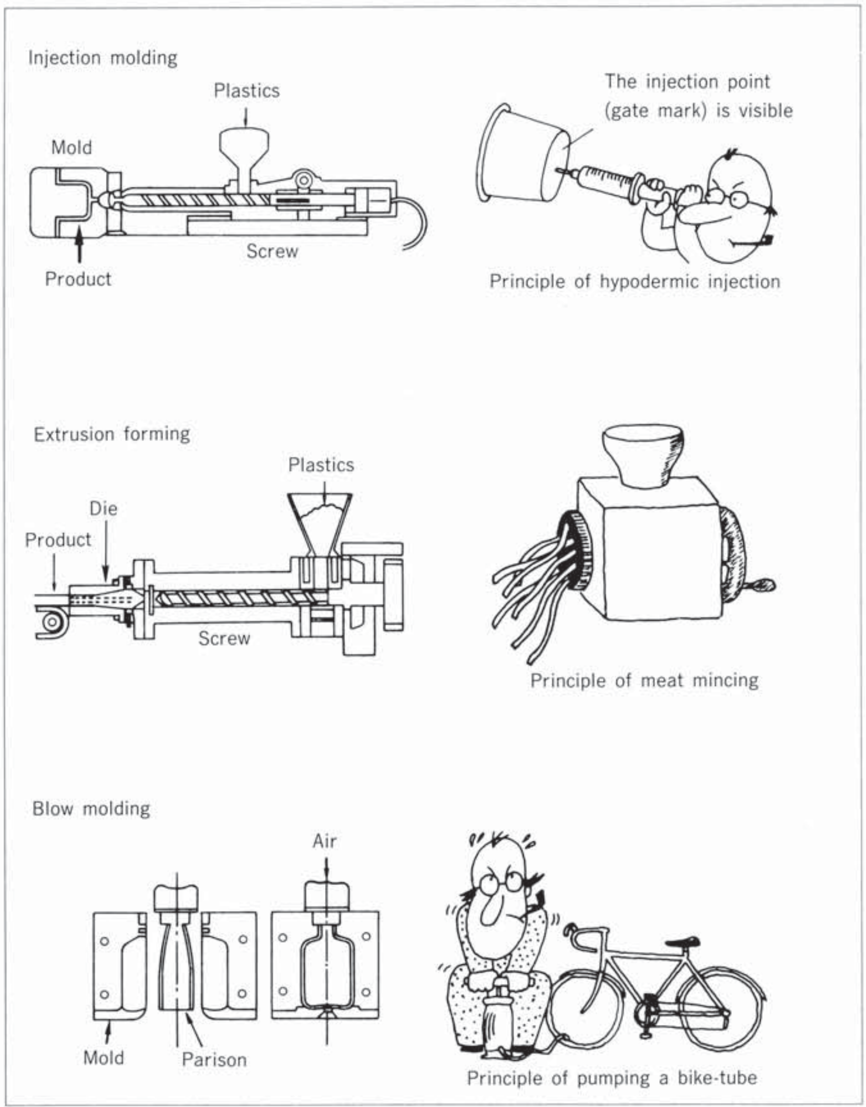


Figure12-1 Methods for Processing Thermoplastics

Injection-molded articles are readily usable as released from the mold.

Thermoplastics have distinctive economic advantages in processing as compared with thermosets or metals. Thermoplastics can melt and solidify over and again; this enables sprues, runners, odd materials or even used parts to go through recycling operations, which involve collecting, granulating or pelletizing, and reprocessing.

Thermosets, on the contrary, stand out of reprocessing because once they have experienced a thermal processing, the molecules are cross-linked into the three-dimensional networks that would never melt again.

Metals cannot but require multiple steps in processing such as cutting of the material (sheets, plates, rods etc), milling, grinding, lathing, drilling, and/or pressing, occasionally followed by finishing operations such as welding, plating and/or painting.

12.2 Selection of method

Melt viscosity is the prime index to determine the method of processing a material. The plastic of a high melt viscosity, i.e. a high molecular weight, is suitable for extrusion forming or blow molding. The plastic of a medium to low melt viscosity is mainly for injection molding.

Those processing methods have a basic operation in common. That is to melt and transfer forward the material in a heated cylindrical steel, called a cylinder or a barrel, that incorporates a screw rotating within it. The rotating screw gives the material a frictional-viscous work, which generates the internal heat. The electric band heaters wrapping on the cylinder supply the external heat to complete the thermal energy enough to melt the material. In some cases, another heater is embedded within the shaft of the screw.

12.3 Injection molding

The injection molding process consists of a series of operations as shown in Figure12-2: closing and clamping the mold, while the heating devices melt and plasticize the material in the barrel; ram the screw forward to inject the molten material into the mold through the flow channels of sprue-runner-gate; filling the cavity, where the product is formed in an exact duplication of the contour of the cavity;

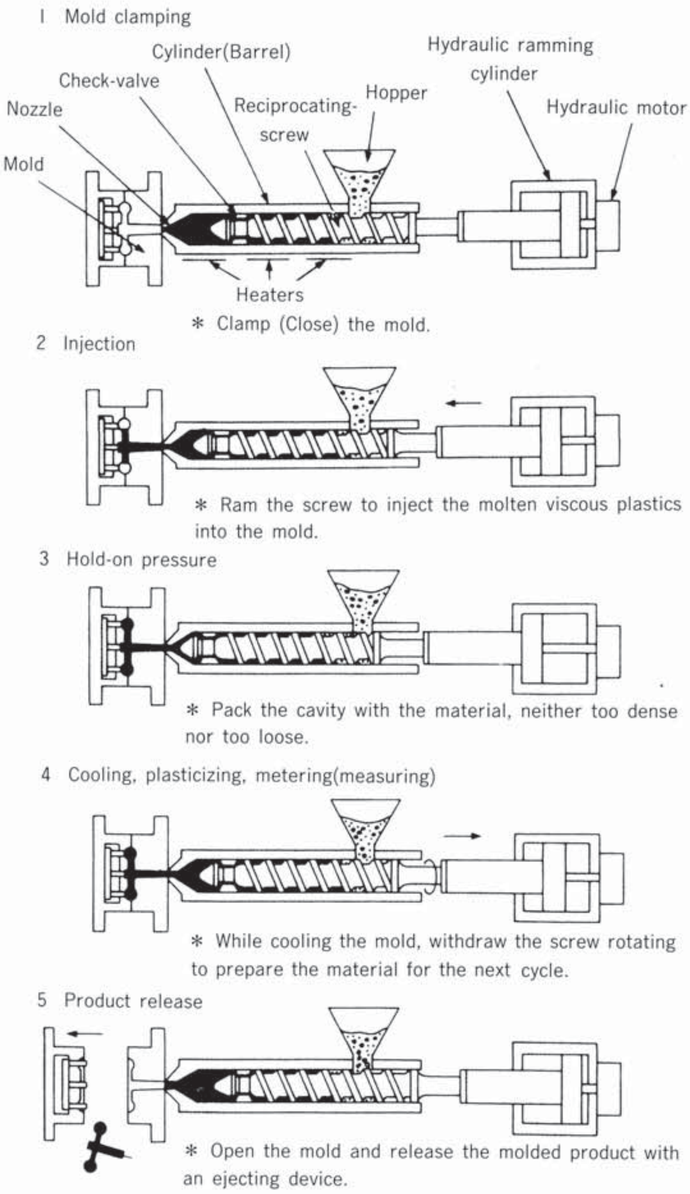


Figure12-2 Injection Molding Process

cooling the product to make it solid, while a portion of the material near the gate is rapidly freezing and sealing the gate to prevent the injected melt from backflowing in the flow channel; opening the mold to release the product, while the screw is rotating and moving backward as it plasticizes and meters (or measures) the newly fed material that waits for being used in the next "cycle" of molding. The term "cycle" here means one series of said operations from the mold clamping through the next clamping. The time needed to complete a cycle depends on the material: usually 7 to 15 seconds per 1mm wall thickness of the product. Table12-1 shows typical molding conditions for engineering plastics.

Injection molding of engineering plastics abounds with advanced technologies such as (1) control on the optimum mold-filling rate and/or pressure of the melt by a signal of detected cavity-pressure, which enables quick and uniform filling of the melt into a large number of small size cavities in one mold, (2) use of an electric servo-motor drive instead of a traditional hydraulic drive in efforts to save energy and to maintain a clean environment for production, and (3) high-cycle molding (reduction in cycle time), and use of a hot-runner(note) in order to save the material by reducing the output of solid sprues and

General-purpose engineering plastics	Injection pressure(MPa)	Mold temperature(℃)	Stock temperature(℃)
POM homopolymer	140 – 70	60 – 120	190 – 220
POM copolymer	140 – 70	60 – 80	180 – 230
PA6	140 – 35	40 – 95	240 – 300
PA66	140 – 35	40 – 95	270 – 325
PA610	140 – 35	40 – 95	230 – 280
PA MXD6	150 – 35	120 – 140	245 – 280
PBT	130 – 75	40 – 80	240 – 265
PET	140 – 60	90 – 140	270 – 305
PC	100 – 70	70 – 120	260 – 340
m-PPE	140 – 85	80 – 100	270 – 310
Specialty engineering plastics			
PPS	100 – 40	130 – 150	320 – 340
PSU	250 – 120	100 – 160	310 – 400
PES	160 – 100	120 – 160	330 – 370
PAR	180 – 140	80 – 130	330 – 390
PEEK	190 – 100	160 – 200	360 – 400
PEK	200 – 100	180 – 220	385 – 450
PEI	140 – 70	90 – 150	340 – 450
PAI	280 – 105	200 – 220	315 – 360
LCP (I.II)	160 – 120	70 – 150	360 – 390
PFA	100 – 40	150 – 200	350 – 390

Table12-1 Typical Conditions for Injection Molding of Engineering Plastics

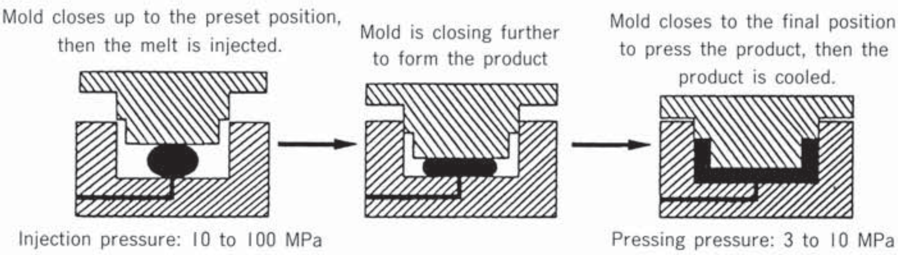


Figure12-3(A) Injection-press Molding Process --- Main Part

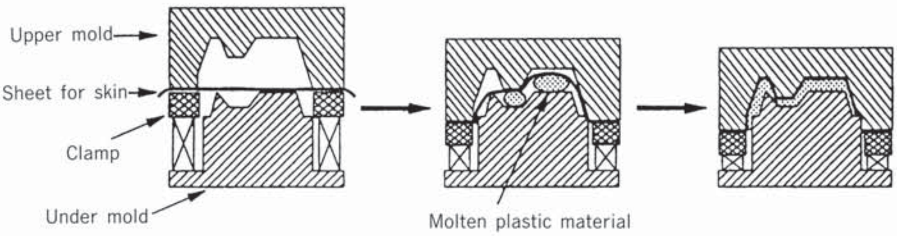


Figure12-3(B) Injection-press Molding Process --- Integral Skin

runners, which are useless items for the products. (Note: A runner that remains molten throughout the continued cycles of molding operation instead of being solidified in each cycle.)

Regular injection molding machines can bring out various products with the use of varied molds and conditions. Some specific machines are aimed at the maximum efficiency of a particular function: for example, SF(Structural Foaming), RIM(Reaction Injection Molding), compact-disc molding, and plastic-lens molding.

Some techniques have been devised and applied to the regular machines to make a product of an increased value at a decreased cost.

One of such techniques is termed as "injection-press molding", which enables a small-clamping-force machine to mold a large-sized product with a minimal warpage and distortion. See Figure12-3(A). The mold closes in the first stroke up to the preset position, the melt is injected into the cavity, then the mold closes in the second stroke toward the final position as it presses the melt within the cavity to form the product. A sheet may be placed in the cavity before injecting the melt, Figure12-3(B), so that the sheet can make an integral skin as the product is formed. That method can add an extra value (a surface decoration) to the product and save the costs of downstream finishing. The injection-press molding is finding ways in various applications.

The others of said techniques include two interest-

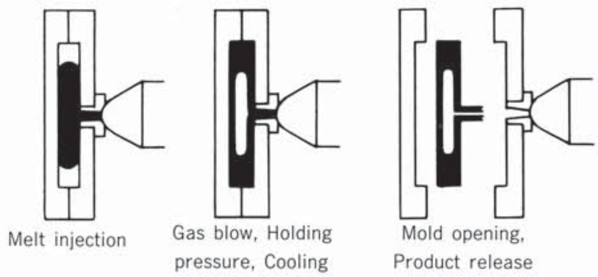


Figure12-4 Concept of Hollow-Product Injection Molding

ing processes for making hollow products.

One process is to blow a gas into the injected melt as shown in Figure12-4. The gas is introduced through either (A) the injecting nozzle on the injection machine or (B) an inlet hole on the mold. The hollow structure results in a lightweight product. The internal gas pressure abates sink marks; this gives designers a large freedom to design and position reinforcing ribs or varying-thickness walls on the product.

The other process, DSI(Die-Slide-Injection) process, is to mold a complicated-shape item in precise dimensions using the injection-molding machine equipped with a die-sliding mechanism. Figure12-5 shows the sequence of operations in the process: the first-stage injection molding forms a pair of halves of the product; then the mold opens and a half of the mold, called the die, slides to the second-stage molding position, where the molding operation joins the halves to complete the product. The DSI process has such advantages that it can form ribs inside the

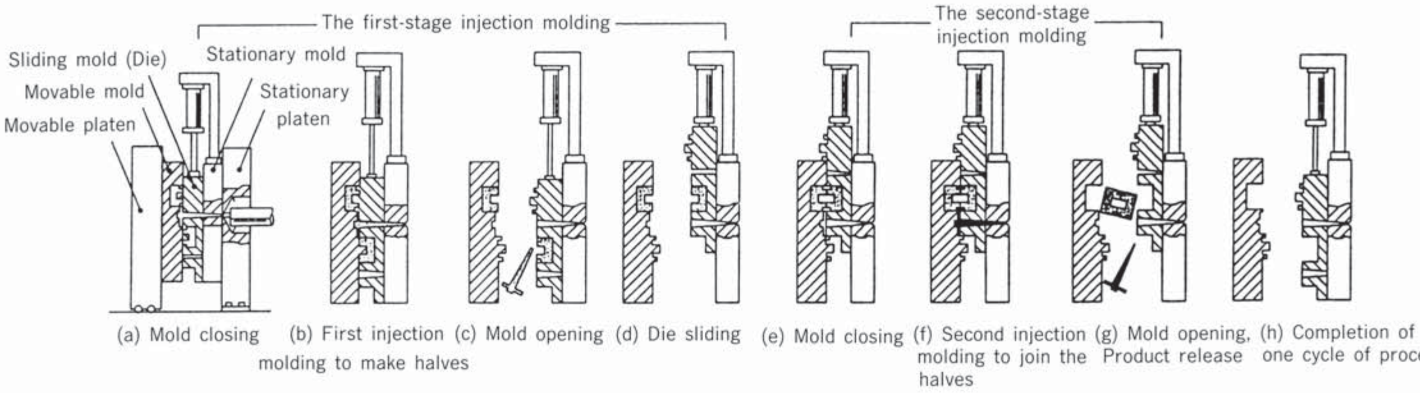


Figure12-5 Sequence of DSI Molding Process

hollow space, make an under-cut that is impossible with a usual injection process, and eliminate the need of a downstream process for joining.

12.4 Extrusion forming

This process is to extrude a molten plastic continuously through a die-hole of a specified geometry to make an endlessly long product. The product will have a cross section as determined by the die-hole geometry such as a circle (to make rods, tubes, or pipes), a rectangle (to make sheets, films, or boards), or even a more complicated shape (profile extrusion). Extrusion of plastics or rubber with a copper wire being continuously fed at the center of the die-hole brings out an electric wire covered with the extruded material.

One interesting development among the extrusion processes is for making a ribbed pipe that has a series of cross sections of specific profiles along the length of the pipe. The essential elements of the process are a cooling core and a number of mold-blocks. The cooling core sits on the die-head. One mold-block comprises two halves, each of which has a cavity to form the ring-ribs on the product pipe. A number of mold-block halves are linked one after another to make a loop-train, which looks like a caterpillar track. Two of such loop-trains are installed so that each mold-block half on one train can pair with its partner on the other train to complete a mold-block at the preset position on the cooling core. The extruded melt fills the cavity in the mold-block; the filled and closed mold-block moves forward as the extrudate comes out allowing the next mold-block to reach the cooling core; meanwhile, the melt cools to solid within the cavity on the cooling core; on completion of the cooling, the block opens, separates to two halves and leaves the product pipe. The produced ribbed-pipe outranks a regular pipe in compression stiffness and joint strength owing to the reinforcement with the ribs. The product is easy to cut along a valley between ribs.

12.5 Blow molding

A plastic bottle, that is a typical hollowware, is a representative product made by blow molding.

The blow molding process is to extrude a molten material to form a tube specifically termed as a "parison"; then enclose the parison in a mold with the ends of the tube pinched to be air-tight; blow air into the parison, which inflates to reach the contour of the cavity; cool the formed material to make it a solid product; and release the product from the mold. This process features production of a hollow article using a low-cost mold. Diverse blow-molded articles are in use in our everyday life.

One example from the recent developments in blow molding technology is the process that uses plural extruders to put out a multilayered parison to be blown to make a product. A different plastic material in each layer is assigned to meet each respective property requirement, which makes a high-functional blow-molded product such as a large-size fuel tank for automobile.

Another example of development also uses plural extruders to make a parison that has different plastic materials along the length of the tube. The extruders share a die-head. They extrude each different material in turn to make the parison. Combined with such extrusion is a technology for positioning and blow-molding the parison in a three-dimensional manner. The product made by the combined technology can be a three-dimensional one-piece item to replace an assembly of plural different-material parts. For example, a conventional assembly of a rigid metal pipe plus a soft rubber hose is giving its place to the simple one-piece blow-molded item made of a stiff plastic pipe and a flexible plastic tube. Automotive industry is ahead of other sectors to employ such products in efforts to consolidate parts, trim weight, and reduce costs.

12.6 Other processing methods

Compression molding can preform such plastics as PTFE and PI, which are heat-meltable but difficult to flow because of a very high melt viscosity. The preform then goes through thermal treatment in a high-temperature oven before cooling to become a product.

Sheeting by extrusion forming is usually followed by press-punching or vacuum thermoforming, which shapes the sheet into a final product.

12.7 Computer-aided engineering (CAE)

Computer simulation of injection molding is becoming a popular practice thanks to the recent remarkable development, downsizing and lowering costs in computer technology.

Structural analysis (strength calculation and deformation calculation) can predict the strength and/or strain of the product (Photo12-1) before making a prototype, and can tell the right conditions to fill the mold in a uniform distribution of the material. Such computations can combine with Stereo-Lithography Technology to rapidly prototype the product model.

The computer technology has been industrially demonstrated in the analysis of flow of material filling the mold, hold-on pressure (Photo12-2), cooling, frozen-in stress, and molecular/fibril orientation. Varieties of softwares are now available for those analyses, as developed in Australia, the U.S.A., and Japan.

Blow molding is following injection molding to use such computer technologies.

The physical properties of the material in a melt-state should be known to execute those analyses. Accordingly, new-type testing machines are emerging for measuring changes in volume, specific heat, flow properties, and other characteristics at an elevated temperature and a high pressure.

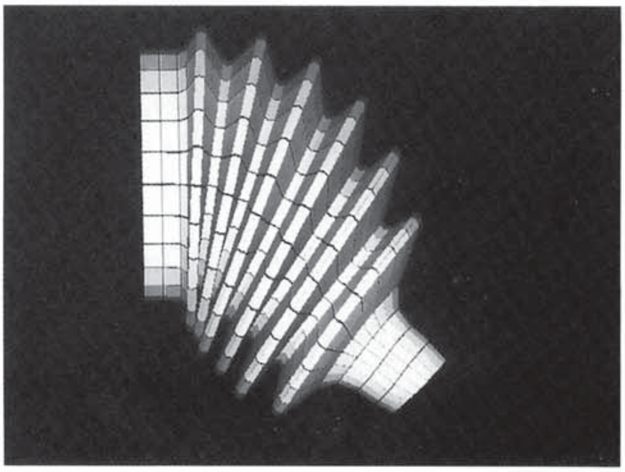


Photo12-1 Structural analysis: Strain in automotive boot

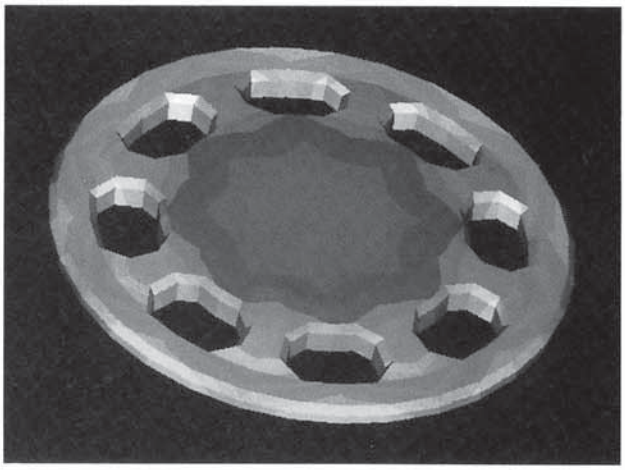


Photo12-2 Hold-on pressure analysis: Automotive wheel cap in a mold

13 SECONDARY PROCESSING: JOINING AND FINISHING

13.1 Joining

Plastic-model-fans and do-it-yourselfers are familiar with welding, adhesive bonding and other skills to assemble plastic parts. Table13-1 shows a variety of techniques to put plastic things together.

- Mechanical joining
  - Tapping screw
  - Press fitting
  - Snap fitting
  - Staking
  - Insert molding/Outsert molding
- Welding
  - Ultrasonic welding
  - Vibration welding
  - Spin welding
  - Hot-plate welding
  - Other welding methods
    - Dielectrically heated welding
    - High-frequency-induction heated welding
    - Hot-gas welding
    - Weld-rod welding
- Chemical bonding
  - Adhesive bonding
  - Solvent bonding

Table13-1 Methods for Assembling Plastic Parts

13.1.1 Mechanical joining

Tapping screw

Tapping screw is a means to fasten molded parts tightly. The plastic parts that have molded holes may skip a separate tapping procedure as is necessary for metal parts. That is because a tapping screw cuts a thread for itself as it fastens the parts. Figure13-1 depicts examples of tapping screws.

A special-type screw for fastening reinforced engineering plastics causes plastic deformation to occur on the inner surface of the hole to form a thread.

Where unscrewing for repair is in sight, embedding of a nut by insert molding or ultrasonic-insertion is recommendable.

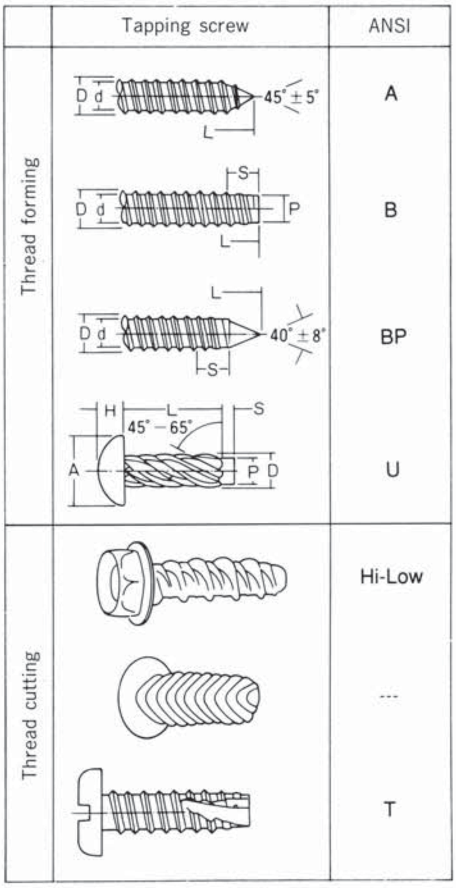


Figure13-1 Tapping Screw

Some specialty screws do not come loose on vibration.

Press fitting

This simple and most economical method of joining is to press a metal pin through the hole that is molded in a plastic part. The diameter of the pin is larger than that of the hole. Such dimensional difference between the diameters is called an INTERFERENCE, which can be made greater for the pin to go through a plastic part than to go through a metallic part.

Normally, a hydraulic or a pneumatic device is used for pressing the pin through the hole at an ambient temperature. An ultrasonic vibration device may be used to melt the plastic around the pin as the pin squeezes in. In some cases, the pin pushes into the part that is still hot immediately after molding.

Snap fitting

This is a simple, economical and unique-to-plastics joining method, which is widely adopted in buckles and industrial-use fasteners. The mechanism exploits the elastic recovery that is characteristic of plastics. There are two fundamental methods of coupling:

(1) A rod-to-cylinder coupling: a protrusion or a depression, formed on the outer surface near one end of a rod, squeezes respectively into a depression or a protrusion formed on the inner surface near one end of a cylinder, then elastically regains each original shape to complete coupling.

(2) A hook-to-hook coupling: a protrusion, formed on the elastic beam in one of the coupling pair, squeezes into a depression formed in the other of the pair, then the beam elastically resumes its original shape to complete coupling.

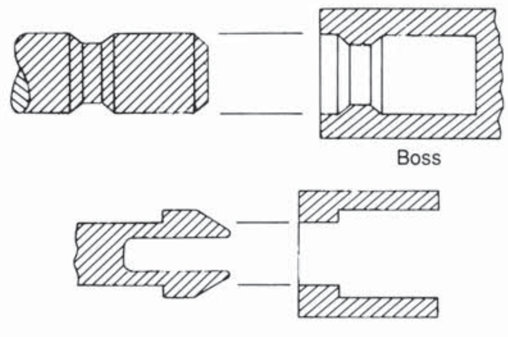


Figure13-2 Snap Fitting

Staking

This method is to form a cylindrical low protrusion on one of the joining plastic parts; prepare a hole on the other part, which is usually a metal or a plastic plate; pair the parts with the protrusion going through the hole; then crush down the head of the protrusion with a mechanical or an ultrasonic press to complete a firm fastening.

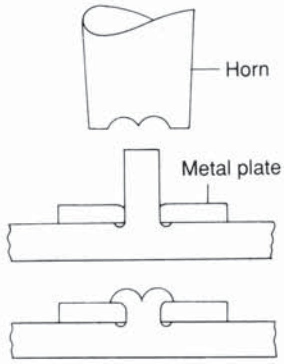


Figure13-3 Ultrasonic Staking

Insert molding/Outsert molding

Insert molding or outsert molding is the method for joining metal to plastic within an injection molding process.

The insert molding is to mold a plastic around a metal piece. In the finished article, the plastic embeds metal rods, nuts, sleeves and other components so that the metallic elements may bear the load beyond the strength of the plastic.

The outsert molding is to form plastic parts, such as pins and bushings, on a metal plate (base plate) placed in a mold. This molding method can form and accurately position a number of plastic parts in one injection process, thereby can eliminate downstream assembling processes. VTR chassis and other wide range of parts employ the outsert molding method.

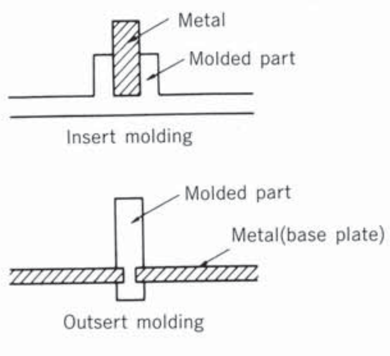


Figure13-4 Insert molding/Outsert molding

13.1.2 Welding

There are two types of heat source for welding. One is the external heat that is supplied to melt the plastic at the welding surface, such as in hot-plate welding and high-frequency-induction heated welding. The other is the frictional heat that is generated at the welding surface, such as in ultrasonic welding, spin welding and vibration welding.

Ultrasonic welding

This is a widespread method for joining engineering plastics.

Ultrasonic-waves come from the generator, through the oscillator and the resonating horn, to reach the contacting plastic surfaces. Where, the waves give rise to ultrasonic vibrations to generate frictional heat, which melt-welds the surfaces.

Ultrasonic welding features:

(1) High-speed welding

(2) The weld of a good appearance, secured tightness and high strength

(3) Consistent and reproducible results of joining.

Figure13-5 depicts the representative designs of joints, which are important to obtain an optimum welding.

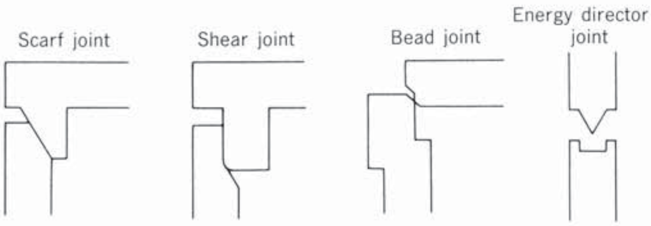


Figure13-5 Various Joints for Ultrasonic Welding

Vibration welding

This method is to press two plastic parts on each other, then vibrate them parallel to the plane of contact in about 3mm displacement relatively to each other so that the generated frictional heat can melt the surfaces to weld the two parts. The vibration usually completes within as short a time as three seconds. There are two vibration modes: the linear vibration mode and the orbital vibration mode.

This method is suitable for welding large sized parts, but takes a substantial investment costs in the facility and the part-clamping jigs.

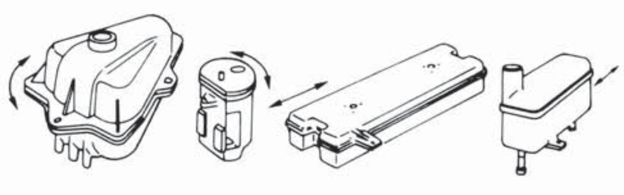


Figure13-6 Example of Vibration welding of Component

Spin welding

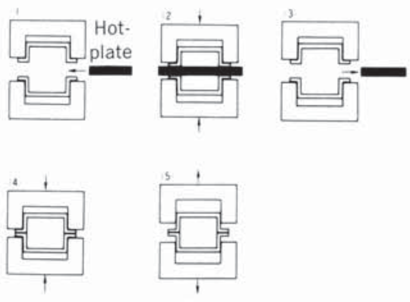
The joining parts rotate in contact with each other at a high velocity revolution, which generates frictional heat at the contacting surface to melt-weld the two parts.

This method has a long history in welding two circular parts or fitting a plug in a hole. The technology makes use of the sequence of phase-changes that is characteristic of thermoplastics: i.e. the plastic melts on heating, then solidifies on cooling.

Hot-plate welding

A simple device makes a very firm joint in hot-plate welding. This method takes time to complete a welding operation, but is suitable for joining large size parts to which ultrasonic welding is not applicable.

Figure13-7 is a rough sketch of the process. A plate, heated to a temperature above the melting point of the plastic parts, contacts the surfaces of the parts, with a FR sheet sandwiched in between. The hot plate melts the contacting surfaces, then retracts. The molten surfaces are immediately pressed against each other to complete welding.



(1) Plastic parts are set in place. Hot plate comes in.
(2) The parts press themselves onto the plate, then the surfaces melt.
(3) The hot plate retracts.
(4) The molten surfaces press against each other, then the melt cools down.
(5) The welded product comes out.

Figure13-7 Hot-plate Welding

Other welding methods

The following methods are not popular today for welding engineering plastics.

Dielectrically heated welding is for the plastic that has a significant dielectric loss. High-frequency-induction heated welding is to set a metal piece on the welding joint and heat the metal by means of electrical-induction.

Some other methods only by name are hot-gas welding and weld-rod welding.

13.1.3 Chemical bonding

There are two major methods of chemical bonding: the method to apply an adhesive, and the method to use a solvent to dissolve the surfaces to be bonded. What counts in those methods is the affinity of the plastic with the adhesive or the solvent.

Epoxide- or cyanoacrylate-adhesives are the most practicable for bonding engineering plastics, particularly semi-crystalline plastics. In some cases, corona discharge, primer coating, or other pretreatment of the bonding surfaces may be necessary.

Semi-crystalline plastics are generally resistant to chemicals and hence difficult to bond chemically. The ultrasonic or other welding will be more suitable to this type of material.

Amorphous plastics are chemically bondable even with a solvent. However, be wary about solvent cracking, which may arise from the contact between the plastic and the solvent or the curing agent.

13.2 Machining

Machining of engineering plastic rods, boards, or other stocks, is a good practice to make a prototype, or to manufacture only a few products in a very high dimensional precision. General-purpose engineering plastic materials are on the market in a broad variety of shapes and sizes.

Milling, cutting, drilling and other fundamental machining techniques for metals are also applicable to engineering plastics. But, the rotational speed, feed speed, tools, or other settings for machining must be prepared to deal with the viscoelastic behavior and the accumulation of frictional heat, which are inherent to the plastic materials. Also, an amorphous plastic such as PC is vulnerable to solvent cracking which may be caused by the cutting oil. A hard-metal cutting tool is suitable for machining GF-reinforced plastics. Thermal annealing is another important skill to remove a residual stress in the machined material.

13.3 Surface finishing

Printing, painting, plating, and other technologies make surface finishing, or decoration.

Engineering plastics have not seen many needs for surface decoration because they are employed mainly in the structural or mechanical parts. However, recent developments of high-added-value housings and other exterior parts are bringing about increasing opportunities of surface decoration on engineering plastics.

Another opportunity to enhance the value of the highly heat resistant plastics is in a plating technology to form electronic circuits.

Printing and Painting

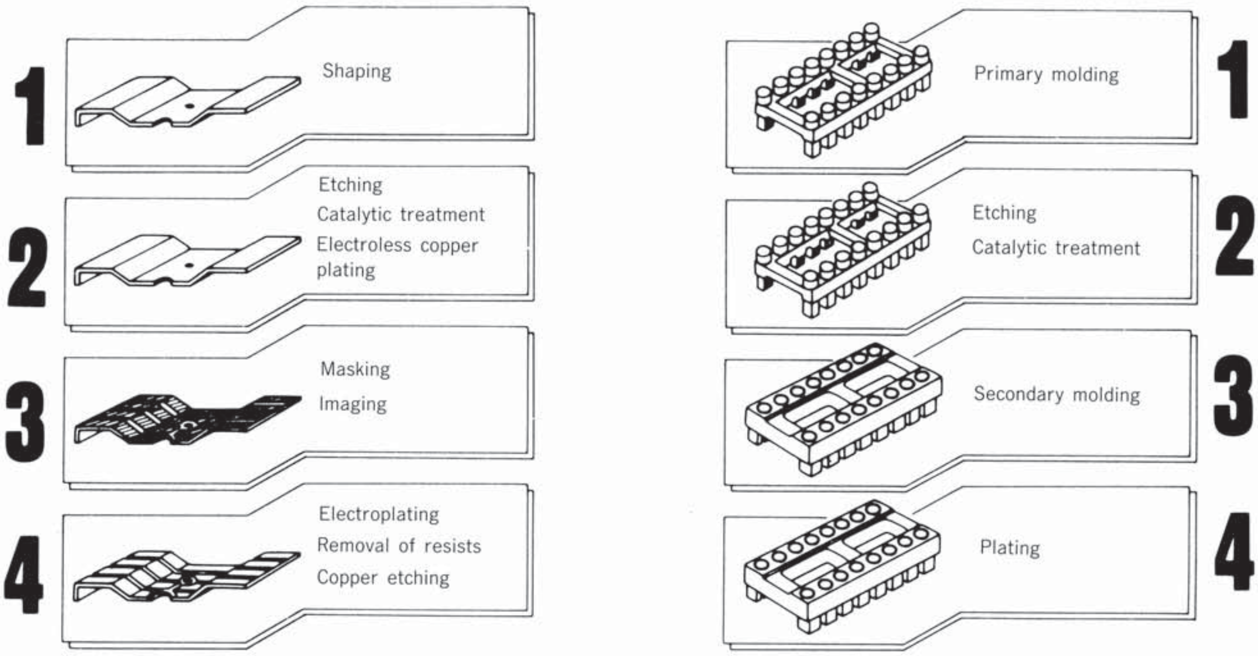
Conventional printing and painting technologies are generally applicable to engineering plastics. Since ink and paint are chemicals, a selection of them is as important as it is in chemical bonding. On semi-crystalline plastics, primer coating or corona-discharge treatment is effective to improve adhesion of the ink or paint to the plastic surface. On amorphous plastics, solvent cracking tests are necessary.

Impregnation printing (sublimation printing) is a technology uniquely applicable to plastics. Special impregnating ink diffuses into the plastics to the depth of several tens of microns resulting in an abrasion-resistant printing. Such printing technology is commercially applied mainly to PBT and POM.

Metallizing

Electroplating, vacuum metallization and spattering are among a few technologies commercially demonstrated to metallize engineering plastics.

One impressive development of late is MID (Molded Interconnection Device), which is made by direct metal-plating on a plastic base to form three-dimensional circuit patterns. The plastic base material is a platable grade of a soldering-heat durable plastic such as LCP. The MID technology has eliminated needs of conventional insert molding of metal parts such as lead frames and contact pins. This new device realized an improved reliability and a reduced cost. MID is taking part in a broad range of surface-mounting electronic parts.



One-shot molding process to form circuit patterns
(Semi-additive process)

Two-shot molding process to make IC socket

Figure13-8 MID Process

14 APPLICATIONS

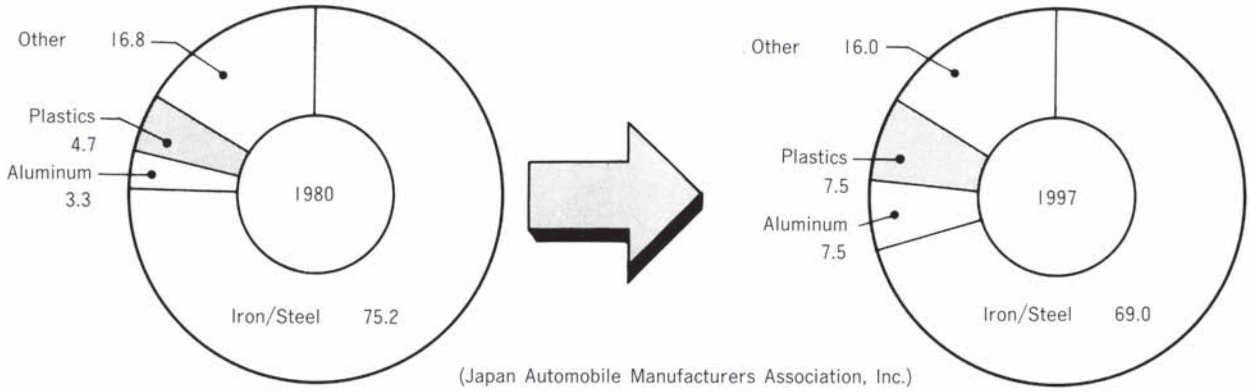
14.1 Automobile and other transportation

Automobile

Automobile is a principal and indispensable means of transportation today. In Japan, the automotive industry has evolved to be one of the leading and most important business players.

Numerous and diverse state-of-the-art technologies support the industry, which does not exclude the developments in the plastics sector. The automotive industry is ever seeking the lightweight materials to improve fuel consumption, which adds to the importance of plastics (Table14.1-2). The industry also appreciates the plastics' ability to design parts of complex shapes. Plastics have replaced a significant portion of metals in the automotive industry in a drive to use an ever lower-density material. The materials of many automotive parts have shifted from iron/steel to aluminum/light-metal-alloys and plastics (Figure14.1-1).

The growth in use of plastics in the automotive applications has been keeping pace with the growth of the automotive industry. In the late 1990s, plastics accounted for nearly 8 percent of the total materials consumed in the automotive industry (Figure14.1-1).



(Japan Automobile Manufacturers Association, Inc.)

Figure14.1-1 Materials Consumed in Automotive Industry, %

Engineering Plastics	Total shipment in Japan tons/year in 1997	Consumption in automotive industry tons/year (% on total shipment)
PA	224,000	90,000(40%)
PC	295,000	15,000(5%)
POM	156,000	55,000(35%)
Modified-PPE	94,000	24,000(25%)
PBT	79,000	28,000(35%)

Table14.1-1 Engineering Plastics in Automotive Industry in Japan

		Source of fuel consumption	Improvement in fuel consumption by reduction in weight
Driving resistance	Mechanical resistance	Mechanical loss in power transmission	No improvement without reduction in weight of power transmission
	Driving resistance	Rolling resistance	Proportionate to weight reduction
		Air resistance	No improvement
		Accelerating resistance	Proportionate to weight reduction
		Hill climbing resistance	Proportionate to weight reduction

Table14.1-2 Improvement in Fuel Consumption by Reduction in Weight of Vehicle

Meanwhile, engineering plastics have found expanding uses mainly in structural and functional components, and now take better than 10 percent of the total plastics for automotive applications. Table14.1-1 shows representative engineering plastics with their Japan total amounts of shipment, and the volumes and percentages as consumed in automotive industry. Plastics will continue to grow as a vital material for automobiles.

However, simple drop-in of plastics behind metals sees only narrowing opportunity in the future because plastics are no matches for metals in modulus, toughness, and other properties. To exploit the merits of plastics, a fundamental re-designing of automotive parts should often be necessary. From now on, the plastics sector should talk more positively to the automotive industry and tap opportunities to take part in the total designing of new components.

Engineering plastics are no longer the simple substitutions for metals and general-purpose plastics. Therefore, the future suppliers of engineering plastics should walk one step ahead of the potential needs and the developments of automotive components. That is, the suppliers should keep themselves prepared to offer new and own value-added materials accompanied by the recommendable processing technologies.

Recycling of materials with a view to environmental protection is another important argument for the plastics to be viable in the automotive industry. At present, only a limited portion of scrapped plastic parts, bumpers for example, is directed to recycling, but not to the same repeated use because of the technical difficulty to warrant the quality. In the circumstances, most of the near-term recycling studies will be centered on the use of recovered material for the parts different from the waste source. Figure14.1-2 is a chart of a recycling system. Many technical hurdles are present yet to be cleared before the whole system comes into practice: for example, how to collect the post-user cars systematically and how to sort the diverse materials recovered from the recycled parts.

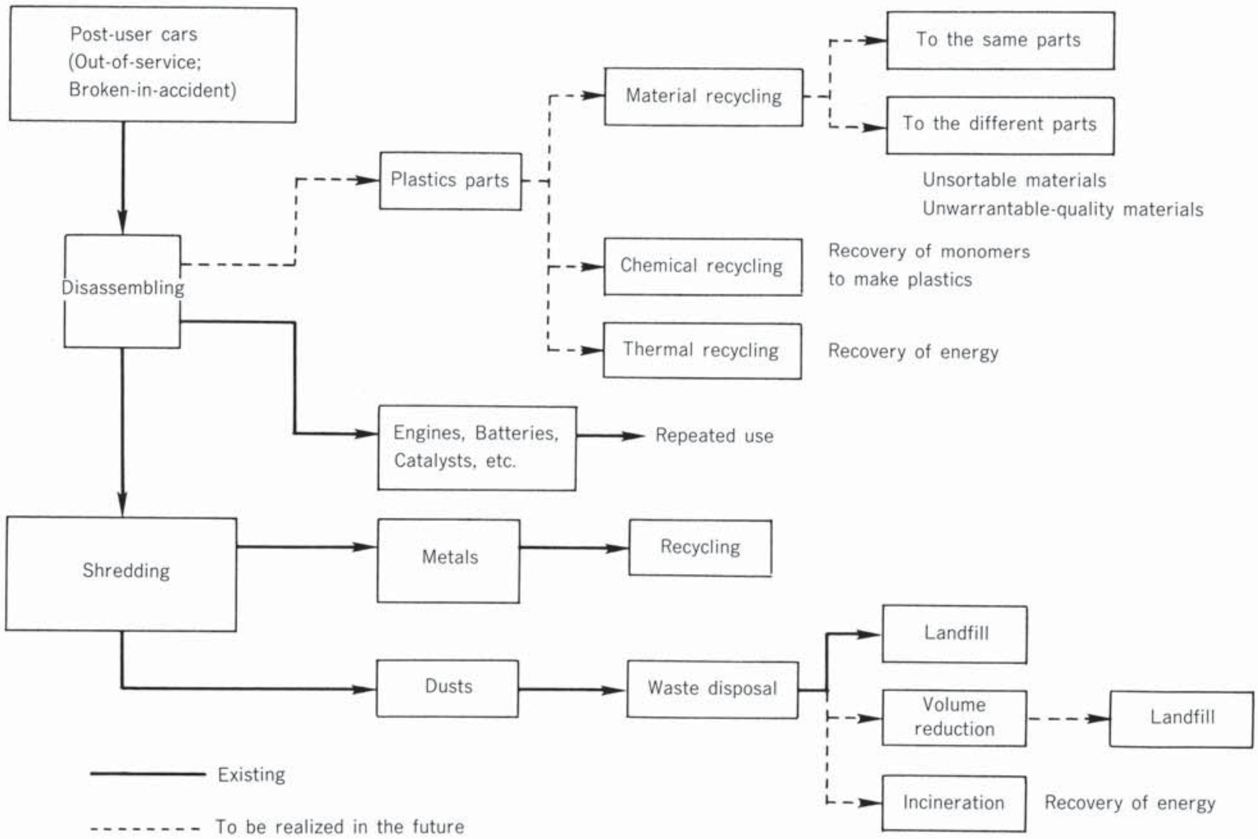


Figure14.1-2 Recycling System in Automotive Industry

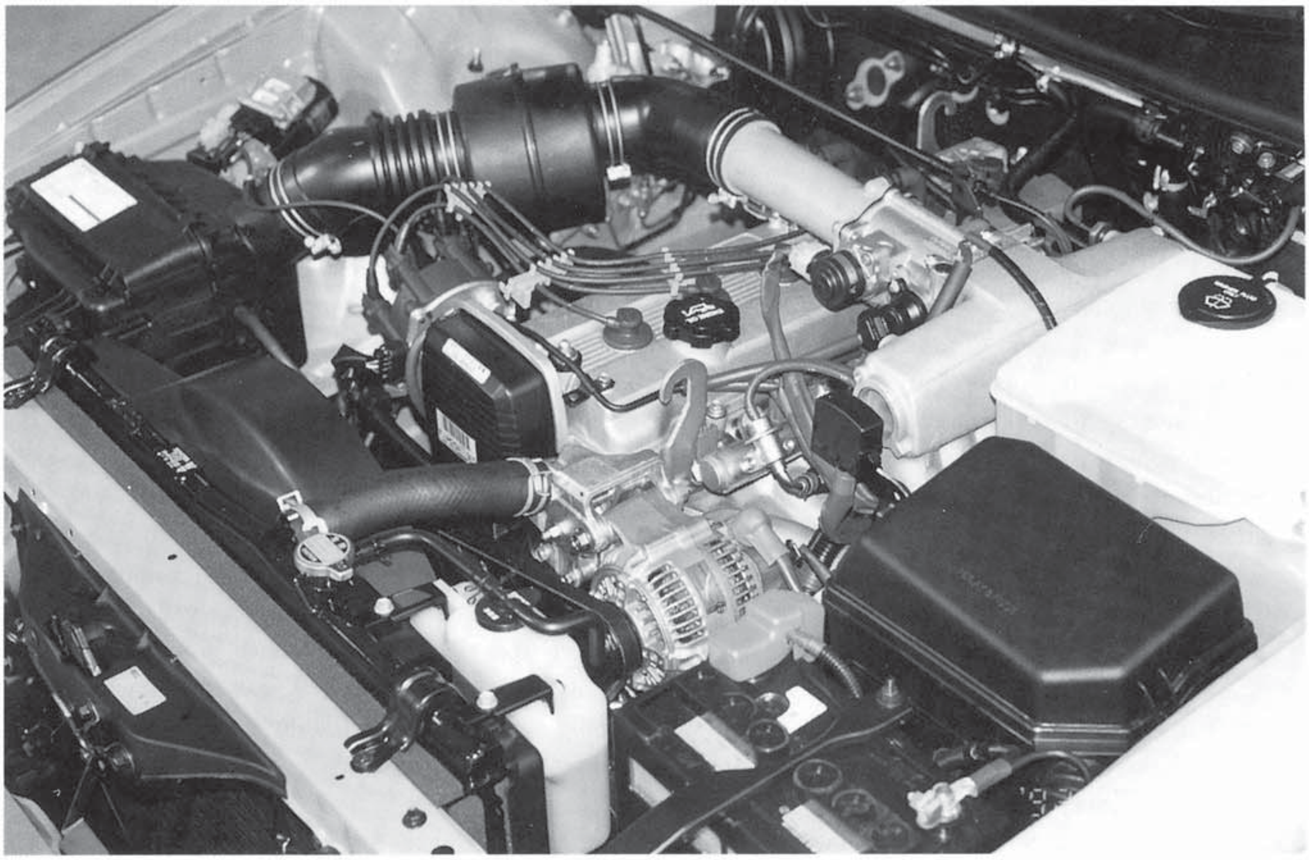


Photo14.1-1 A typical underhood view of a passenger car

Components around the engine

The underhood compartment of a passenger car is much smaller today than it was years ago. What restricts the compartment volume is a streamlined body for a better pneumodynamic performance, or an enlarged cabin for more comfort of passengers. Such a small compartment accommodates so many components: the engine and the drivetrain mechanisms; radiator and air cleaner; ventilator and air conditioner; various safety devices; driving equipment such as power-steering gadgets and automatic cruising controls; exhaust-gas treater; and so on. Photo14.1-1 shows a typical underhood view of a passenger car; it looks almost like a rain-forest. As such, the underhood temperature rises very high; and even higher if a turbo engine is installed for a higher power output, or if a noise-insulating cover is placed for a quieter passenger cabin.

A growing number of the underhood parts trust engineering plastics in respect that the material can stand up to the elevated temperatures. The engineering plastics for the underhood-service must have the following characteristics.

1 Stiffness at a high temperature
2 Resistance to chemicals: oil, grease, gasoline, and long-life coolant
3 Resistance to creep
4 Continuous-use-temperature rating not lower than 120℃
5 Good mechanical damping for suppression of resonant vibration
6 Impact strength
7 Dimensional stability
8 Manageability with the primary processing technologies (injection molding, blow molding, extrusion, etc.)
9 Manageability with the secondary processing technologies (welding, machining, etc.)

In addition to those characteristics, lightweight is another important merit of plastics. A future likely use in the fuel-system parts will claim an improved barrier to permeation of fuels.

Expectations are running high on engineering plastics in favor of their ability to design a complex-shape part that can fit snugly into a niche among the jammed underhood components. In this respect, engineering plastics should deal with the diverse and demanding service conditions that may arise from placement of components in the underhood compartment: for example, exposure to a localized high-temperature spot, an impact delivered by a bounced-up rock, and a chemical attack by an anti-freezing agent splashed from road in wintertime.

The following texts introduce some of the engineering-plastic automotive components that are mature or nearly fledged to be the commercial items.

Underhood components

Cylinder head cover

GF-PAs (PA6, 66) are employed for being lightweight to replace die-cast aluminum. The polyamides are favored for heat resistance, oil/grease resistance, mechanical strength, stiffness, and a noise barrier characteristic.

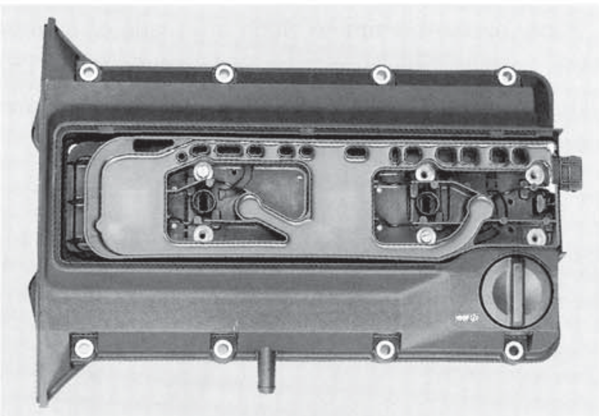


Photo14.1-2 Cylinder-head cover (GF-PA66)

Air intake manifold

Photo14.1-3 shows an air-intake manifold and air-cleaner made of GF-PA6. Either a lost-core method (using a core of a low-temperature-meltable metal) or a vibration-welding method is suitable for making a PA manifold, which is about 50 percent lighter in weight than a die-cast aluminum manifold. Reportedly, a 2-3 percent higher power output is obtainable from an engine equipped with the PA-made manifold because the plastic gives a smoother inner-surface and a higher heat-insulation as compared with the die-cast aluminum.

Shown in Photo14.1-4 is a multilayer-molded manifold. Lately, automakers are developing a broad variety of processing technologies relating to blow molding, injection molding and vibration welding. One of such technologies is to insert a blow-molded multilayer article (non-reinforced PA11 inner layer; GF-PA6 outer layer) into an injection tooling, then injection mold the outermost layer with GF-PA6.

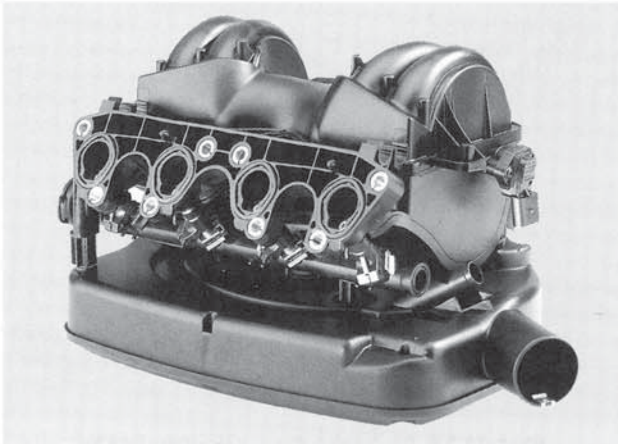


Photo14.1-3 Air intake manifold (GF-PA6, assembled with vibration-welding method)

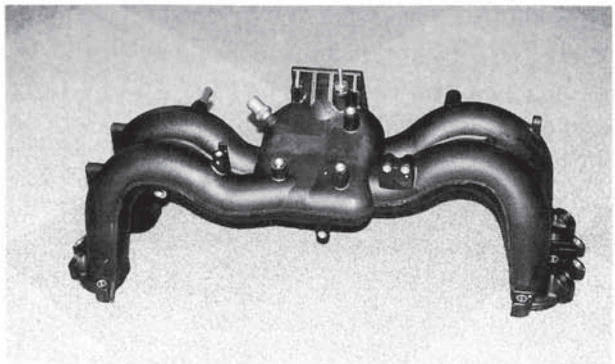


Photo14.1-4 Air intake manifold by multilayer-molding (PA11, GF-PA6)

Air intake duct

Photo14.1-5 shows an air intake duct made of a stiff body of GF-PA6 combined with a flexible end of PA12. Such combination of materials features absorption of vibration which may arise during assembling the parts as well as driving the vehicle.

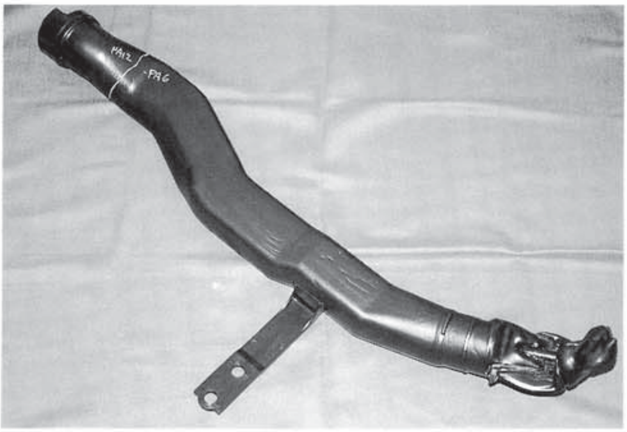


Photo14.1-5 Air intake duct (GF-PA6, PA12)

The duct to lead air from air cleaner to intake manifold is located very close to the engine. The material of the duct must have oil/grease resistance, a high heat endurance and a high modulus at an elevated temperature. Blow molding of GF-PA6 is practicable to make the duct.

Cooling fan

Cooling fans are made of PA66 or GF-PA6(for large size fans), which has strength, heat resistance and fatigue endurance.

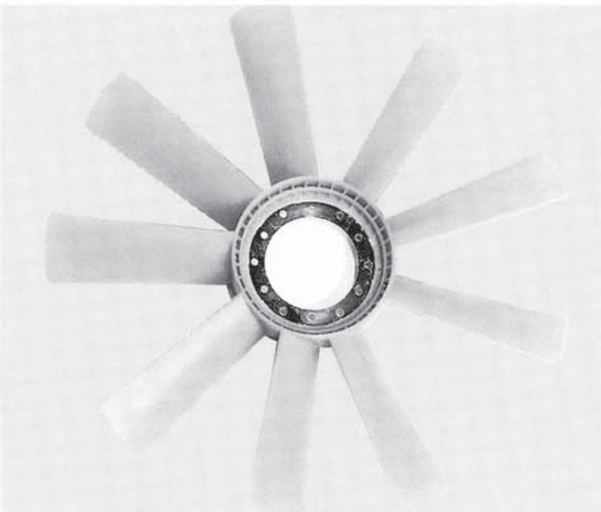


Photo14.1-6 Cooling fan (GF-PA6, GF-PA66)

ABS (Antilocked Brake System) module

A special PA66 with improved weld-line strength is used as the material of this module. Particularly demanded are the weld-line strength and the chemical resistance to calcium chloride, besides such fundamental properties as strength and heat resistance.

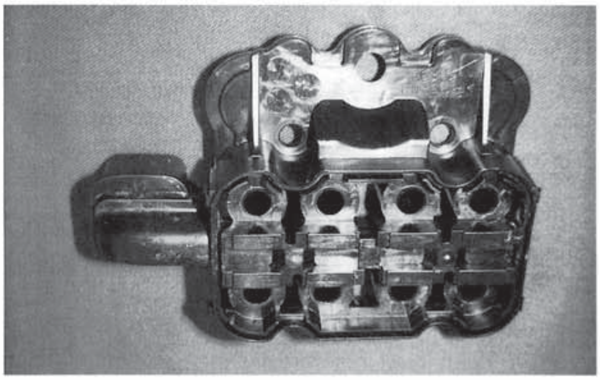


Photo14.1-7 ABS module (PA66)

Chain guide and tensioner

Those parts of a timing chain are made of PA6 or PA66, either reinforced or non-reinforced. The materials are resistant to heat, oil/grease, and frictional wear.

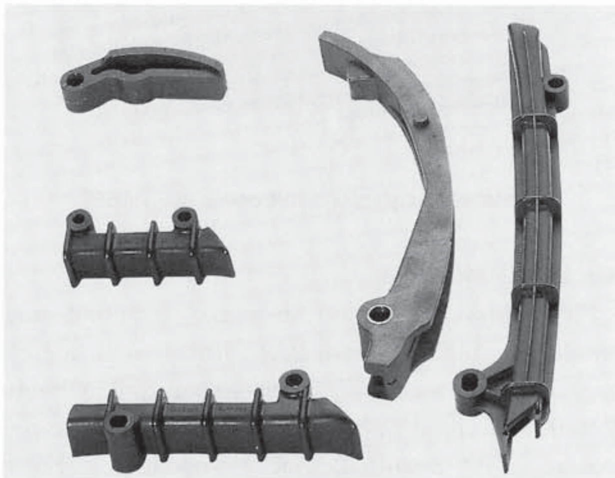


Photo14.1-8 Chain guide and tensioner (PA6, PA66)

Clip

PA/PP-alloy is a low-density material with low absorption of water and makes good integral hinges, hence favorable for making clips. The alloy takes the merits and avoids the demerits of PA.

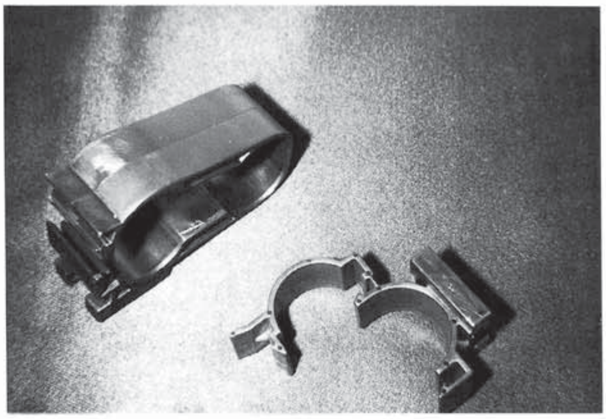


Photo14.1-9 Clip (PA/PP-alloy)

Engine mounting part

Photo14.1-10 shows an engine mounting part made of an impact-improved GF-PPS. The material of this part is shifting from metal to PA, or to PPS. The most needed property is the chemical resistance to LLC(Long Life Coolant) followed by stiffness and impact strength.

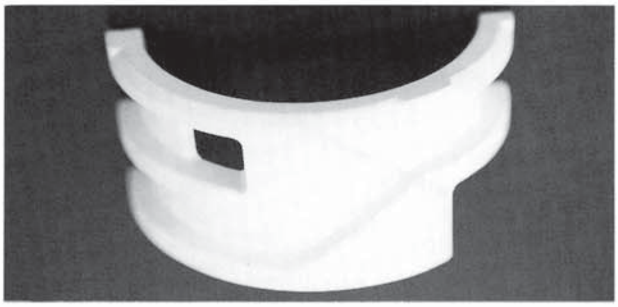


Photo14.1-10 Engine mounting part (GF-PPS)

Water pump impeller

PPS applies its toughness, dimensional stability, hot-water resistance, and chemical resistance to making the water pump impeller.

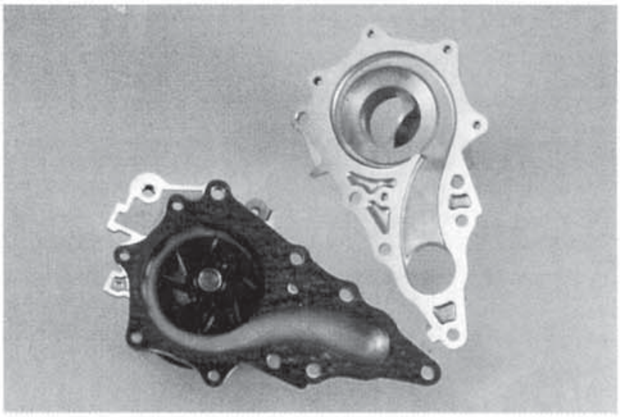


Photo14.1-11 Water pump impeller (PPS)

Pipe joint

A pipe joint on a fuel line that leads to the fuel tank is made of PPS, which is mechanically strong, and resistant to heat and chemicals.

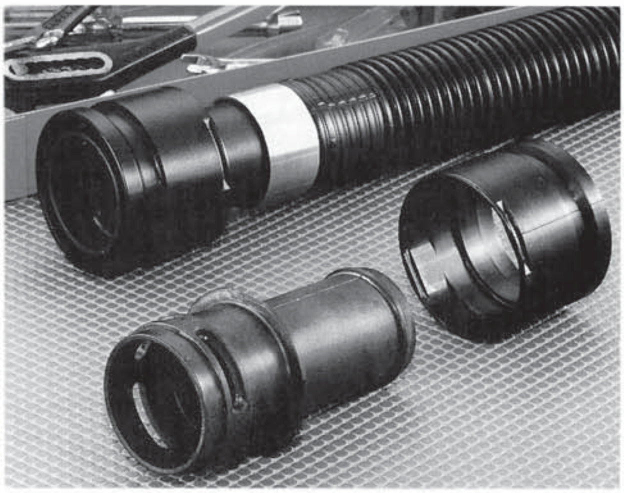


Photo14.1-12 Pipe joint (PPS)

Thermostat housing

PPS, which is tough and heat resistant, makes a thermostat housing attached to the engine block.

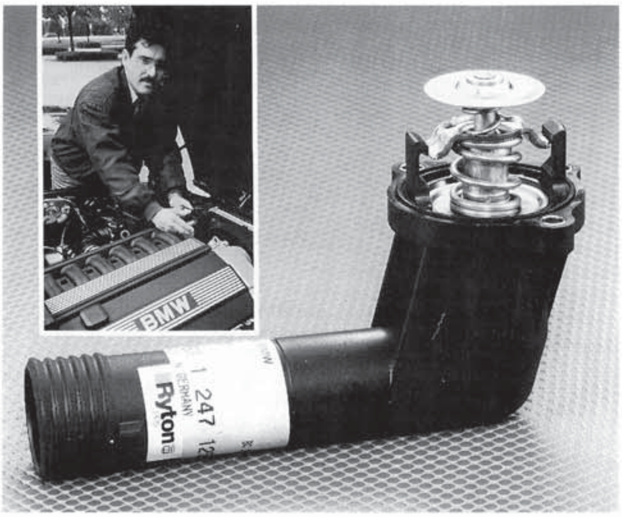


Photo14.1-13 Thermostat housing (PPS)

Air flow meter

Use of MD-PBT was successful to make an air flow meter of 30-percent less volume and 50-percent less weight. The air flow meter monitors the amount of intake air to make an optimum mixture of air-and-fuel gas for an electronic fuel injector.

The developmental study exploited the design freedom of plastics to make an air flow meter of higher-in-performance and lighter-in-weight than a conventional die-cast aluminum device.

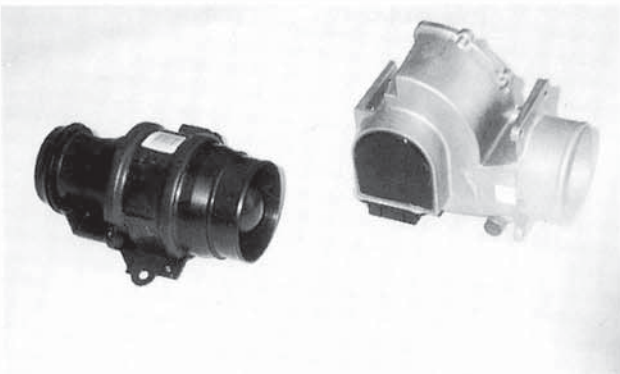


Photo14.1-14 Air flow meter (MD-PBT)

Ignition coil cover

The automotive ignition device employs GF-PBT as its material in favor of toughness, heat resistance, electrical insulation and a good moldability.

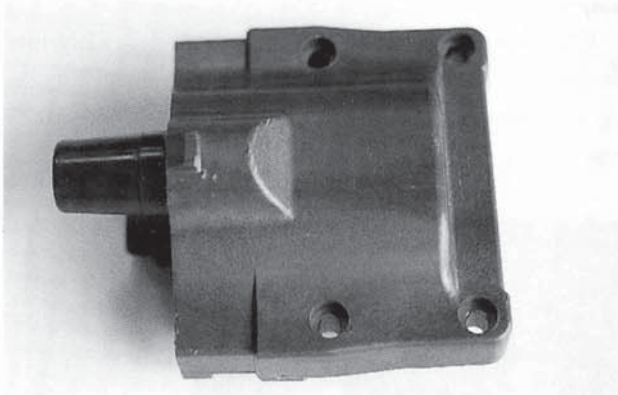


Photo14.1-15 Ignition coil cover (GF-PBT)

Accelerator cable liner

PTFE/PFEP replaced metal in this device. The friction/wear properties of PTFE/PFEP provide the driver with a smoother feel on the pedal movement. This material also meets the requirement for heat resistance of the cable that runs close to a hot engine.

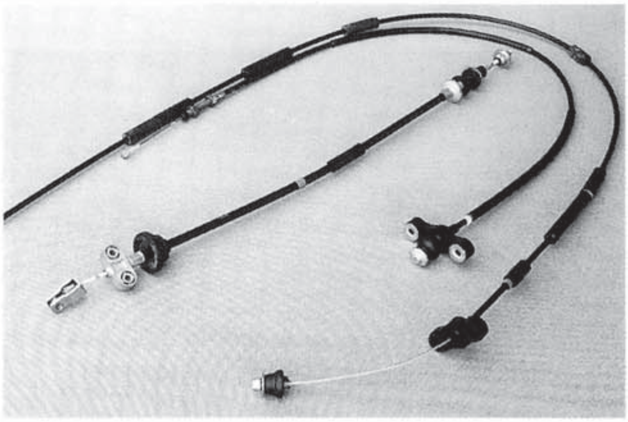


Photo14.1-16 Accelerator cable liner (PTFE/PFEP)

Actuator case

GF-PBT lends itself to making the actuator case in Photo14.1-17 because this material is dimensionally stable, resistant to heat and chemicals, and workable with hot staking.

The actuator is a device to control the accelerator aperture automatically to maintain a cruising speed even on a slope.

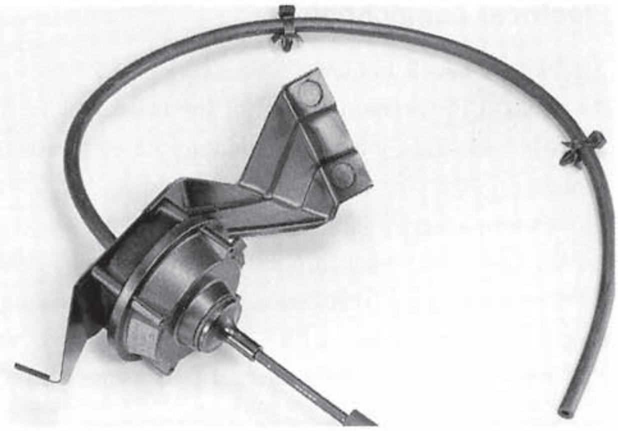


Photo14.1-17 Actuator case (GF-PBT)

Fuel tank

Photo14.1-18 shows a blow-molded tank with the wall construction of HDPE/Adhesive/PA6-barrier-layer/Adhesive/HDPE. The tank has the enhanced fuel barrier that outclasses conventional HDPE monolayer tanks.

Development of a plastic fuel tank has been a subject of study aimed for a higher safety, light-weight, non-rusting quality, and less assembling steps to cut costs. Also intended for applying the design freedom of plastics to sparing more room for the passenger compartment. Some developments have been commercially demonstrated.

Photo14.1-18 Fuel tank (HDPE/Adh./PA/Adh./HDPE)

Fuel tank flange

POM, with dimensional stability and chemical resistance to fuel, is the material of choice to make the flange that incorporates a fuel level meter.

Fuel tube

A tube of PA11 or PA12 has replaced the rubber joint on the bent segment of a conventional metal fuel tube. The essential requirements to the plastic material are lightweight, flexibility, the chemical resistance to gasoline, the mechanical endurance to pressure, and the barrier to permeation of fuels. In order for PA to replace all of the metal in the tube, the barrier-to-fuel property has yet to be improved with little effect on other properties.

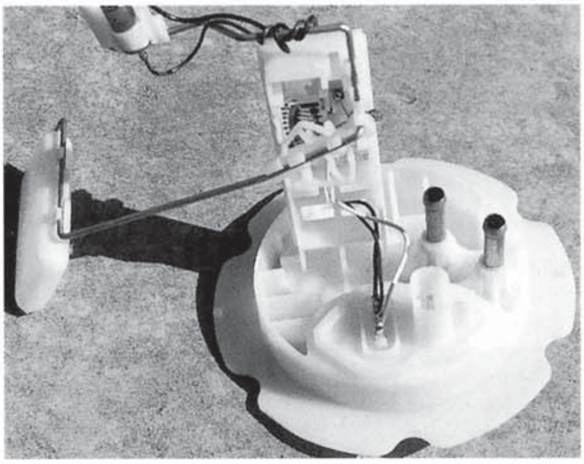


Photo14.1-19 Fuel tank flange (POM)

Photo14.1-20 Fuel tube (PA11)

Exhaust gas sensor

PTFE, with its high resistance to heat and corrosion, can deal with the difficult service conditions on an exhaust gas sensor.

The exhaust gas sensor monitors the oxygen content and the temperature of the exhaust gas. This is an indispensable device to control the engine, and to protect the gas treating catalyst. The sensor is exposed to a heated gas, and encounters such corrosive gases as CO and NOx.

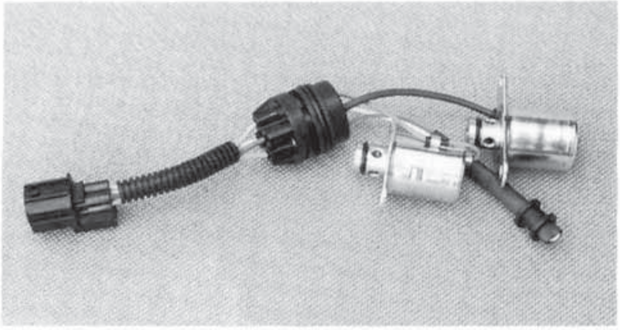


Photo14.1-21 Exhaust gas sensor (PTFE)

Fuel chamber

PA6 has replaced conventional metals to trim the weight and reduce the cost of a fuel chamber. The chamber is installed within a tank to let the fuel flow into the engine even when the car tilts.

POM, with dimensional precision and gasoline resistance, is the practicable material for the electrical elements fitted on the chamber.

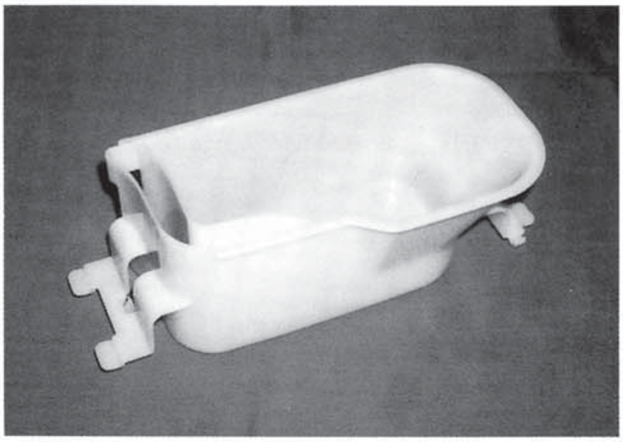


Photo14.1-22 Fuel chamber (PA)

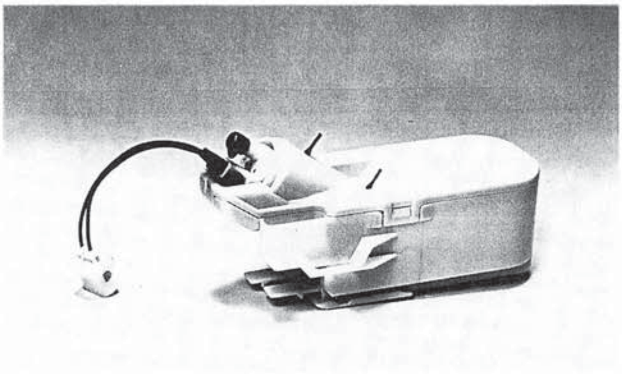


Photo14.1-23 Electrical elements on fuel chamber (POM)

Electrical components

Alternator brush holder

GF/MD-PPS is the material of the brush holder in Photo14.1-24. This injection-moldable material offers a high productivity and low costs, and is replacing conventional thermosets.

PPS also offers such property advantages as heat resistance, chemical resistance, stiffness, dimensional precision, workability with epoxide adhesives, as well as high-cycle moldability and flow properties.

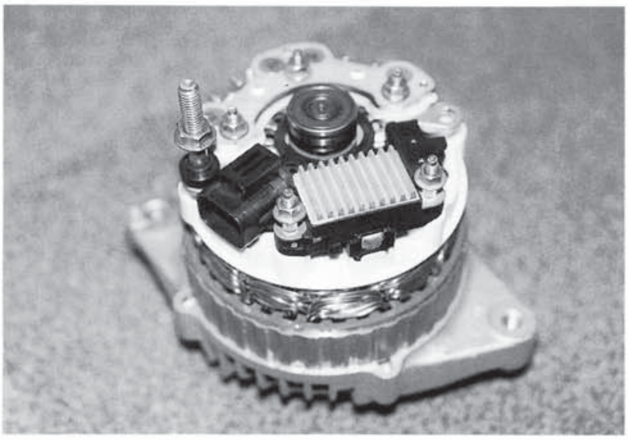


Photo14.1-24 Alternator brush holder (GF/MD-PPS)

Structural components

Pedal module

GF-PA6 and PA66 are employed after having passed the very demanding property tests for stiffness, impact strength, thermal shock, bending fatigue, and creep.

A study was made for using a plastic material to

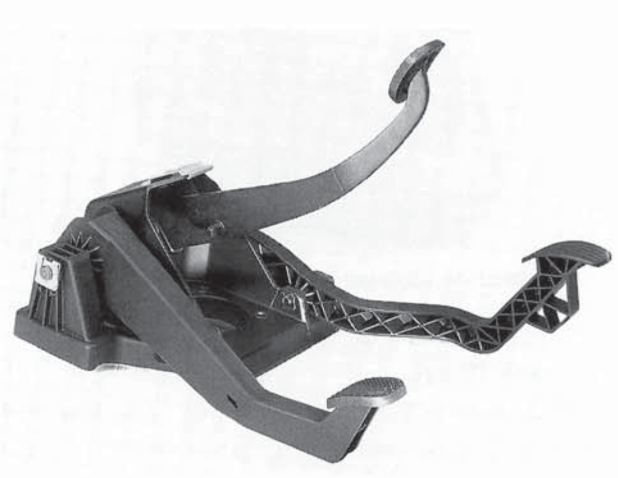


Photo14.1-25 Pedal module (GF-PA6, GF-PA66)

replace metal in an effort to reduce the weight and the costs of a pedal module. The development took advantage of the design freedom of plastics.

Shift lever base

GF-PA6 and PA66 are employed for their stiffness, strength, and frictional wear resistance.

Use of plastics in place of metal was a subject of study intended for reducing the weight and the costs of a shift lever base. The R&D exploited the design freedom of plastics to mold this item in a single piece.

In some instances, use of those polyamides in place of metal trimmed about 50 percent of weight of this component.

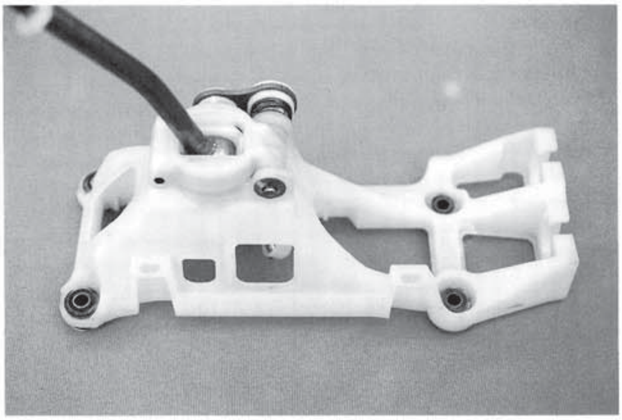


Photo14.1-26 Shift lever base (GF-PA6)

Components around the suspension

Constant-velocity joint boot

A blow-moldable polyester elastomer is the undisputed material to replace conventional rubber to make a constant-velocity joint boot. With property advantages to its credit, the elastomer has realized a reduced weight and an increased productivity of the boot.

The boot protects the constant-velocity joints, which is exposed to the severe service environments around the suspension. Hence, the boot material must retain flexibility at a very low temperature (-40℃), possess flexural-fatigue endurance, and be chemically resistant to oil and grease.

Photo14.1-27 Constant velocity joint boot (TPEE)

Name	Property highlights	Applications
PA	Toughness, Heat resistance, Chemical resistance, Frictional wear resistance	Air intake manifold, Air duct, Cylinder head cover, Oil pipe, Engine cover, Shift lever base, Accelerator pedal, Radiator tank, Reservoir tank, Fan blade, Ball joint seal, Shock absorber piston ring, Air control valve, Surge tank, Connectors, Fuel tank, Fuel chamber, Fuel tube, Fuel strainer, Door check lever, Bearing retainer, Speedometer gear
POM	Mechanical strength, Fatigue endurance, Elastic recovery, Chemical resistance, Creep resistance, Frictional wear resistance	Fuel tank flange, Fuel chamber, Radiator-drain stopcock, Fuel tank cap, Oil tank cap, Exhaust gas control valve, Heater fan, Turn-signal switch, Brake parts, Fuel pump, Gears, Pulleys
PC	Transparency, Impact strength, Dimensional precision, Weatherability, Hard burning	Sirocco fan, Transparent parts(Headlamp, Corner lamp, Rear windows
Modified-PPE	Dimensional stability, Physical-property stability, Heat resistance, Low dielectric constant	Air filter, Washer nozzle, Outer body panels, Door mirror body, Wheel cover, Instrument panel, Bumper facia
PBT	Heat resistance, Water resistance, Chemical resistance, Impact strength, Electrical properties	Air flow meter, Actuator, Ignition coil, Distributor cap, Fuel tank cap, Fuse case, Connectors, Door handle
UHMw PE(Ultra-high-molecular-weight Polyethylene)	Self-lubrication, Frictional wear resistance	Gears, Clutches, Washers
PSU	Heat resistance, Hot-water resistance, Dielectric property, Dimensional precision	Fuse case
PES	Stiffness, Dimensional precision, Creep resistance, Heat resistance, Transparency	Gear box/bearing retainer, Brake shaft bushing, Thrust washer
PAR	Heat resistance, Transparency, Weatherability	Lamp reflector, Amber cap/turn signal lamp
PPS	Heat resistance, Chemical resistance, Hard burning, Dimensional stability	Alternator brush holder, Solenoid, EGR valve, Carburetor parts
PAI	Friction/wear properties, Heat resistance, Stiffness	Distributor cam, Transmission thrust washer, Rotary sealing, Turbocharger impeller
PEI	Stiffness, Hardness, Toughness, Weatherability, Snap-fit property	Turbocharger impeller/bearing retainer, Speed sensor shaft
PEEK	Resistance to heat aging, Chemical resistance, Strength, Fatigue endurance	Piston skirt, Bearing retainer, Distributor, Rotor arm, Alternator cover
PI	Heat resistance, Frictional wear resistance, Creep resistance	Push rod, Connecting rod, Timing gear
FR	Heat resistance, Chemical resistance, Corrosion resistance, Friction/wear properties	Accelerator cable liner, Exhaust gas sensor, Brake hose, Gasket, Packing, Sealer
GF PET	Heat resistance, Chemical resistance, Dimensional precision, Stiffness at a high temperature, Surface gloss	Intake/Exhaust air control valve, Lamp reflector/subreflector, Power window regulator(case/chassis)

Table14.1-3 Engineering Plastics in Automotive Industry

Exterior/Interior, Body components

Some plastic exterior components are already commercially demonstrated. Most of them are vertically-installed panels or small-size components because the high-temperature stiffness of the thermoplastics is not adequate to make horizontally-installed panels or large-size components.

In recent years, trimming of weight of an automobile has a new significance of making good on mitigation of global warming to protect the environments. The plastics today are more important materials than ever to make lightweight components to be fitted on the coming hybrid cars or electric-powered vehicles.

An American automaker has released to the market a motorcar with all plastic vertical-outer-panels, which has much appeal to us. The statistical content of plastics in Japanese cars is only about 7 percent of a car weight as compared with 12 percent in the U.S.A. and 15 percent in Europe. These days, some Japanese cars with all plastic outer-panels come out on display as concept cars. A commercial demonstration of such cars will not be far-fetched thanks to the recent development of processing technologies.

In the exterior applications, engineering thermoplastics will play matchless major roles taking advantage of their heat resistance, performance of many functions, and recycling capabilities.

In the interior applications, PP, ABS, or other general-purpose plastics abound because the interior usually requires only a fair-level heat resistance. Lately, however, engineering plastics are finding opportunities for use in the interior applications as well as the exterior. The background is that many of the car-designs in recent years adopt large window-panes, which elevate the temperature in the passenger compartment. Such designs accordingly demand the interior materials that have a high heat resistance and a good dimensional stability in the high-temperature conditions.

With a view to the global environmentalism, selection of the right plastic material means not only to satisfy the use-requirements but also to facilitate recycling of the material. Development of easy-recycling plastics and use of a common material for different automotive parts will encourage efficient recycling. In the future, establishment of the systems for material recycling and waste-disposal will have an immediate influence over the promotion of use of plastics.

Exterior body panel

Most of the panels are made of steel. Only on some car-models, plastics are adopted in the vertical applications, such as a front- and a rear-fender panel, that do not require a high stiffness at high temperatures. A modified-PPE/PA alloy or a polyester elastomer is employed in favor of the design freedom and the lightweight of the material. Those materials are selected also for their good combination of properties: dimensional stability, chemical resistance, paintability at high temperatures, and impact strength at low-temperatures.

In the horizontal applications, which requires a high stiffness at high temperatures, only few engineering plastics are used except for some small size parts.

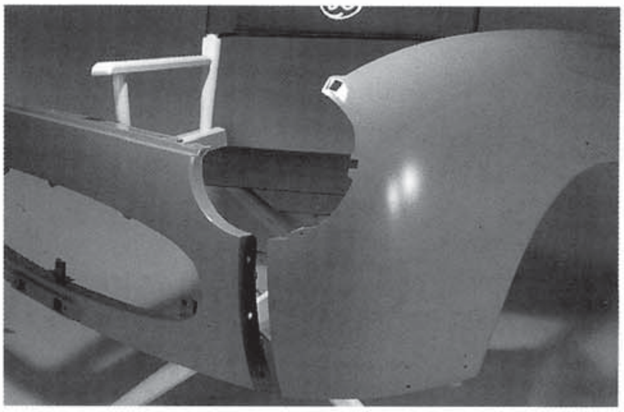


Photo14.1-28 Front fender panel (PPE/PA alloy)

Bumper facia

A modified-PPE/PA alloy or a polyester elastomer is employed in the bumpers of some car-models.

The plastic bumper started with polyurethane, then turned largely into PP; it has a longer history among other plastic exterior components.

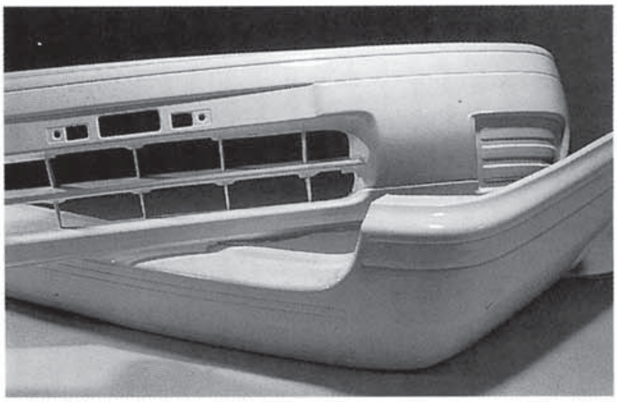


Photo14.1-29 Bumper facia (PPE/PA alloy)

Outer door handle

Different automakers and different car-models use a wide variety of plastics: PA, POM, PC, PBT and Modified-PPE/PA alloy. Impact strength is the most needed mechanical property of the material. Coloring capability and weatherability are also necessary.

Switching the material from conventional die-cast aluminum to plastics began in the middle of the 1980s, and the replacement has almost completed. Now that the adequate technologies are available for painting and metal plating on the plastic surface, the plastic materials have established a strong presence in the automotive outer door handles. The plastic handles are fitted even on the high-class cars.

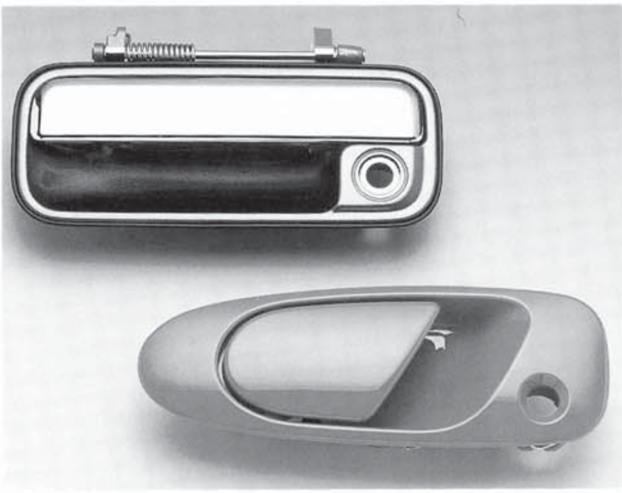


Photo14.1-30 Outer door handle (PC)

Door mirror

Use of plastics in the door mirror historically started in the body of mirror assembly; PP or ABS bodies are plentiful today. The engineering plastics have replaced die-cast metals to make the stay that connects the mirror-body to the car-body. GF/MD-PAMXD6 is employed for being lightweight, stiff and vibration-damping. GF-PBT has its share for being low in cost.

Door-mirror angle is remote-controllable on most cars; the controlling mechanism benefits from POM the friction/wear properties, fatigue endurance and dimensional stability.

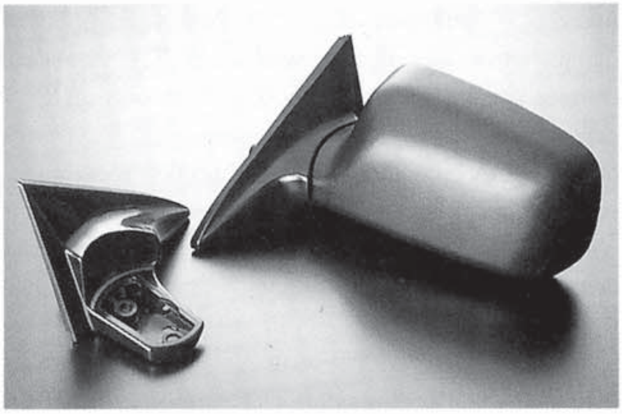


Photo14.1-31 Door mirror stay (GF/MD-PAMXD6)

Photo14.1-32 Door mirror stay (GF-PBT)

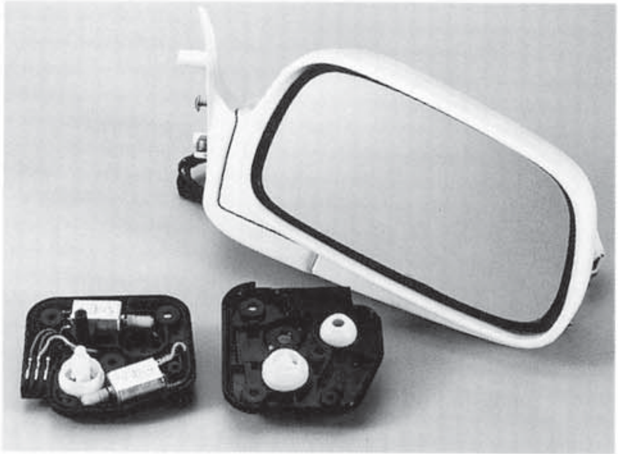


Photo14.1-33 Door mirror angle controller (POM)

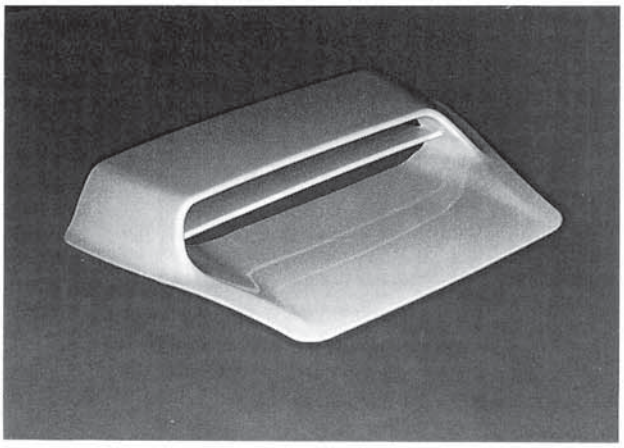


Photo14.1-34 Hood garnish (MD-PA6)

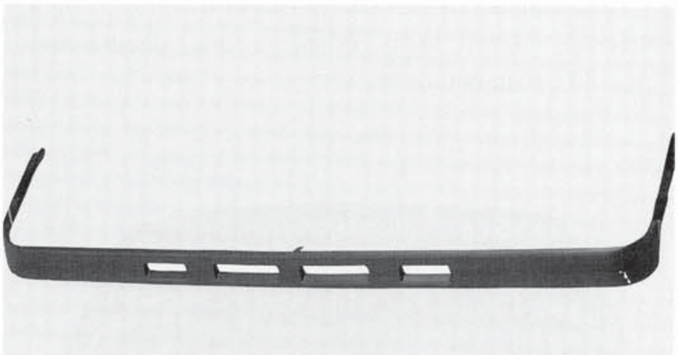


Photo14.1-35 Sunroof deflector (GF-PA)

Hood garnish

MD-PA6 and Modified-PPE/PA alloy meet the requirements for this use.

The garnish is an air-inlet grill fitted on the hood to take fresh air into the underhood compartment. The service environments require that the material must have paintability, aesthetic appearance, and dimensional stability at an elevated temperature.

Sunroof deflector

GF-PA is used as a material of the part of a sunroof.

The deflector, i.e. the frame on the sunroof, must have a high stiffness and weatherability as well as a good appearance and paintability.

The sunroof is a device on a rising popularity.

Clip

Photo14.1-36 shows the examples of clips made of POM.

The clip materials differ depending on the service conditions, but they must commonly have creep resistance and a spring-like elastic recovery combined with some stiffness and toughness.

Multitudes of clips are seen fastening interior items and electric wires not only in the underhood compartment but also in the passenger compartment.

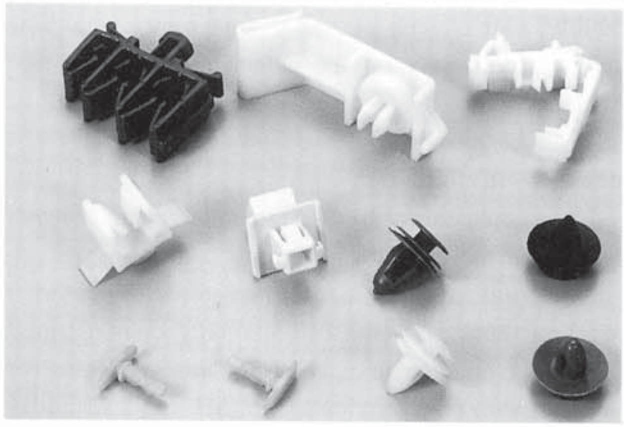


Photo14.1-36 Clip (POM)

Lamp --- Front lens

Photo14.1-37 shows a front turn-signal-lamp assembly. Incorporation of a colored lens in the assembly makes the inside space small, and raises the temperature to as high as 170℃. This example employs PAR for heat resistance and transparency.

Many of the lamp designs in recent years incorporate a number of different lamps such as a headlamp, turn signal lamp and foglamp into a single assembly of a complex geometry. Such an assembly opts for plastics rather than conventional glass to exploit the plastic's lightweight and processing versatility to make the complex geometry.

PC is the material of choice for this application. Hard coating on PC is the norm to guard the surface against scratches, and to enhance weatherability and chemical resistance.

Photo14.1-37 Turn signal lamp (PAR)

Lamp --- Taillamp lens

Acrylic is the most popular material. PC is for use in some applications that demand a higher weather-ability, clarity, and aesthetic appearance. PC, however, is decisively on the defensive in cost against the acrylic.

Lamp --- Reflector

Thermoplastics are looked upon to replace conventional thermosets with a view to facilitating recycle or disposal of scraps. At present, PPS is in a trial-use but yet to be commercially demonstrated. PAR is employed in a rotating lamp reflector, on which the service environments are mild. (Photo14. 1-39)

The plastic material must present a smooth surface that receives a vapor-phase metallization to form a reflecting mirror. Also, heat resistance is

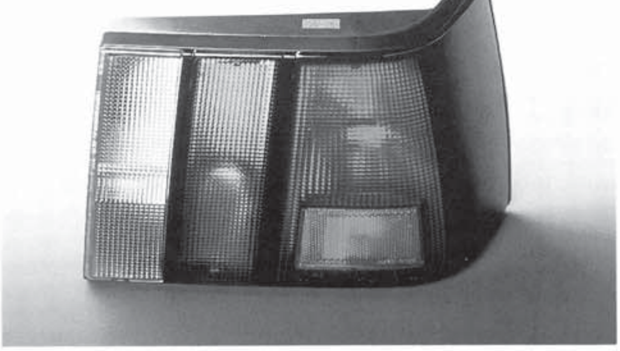


Photo14.1-38 Taillamp lens (PC)

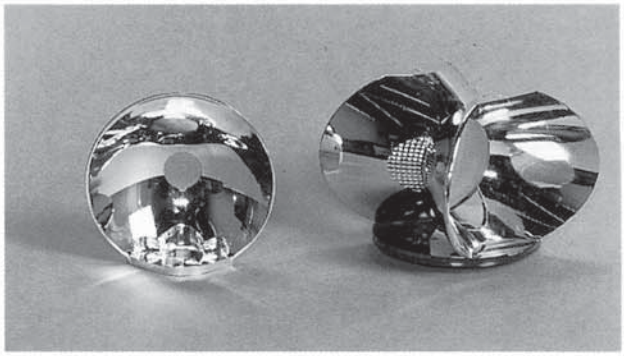


Photo14.1-39 Rotating lamp reflector (PAR)

gaining a greater importance as a lamp goes downsized and thereby elevates the temperature in the housing.

It is hopeful that the reflector application will place a high value on engineering plastics in the future.

Instrument panel

Engineering plastics are beginning to be employed, behind the conventional PP and ABS, in order to deal with high-temperature environments.

Many of the recently designed car-bodies have a very inclined windshield for pneumodynamic and aesthetic reasons. Such a design causes the instrument panel to extend forward and suffer from the elevated temperature under the windshield. In the circumstances, the instrument-panel material should have a higher heat resistance and dimensional stability than before.

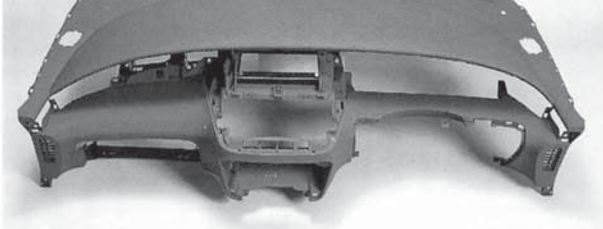


Photo14.1-40 Large-size instrument panel (Modified-PPE)

Speedometer case frame

PBT meets the requirement for a small warpage, which is an important characteristic for a frame to be joined with other components.

The complex-shape frame of a speedometer case is fitted on an instrument panel.

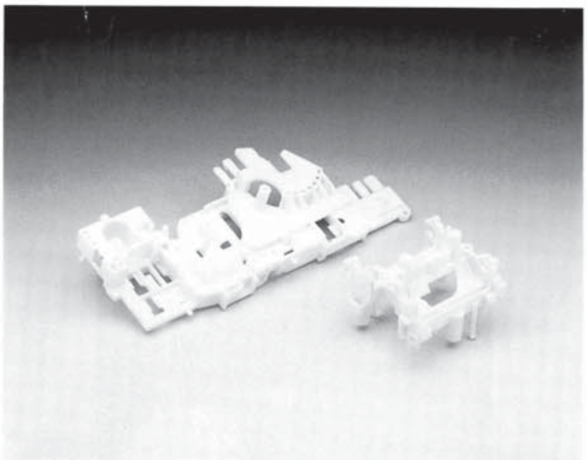


Photo14.1-41 Speedometer case frame (PBT)

Airbag housing

TPEE is one of the materials selected for this use.

The airbag, termed as SRS airbag, is a safety device, which dominates the designs of almost all new-model cars today.

The airbag housing must break-open without fail when actuated. Since the device is located in front of the driver, the airbag housing must have the interior-component appearance as well as the functional properties such as impact strength at low temperatures and mechanical strength at high temperatures.

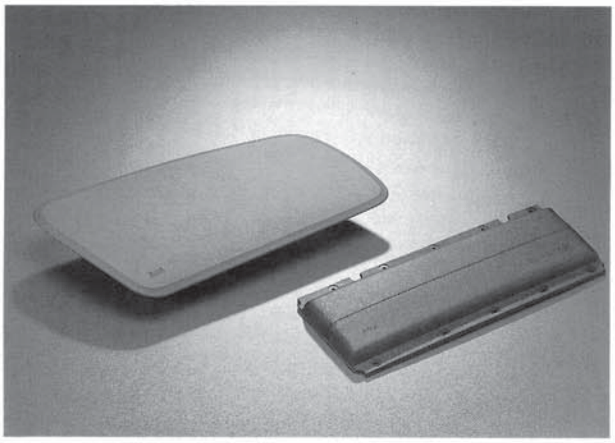


Photo14.1-42 Airbag housing (TPEE)

Combination switch body

MD-PA66 satisfies the requirements for friction/wear properties and electrical properties.

The combination switch assembly sits on the steering-wheel-column in front of the driver. The switches should work smoothly and quietly to control the turn signals, the wipers, and other devices. Accordingly, the material must have good friction/wear properties in a plastics-on-plastics contact as well as adequate electrical properties.

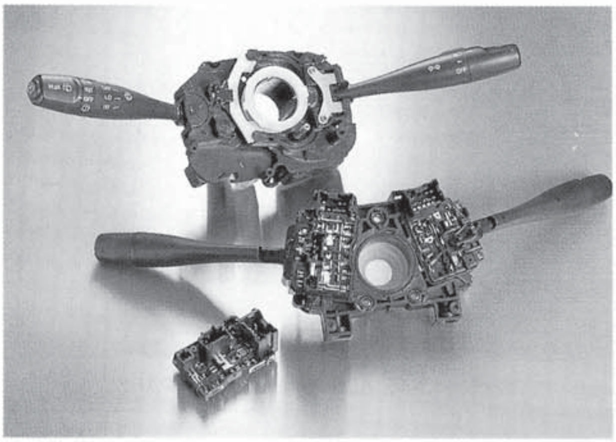


Photo14.1-43 Combination switch body (MD-PA66)

Power seat base

PBT meets the property requirements. Also, use of PBT has eliminated some processing/assembling steps that are otherwise necessary with metals.

A power-driven seat is becoming a prevalent piece of equipment for more comfort of the driver. A major part of the equipment is the power seat base where a power-driving device is mounted.

The base must have an adequate stiffness to bear not only the driver's weight but also the enormous load exerted in the case of an accident. Also, the base must have the electrical characteristics suitable for installation of an electric motor.

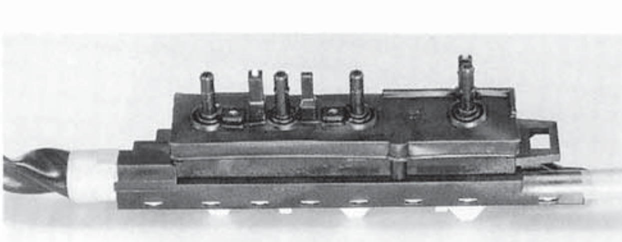


Photo14.1-44 Power seat base (PBT)

Sensor case --- ABS(Antilocked Brake System) sensor case

A PA66 is upgraded specifically for use in this application.

The ABS sensor case is fitted under the body, therefore likely to contact water. The casing must be securely watertight because accidentally leaked-in water can cause an incorrect electrical contact, which may lead to a fatal safety problem.

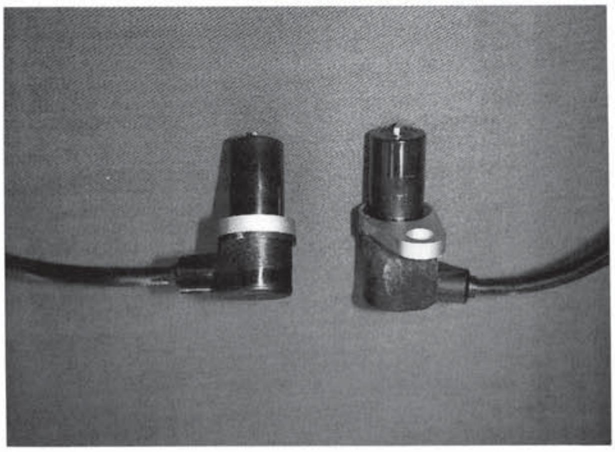


Photo14.1-45 ABS sensor case (PA66)

Sensor case --- Height sensor case

PBT is resistant to thermal shock and hydrolysis; and meets other requirements as well.

The height sensor monitors the distance between the road surface and a low point of the car-body for electronic control of the suspension mechanisms. The case containing the sensor is set in a place where it is frequently exposed to thermal shocks and splashing water.

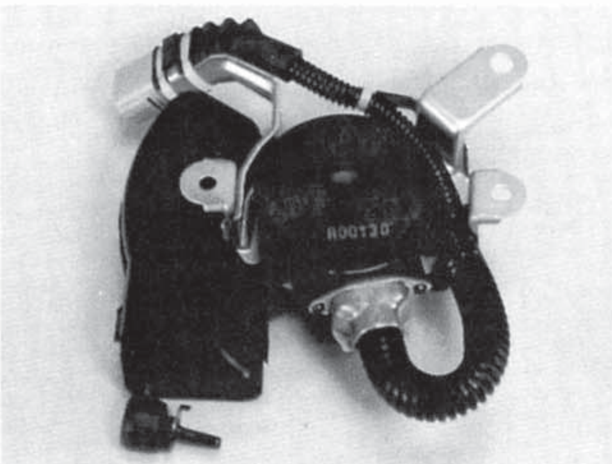


Photo14.1-46 Height sensor case (PBT)

Carrier plate on window regulator

POM is the practicable material of the plate in Photo14.1-47.

The window regulator is a mechanism to operate a windowpane up and down. A cable-type regulator has the carrier plate that must have good friction/wear properties, a high dimensional precision, and creep resistance.

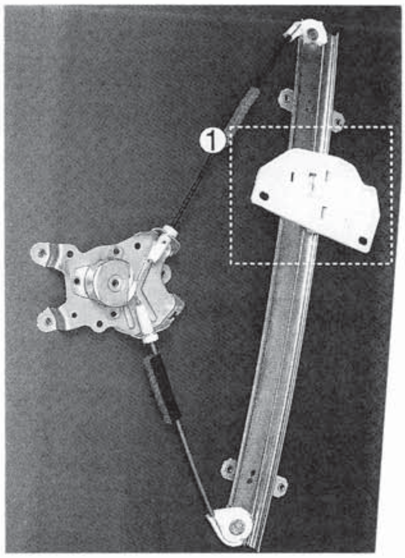


Photo14.1-47 Carrier plate on window regulator (The white part) (POM)

Stabilizer link rod

Photo14.1-48 shows two pieces of the link rods made of GF-POM. This material is employed for

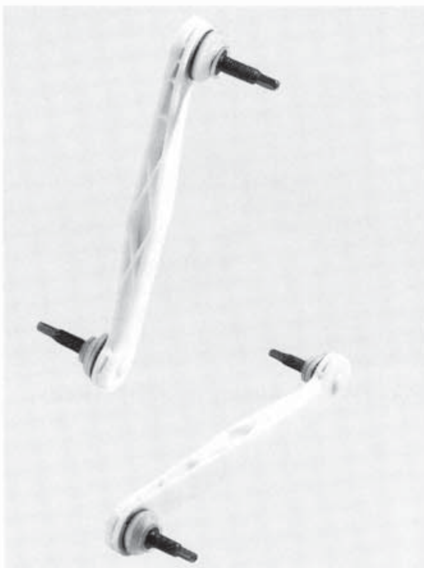


Photo14.1-48 Stabilizer link rod (POM)

having fatigue endurance, a high dimensional precision and chemical resistance.

The stabilizer is a device to mitigate outward rolling of an automobile during cornering. The link rods of the stabilizer, conventionally made of iron, are being made of plastics in the U.S.A. and Europe.

Automatic antenna

POM makes the gears, pulleys, racks and other parts in a remote-controller of a car-radio antenna. This material offers a good resistance to frictional

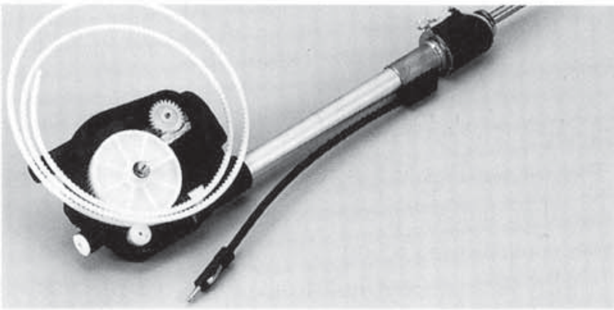


Photo14.1-49 Automatic antenna (gears, pulleys, racks) (POM)

wear and a high durability to repeated bending.

Gears in door lock actuator

POM is the representative material of this application making use of its property advantages: a low emission of rotational noises, good friction/wear properties, and the chemical resistance to grease.

So many plastic gears are in service often in hidden corners in a motor vehicle.

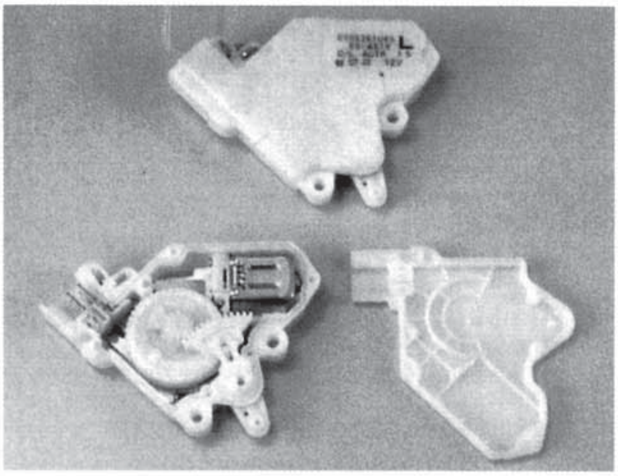


Photo14.1-50 Gears in door lock actuator (POM)

Motorcycle cowling

The cowling in Photo14.1-51 is made of GF-PA.

The frictional heat generated in the tires while running on the road can bring about a serious problem to solve in designing a vehicle. Since a large-size motorcycle generates much heat, it requires an elaborate design to release the heat. Use of a heat resistant engineering plastic in the cowling has saved some of such difficult heat-handling designs that had otherwise been necessary with the use of general-purpose plastics.

On a compact-size motorbike where generation of heat is not so critical, general-purpose plastics are the popular material to make a cowling.

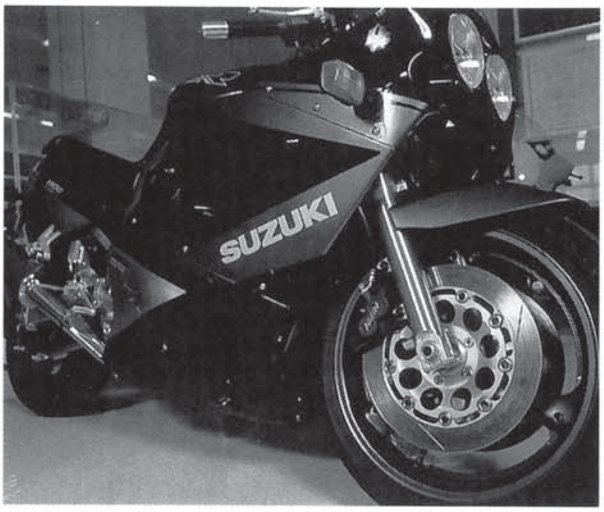


Photo14.1-51 Motorcycle cowling (GF-PA)

Aircraft/Spacecraft

As the space vehicles have evolved into the supersonic passenger aircraft and further into the space shuttles, expectations are mounting for the lightweight, tough and heat-resistant advanced composite-materials to replace metals in the structures of those high-technology vehicles.

A civil aircraft is built in two levels of structures: the primary structure and the secondary structure. The primary-structure components must be flawless; the representative components are the fuselage and the main wings. The secondary-structure components are on relatively mild specifications; such as doors and flappers.

The plastic composite materials, mainly the carbon-fiber-reinforced thermoplastic composites, are now for use only in the secondary-structure components such as cabin doors and floor beams. Once the plastic composite has gained adequate trust in quality, the material may well be for use in the primary-structure components such as fuselage-panels(stringers), cowling components, and rudder parts. CF-PI and other high-performance plastic materials are the candidates under great expectations. The thermoplastic materials offer such merits as processing versatility and quality stability, and such properties as impact strength, durability, and toughness. (Photo14.1-52, Table14.1-4)

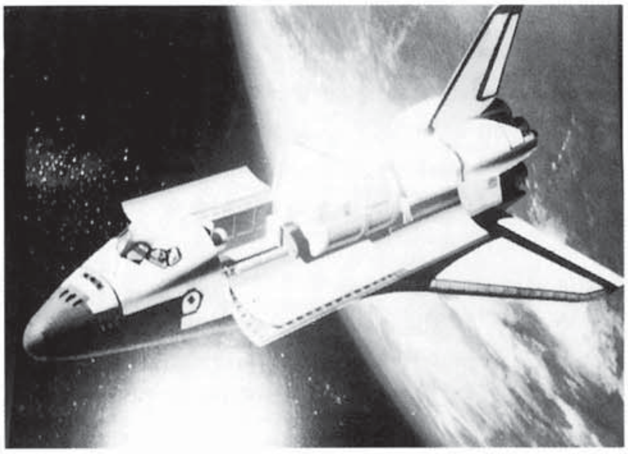


Photo14.1-52 Space shuttle

Components	Materials	Remarks
Parts on the Star-ship fuselage and main wings	CF/Epoxide-resin	---
AV-8 Fighter fuselage	CF/Bismaleimide	The parts exposed to the heated exhaust gas
F404 Jet-engine duct, flanges, engine-mount	CF/PI	Toughness, Processability, Impact Strength, Machinability
C-130 Transport fuselage fairing panel, Ariane rocket cone	CF/PEEK	Heat resistance, Strength at a high temperature, Machinability, Ease of repair, Fatigue endurance
Interior side-wall panel, passenger-seat side panel, stowage	CF/PPS	Processability, Strength
Helicopter stabilizer	ARA-fiber/Epoxide-resin	Stiffness, Lightweight
Civil-aircraft cabin-window interior frame	PEI	Flame retardancy, Chemical resistance

Table14.1-4 High-performance Plastic Materials Employed in Aircraft/Spacecraft

Boeing 757 strut fairing

Use of GF-PEEK has realized a 30-percent weight reduction and a 90-percent cost saving as compared with conventional aluminum.

PEEK was singled out from all tested plastics in appreciation of its outstanding properties as cited below.

1) Mechanical strength and chemical resistance
2) Impact strength
3) Resistance to frictional wear
4) Flexural modulus and tensile strength
5) Dimensional stability at a temperature as high as

almost 300℃

Radome

PES composite has replaced CF/epoxide-resin because PES is inherently self-extinguishing, and emits neither a toxic gas nor much smoke if burnt. Also, this material has the properties suitable for exterior services: weatherability, impact strength, and the resistance to attack by raindrops.

A radome encases a radar antenna in the nose at the front-end of an aircraft, therefore encounters a particularly heavy dynamic load and a frictional heat.

Photo14.1-54 Radome (PES)

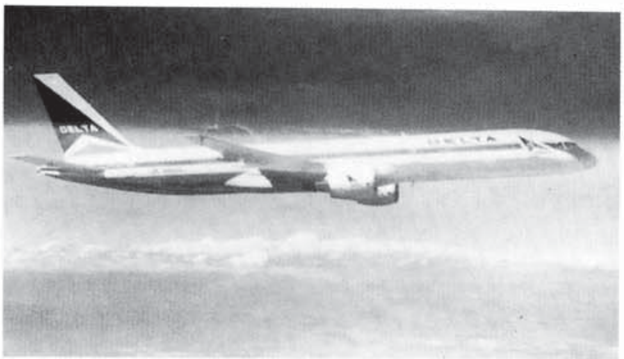


Photo14.1-53 Boeing 757 strut fairing (GF-PEEK)

Aviation safety devices

FR is the multifunctional and exceptionally high-performance material, which is well trusted to endure the extremely severe conditions during flight. FR exhibits a very high performance in each of heat resistance, corrosion resistance, low-friction characteristic and electrical insulation.

Many components on an aircraft benefit from the characteristics of FR. Some examples are electric cable insulation, fuel hoses, bearings, and the seals on hydraulic lines.

Safety is the name of the game in aviation. The safety is ensured by the performance of the materials that constitute the aircraft, as well as the attentive maintenance of the machine. FR certainly contributes to the safety of an aircraft.

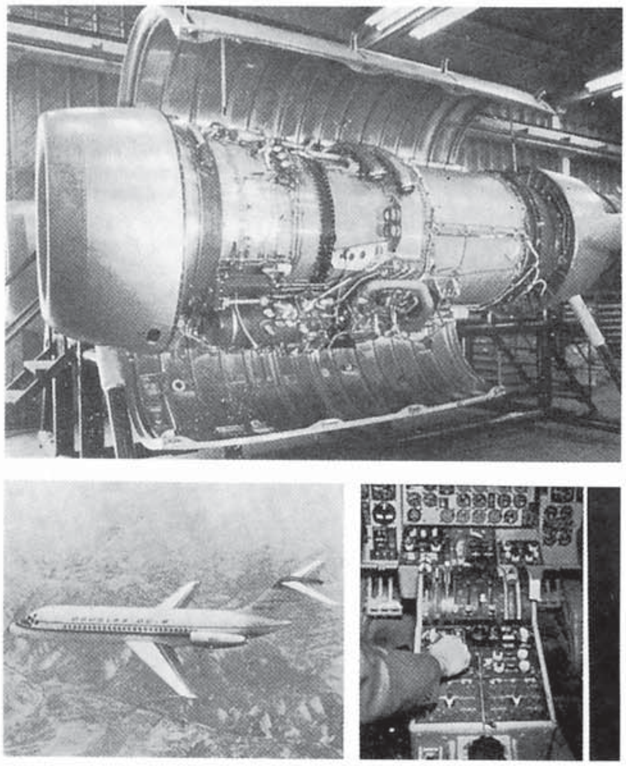


Photo14.1-55 Aviation components (FR)

Railway

The history of Japanese railway started on October 14, 1872, when the first locomotive left Tokyo for Yokohama. The railway was a leading-edge industry of the time and was pioneering the Japanese industrial activity. Since then, the railway has grown to be a mass transportation system, which now serves the nation with indispensable means of travelling.

The railway facilities are usually managed by several different divisions including Track division, Civil-engineering and Construction division, Electrical facility division, and Train division. The opportunities for use of engineering plastic are largely in the Track division and some in the Train division.

The material applicable to the railway must retain its stable performances for long periods in the difficult service environments that involve load, speed, vibration, impact, and combinations of them. Also, the material should render services for a low total cost. Overall, the plastic material for use in the railway must have a proper cost-performance without payment of reliability on quality.

The table shows that the engineering plastics are yet to be employed more extensively in the railway applications. Actually, the plastic materials are still the supporting players in this theater. Lately, however, a new concept railway system is under study, in which plastics and rubbers are to play the important roles. FRP trucks, plastic crossties, and plastic windowpanes are among the subjects of the research and development.

Track	Rail fastener insulation plate (PF→SMC, PA, PC), Insulation collar (PC), Spring support plate (PA, BMC), PC sleeper plug (BMS, PA), Track-slab/sleeper embedded collar (PE), Rail insulation (PF→EP-G), Glued-insulated joint rail (EP-G), Adjustable pad (UP→vinyl ester), Electric heating pad (HMP), Plastic filler for track (EP, PUR, PS), Sleeper covered with resilient material (PUR), Mortar for repair
Civil-engineering and Construction	Bridge shoe seat (EP-G), Tunnel water-proofing sheet (EVA, PVC), Tunnel icicle preventing heat insulation (Cross-linked PE, PUR), Concrete repair material (EVA, EP), Station building material (PVC, MF, P-G), Guide signboard (PMMA), Gutter (PVC), Platform chair (UP-G)
Electrical facility	Motor coil encapsulation(Si, EP), Switchboard (PF), Passive equipment insulator (FE), Contact wire insulation (Si-G), Dropper cover (PC, PA), Printed circuit board (PF), Signaling/communication relay insulation (PF→DAP), Casing (PS, PMMA, PC), Coil insulation (PI)
Train	Electric insulated roof sheet (PVC), Inside panel (MF), Hand strap (UF, PC), Chair-armrests/Air-louvers/Wainscoting (PC), Lamp cover (PMMA, PC), Door roller (PUR), Piping and fitting (PVC), Gutter (PVC), Electric wire joint (DAP), Coupler bellows (PVC), Heat insulation (PUR), Flooring (PVC), Tanks for water/excreta/fuel (EP-G), Lavatory unit (UP-G), HIKARI-express front end nose (EP-G), Berth (UP-G)

(Railway Technical Research Institute)

Table14.1-5 Use of Plastics in Railway Application

Spring-support plate

PA is employed for having strength, toughness, electrical insulation, weatherability, and a vibration-damping property. The PA-made spring-support plate can survive an extremely long-term use, which facilitates efficient maintenance of tracks. This is the representative use of plastic material in the railway track.

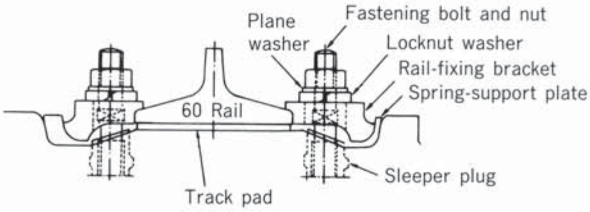


Figure14.1-3 Rail Fastening System PC-11Type 60

Grip on a strap

The PC-made grip on a strap is to support a standing passenger on a packed train where no vacant seats are available.

The material of the grip must have impact strength besides a good appearance because the grip swings on the strap and may hit things around as the train joggles. PC, an engineering plastic, is one of the materials that meet such needs.

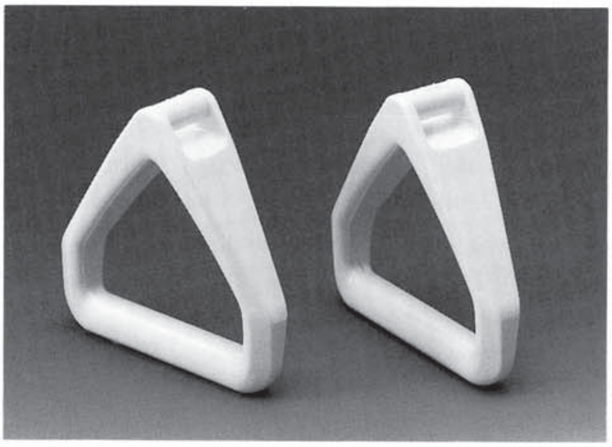


Photo14.1-56 Grip on a strap (PC)

Air outlet

PC is used as the material of the conditioned-air-outlet on a SHINKANSEN, the Japanese bullet train. This device requires the material with hard-burning characteristic, electrical insulation, and a good appearance.

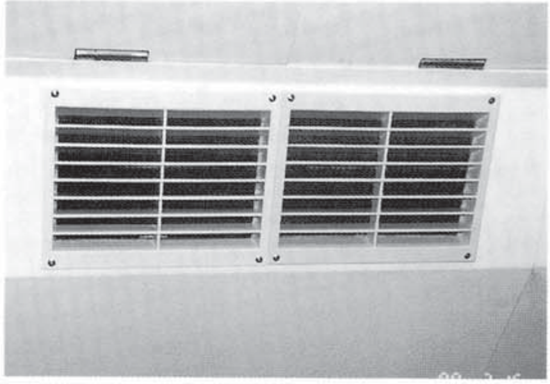


Photo14.1-57 Air outlet (PC)

14.2 Electric/electronic appliances

Introduction

Production of electric/electronic household-appliances is one of the representative industries of Japan rolling out color TVs, VTRs and other varieties of home-use appliances.

The materials for use in this industry must live up to the ever-expanding requirements for improved quality, reduced size, trimmed weight as well as increased productivity of the products. Engineering plastics have long been appreciated as the material that can handle those requirements. As household appliances and OA(Office Automation) equipment have adopted more of electronic technologies, engineering plastics have picked up more importance as a material to make electronic parts,

Engineering plastics are beginning to find ways to make housings, besides mechanical and functional parts, in such areas as information appliances, communication devices, and OA equipment. PS and ABS have long been the major material of housings, but the use of engineering plastics such as PPE, PC and PA is on the increase. The engineering plastics can deal with the recent requirements for heat resistant materials to enhance the products' performance of functions while promoting downsizing and weight-trimming.

POM is largely employed in the mechanical/functional parts such as gears, cams, levers and pulleys. PA and PBT also have their shares in those applications. PBT, PC, PA, PPS and LCP are the popular materials of connectors, relays and coil-bobbins.

Overall, use of engineering plastics in this industry is increasing in appreciation of their property advantages: lightweight, processing versatility, long-term stability, heat resistance and other high-performance characteristics.

The following list shows the consumption of engineering plastics in the electrical products including household appliances, electronic parts and OA equipment.

Plastics	Total domestic demands	Consumption in electrical products
Modified-PPE	94,000	28,200
POM	99,200	38,700
PA	191,000	28,300
PBT	46,300	15,700
PC	174,900	68,200

(1997 in Japan unit: tons/yr)

AV(Audio/Visual) equipment

The audio equipment includes cassette decks, CD(Compact Disc) players, and DAT(Digital AudioTape) decks. The visual equipment includes VTR decks, VTRs with a built-in camera unit, and LD(Laser Disc) players.

Diverse technical developments are emerging very quickly to add new functions to a more compact piece of equipment. Some of those developments have resulted in DCCs(Digital Compact Cassettes), MDs(Mini Discs), and DVDs(Digital Versatile Discs).

Headphone-type stereophonic player

POM is most popularly employed in such mechanical parts of the player as driving gears, pulleys and cams. This plastic is favored for its fatigue endurance, friction/wear properties, and a low generation of noise.

LCP is one of the materials chosen for a cassette lever, which requires a high stiffness.

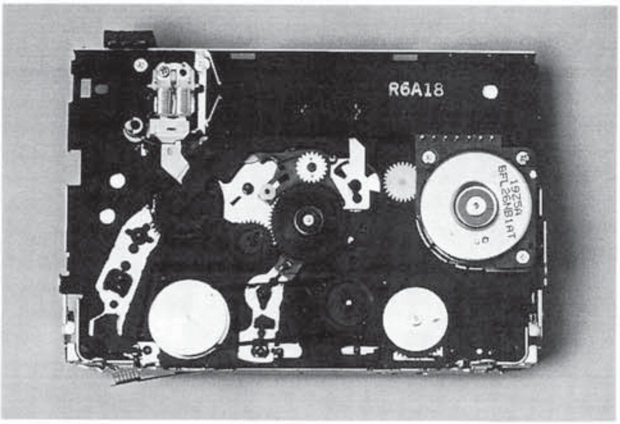


Photo14.2-1 Mechanical parts of stereophonic player (POM)

CD player and LD player

Photo14.2-2 shows a chassis made of PBT.

Correct functioning of the optical pickup is essential to the performance of CD/LD player. The chassis is the base of the mechanical components that determine exact positioning of the optical pickup over a disc. To ensure correct functioning of the components on the chassis, the dimensional precision of a CD/LD-player chassis must be higher than that of a cassette-deck chassis.

Photo14.2-3 shows a PPS-made traverse unit in a LD player. The traverse unit calls for a high dimensional precision, heat resistance, stiffness and long-term stability of properties.

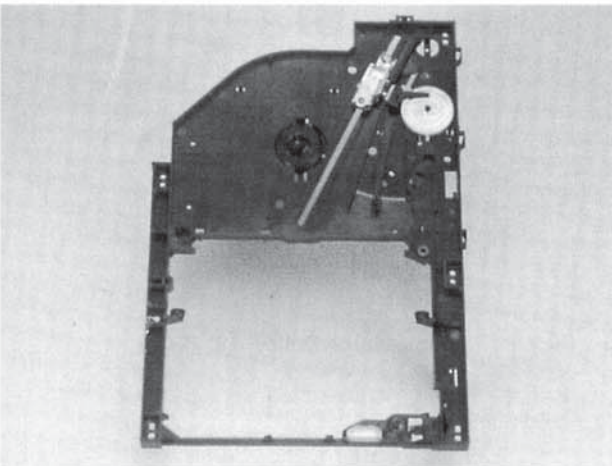


Photo14.2-2 CD player/chassis (PBT)

Shown in Photo14.2-4 are examples of the base and the carrier in a LD player. They are made of PAMXD6, whose mechanical strength, elastic modulus, and damping of vibration have successfully

Photo14.2-3 LD player/traverse unit (PPS)

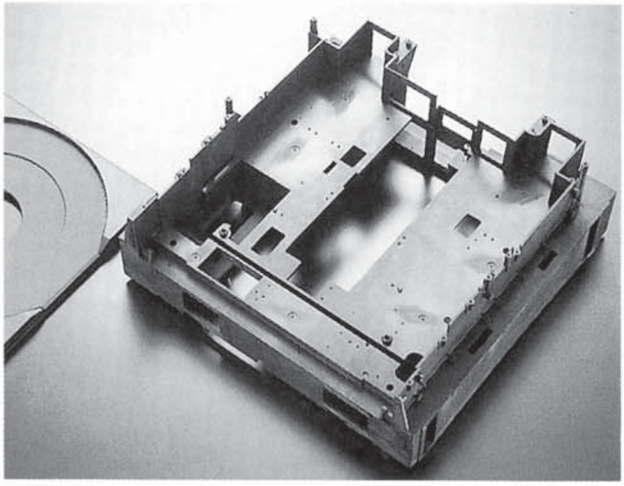


Photo14.2-4 LD player/base and carrier (PAMDX6)

eliminated resonant noises, and thereby improved the quality of the sounds and pictures.

So many POM gears are used in a CD/LD player on its main mechanisms for disc loading, disc rotating, and pickup positioning; particularly on the pickup-slide-rack. (Photo14.2.5:CD player, and Photo14.2-6:LD player)

The pickup component is the assembly of the base, coil-bobbin, and lens holder. LCP is employed to make the lens holder that requires dimensional stability. The stability comes from a small coefficient of linear expansion and a low shrinkage of LCP. (Photo14.2-7)

PPS replaced metal to make the actuator on a CD-pickup base. This material is favored for its stiffness, dimensional precision, and long-term stability.(Photo14.2-8)

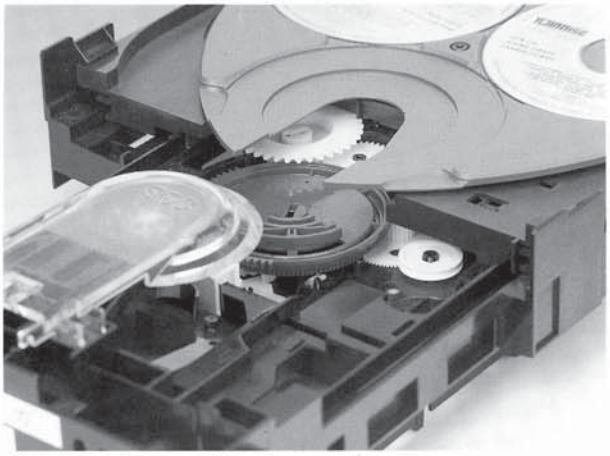


Photo14.2-5 CD player/gear (POM)

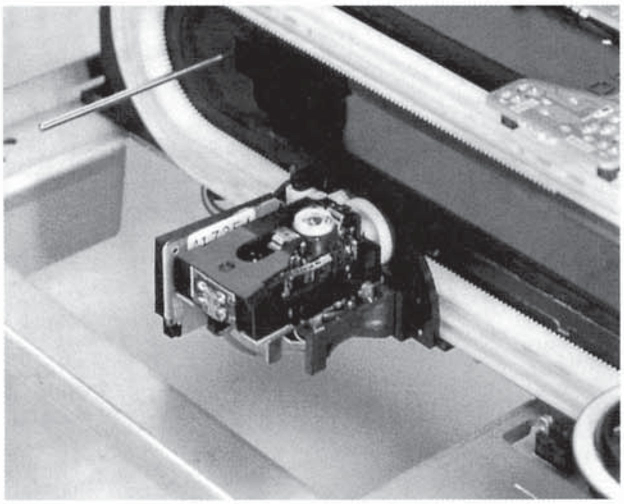


Photo14.2-6 LD player/pickup gear (POM)

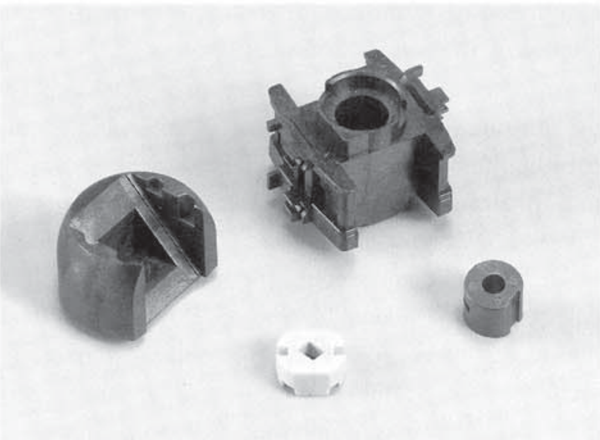


Photo14.2-7 LD player/lens holder (LCP)

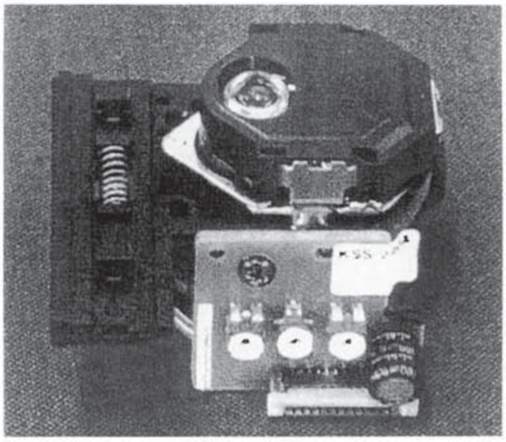


Photo14.2-8 CD player/actuator on pickup base (PPS)

Optical disc --- CD and LD

PC is a suited material to this application because of its transparency and other optical characteristics. Also favored are dimensional stability and impact strength. Use of a very high precision molding technology makes the most of the PC properties to bring out the products of well-controlled quality. (Photo14.2-9:CD and Photo14.2-10:LD)

Photo14.2-9 Optical CD (PC)

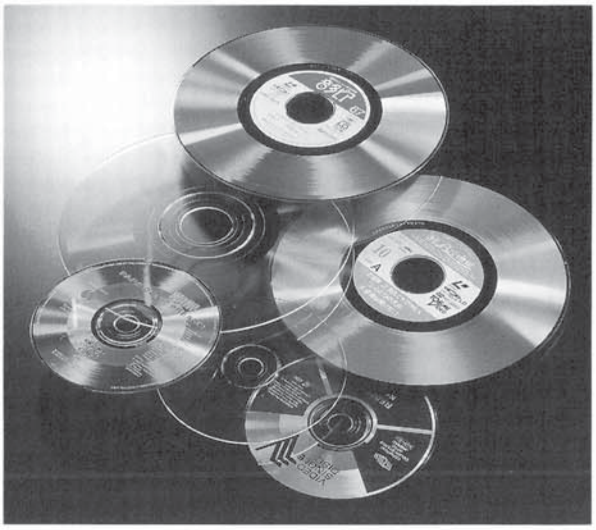


Photo14.2-10 Optical LD (PC)

Portable CD-player housing

Strength and lightweight are the key requirements to the housing. PC is employed for its mechanical strength, impact strength, aesthetic appearance, and dimensional stability.

Photo14.2-11 Portable CD-player housing (PC)

DVD player

A heat resistant grade PPE is the material of choice to make the chassis. Stiffness, dimensional stability and processability of this material come together.

DVD player is a newly developed AV machine that is on a rising popularity.

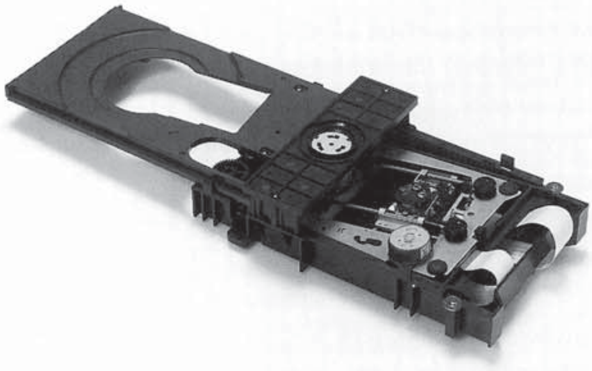


Photo14.2-12 DVD-player chassis (PPE)

DAT deck, VTR deck, VTR with a built-in camera unit

Photo14.2-13 shows the cassette loading mechanism on a DAT deck. The side-panel material is GF-PBT, which provides stiffness and a low warpage. The worms, cams, gears, and other parts in the loading mechanism on the side-panel are made of POM for creep resistance, grease resistance, and friction/wear properties.

The mechanical parts in VTR and DAT demand the material that has mechanical strength, creep resistance, fatigue endurance, dimensional stability, and friction/wear properties. PC is useful in the parts that require stiffness and dimensional stability. POM is most prevalent in gears and other parts that must have good friction/wear properties. GF-PBT takes some parts where POM could not offer a sufficient strength and stiffness.

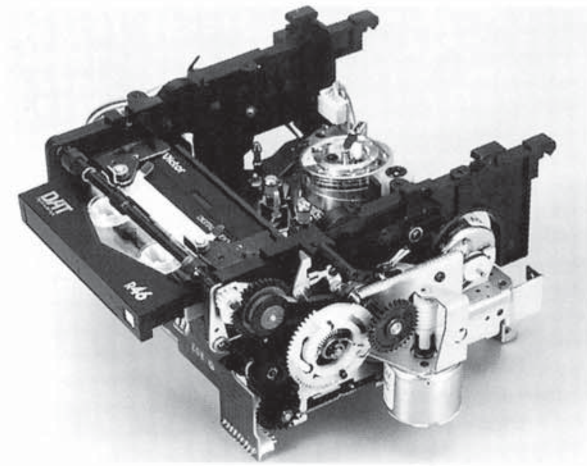


Photo14.2-13 DAT-deck tape loading mechanism (POM parts, PBT side panel)

The VTR with a built-in camera unit is a typical product coming with small-size, thin-wall and light-weight. Engineering plastics are for use in the main lens-tube and the driving-mechanism.

The main lens-tube in Photo14.2-14 is made of GF-PC. This material has toughness and dimensional stability, and can be molded into a thin-wall, complex-shape article with a good aesthetic appearance.

In the driving-mechanism, POM makes cams, ratchets, guide-rollers and gears for being strong, grease resistant, and superb in friction/wear properties.

Photo14.2-15 shows a VTR chassis made of PPS, which has stiffness and dimensional precision. A double-outsert-molding technique is applied to making the chassis to eliminate some of conventional processing steps.

The material of the VTR motor stators (Photo14.2-16) is LCP, which has thin-wall-moldability, heat resistance, and vibration-suppressing properties. The VTR motor parts are becoming progressively thinner to meet the strong demands for downsizing and weight-trimming of the product.

Photo14.2-14 VTR camera lens-tube (GF-PC)

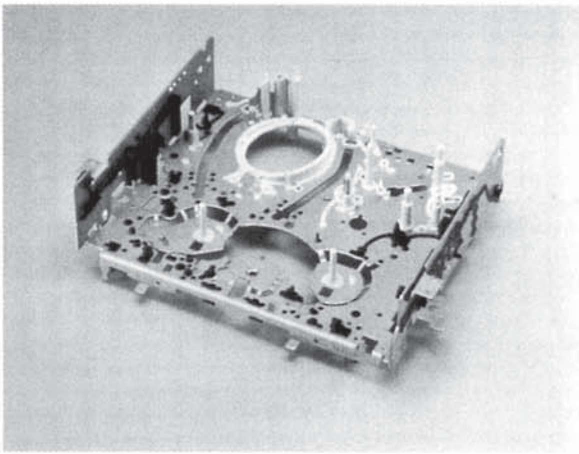


Photo14.2-15 VTR chassis (PPS)

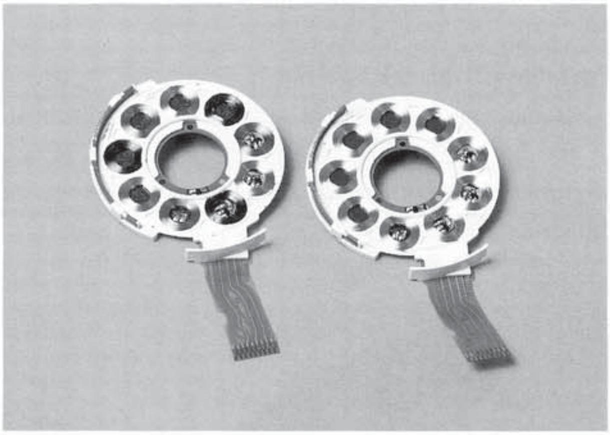


Photo14.2-16 VTR motor stator (LCP)

Household appliances

Household-appliances present engineering plastics with a vast field of applications, where new products are born at an amazing rate. Introduction of electronic technologies into this field immensely promotes improvement of existent models. As such, the plastics industry is encouraged to develop new materials and broaden the application horizons.

Engineering plastics are for use in both the internal mechanisms and the external housings. The processing method and the quality requirements determine the material to be employed. The quality requirements include heat resistance, electrical insulation, friction/wear properties, fatigue endurance, chemical resistance, and so on.

In recent years, safety considerations urge the electrical parts to be more hard-burning and more heat resistant than ever, yet within an allowable cost frame. To understand the exact scope of property requirements is increasingly important today in order to select the material of an appropriate cost-performance.

Pressing iron

A pressing iron is composed of a heated metal and a handle with a heat insulation plate sandwiched in between.

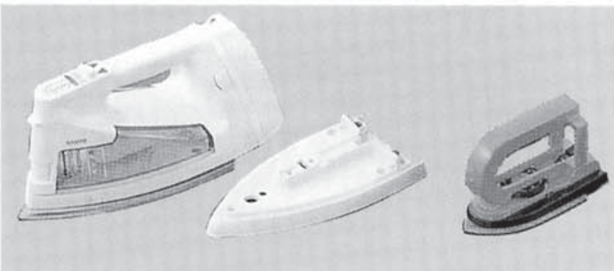


Photo14.2-17 Pressing iron heat-insulation plate (PET)

Photo14.2-18 Pressing iron handle and stand (PBT)

The material of the heat insulating plate (Photo14.2-17) has switched from a painted phenolic resin to GF-PET. The thermoplastic material offers ease of coloring and finishing, heat resistance, and a low warpage, which altogether translates into a reduced cost.

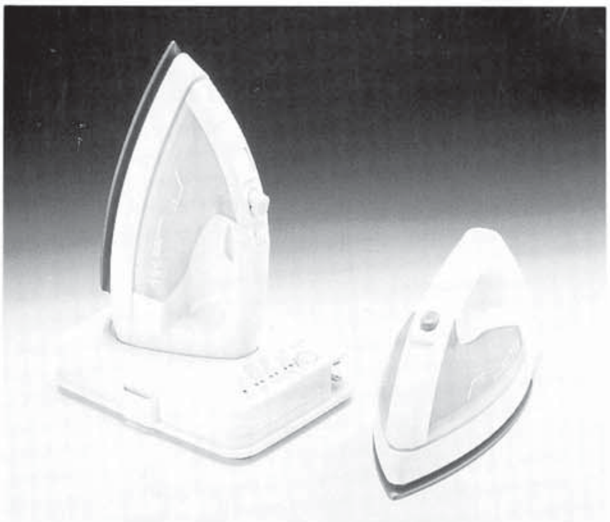


Photo14.2-19 Pressing iron water reservoir (PC)

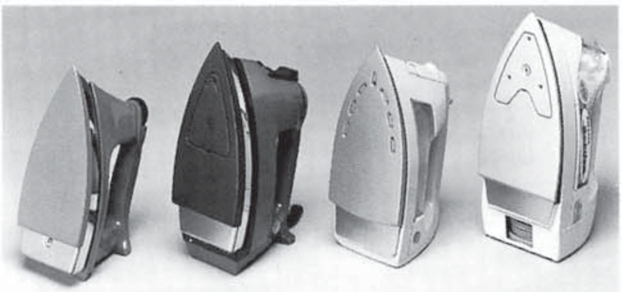


Photo14.2-20 Pressing iron bottom plate (coated with PTFE-enamel)

Photo14.2-18 shows a handle and a heel-rest stand made of GF-PBT, which has a good aesthetic appearance and resistance to thermal discoloration.

The water reservoir of the steam-and-dry iron in Photo14.2-19 is made of clear PC, which is resistant to steam and heat.

Photo14.2-20 exhibits the pressing-iron soles coated with PTFE-enamels. PTFE is suited to this application for its low-friction and non-sticking characteristics as well as heat resistance.

Various engineering plastics are used in the pressing-iron parts to exploit the heat resistance of the materials.

Hair dryer and hair curler

As the hairstyle fashion changes, diverse hairstyling implements come on the market: for example, hair dryers, iron-treatment hairbrushes, and comb hair curlers. Engineering plastics are the indispensable materials to make those hairstyling tools.

Reinforced PBT or reinforced PET is used for making a handle and an air-outlet grill because of a good aesthetic appearance, and the resistance to thermal discoloration.

PBT is employed, for being heat resistant, also to make the fan of a hair-dryer air blower as shown in Photo14.2-21.

TPEE is used as the material of the hot comb hair curlers in Photo14.2-22 because of its tactile comfort, heat resistance and processing ease.

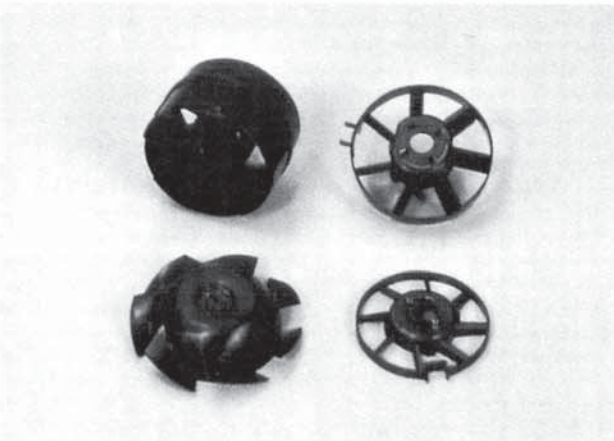


Photo14.2-21 Hair dryer fan (PBT)

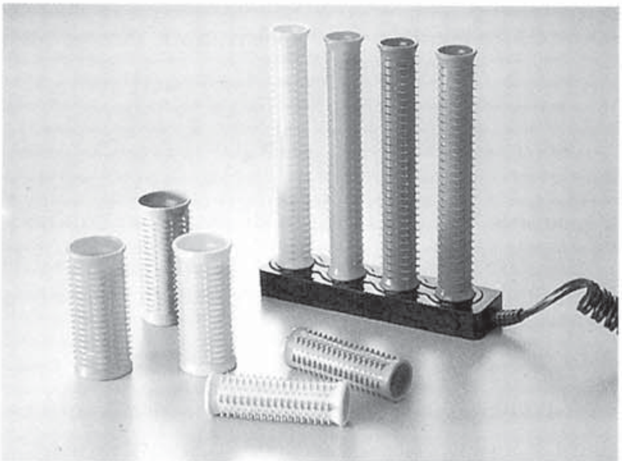


Photo14.2-22 Hot comb hair curler (TPEE)

Washer and dryer

A washing machine has the planetary gear that serves on stirring and speed reduction. The gear is made of POM and GF-POM, which replaced metal. Those materials are employed not only for their friction/wear properties, fatigue endurance, and lightweight, but also for their ability to save driving power, decrease noise, and lower costs. (Photo14.2-23)

Home-use clothe dryers are now on a growing popularity. The heater holder in a dryer, Photo14.2-24, is made of PPS chosen for having a very high heat resistance, chemical resistance, and processability.

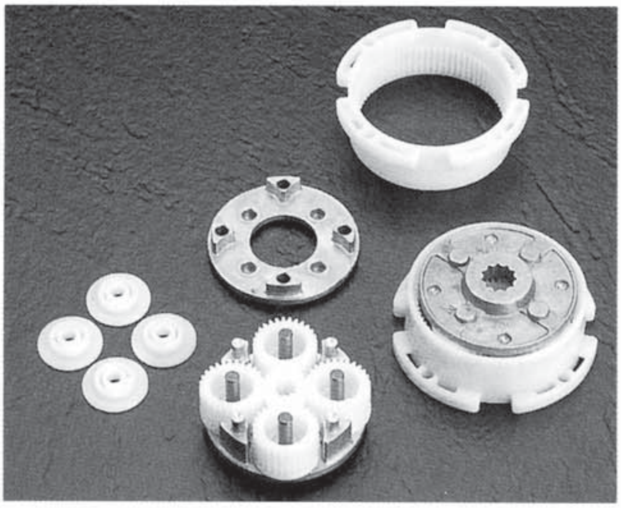


Photo14.2-23 Washer planetary gear (POM)

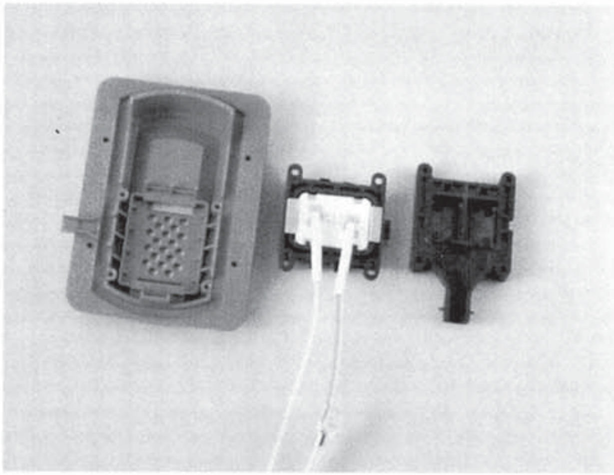


Photo14.2-24 Clothe dryer heater holder (PPS)

Vacuum cleaner

GF-PET serves as the material of the motor-bracket/air-guide (Photo14.2-25) for dimensional precision, stiffness, and heat resistance. The material

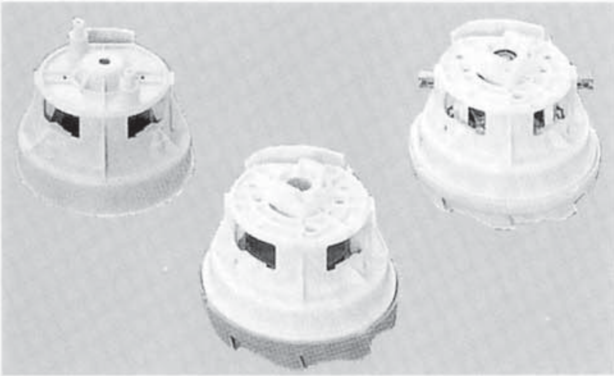


Photo14.2-25 Vacuum cleaner motor-bracket/ air-guide(PET)

Photo14.2-27 Griddle (PET)

was switched from iron plates to GF-PET in order to lower part counts by molding the consolidated parts.

POM or PA6 is used as the material of the shafts and the bearings in a cord-reel, rollers and pulleys to deal with friction and wear.

Microwave oven

Photo14.2-26 shows a door cover made of a reinforced PET which has a good heat resistance and an aesthetic appearance as well as currently favored antibacterial properties.

A microwave oven more often comes in a combination of oven and roaster. In order to handle the elevated temperature, engineering plastics are in wide use for electrical insulations, heat-resistant housings such as frames and choke-coil covers, and friction/wear parts such as latches and levers.

Cooking utensil

Photo14.2-27 shows a use of reinforced PET for a cooking griddle. The merits of the material are heat resistance, coloring versatility, chemical resistance, aesthetic appearance, and the overall economy.

Engineering plastics have cultivated a strong presence in cooking utensil applications making the most of their heat resistance in this typical high-temperature use. Use of hard-burning thermoplastics in this application is increasing, and taking hold of a substantial market by replacing conventional thermosets. The thermoplastics, with its processing versatility, can meet the recent demands for colorful appearance.

Photo14.2-26 Microwave oven/door cover (PET)

Garbage dispenser

Home-use garbage dispensers are commercialized with an appeal to environment-conscious minds.

The practical methods of treating garbage are biodegradation and thermal dehydration/decomposition. In any method, a dispenser incorporates rotating parts equipped with gears as shown in Photo14.2-28. Those gears are made of POM, which has good friction/wear properties.

PPS is used in some cases for making a thermal-treating vessel because the material is resistant to heat and chemicals.

In the biodegradation method, mixing of garbage with specific microorganisms turns the garbage into carbon dioxide and water. In the thermal dehydration/decomposition method, heat drying of the garbage removes about 80 percent of the contained water.

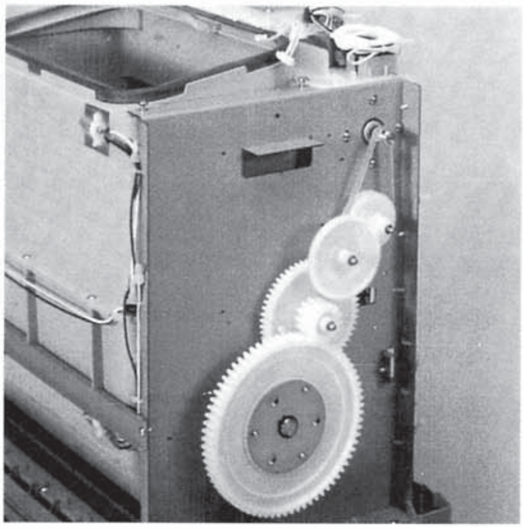


Photo14.2-28 Garbage dispenser/gear (POM)

Dishwasher

POM gives the benefits of dimensional precision, chemical resistance, and processability to the three-part assembly of a pump casing in Photo14.2-29.

Dishwashers are beginning to gather household popularity in Japan.

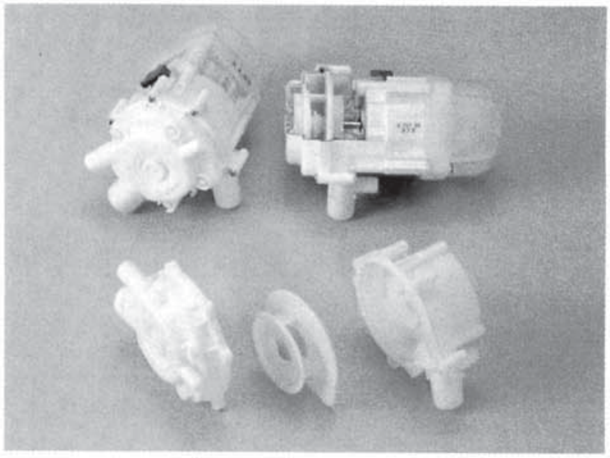


Photo14.2-29 Dishwasher/pump casing (POM)

Fluorescent lamp

Coil bobbins and housings are made of engineering plastics. The vast mass-production of fluorescent lamps calls for high-cycle molding of the parts, which requires a good flow material.

Reinforced PET is a trusted material to make the coil bobbins of the ballast choke coils to generate a high voltage (Photo14.2-30). This material has good electrical properties at high temperatures, thin-wall flowability, dimensional precision, and applicability to automatic assembling.

The housings in Photo14.2-31 are made of PBT for aesthetic appearance, stability in UV-light and resistance to thermal discoloration.

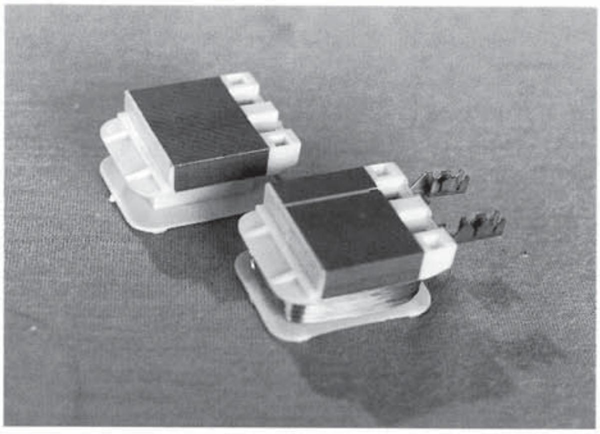


Photo14.2-30 Fluorescent lamp/coil bobbin (GF-PET)

Television set

Modified-PPE is employed in the electron-beam polarization yoke, which controls electron beams in the magnetic field at the neck of the picture tube (Photo14.2-32). The yoke is exposed to a high temperature, therefore demands a combination of heat resistance and hard-burning characteristic besides a high dielectric breakdown voltage.

Engineering plastics are used also in the flyback transformer that supplies high-voltage DC pulses to the picture tube.

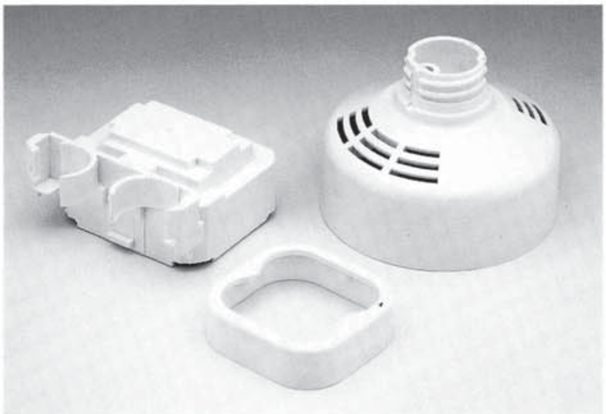


Photo14.2-31 Fluorescent lamp/housing (PBT)

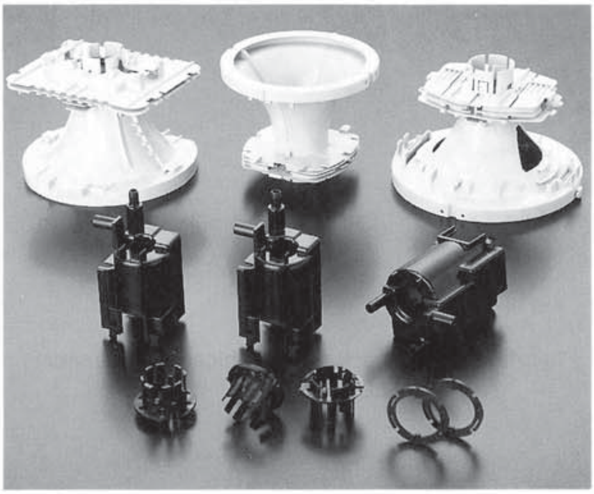


Photo14.2-32 Television set/polarization yoke (PPE)

Portable socket outlet

PBT is the material of the body and around the slots of a portable socket outlet (Photo14.2-33).

This plastic is hard-burning and highly resistant to tracking. Also features thin-wall flowability, better snap-fit fastening and a higher productivity as compared with conventional thermosets.

Photo14.2-33 Portable socket outlet/body and around slots (PBT)

Electronic parts

In the recent development of electronic technology, the increases in performance of equipment and the decreases in size of product are progressing very rapidly. Engineering plastics have been in this field as heat-resistant and insulative materials to make connectors, sockets, coil bobbins, switches, transformers, relays, sensors, and many other items.

More variety of plastics are in use today than earlier days to cope with the new needs for a larger-scale circuit integration and a higher reliability in performance.

Relay

Relay cases employ PBT, Modified-PPE, and other plastics. The case in Photo14.2-34 takes benefits of GF-PBT: high-flow characteristic and little emission of harmful gases to relay contact points.

Shown in Photo14.2-35 is a circuit protector made of GF-PBT, which is employed for a reliable long-term stability as well as electrical properties, heat resistance, hard-burning characteristic, and oil resistance.

The relays in Photo14.2-36 are the telecommunication-equipment parts to be assembled by a surface-mounting technology (SMT). GF-LCP is employed for its small emission of harmful-to-metal gases as well as heat resistance and processing ease.

Heat resistant and clear PC is used as the material of the relay housings in Photo14.2-37.

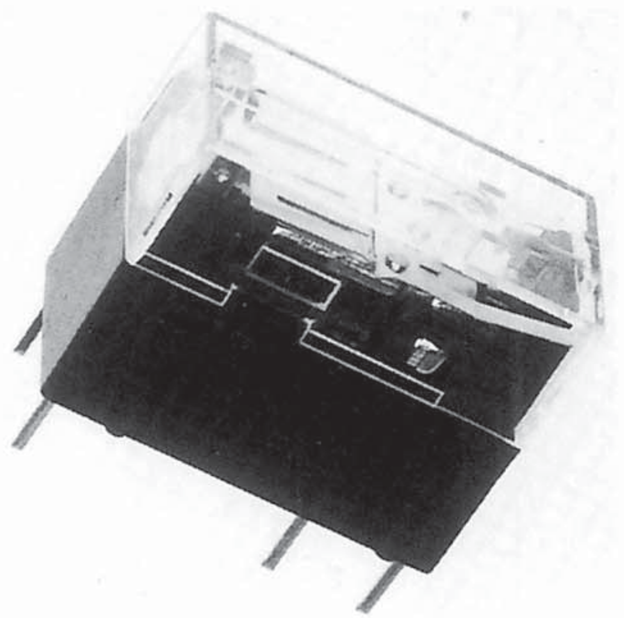


Photo14.2-34 Relay case (PBT)

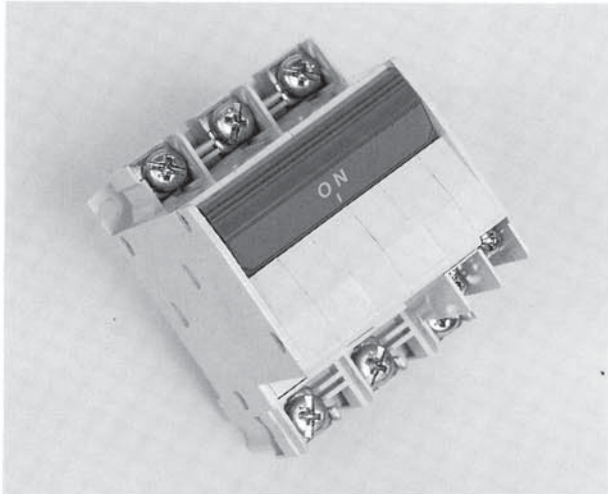


Photo14.2-35 Relay/circuit protector (PBT)

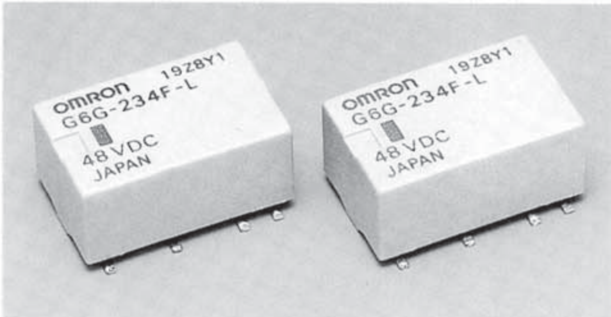


Photo14.2-36 Relays for communication equipment (GF-LCP)

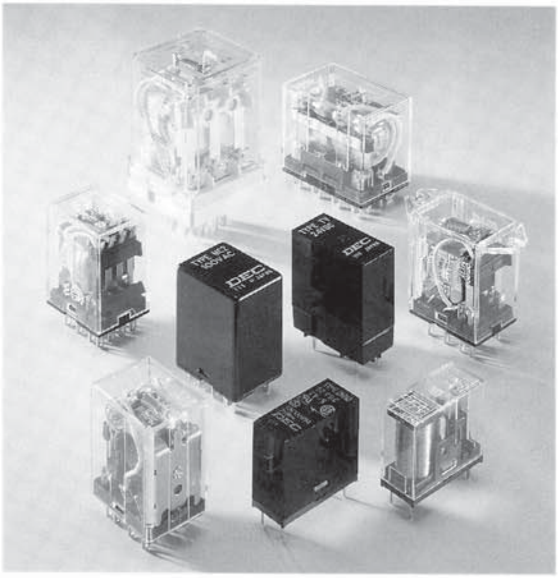


Photo14.2-37 Relay housing (PC)

Connector

Connectors, semi-conductors and ICs are the representative parts in the electronic industry. Among them, tens of thousands of connectors are used in so diverse ways that a vast number of connectors are made of a wide variety of engineering plastics.

Shown in Photo14.2-38 together with coil bobbins are connectors made of PBT, which provides electrical insulation property, hard-burning characteristic, dimensional precision, and processing ease.

The connectors shown in Photo14.2-39 are made of reinforced PBT, which gives dimensional precision, heat resistance, and stiffness.

Photo14.2-40 shows connectors for a video camera. GF-PA46 is employed for heat resistance, stiffness, and particularly for integral-hinge properties.

The connectors shown in Photo14.2-41 are applicable to SMT(Surface Mounting Technology). They are made of PPS for stiffness, toughness, and endurance to heat at a re-flow soldering temperature.

LCP makes use of its good flow-properties and soldering-heat endurance to be employed in the connector for a personal-computer card as shown in Photo14.2-42.

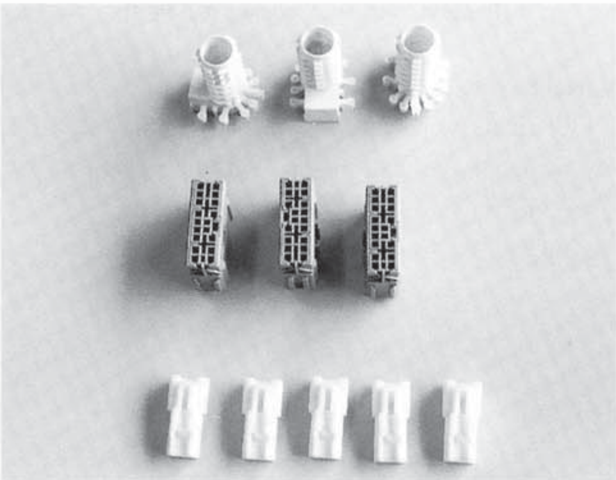


Photo14.2-38 Connector and coil bobbin (PBT)

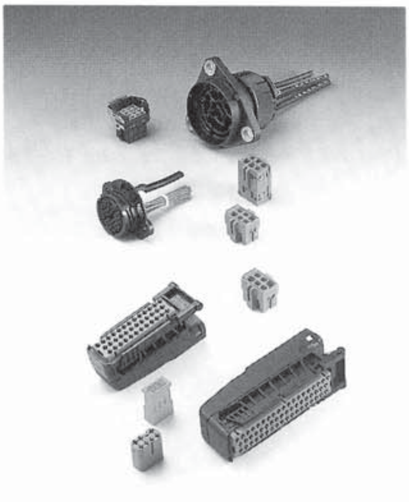


Photo14.2-39 Connector (PBT)

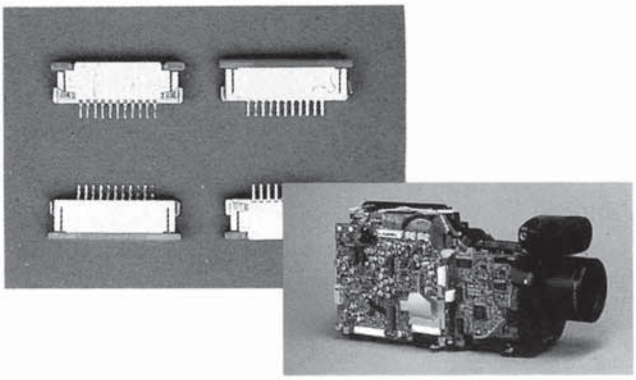


Photo14.2-40 Connectors for VTR camera (PA46)

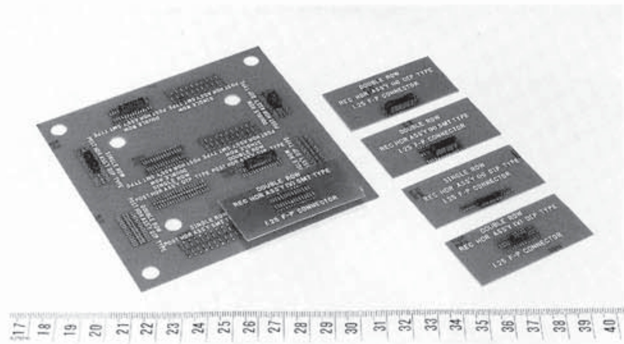


Photo14.2-41 Connectors applicable to SMT (PPS)

Photo14.2-42 Connector for PC card (LCP)

IC(Integrated Circuit) burn-in socket

Photo14.2-43 exhibits a use of GF-PES. The glassfiber reinforced material applies its high heat resistance and dimensional stability to making the IC burn-in socket.

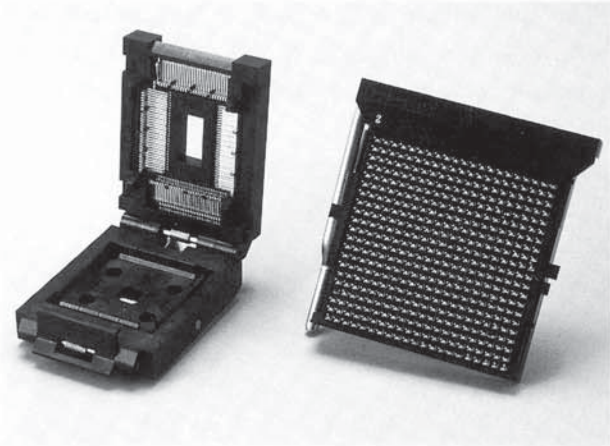


Photo14.2-43 IC burn-in socket (GF-PES)

Socket for testing IC performance-reliability

Photo14.2-44 is another use of GF-PES in a socket for testing IC performance-reliability in high-temperature environments. The GF-PES for this use contains 30%-glassfiber reinforcement to have a high heat resistance and dimensional stability.

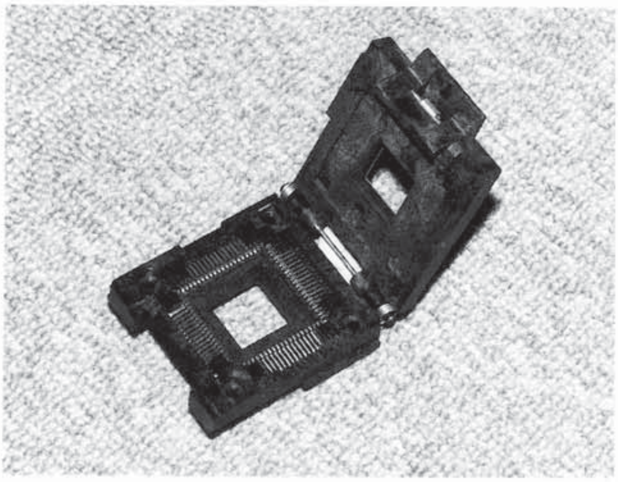


Photo14.2-44 Socket for testing IC (GF-PES)

PGA(Pin Grid Array)

A 30%-GF-PES is employed to make the PGA sockets which are prevalent in personal computers. This material is dimensionally stable and heat resistant.

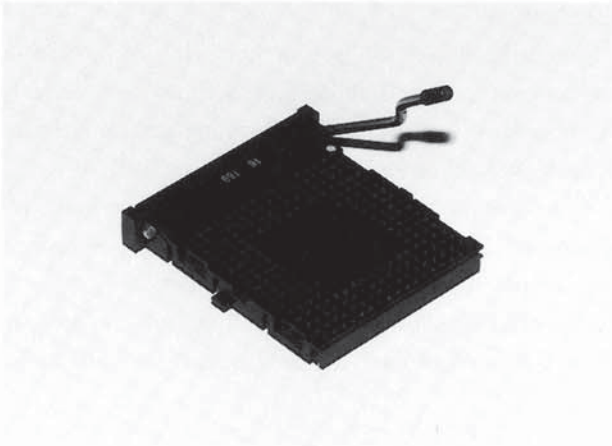


Photo14.2-45 PGA socket (GF-PES)

Variable resistor

Electrical properties and processability of PBT are favored to make the variable resistors in Photo14.2-46.

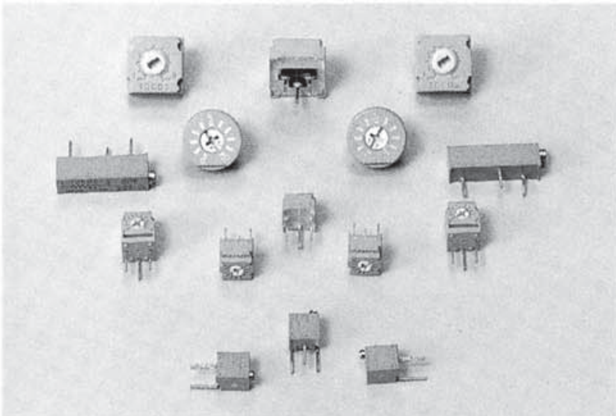


Photo14.2-46 Variable resistor (PBT)

Transformer coil bobbin

GF-PET is used as the material of the transformer coil-bobbin in Photo14.2-47. This plastic is hard-burning even in a small thickness, and holds properties at elevated temperatures.

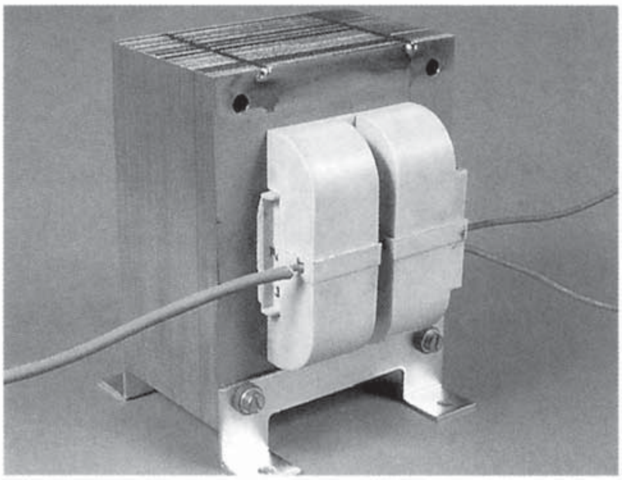


Photo14.2-47 Transformer coil bobbin (PET)

IC tray

As shown in Photo14.2-48, the tray, made of Modified-PPE, is to hold and carry a large number of ICs on a flat plate.

The tray requires a stiff and low-warpage material with electro-conductivity to protect ICs from static charge. Also required is a thermal stability to facilitate molding. Modified-PPE can handle the needs.

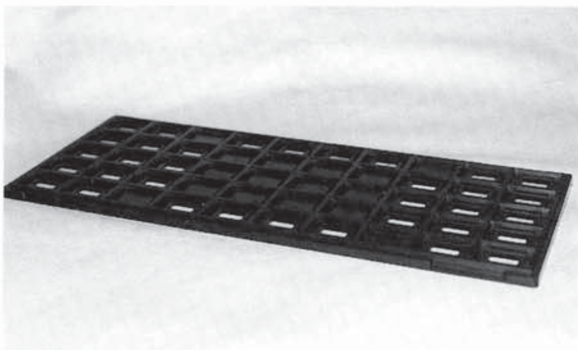


Photo14.2-48 IC tray (PPE)

Fuse holder

The fuse holders in Photo14.2-49 are made of Modified-PPE for its high dielectric breakdown voltage, UL94 V-0 rated hard-burning characteristic, and heat stability.

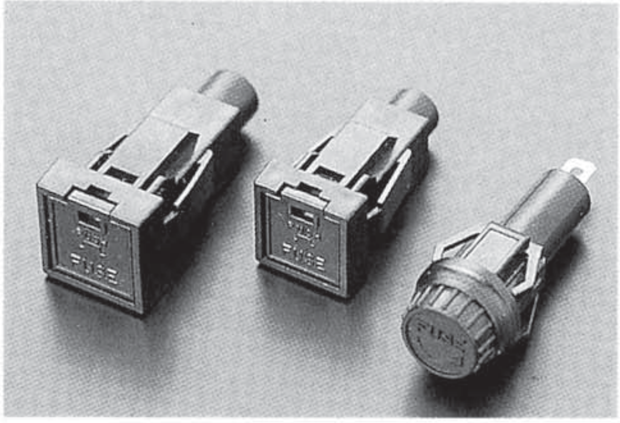


Photo14.2-49 Fuse holder (PPE)

IC-Wafer carrier

PFA is used for molding the wafer carriers in Photo14.2-50. Since the carriers run on a wafer-cleaning line and go through an etching process, they must be free from impurities and resistant to chemicals and heat. PFA is a trusted material in this application.

The antistat-type PEEK that scarcely attracts dusts is another material of the carriers. Its characteristics include chemical resistance, a low content of solvent-extractables, and a small emission of gas.

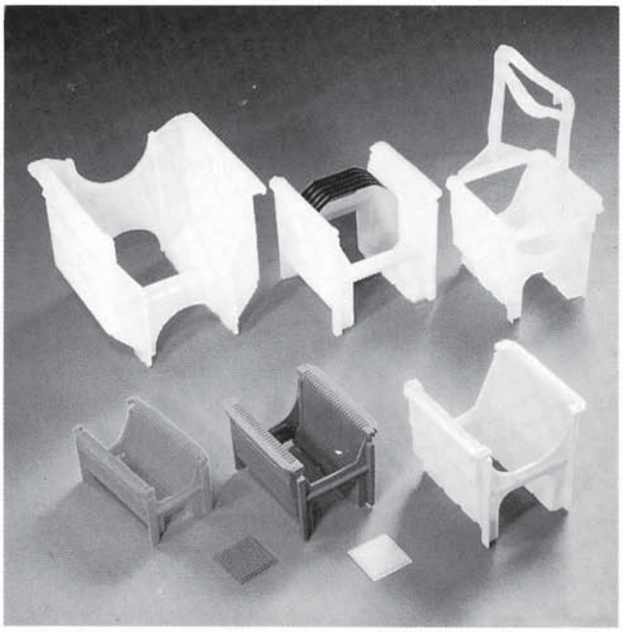


Photo14.2-50 IC-Wafer carrier (PFA)

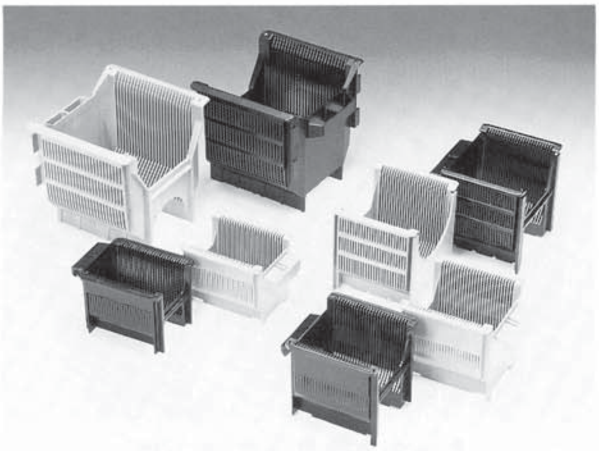


Photo14.2-51 IC-Wafer carrier (PEEK)

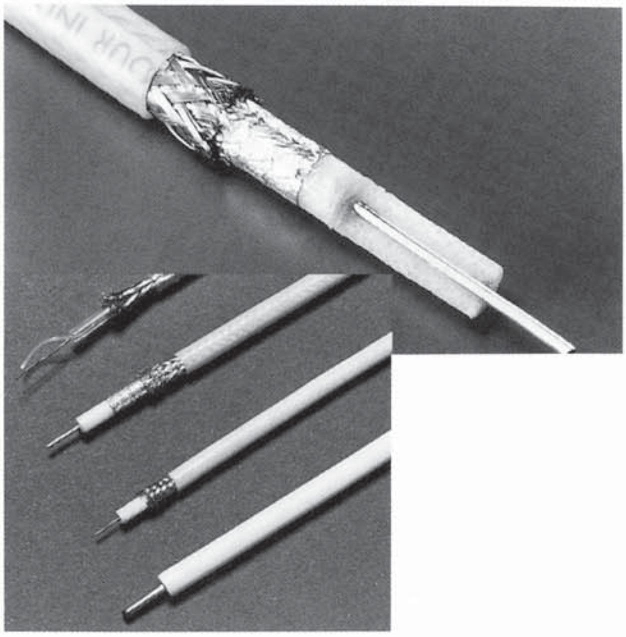


Photo14.2-52 Electric-cable insulation (PTFE, PFEP)

Electric wire/cable

Photo14.2-52 exhibits PTFE- or PFEP-insulated cables for connecting network computers. Those fluorine-containing plastics offer their low dielectric constants and the low dissipation factors.

An electric wire/cable comprises a copper- or aluminum-conductor, an insulation that wraps the conductor, and an outer-covering. Reliability is essential to the insulation material since the wire/cable serves an important task of transmitting power or signals.

Plain PTFE tapes are used for sealing the screw-joint-fittings of threaded pipes, and for insulating wires and other parts. Those uses exploit such properties of PTFE as chemical resistance, heat resistance, and self-lubricating characteristics.

Office ware and Information appliances

The market demands are on a sharp increase for office wares and information appliances such as office computers, personal computers, facsimiles, word processors, and copying machines. Keeping pace with it, the types and the quantities of engineering plastics for use in those applications are rapidly expanding. Particularly in the area of personal-use machines like word processors and personal computers, engineering plastics greatly help the parts meet the strong drive for downsizing, weight trimming, and wall thinning of the products.

Printer, copying machine, and facsimile

Photo14.2-53 shows printer chassis which employ PC as the material.

The chassis of a printer, copying machine and facsimile must have stiffness and dimensional stability. PC has adequate stiffness, dimensional stability, heat resistance, and UL94 V-0 rated flame retardant characteristics.

The copying-machine internal chassis, Photo14.2-54, employs MD-PPE, which offers heat resistance, flame retardant qualities, stiffness, and dimensional stability. In this example, a combination of a gas-assisted injection molding technology and a parts-consolidation design was adopted to realize low-pressure molding, which resulted in the product of a high dimensional precision with curtailment in assembling cost.

Photo14.2-55 and 56 show examples of POM-made gears for a printer and a copier. This material is employed for dimensional precision, friction/wear properties, and self-lubricating characteristic.

POM and PC are the widespread materials to make driving-mechanism parts such as gears, sprockets and pulleys. In some applications where suppression of noise is critical, those materials

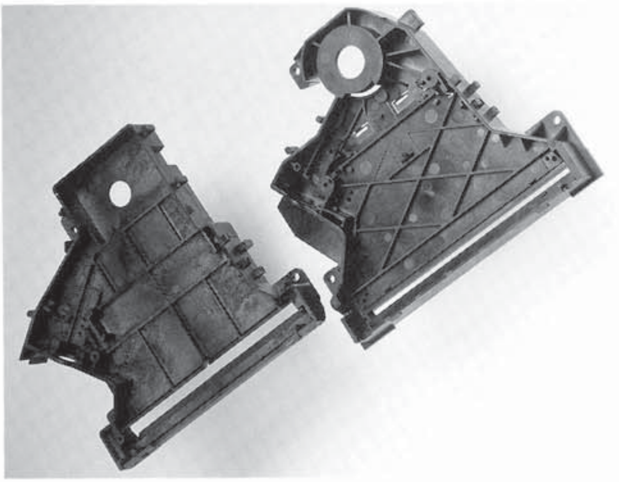


Photo14.2-53 Printer chassis (PC)

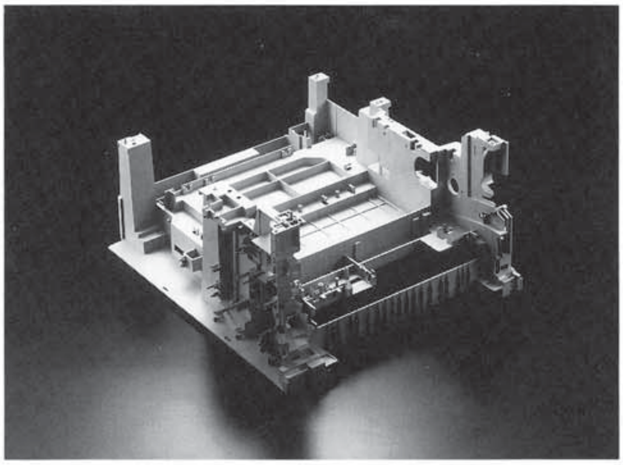


Photo14.2-54 Copying machine/internal chassis (PPE)

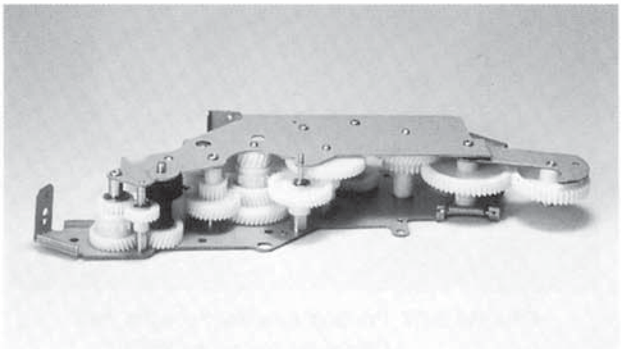


Photo14.2-55 Printing machine/gears (POM)

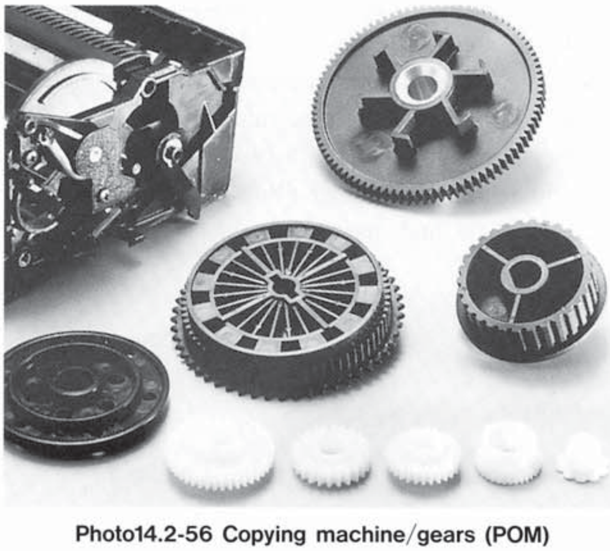


Photo14.2-56 Copying machine/gears (POM)

combine with PA or rubber.

Photo14.2-57 shows paper-peeling nails made of a whisker-reinforced PEEK for being stiff, tough and resistant to heat. PAI, PPS and PI also have their shares of use in this application.

In a copying machine, the toner powders fuse and fix on the sheet of paper that is being pressed against a heated roll; then the nails peel the sheet off the surface of the roll. As such, the material of the peeling nails must have heat resistance, frictional wear resistance, ease of sliding, and strength to make a tough tip point that contacts paper.

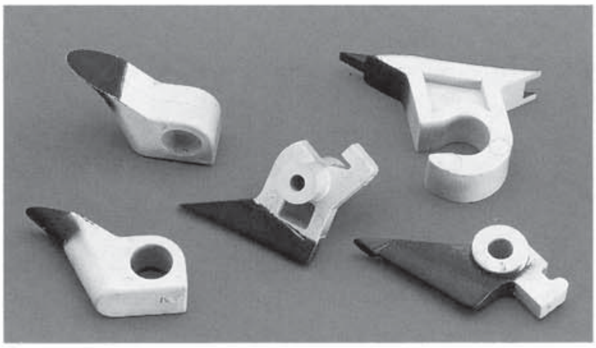


Photo14.2-57 Printing machine/peeling nail (Whisker-reinforced PEEK)

Personal computer

A GF/MD-PA6 alloy is the material of the housing of the notebook-size personal computer in Photo14. 2-58. The material of a personal-computer housing must be moldable into a thin-wall yet retaining stiffness; also moldable with ease yet without lowering impact strength. The alloy can live up to the requirements, and has stiffness, UL94 V-0 rated hard-burning characteristic, a low warpage, and a good appearance.

Photo14.2-58 Personal computer/housing (GF/MD-PA)

Keyboard tops employ such materials as ABS, POM, and PBT, which have frictional wear resistance, dimensional stability and chemical resistance. Photo14.2-59 is a picture of PBT-made key-tops showing the letters, figures and signs printed with an impregnating ink.

The key-stems, which connect the key-tops to the switches underneath, must operate smoothly and steadily in response to the delicacies of finger movement. POM has long been the material of the stems for its friction/wear properties and dimensional stability. The key-stem takes various configurations depending on the type of computer: desktop, notebook-size, and much slimmer mobile computers. Photo14.2-60 shows a POM-made keyboard on a notebook-size computer.

Photo14.2-61 shows a SIMM (Single Inline Memory Module) socket which benefits from such properties

Photo14.2-59 Keyboard/key-top (PBT)

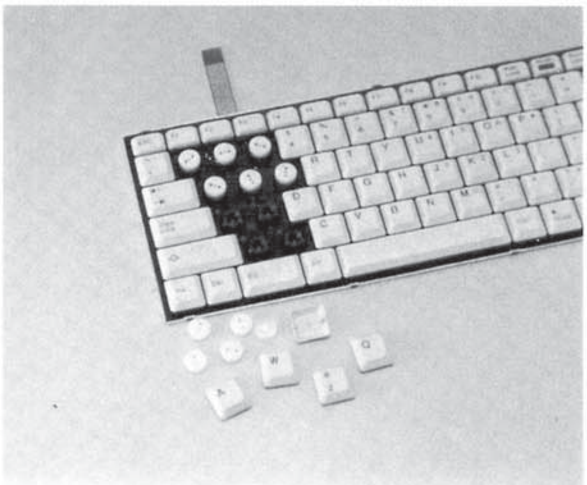


Photo14.2-60 Keyboard/key-stem (POM)

of LCP as soldering-heat endurance, flowability, stiffness, and precision moldability.

Photo14.2-62 shows another type of LCP socket: a ZIF (Zero Insert Force) socket.

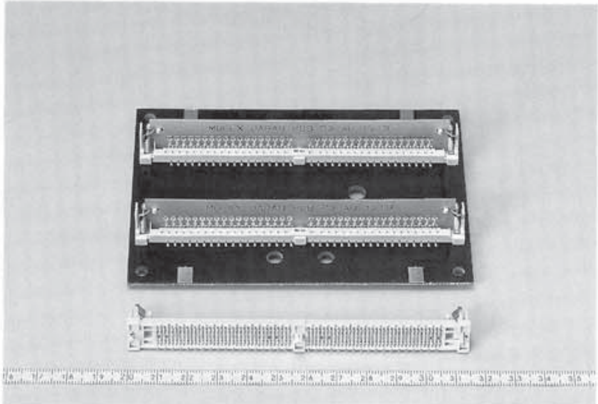


Photo14.2-61 Personal computer/SIMM socket (LCP)

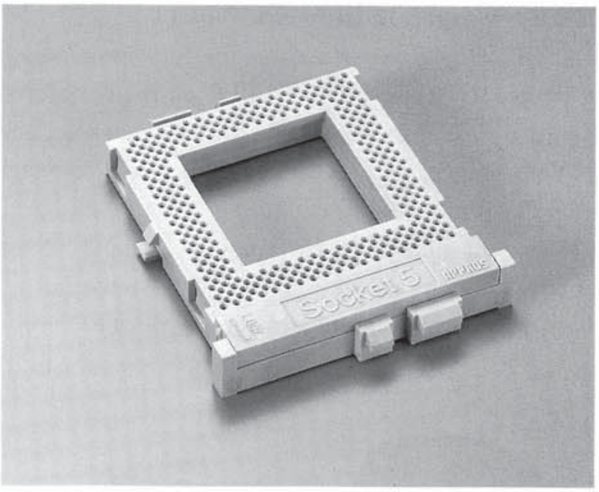


Photo14.2-62 Personal computer/ZIF socket (LCP)

Cooling fan

The cooling fan is an important device in a computer because the high concentrations of integrated circuits elevate the temperature within the enclosure. The fans in Photo14.2-63 and 64 are made of GF-PBT and GF-PET, respectively. The materials feature a low warpage; hence, little deformation occurs on the fan-blades or the axle even in a high-temperature/high-revolution condition.

Floppy-disk access-window shutter

The material of the shutter in Photo14.2-65 is a high-flow grade POM, which replaced stainless steel. The POM was employed in favor of its friction/wear properties, fatigue endurance, spring-like elastic

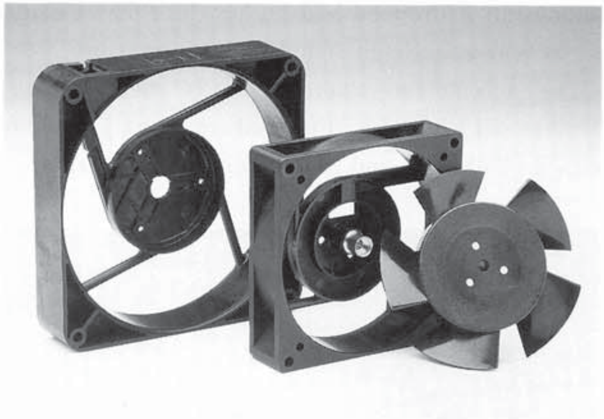


Photo14.2-63 Cooling fan (PBT)

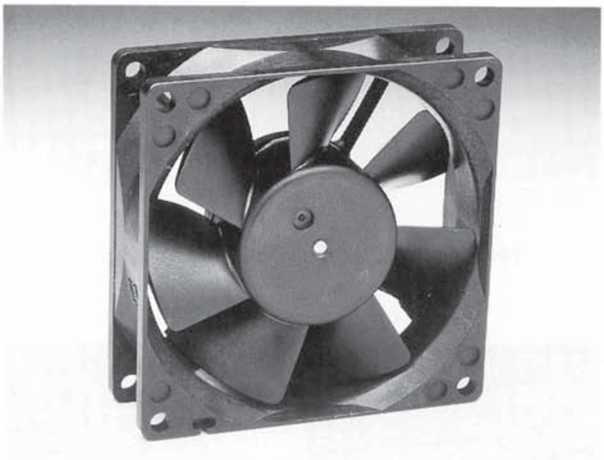


Photo14.2-64 Cooling fan (PET)

Photo14.2-65 Floppy-disk access-window shutter (POM)

response, high flow, as well as the benefits of downsizing, cost reduction, and versatile coloring.

Mobile-phone/Cordless handset

In Photo14.2-66 and 67 are mobile-phone housings made of PC. This material is employed due to impact strength great enough to prevent the break of housing if dropped and hit on the floor. PC also presents heat resistance and design versatility.

The antenna in Photo14.2-68 is sheathed in a flexible TPEE. This material facilitates molding with its high-flow and mold-release characteristics.

Photo14.2-66 Mobile-phone/housing (PC)

Photo14.2-67 Mobile-phone/housing (PC)

Photo14.2-68 Cordless handset/antenna sheath (TPEE)

Battery charger/Battery case

The battery charger and the battery cases shown in Photo14.2-69 use Modified-PPE as their material. Modified-PPE imparts hard-burning characteristic, heat resistance, and electrical properties (dielectric breakdown voltage).

Now that notebook-size personal computers and mobile-phones proliferate in the society, the battery charger is an indispensable auxiliary device.

Photo14.2-69 Battery charger and battery case (Modified-PPE)

Circuit breaker

The circuit-breaker covers in Photo14.2-70 employ GF-PA6 as the material that brings about a high stiffness and a low warpage.

The circuit breakers in Photo14.2-71 are the examples of use of GF-PES, which has heat resistance, hard-burning characteristic, electrical properties, and dimensional precision.

In Photo14.2-72 are the end-caps of small-size motors. GF-PA66 is suitable for this application with its stiffness, strength, and chemical resistance.

In Photo14.2-73 are PPS insulator parts for small motors. PPS is employed for its strength and precise moldability.

Dry-cell

Photo14.2-74 shows dry-cell gaskets to prevent leakage of electrolytes and protect the cells from rupture. Non-reinforced PA66 is the material of this example for a good flow, strength and chemical resistance.

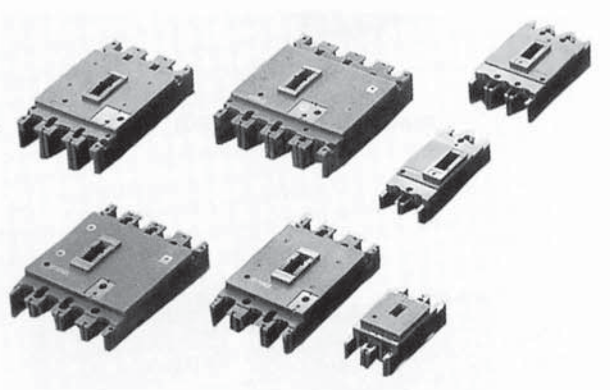


Photo14.2-70 Circuit breaker cover (GF-PA6)

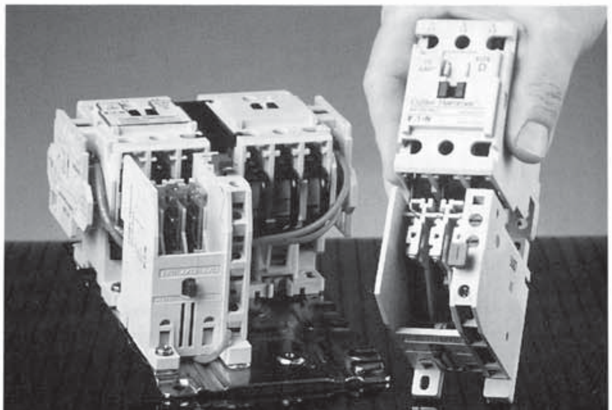


Photo14.2-71 Circuit breaker (GF-PES)

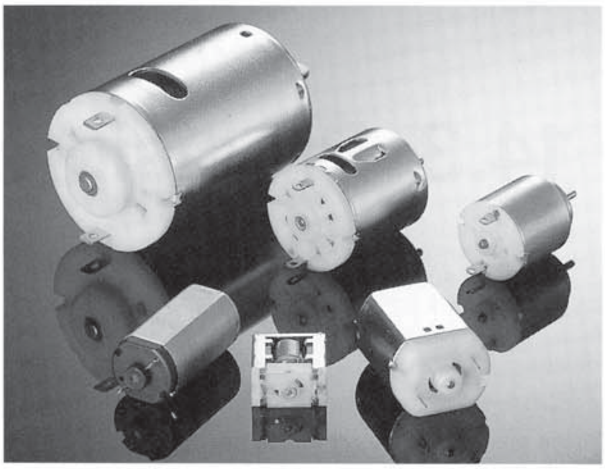


Photo14.2-72 Small-size motor/end cap (PA66)

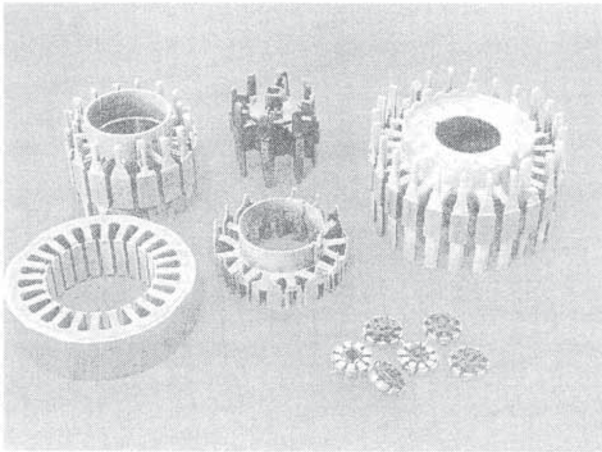


Photo14.2-73 Small-size motor/insulator (PPS)

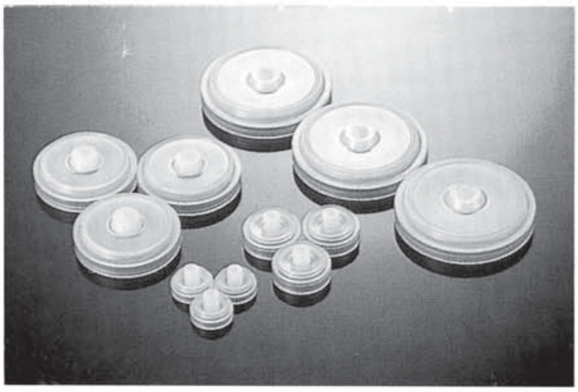


Photo14.2-74 Dry-cell/gasket (PA66)

14.3 Precision equipment

Cameras and wristwatches are the prevalent products that incorporate plastic precision parts. Those products must be aesthetically good in appearance as well as mechanically functional in performance; hence, the quality requirements to those products include tactile feel, colors and styles besides mechanical functions. See Table14.3-1.

Equipment \ Requirements	Impact strength	Aesthetic appearance	Dimensional stability	Heat resistance	Stiffness	Flow properties	Friction/wear properties
Camera(case)	○	○	○		○	○	
Camera(press plate)			○		○		○
Wristwatch(housing)		○	○		○		
Binoculars(scope tube)		○	○		○		

Table14.3-1 Property Requirements to the Materials of Precision Equipment

Photo14.3-1 Camera (PC)

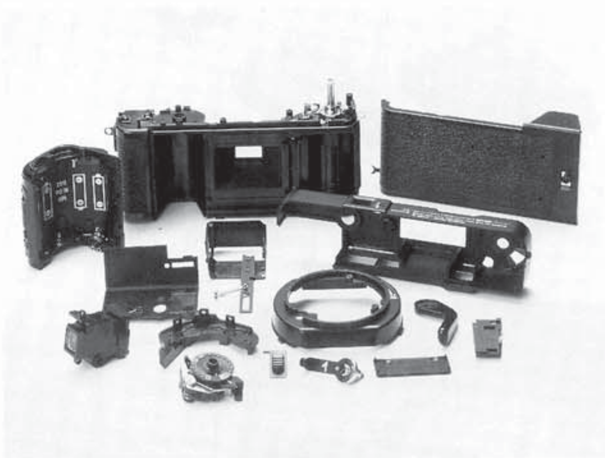


Photo14.3-2 Camera parts (PC)

Camera

Photo14.3-1 and -2 show a camera and its parts. Plastic parts account for 15 to 20 percent on the number of all parts in a camera.

GF-PC is the most widely employed material in favor of its small coefficient of linear expansion, which is near that of aluminum, thereby can cope with a very stringent requirement for dimensional precision.

The body, the frame, and the scope tube do not allow painting. Therefore, the material must present a smooth surface even if reinforced with glassfibers.

Camera makers use plastic materials in an attempt to trim the weight and reduce the size of their products. They also intend to lower the costs through streamlining the manufacturing process by introducing a parts-consolidation design; for that purpose, plastics are far more advantageous than metals in the design freedom.

Clock and watch

A high dimensional precision is the essential requirement for gears to transmit mechanical power smoothly, and to lower the noise that intermeshing cogs generate.

POM is the most suited material to gears for its dimensional precision, fatigue endurance and friction/wear properties.

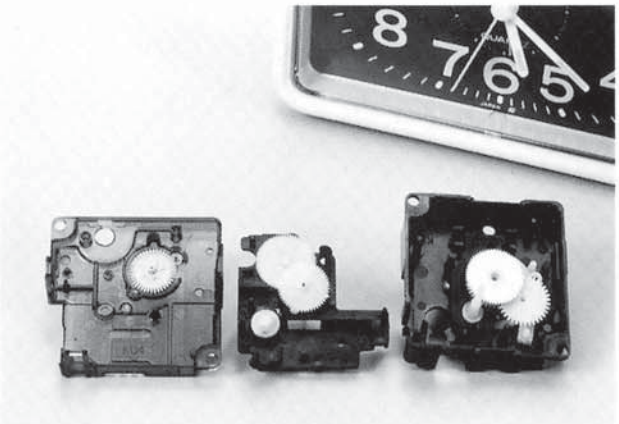


Photo14.3-3 Clock gear (POM)

Photo14.3-4 Wrist-watch mechanical parts and gear (POM)

Photo14.3-5 Wrist-watch case (GF-PAR)

Many of the wristwatch cases must be shaped to a perfect-circle and be dimensionally stable to seal the mechanism tightly. Also, the cases must stand up to varying outdoors-use conditions including possible

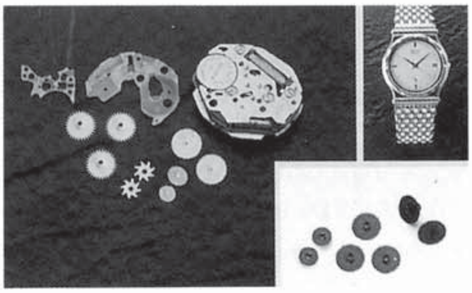


Photo14.3-6 Wrist-watch face plate and movement (PC)

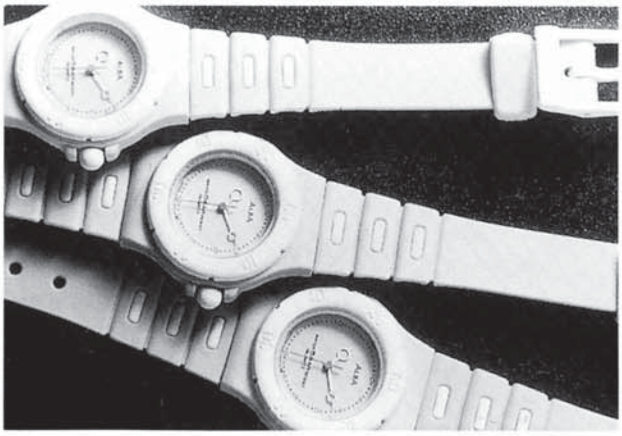


Photo14.3-7 Wrist-watch band (Polyamide elastomer)

contact with chemicals. The cases of some models directly contact the human skin, therefore should have a smooth surface for tactile comfort. The watchcase material must be tough enough to pass the drop-impact and other strength tests so that the watchcase can protect the vital part of the watch such as the module (the liquid crystal part).

The faceplate and the movements of a watch must maintain a precise, accurate and steady operation for long periods. PC is used for manufacturing those parts in appreciation of its dimensional stability, stiffness, and strength.

Young people go for a lightweight and colorful wristwatch band. PVC and polyurethane abound in the band materials. A polyamide elastomer is coming out in this field because this engineering plastic retains softness and flexibility all the year round, in the summer heat or the winter cold.

Binoculars

A lightweight and easy-to-operate pair of binoculars is a favored tool for enjoying an opera or bird watching.

The main scope tubes of the binoculars in Photo14.

3-8 are made of GF-PAMXD6. The material of the parts must have stiffness so that the lens may sit accurately in the right position. Also, it must offer a stabilized dimensional precision including the ability to make a scope tube with a perfectly circular cross-section. GF-PAMXD6 is the material of choice to replace conventional die-cast aluminum or zinc. This polyamide plastic has a sufficient stiffness; a small coefficient of linear expansion which comes close to that of metal; a low water absorption among PAs; hence, a good dimensional stability.

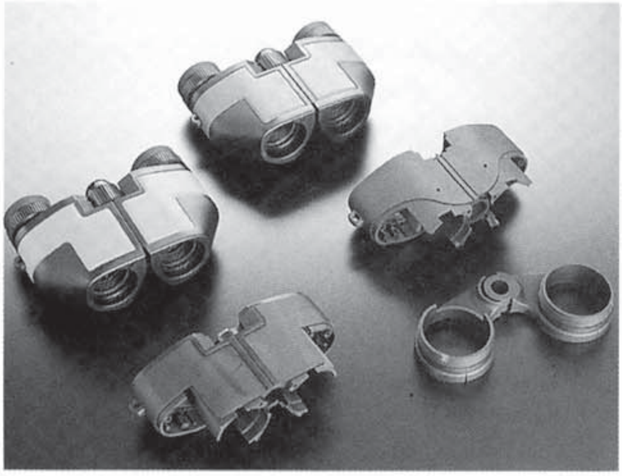


Photo14.3-8 Binoculars (GF-PAMXD6)

14.4 Industrial machine

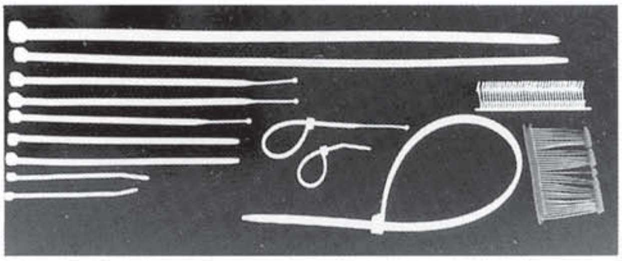
The development of industrial machines has brought about a high productivity, and saved on human labor chores in the modern industrialized society.

Engineering plastics contribute to the progress of Office Automation, Factory Automation and other automated operations. In the industrial traits for downsizing and weight-trimming of equipment, so many functions and parts are squeezed into a small space in equipment to result in an elevated temperature within the enclosure. Engineering plastics are gaining a higher importance as the materials that can cope with the requirement for an ever-higher endurance to heat.

Strapping fastener

PA is the material of the strapping fasteners in Photo14.4-1. PA makes a good snap-fitting, is soft and pliable, durable in heat, resistant to oil/grease, and moldable into a thin wall at a high-cycle.

The strapping fasteners are pliable, resilient, easy to handle, and useful for organizing electric wires in automobiles and electrical appliances. Use of the fasteners helps reduce steps in assembling those machine products,



Power-tool housing

GF-PC or GF-PA is replacing conventional die-cast aluminum as a material of housing. The plastic material utilizes its property advantages such as lightweight, electrical insulation, impact strength, long-term dimensional stability, and a good appearance.

Photo14.4-2 shows some electric-power tools: a circular saw, a drill, a sander, and a grinder. Use of power-tools instead of traditional hand-tools is the norm in carpentry work today.

Photo14.4-2 Power-tool housing (GF-PC)

Chainsaw handle

GF-PA is used for making a chainsaw handle to trim the weight of the tool. This material provides the handle with stiffness, impact strength, and oil/grease resistance.

The chainsaw has greatly reduced the time and labor needed to cut down a lumbering tree; and for that sake the tool ever claims to be lighter in weight.

Photo14.4-3 Chainsaw handle (GF-PA)

Liquid flow meter

A transparent PA is adopted as the material of the liquid flow meter that features a visible flow of liquid: Photo14.4-4. PA is resistant to chemicals, resistant to heat, very light in weight and less likely to break than glass.

A liquid flow meter is an everywhere-instrument in chemical plants.

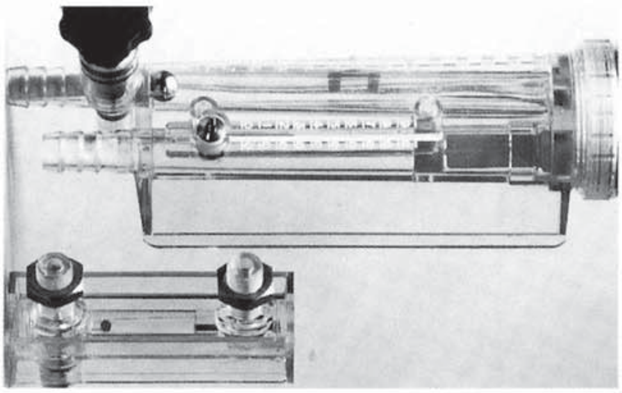


Photo14.4-4 Flow meter (Transparent PA)

Gas handling equipment

Introduced here for information are gas-handling equipment used in Europe where a gas-meter is changed over to a new one every 12 to 30 years.

Photo14.4-5A: POM replaced conventional metals in the body and the diaphragm of the gas-meter to ensure a long-term reliability. This plastic is well balanced in its properties including resistance to corrosion by gases,

Photo14.4-5B: POM is also used for making an orifice in the pressure-reducing valve. PA66 is employed in the disc holder for its good friction/wear properties in contact with POM.

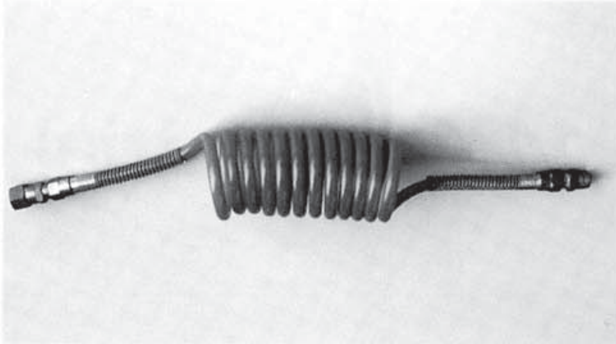


Photo14.4-6 Air tube (PA11)

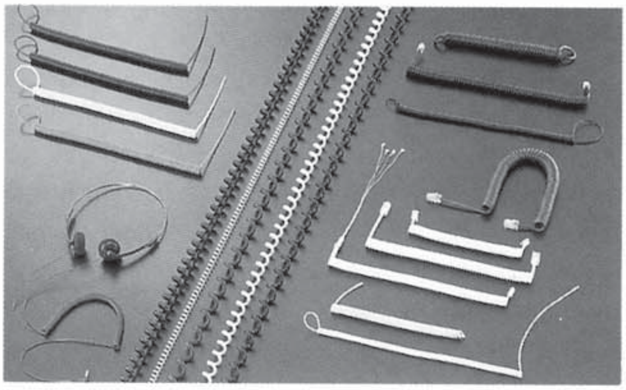


Photo14.4-7 Helical cord (TPEE)

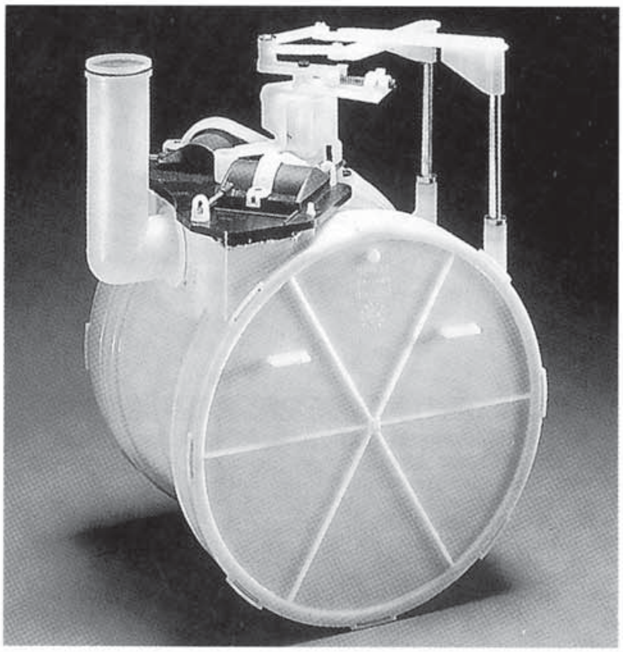


Photo14.4-5A Gas-meter body (POM)

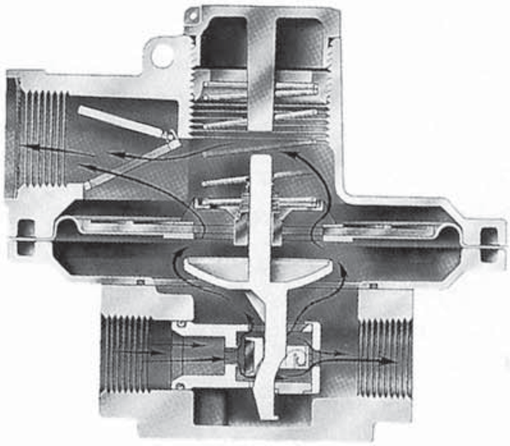


Photo14.4-5B Pressure reducing valve (POM, PA66)

Air tube and helical cord

PA11 and TPEE are replacing such conventional materials as polyvinyl chloride, rubber, and polyurethane. That is to meet strong demands from market for lightweight and easy recycling.

The replacing materials are favored for their flexibility, toughness, and a spring-like elasticity.

Solar cell housing

Photo14.4-8. The employed material is a transparent PC formulated for an improved chemical resistance and weatherability.

Photo14.4-8 Solar cell housing (PC)

Lining of chemical-process equipment

As shown in Photo14.4-9, developments of a PTFE-sheet/glassfiber-cloth laminate and a PTFE-on-PTFE melt-bonding technology come together to enable an on-site application of anticorrosion lining on a large drum.

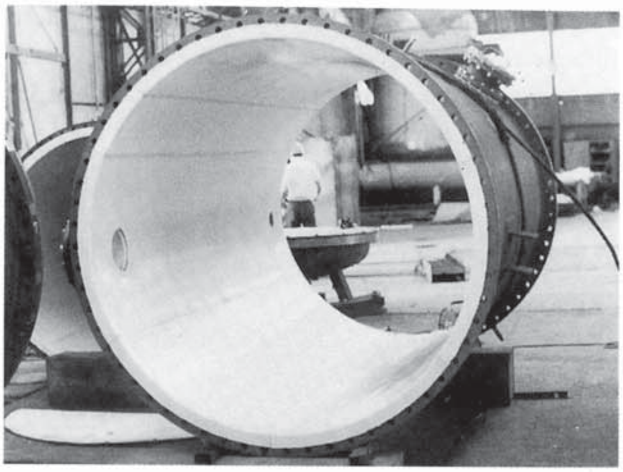


Photo14.4-9 Anticorrosion sheet lining (PTFE)

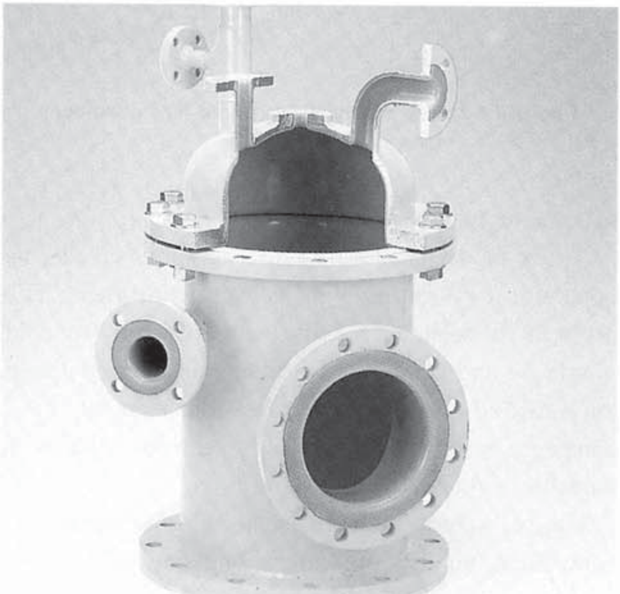


Photo14.4-10 Anticorrosion rotational-lining (PFA/ETFE)

The lately developed static-charge-painting and rotational-lining enable PFA or ETFE to form a thick lining. That resulted in a lining on a complex-shape article with branching pipes as shown in Photo14.4-10.

Transfer rack of photo-film developer

Modified-PPE replaced conventional metal as the material of the transfer rack in Photo14.4-11. The rack makes use of the property advantages of Modified-PPE: resistance to inorganic acids and alkalis, adequate heat resistance up to 120℃, a low warpage and a small mold-shrinkage.

A number of units, each measuring 270x300

~450mm, join together to make a rack. A photo-film-development service used to take a day or more; the modern system equipped with the transfer rack has realized even a one-hour service.

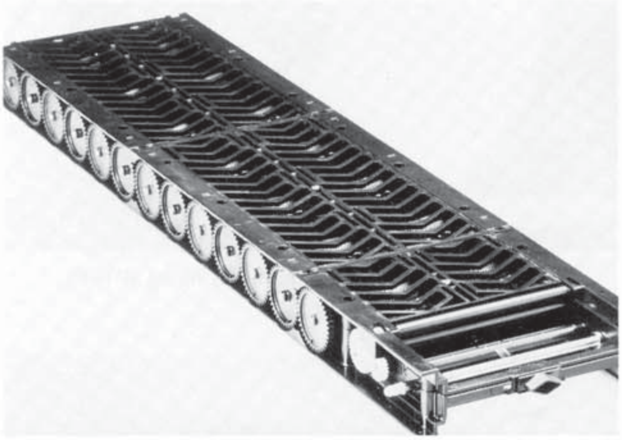


Photo14.4-11 Transfer rack of photo-film developer (Modified-PPE)

pH-sensor electrode case

A new-model casing of a pH-sensor electrode has opted for PPS rather than conventional glass. This material is selected for its being resistant to acid, alkali, oil and fat. The PPS casing accommodates an ion-sensitive electrolytic transistor element in a compact, strong and durable electrode, which is portable and easy to use.

The pH sensor is an indispensable instrument for controlling quality of water. The new-model electrode remains wet for a prolonged period, and needs only a very small amount (several microliters) of water for measurement.

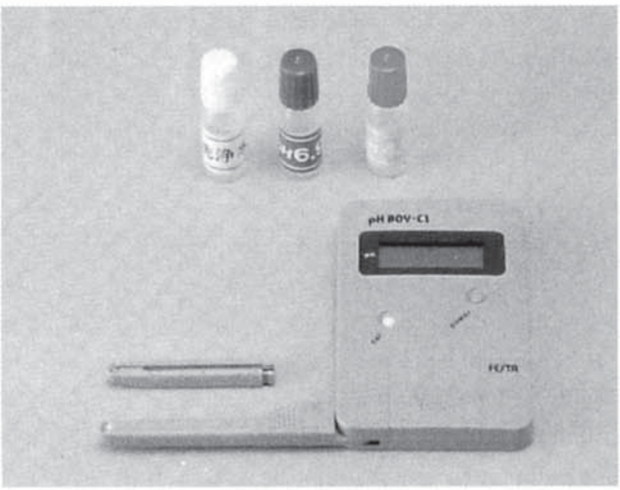


Photo14.4-12 pH sensor electrode case (PPS)

Frame for supporting magnet on laser condenser

GF-PPS is the material of the frame, Photo14.4-13: an oval article with 70mm major diameter for supporting a magnet on a laser condenser. This application exploits the property advantages of GF-PPS: insulation with $7.5x10^{16}$ohm-cm volume resistance, maximum use-temperature at 130℃, stiffness with approx. 0.5GPa flexural modulus at 300℃, flame retardancy with V-0 rating at 1.57mm thickness, and dimensional precision within +/-15 micrometer.

Laser is useful in wide-ranging fields including optical communication, holography, clinical medicine, and cutting of metal.

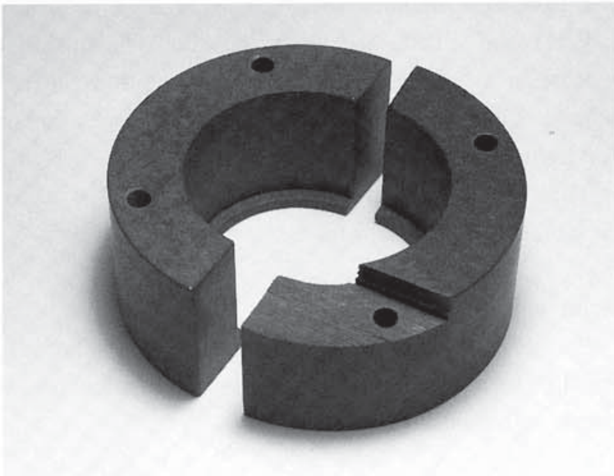


Photo14.4-13 Frame for supporting magnet on laser condenser (GF-PPS)

Photoelectric sensor

GF-LCP is the practicable material for the photoelectric sensor, Photo14.4-14, which is incorporated in a broad variety of instruments.

This plastic is chosen for having such properties as a flowability to perform encapsulation at a low pressure(approx.$100kg/cm^2$), a dimensional stability with a coefficient of linear thermal expansion not exceeding $2x10^{-5}$/℃, ease of fitting on other plastic parts(casing, lens assembly, etc), and tight joining onto the metallic inner parts.

Photo14.4-14 Photoelectric sensor (GF-LCP)

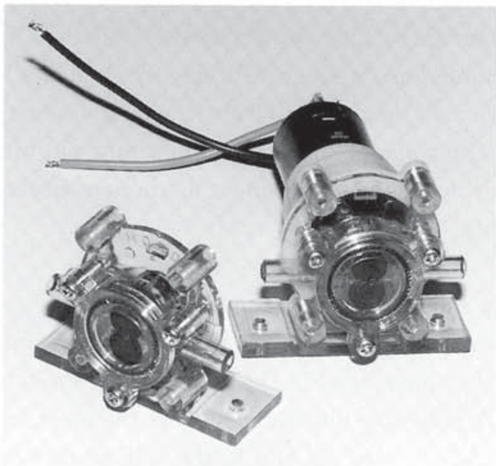


Photo14.4-15 Gear pump (PES)

Gear pump

The gear-pump housing in Photo14.4-15 uses PES in place of conventional PA to increase strength at an elevated temperature. Such improvement brings about a stable discharge of liquid at 70-80℃. PES is a transparent material and resistant to chemicals, therefore suitable for the housing of a pump to spray agricultural chemicals. The clear housing features a visible moving liquid.

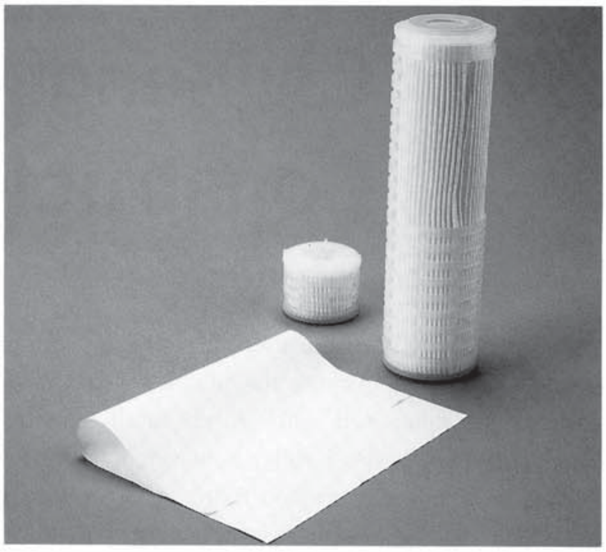


Photo14.4-16 Membrane filter (PES)

Membrane filter

PES makes the membrane filter, Photo14.4-16, for handling pure water at 60-80℃ in medical, pharmaceutical, and food-processing industries. The filter must stand sterilization in an autoclave at 121℃ for 30 minutes.

A cast film having the micropores of 0.2-0.5micrometers in diameter is shaped into the filter.

Bearing-ball retainer

Photo14.4-17 shows bearing-ball retainers made of CF-PEEK. The bearings are for use in the industrial robots that must survive severe use conditions. CF-PEEK provides the retainer with a sufficient heat resistance, friction/wear properties and a low friction coefficient.

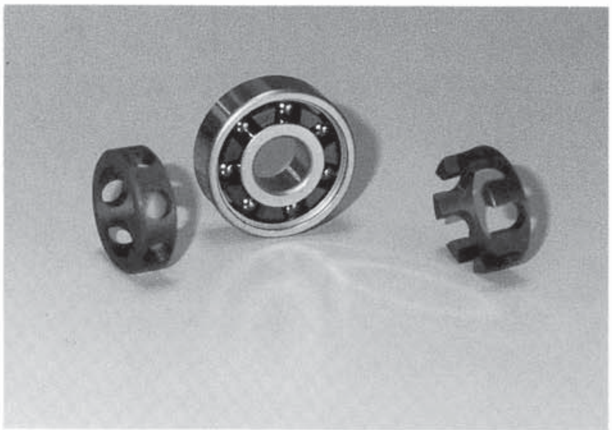


Photo14.4-17 Bearing-ball retainer (CF-PEEK)

14.5 Civil-engineering Construction machine

Varieties of plastics are used in civil-engineering/construction fields. Among the plastics, engineering plastics are consumed only in a small quantity because of high costs. Lately, however, engineering plastics are beginning to find more opportunities to make use of their property advantages such as toughness, weatherability, hard-burning characteristic, corrosion resistance, processability, coloring versatility, and lightweight.

Explanations follow on some of the demonstrated uses.

Control of flying dust

The two shots in Photo14.5-1 show the live scenes of spreading cement and lime at a road-construction site. A big difference is apparent in dusting with or without use of a PTFE-treated soil stabilizer.

An easy-to-fibrillate PTFE is dispersed in cement or lime at about 500ppm concentration, then treated to develop invisibly fine cob-web-like networks, which process makes the soil-stabilizer. The networks trap the particles of the cement or the lime and prevent 99 percent of the dust from flying up into the air.

This development was motivated by the complaints raised by the residents around road-construction sites stating that the flying dust worsened the residential/habitation environments. Also, the workers at the construction site called their working conditions as a trinity of Ds: dirty, dangerous, and demanding.

In Japan, the Law for Promotion of Utilization of Recyclable Resources urges to reduce dumping of the surplus soil that comes from building construction sites. The soil-stabilizer is an important aid in using the surplus soil for road construction instead of dumping.

Lining tube to rejuvenate old gas pipe

A new technology rejuvenates the underground gas pipes that have aged in the soil for long stretches of time. A polyester tube lining covers the inner surface of an old gas pipe, as laid in the soil, to prevent the gas from leaking.

Digging out only a section of an old pipeline is enough to use a special jig that guides and inserts an adhesive-coated tube into the old pipe. The thin and

PTFE-treated soil stabilizer

Not Used　　　Used

Photo14.5-1 Flying dust at road-construction site

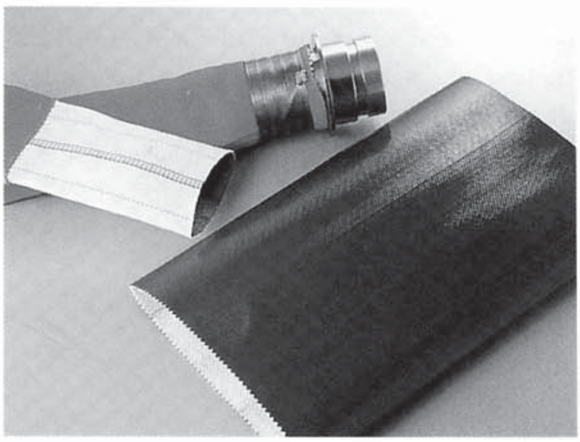


Photo14.5-2 Gas pipe inner-lining tube (Polyester-based elastomer)

flexible tube, Photo14.5-2, is made of an artificial-textile jacket coated with a polyester-based elastomer.

The opportunities to use this technology are broadening: for example, leak-preventive lining of gas pipes in a frequent-earthquake area, reinforcement of gas pipes within a building, and lining to curb invasion of water into an underground sewer system.

Membrane structure building

Tokyo Dome is a well-known air-supported membrane structure in Japan. Its membrane-roof material is a glassfiber cloth with a fluoroplastic coating. The membrane-roof warrants twenty-year durability, and offers performance of many functions, a beautiful appearance and a bright interior. The roof has earned the no-burn rating in conformity with Building Standard Law.

Other types of membrane structure are coming out in recent years. They are a suspension-membrane structure (Photo14.5-3) and a frame-membrane structure. The curved surfaces of a membrane structure blend well with the surroundings to make a good landscape. Many sports arenas, exhibition halls, and arcades are now under the membrane roofs.

Photo14.5-3 Suspension-membrane structure (FR)

Noise-barrier side panels on expressway

Some of the expressways running through the hub of Tokyo are now flanked with embossed and clear PC panels, instead of undecorated and opaque conventional walls.

The PC panels are intended for giving drivers a relaxed feeling, and aimed to rectify the claims raised by neighboring residents for the right to enjoy sunlight. This could be an example of the application unattainable without PC. This material renders superb impact strength and 75%-plus light transmission.

Photo14.5-4 Noise-barrier board on expressway (PC)

Arcade parking place

PC roof panels retain the quality for a long time thanks to the transparency, weatherability, and impact strength of the material. The impact strength of PC is higher than that of PMMA and glass.

Photo14.5-5 Arcade parking place (PC)

The clear roof of the entry way to the parking area of a housing project (pictured above in Photo14.5-5) invites plenty of light and offers an open, expansive atnos phere.

Roof of indoor swimming pool

Transparent and impact-resistant PC sheets are used for making the roofs of the indoor swimming pools as viewed in Photos14.5-6A and 14.5-6B. Use of the PC sheets made it possible to design a window with a curved-surface to take in light and create a classy atmosphere.

The PC sheets greatly facilitated the construction work with their lightweight, ease of making curved surfaces, ease of drilling holes, and other characteristics which were unobtainable with glass.

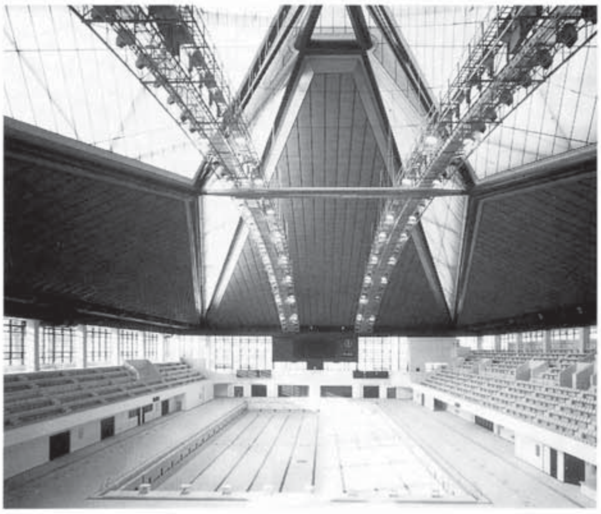


Photo14.5-6A Roof of indoor swimming pool (PC)

Photo14.5-6B Roof of indoor swimming pool (PC)

Bolt, nut, nail

Photo14.5-7 shows various bolts, nuts, and nails made of GF-PA.
Those plastic items are corrosion resistant and rustproof, as compared with their metallic counterparts. They are therefore most suitable for use in chemical plants and in the areas susceptible to salt damage. The heat conduction rates of plastics are smaller than those of metals, therefore the plastic items are effective to mitigate in-room condensation of water. They also have coloring versatility.

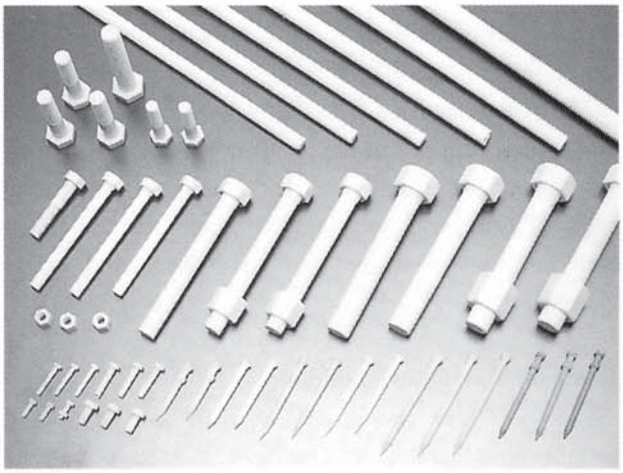


Photo14.5-7 Bolt, nut, and nail (GF-PA)

Water boiler

Water-boiler parts employ varieties of engineering plastics.

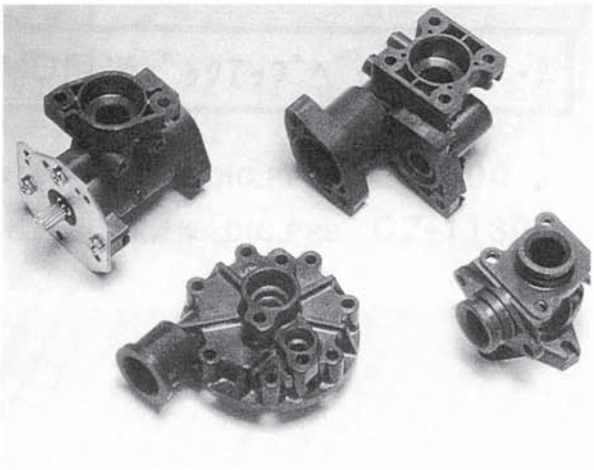


Photo14.5-8 Fitting, valve (PPS)

Photo14.5-9 Integrated hot/cold water mixing faucet (POM)

PPS makes the fittings and valves in Photo14.5-8, putting together its stiffness, heat resistance, oil/grease resistance, and chemical resistance.

POM serves as a material of the parts in the integrated hot/cold water mixing faucet in Photo14.5-9, making use of its frictional wear resistance, water resistance, and heat resistance.

POM is also for use in plumbing parts and pump parts.

Pump parts

Various plastics have replaced conventional metals for making lightweight and rustproof parts in a pump.

Modified-PPE is suited to the parts of a hot-water pump because the material has a low absorption of water, mechanical strength, heat resistance, hot-water resistance, and dimensional stability.

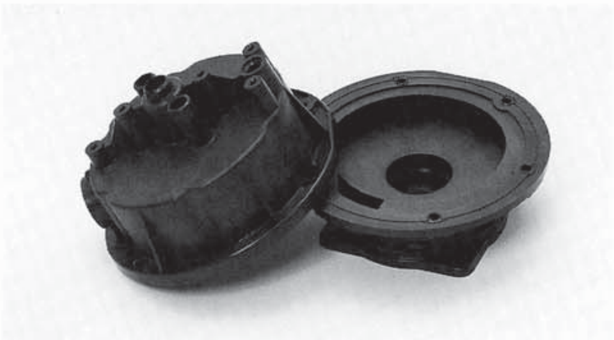


Photo14.5-10 Hot-water pump parts (Modified-PPE)

14.6 Medical equipment

Plastics are cultivating a strong presence in medical applications in the rapidly aging society of Japan, where the life expectancy has exceeded eighty years of age.

Many medical treatments would not be practicable today without use of plastics. A nunber of plastics are suitable for use in this field because they will induce much lower vital reactions than other materials may do. The actually employed plastics have been meticulously tested for carcinogenicity and toxicity, and verified for medical safety.

Representative uses of plastics include PP-made disposable injection-syringes, PVC-made intravenous infusion packages, and PA-made suture threads. Among engineering plastics, PC, PSU, PES, and FR are suitable for medical uses because they withstand steam- and/or gamma-ray-sterilization.

Dialyzer housing

A kidney machine is a typical medical device that exploits property advantages of PC such as steam resistance, clarity, and non-toxicity.

PC has replaced conventional AS in the models for steam-sterilization; and is growing also in the models for gamma-ray radiosterilization. PC is favored for its little discoloration in PCT (pressure cooker test) and in exposure to gamma ray.

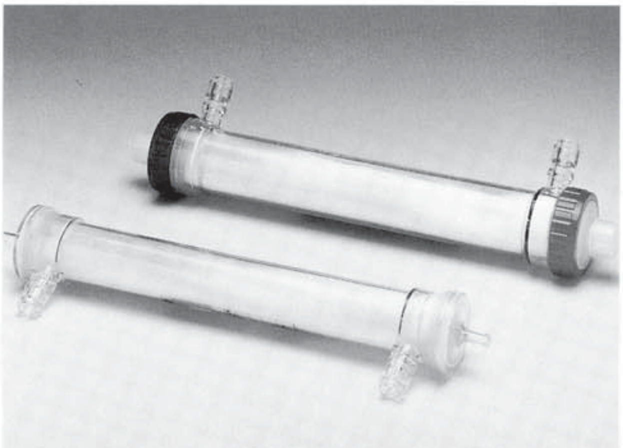


Photo14.6-1 Dialyzer housing (PC)

Cardiopulmonary pump

PC offers design freedom and processing versatility, besides transparency and non-toxicity, to make the blood filter in a device utilized during surgical operations.

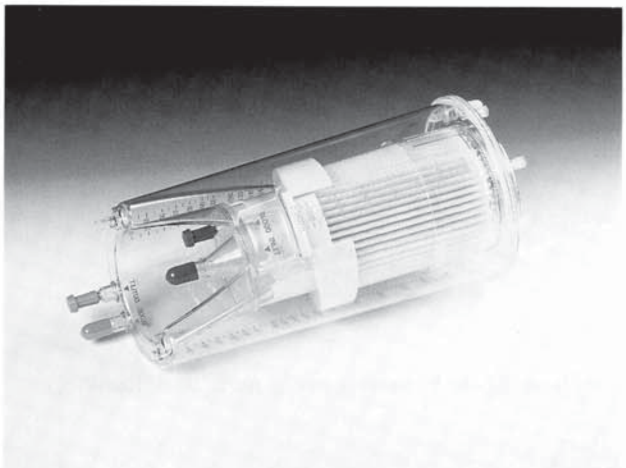


Photo14.6-2 Blood filter (PC)

Eye dropper

PC is the major material of eye-drop containers. PAR is coming in second with its weatherability in moisture barrier and UV-light resistance.

Dental instrument

Dental clinical instruments use an FDA-approved non-reinforced PES in favor of its durability, resistance to chemicals and resistance to hydrolysis.

Photo14.6-3 Eye dropper (PAR)

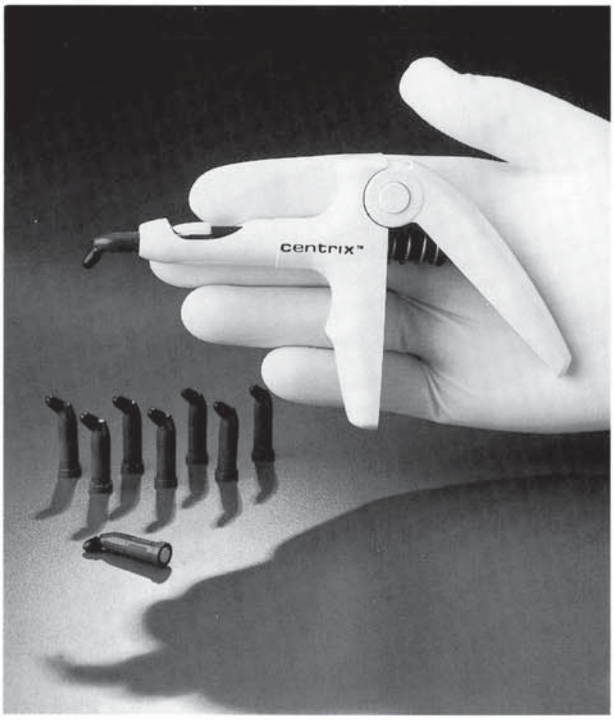


Photo14.6-4 Dental instrument (Non-reinforced PES)

14.7 Safety equipment

Introduced here are some of the safety equipment to protect us from unexpected hazards.

The material of safety equipment must have mainly impact strength, heat resistance and chemical resistance.

Safety helmet

This application benefits from the impact strength of PC. PC is also excellent in appearance and electrical properties. As such, this plastic is the designated material of the formal safety helmets for electrical-work in spite of its higher cost than that of FRP.

The helmets for motorcycle drivers use a specific grade PC that can withstand forced ejection at an inevitable undercut during molding. Some helmets take an impact-improved PA.

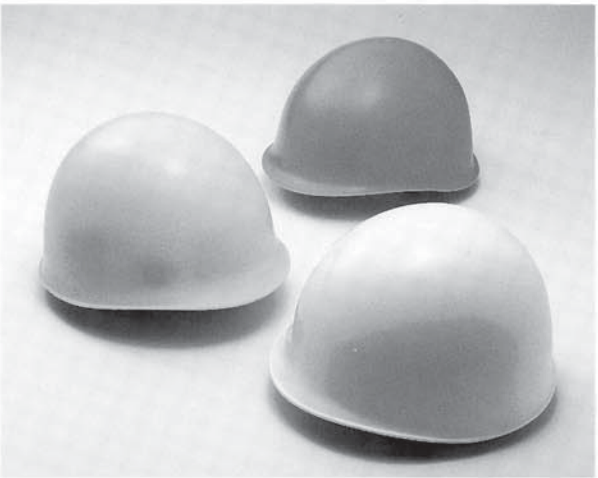


Photo14.7-1 Safety helmet (PC)

Safety glasses

The safety glasses made of clear PC can protect eyes from accidental splashes of harmful chemicals. PC, with its high impact strength, is less likely to break than glass.

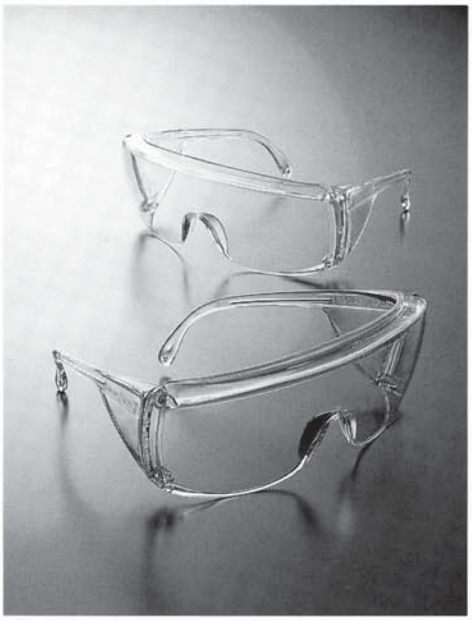


Photo14.7-2 Safety glasses (PC)

Traffic light

PC replaced metal to make the body of the traffic light in Photo14.7-3. The advantages of the plastic are weatherability, strength, and rustproof properties.

PC is a transparent material; hence, also makes a traffic-light lens.

Reflector for traffic safety

PC is a material of the light-reflectors installed on the surface or the sides of the roads, especially the expressways. Such a reflector, called "delineator", must have weatherability for outdoor use. Some delineators are set on the surface of roads, therefore must have mechanical durability and impact strength. In addition, a processing ease is required to make a large number of diamond-cut patterns on the backside of reflectors.

PC can live up to all of those requirements, and has clarity, coloring versatility, and a good reflection

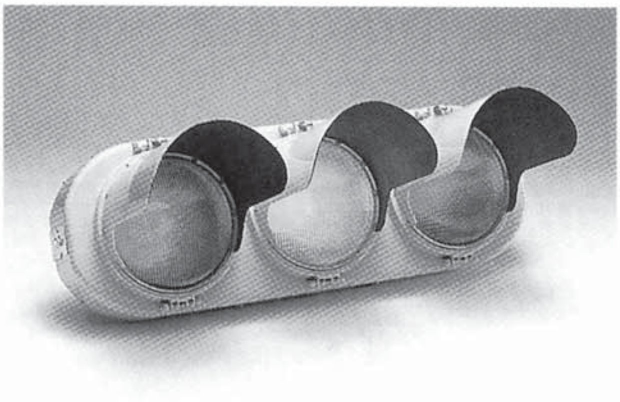


Photo14.7-3 Traffic light body (PC)

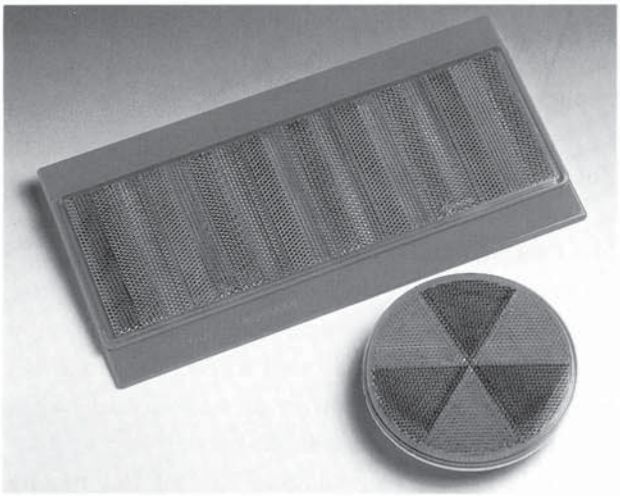


Photo14.7-4 Road reflector (PC)

of light.

14.8 Food containers and food-processing machines

Food containers and food-processing machines have boosted the amazing growth of plastic materials. Plastics are favored for their lightweight, strength, cleanliness, low costs, and most importantly food sanitation.

In Japan, Food Sanitation Law controls the plastics that are exposed to foods. The law contains two categorized standards: the general standards which are commonly applicable to all plastics, and the individual standards which are applicable to the application-specific plastics. The plastics on the individual standards can be employed as a material of soft-drink bottles.

Another control on food-contacting plastics comes from Japan Hygienic Olefin and Styrene Plastics Association, which is a voluntary organization of the industries involved in the relevant areas. Many of the engineering-plastic manufacturers are enrolled in the association.

General-purpose thermoplastics such as polyolefins and polystyrenes take a majority of the materials in food containers and food-processing machines. Engineering plastics also have their shares because of the following advantages:

1 Gas barrier characteristic
2 Heat resistance
3 Non-sticking characteristic
4 Toughness

Table14.8-1 shows the gas-barrier characteristics of various plastic films.

Polyolefins can cause a quality problem (shelf life) of packed foods due to the insufficient barrier to oxygen and other gases. One of the solutions to the problem is to combine a polyolefin with one or more of the high-gas-barrier plastics such as PA, EVOH(saponified copolymer of ethylene-vinylacetate) or LCP, either by blending the materials or laminating the films. Such technical developments have resulted in various value-added packaging materials. The most useful of them include: (1)the laminated film comprising polyolefin film(s) and biaxially oriented PA6 (or polyester) film(s), and (2)co-extruded multilayer film comprising polyolefin(s) and engineering plastic(s). Also, newly developed PC-based multilayer films are finding new applications.

Soft-drink/wine bottle

Plastics are very rapidly replacing conventional glass and metal as the material of home-use (0.5, 1.0, 1.5-liter) soft-drink bottles. Monolayer PET bottles are for everywhere general use. A combination of PET with PAR, or PET with a specialty-grade PA, is for the fruit-drink bottles or wine bottles, which require heat resistance and gas-barrier.

Multilayer bottles will grow to fill the requirements for a higher-level container utilizing the property advantages of PET: a good appearance, lightweight, tough and hard-to-break characteristic.

Law for Promotion of Sorted Collection and Recycling of Containers and Packing, which took

Photo14.8-1 Soft-drink plastic bottle (PET/PAR)

effect in Japan in 1997, stipulates the obligation of recycling emptied bottles. The multilayer bottles are as well recyclable as the monolayer bottles.

Food bag, shrinkpack, deep-drawn container

PA film, an engineering plastic film, is widespread as a food packaging material. With its outstanding strength enough to prevent accidental bursting, it has materialized vacuum packaging, liquid packaging, and gas-filled packaging. Those bags are made of a laminate comprising an oriented PA film and a polyethylene sealant film. Coextruded-and-nonoriented films are also used.

PA is suitable for deep-drawn thermoforming. A thick PA sheet is thermoformed into a tray-shaped container for ham/sausage packaging. (Photo14.8-2)

Shrinkpack is another growing packaging method,

Photo14.8-2 Food packaging (PA)

Material/Type of film	Gas permeability[a] ASTM D1434			Water vapor permeability[c] ASTM D1434
	Carbon dioxide	Nitrogen	Oxygen	40°C, 90%RH
LDPE	42,500	2,800	7,900	24～48
HDPE	9,100	600	2,900	22
Cast PP	12,600	760	3,800	22～34
Biaxially oriented PP	8,500	315	2,500	3～5
Biaxially oriented PP, coated with PVDC	8～80	8～30	<16	5
Cellophane, uncoated	6～90	—	3～80	>720
Cellophane, coated with PVDC	—	11～16	15[a]	<12
Polyester	240～400	14	95～130	20～24
Cast PA	160～190	—	40	240～360
Biaxially oriented PA	—	—	30[b]	90
Biaxially oriented PA, coated with PVDC	—	880	10[b]	4～6
PS	14,000	790	5,500	110～160
PC	17,000	30～80	4,700	170
PVC	320～790	2～23	80～320	5～6
PVDC(VDC-VC copolymer)	60～700	—	10～110	3～6
PVDC(VDC-MA copolymer)	—	—	1.5[b]	1
EVOH(saponified EVA)	—	—	2[b]	30
OV(biaxially oriented PVA, coated with PVDC)	—	—	3[b]	4
PAMXD6 (poly-m-xylylene adipamide)	—	—	4[b]	23
PAN(polyacrylonitrile)	—	—	5[b]	20

Note: a) The data of the PVDC-coated films depend on the type and quantity of the coating agent.
Gas-permeability-test conditions and test method: 25C, 50%RH ASTM D 1434-66
b) 27°C, 65%RH
c) All listed data are converted values to 25micrometer thickness.

Table14.8-1 Gas Barrier Characteristic of Plastic Film

which is most popular in packing meat. This packaging employs an oriented film of a PA6, PA66, and PA copolymer. In this method, the oriented-film bags already filled with the content are heated to shrink the film, which fits tightly onto the contour of the content.

The diversified modes of food packaging and the developments of packaging materials obviously support today's food distribution systems for supermarkets and convenience stores.

Mineral water bottle

PC is used as a material of mineral water bottles. Its sanitary properties, clarity and strength are key characteristics.

The mineral water boom, and the ecological aduantages of recycling containers will continue to boost PC sales.

Photo14.8-3 Mineral water bottle (PC)

Lunchbox

Some of the food containers for repeated home-use are made of engineering plastics, while the use-and-throwaway type containers avoid that material for the high cost. Various kitchen utensils are made of engineering plastics to stand up heat for re-warming foods in a microwave oven. PBT imparts heat resistance and paintability to a lunchbox.

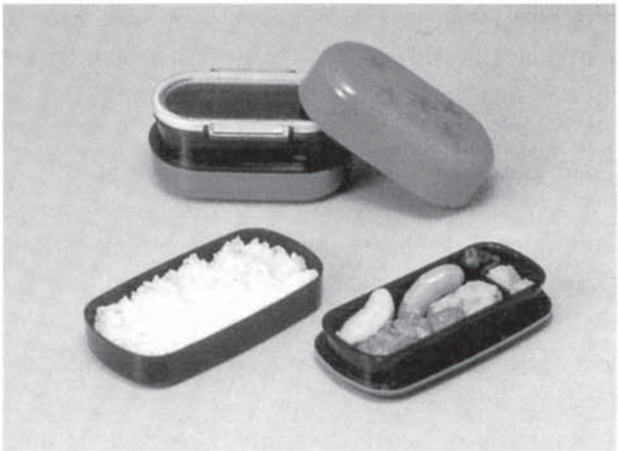


Photo14.8-4 Lunchbox (PBT)

Coating on cooking utensil

The coating on cooking utensils makes use of the unique non-sticking characteristic of FR, as well as its heat resistance, chemical inertness and chemical resistance.

Photo14.8-5 Coating on cooking utensil (FR)

Roll in industrial food-processing device

The simplest way for making a non-sticking roll is to cover a roll with a heat-shrinkable FR tube. By blowing hot air onto the tube, the tube shrink-fits tightly on the surface of the roll. Such a roll has amazingly wide applications in food processing, textile and printing industries, where the FR coverings greatly help save on machine-maintenance costs, improve the product quality, and reduce the material loss. This application makes the most of the merits of FR: excellent non-sticking property and resistance to solvents and corrosive chemicals.

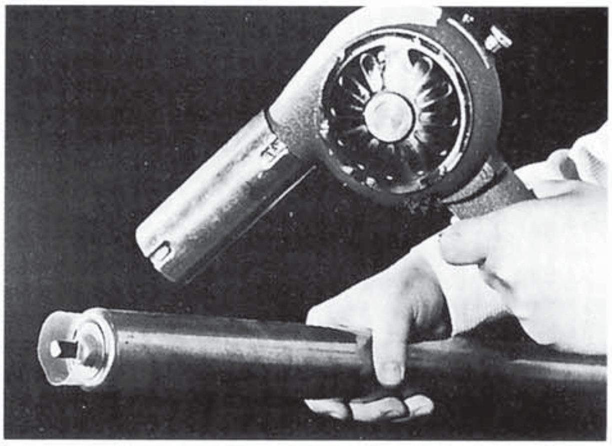


Photo14.8-6 Heat-shrinkable tube to cover a roll (PFEP)

14.9 Office, household, and personal articles

Plastics show an ever-increasing diffusion ratio among the articles for use in our daily life. Most of those plastic articles are made of general-purpose thermoplastics, yet not a few items are made of engineering plastics as introduced below.

Office desk and chair

Office desks and chairs are making a turn from their traditional, uniform and monotonous designs to the more user-friendly and easy-to-use designs aimed at more comfortable, sturdy, and better-looking furniture.

In the circumstances, GF-PA66, GF-PET and GF-PBT are either replacing metals or emerging as novelty materials in the office furniture to sell their merits in design freedom, aesthetic appearance, and tactile appeal.

Photo14.9-1 shows a popular model swivel chair, which has five bases made of GF-PA66. The armrests that bridge the seat and the back are made of GF-PET. Many parts in the internal mechanisms are made of POM, which offers mechanical strength and friction/wear properties.

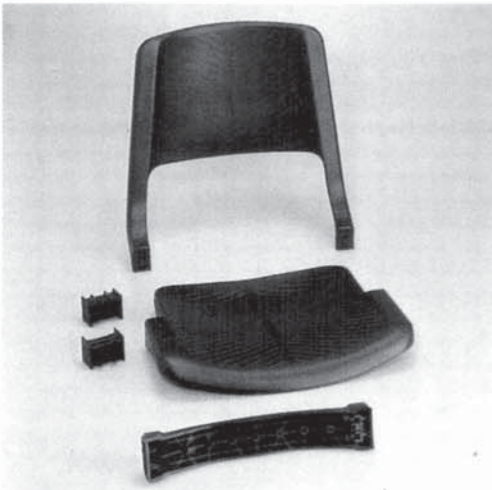


Photo14.9-2 Traverse of chair (GF-PBT)

Photo14.9-2 exhibits a traverse of a chair. The traverse is made of GF-PBT for stiffness, toughness, durability, dimensional stability, and workability with a self-tapping screw that facilitates assembling.

Photo14.9-3 is a view of stackable chairs, which recently employed GF-PA(6+66) as a material of the

Photo14.9-1 Office swivel chair (GF-PA66, GF-PET)

Photo14.9-3 Stackable chair (GF-PA)

frame and the legs. The frame and the legs have long been made of a sturdy metal because they must survive concentrated loads and vibrations to avoid an accidental break. The concentrated loads and vibrations on the stackable chair are greater than those on the swivel chair due to the chair configuration. The toughness and impact strength of GF-PA have earned the designer's trust thanks to the use experiences in automotive parts and sports equipment. Elaborate studies including CAE(computer aided engineering) supported the employment of the plastic material.

Hammer

Engineering plastics are beginning to replace metal and wood to make the handle of a hammer; the upper half of the handle in Photo14.9-4 is made of GF-PA6. This plastic material overrides wood with lightweight, rustproof property, and lower cost.

Photo14.9-4 Hammer handle (GF-PA6)

Zipper

POM, PET, and PA are replacing conventional metal. The plastic zippers feature rustproof property and coloring versatility.

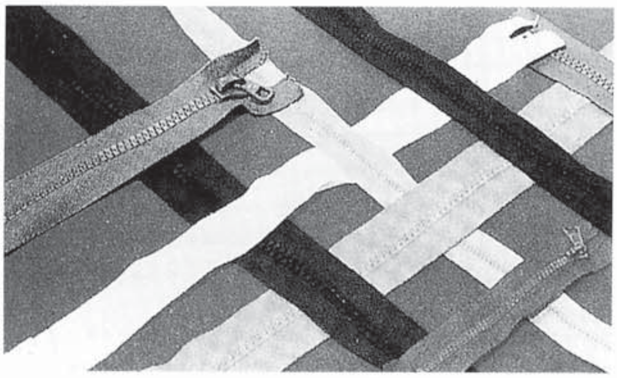


Photo14.9-5 Zipper (POM, PET, PA)

One important, but yet to be known, fact is that the artificial turfs in TOKYO DOME are joined with zippers of engineering plastics.

Buckle

A rising number of color-coordinated buckles are adopted on the belts of knapsacks and pouches. Engineering plastics such as POM and PA are preferred to metals in favor of mechanical strength, lightweight, and coloring versatility.

The examples in Photo14.9-6 exploit the spring-like elastic response and friction/wear properties of POM to make the snap-fit type buckles. Those buckles lock and unlock far more easily than the olden type buckles.

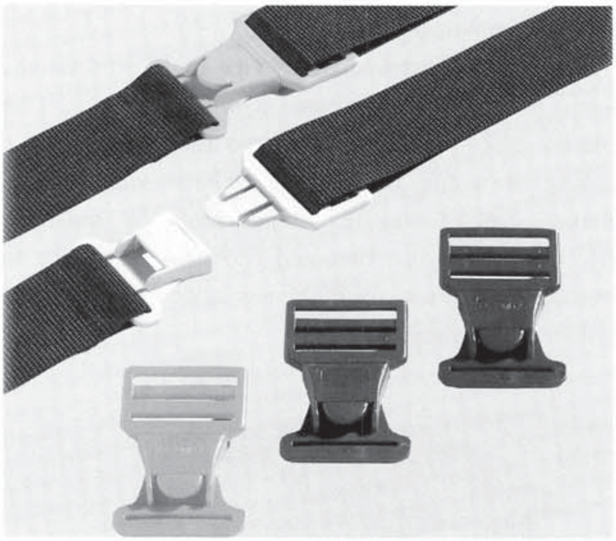


Photo14.9-6 Buckle (POM)

Office stationery

POM is used as a material of the parts in the office-use stamps shown in Photo14.9-7. The office-use stamps keep trampling under demanding conditions, which requires a material with fatigue endurance, spring-like elastic response, and friction/wear properties. POM meets those requirements and offers a processing versatility to allow a one-piece molding of the body and the spring.

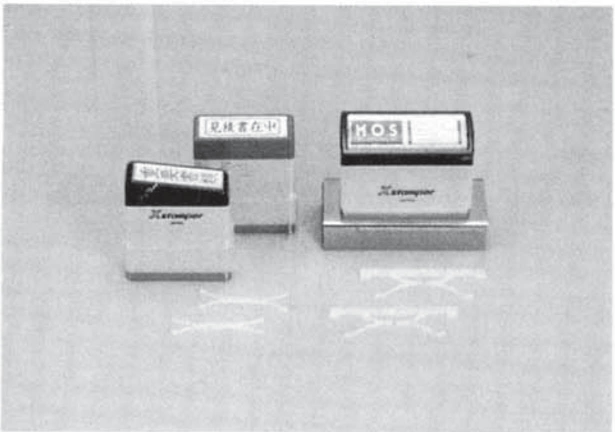


Photo14.9-7 Office-use stamp (POM)

Kerosene stove

It may come of something of a surprise that even a "heating" apparatus, a kerosene stove, incorporates thermoplastic parts.

POM is employed in the device that turns off the stove automatically in case of an earthquake. This plastic also makes an oil-tank receptacle, and a casing of a fan to absorb kerosene vapor. POM makes use of its advantages such as stiffness, friction/wear properties, and chemical resistance to kerosene. The use of POM has added a benefit of reduced processing costs.

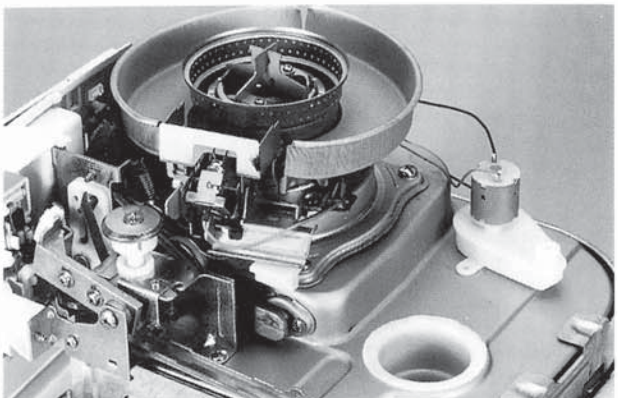


Photo14.9-8 Kerosene stove parts (POM)

Disposable cigarette lighter

Plastics have much contributed to creating today's popularity of this handy-to-buy item. The parts such as nozzles and rings benefit from POM a spring-like elasticity and a chemical resistance to alcohols.

Music box

The molded POM replaced the pressed-metal gears in the music box shown in Photo14.9-10. POM presents lightweight, non-rusting advantage, stiffness, friction/wear properties, and reduced costs of assembling.

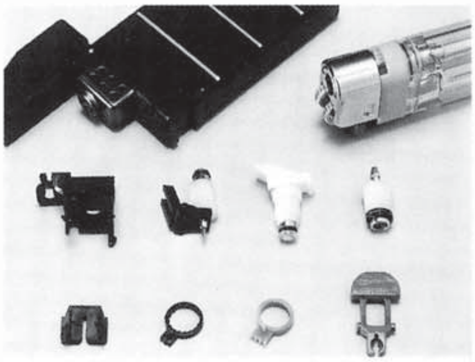


Photo14.9-9 Disposable cigarette lighter parts (POM)

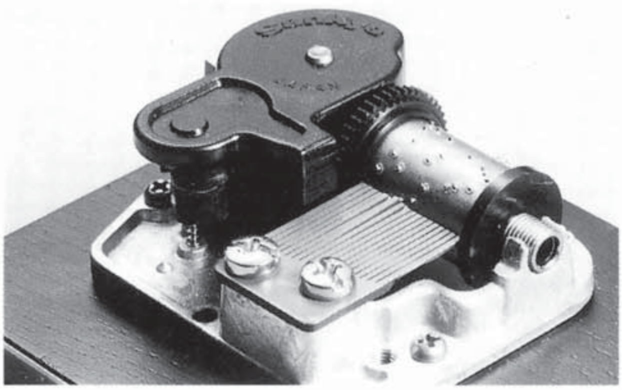


Photo14.9-10 Music box gear (POM)

Gas-fired cooking oven

Even a gas-fired cooking oven uses the thermoplastic parts which must withstand a very difficult environment for the material. A hard-burning-grade

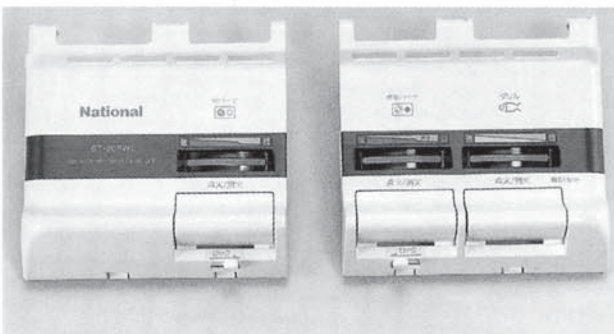


Photo14.9-11 Gas cooking oven front-face panel (Hard-burning PBT)

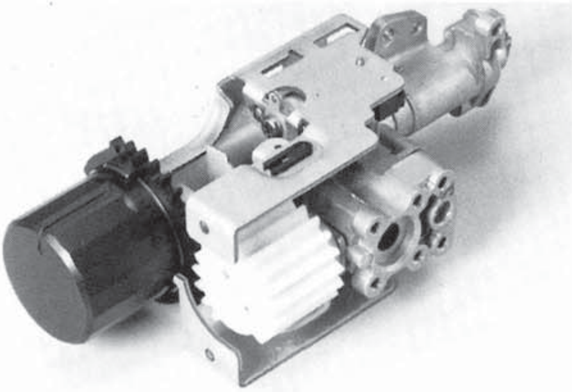


Photo14.9-12 Gas cooking oven flame-controlling knob (Hard-burning PBT)

Photo14.9-14 Tooth-brush bristles (PA610, PA612, PBT)

Photo14.9-13 Gas cooking oven drawer pull (GF-PET)

Photo14.9-15 Hair-brush (TPEE)

PBT replaced conventional metal in the front face panel of the oven (Photo14.9-11). PBT provides the property advantages of stiffness, heat resistance, chemical resistance, and oil/grease resistance. The plastic material makes the non-rusting panel at a reduced manufacturing cost.

PBT is also for use in the flame-controlling knob in Photo14.9-12 with the friction/wear properties and stiffness to its credit.

GF-PET makes the drawer pull in Photo14.9-13 for being resistant to heat and chemicals, and good in surface appearance.

Tooth-brush

Plastic bristles replaced conventional hog-hairs. Monofilaments of PA610, PA612 and PBT are in use for their flexibility, elastic recovery and low costs.

Hair-brush

A heat resistant thermoplastic polyester elastomer is the material of the brushes in Photo14.9-15. One-piece molding of the elastomer consolidated the body and the bristles. The new-type brush is replacing the conventional brushes with the bristles of filled PA monofilaments or injection-molded POM on a silicone-rubber base.

Those lately developed hair-brushes use new ideas and new materials to better meet users' satisfaction. Use of the elastomer has brought about such merits as a good tactile comfort to the skin, heat resistance to a hot hair-drying air, and a saving in costs.

Institutional-use chopsticks

PPS is molded into the institutional-use chopsticks (Photo14.9-16). Those chopsticks must be tough enough to stand repeated using and washing, and be resistant to heat and chemicals to endure sterilization.

Cushion

Thermoplastic polyester elastomer makes a cushion of a spring-like structure, which is useful for bed mattress, office chair cushion, pillows, seats, and caregivers' implements.

The plastic cushion is finding ways for more various uses because it is breathable, i.e. not apt to get sweaty; properly stiff, i.e. durable in cushioning quality; and easy to wash-and-dry, i.e. hygienic.

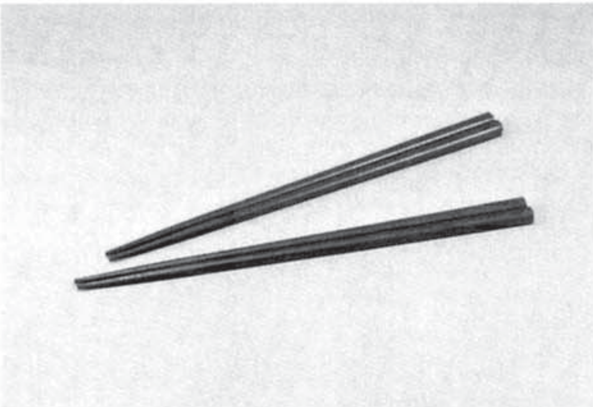


Photo14.9-16 Institutional-use chopsticks (PPS)

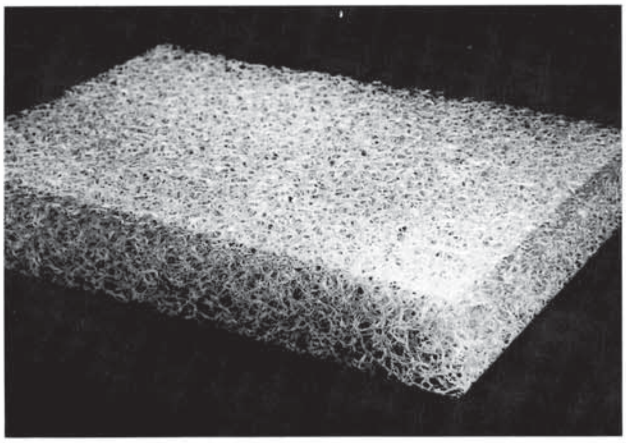


Photo14.9-17 Cushion (TPEE)

14.10 Sports/Outdoor goods

Not only professional athletes and young sters, but also office-workers, housewires and senior citizens enjoy exercising and playing sports for its many health benefits. In such a diversified market, the common property requirements to sports goods are:

1 Lightweight
2 Sturdy and durable
3 Aesthetically good during a long use
4 Maintenance free.

Many engineering plastics can satisfy those requirements. In addition, many of them can retain impact/mechanical strength and stiffness even at a low temperature.

Golf shoes

PA11, PA12 or a grade of POM is used as a material of the shoe-sole to replace urethane rubber.

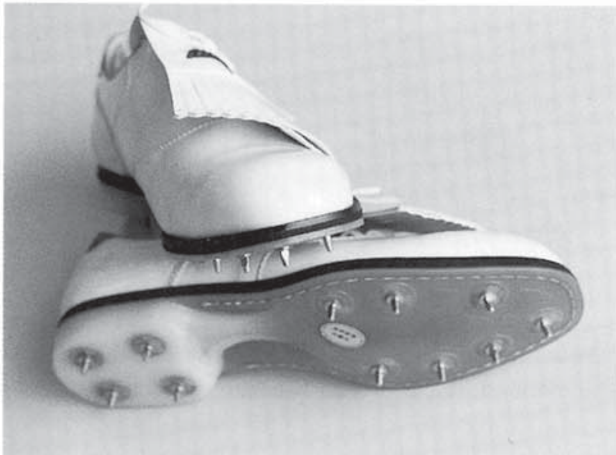


Photo14.10-1 Golf shoes (PA11)

Fishing gear

GF-PA is the material of the long body of a lightweight, rustproof and smoothly winding spinning reel in Photo14.10-2.

GF-PET is adopted as a material of a drum-type body.

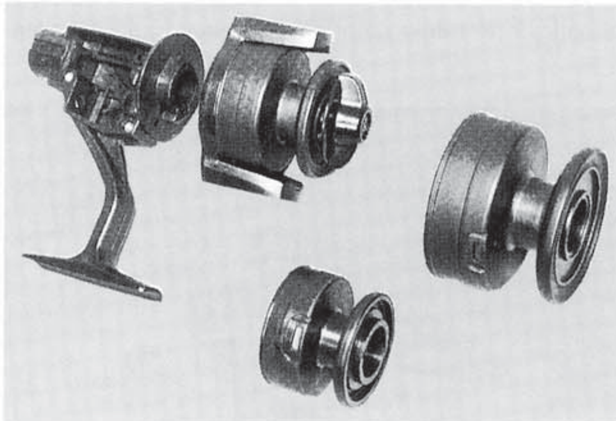


Photo14.10-2 Spinning reel (PA)

KENDO protector

Students of KENDO, the Japanese art of fencing, put on protectors while practicing the art.

PA is employed in the chestguard, which must stand up to repeated impacts and abrasion. Surface gloss and paintability are also important for the appearance.

A clear PC panel is used as the face cover of a head-gear instead of a conventional metal grid

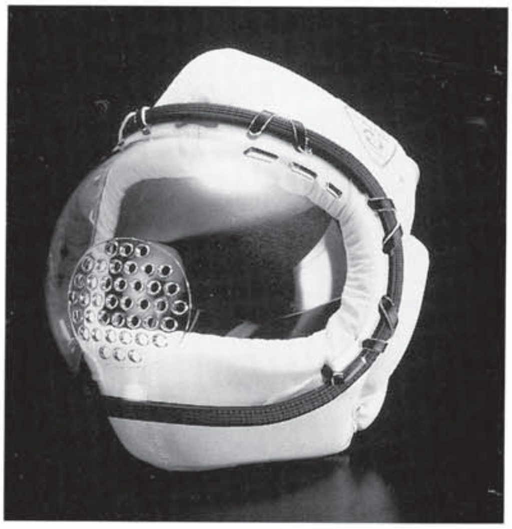


Photo14.10-3 KENDO head-gear (PC)

(Photo14.10-3). The risk of injury is lower with the PC panel than with the metal grid.

Marine sports

The housing on the marine jet in Photo14.10-4 is made of a PC alloy.

Marine sports equipment must have an adequate toughness and impact strength to survive angry waves as well as weatherability and non-rusting property. Also, the equipment must be resistant to chemicals to allow painting for a good appearance.

Photo14.10-4 Marine jet (PC alloy)

Baseball helmet

PC, with its lightweight and impact strength, replaced metal in the helmet for protecting a baseball player from injury. The safety helmet is another important player in the popular national sport.

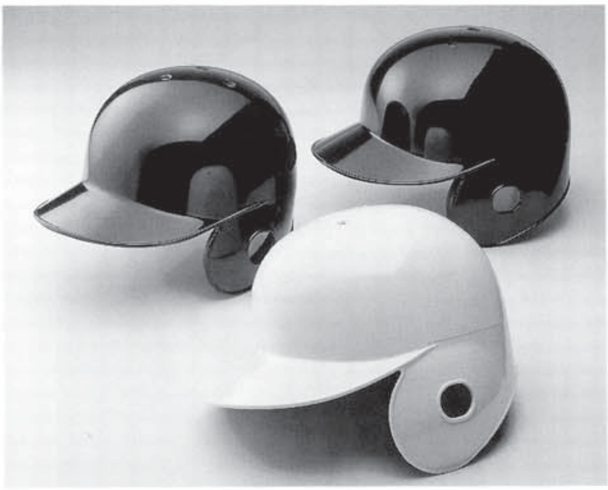


Photo14.10-5 Baseball helmet (PC)

Bicycle

Bicycles are coming with an increasing number of plastic parts. For example, the speed changing device uses the parts made of POM.

In Sweden, a plastic-made bicycle is on the market: molded with a 45%-GF-PET, equipped with GF-PA rims to hold tires, and reduced in weight by 35 percent or more.

A high-speed racer bicycle runs a risk of considerable danger; hence, it demands the parts with a high strength and a high dimensional precision. Photo14.10-6A and 6B show the racer-grade headlamp reflectors made of MD-LCP.

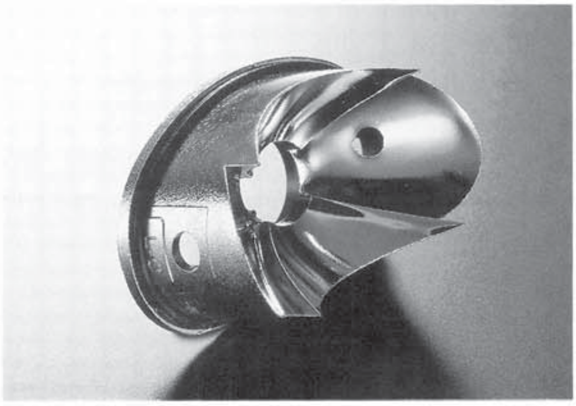


Photo14.10-6A Racer bicycle headlamp reflector (MD-LCP)

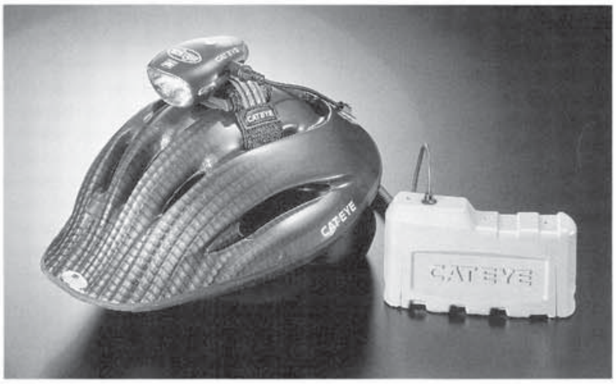


Photo14.10-6B Racer bicycle headlamp reflector (MD-LCP)

Appendix-1 Abbreviations and chemical names of thermoplastic engineering plastics

ABS	Acrylonitrile-butadiene-acrylate
ETFE	Ethylene-tetrafluoroethylene
EVOH	Ethylene-vinyl alcohol
PFEP	Perfluoro(ethylene-propylene)
LCP	Liquid-crystal polymer
PA	Polyamide
PA46	Polymer of tetramethylenediamine and adipic acid
PA6	Polymer of ε-caprolactam
PA66	Polymer of hexamethylenediamine and adipic acid
PA610	Polymer of hexamethylenediamine and sebacic acid
PA612	Polymer of hexamethylenediamine and dodecandioic acid
PA6/66	Copolymer of ε-caprolactam/hexamethylenediamine and adipic acid
PA6/12	Copolymer of ε-caprolactam and ε-dodecanolactam
PA6T	Polyamide of hexamethylenediamine and terephthalic acid
PA11	Polymer of 11-aminoundecanoic acid
PA12	Polymer of ω-dodecanolactam
PA1212	Polymer of dodecannodiamine and dodecandioic acid
PAMXD6	Polymer of m-xylylenediamine and adipic acid
PAI	Polyamidimide
PAR	Polyarylate
PBT	Poly(butylene terephthlate)
PC	Polycarbonate
PCT	Polycyclohexane terephthalate
PCTFE	Polychlorotrifluoroethylene
PEEK	Polyetheretherketone
PEI	Polyetherimide
PEK	Polyetherketone
PEKK	Polyetherketoneketone
PEN	Polyethylene naphthalate
PES	Polyethersulfone
PET	Poly(ethylene terephthalate)
PFA	Perfluoro alkoxyl alkane polymer
PI	Polyimide
POM	Poly(oxymethylene);Polyformaldehyde
PPE	Poly(phenylene ether)
PPS	Poly(phenylene sulfide)
PSU	Polysulfone
PTES	Polythioethersulfone
PTFE	Polytetrafluoroethylene
PVDF	Poly(vinylidene fluoride)
TPEE(TPC)	Thermoplastic polyester elastomer

(ISO 1043-1: 1997)

Appendix-2 Symbols for fillers and reinforcing materials

Symbol	Material
B	boron
C	carbon[1]
E	clay
G	glass
K	calcium carbonate
L	cellulose[1]
M	mineral[1][2], metal[1]
P	mica[1]
Q	silicon
R	aramid
S	synthetic, organic[1]
T	talcum
W	wood[1]
X	not specified
Z	others[1]

Symbol	Form/Structure
B	beads, spheres, balls
C	chips, cuttings
D	powder
F	fibre
G	ground
H	whisker
K	knitted fabric
L	layer
M	mat(thick)
N	non-woven(fabric, thin)
P	paper
R	roving
S	scale, flake
T	cord
V	veneer
W	woven fabric
X	not specified
Y	yarn
Z	others[1]

Note: ISO 1043-2 : 1988(JIS K6899-2 : 1996)

1) These materials may be further defined by their chemical symbol, for example, or additional symbols defined in the relevant International Standard. In the case of metals (M) it is essential to indicate the type of metal by means of its chemical symbol.

2) Mineral fillers should be designated more precisely if a symbol is available, e.g. "E", "P".

Appendix-3 Brand names of engineering plastics as manufactured by the member companies of Japan Engineering Plastics Technical Committee

Companies	Nylon6	Nylon66	Other Nylon	Poly-acetal	Polycar-bonate	Modified PPE	PBT	PET	Poly-arylate	Fluoro-polymers	PPS	PSU & PES	PEEK. PEK & PAEK	LCP	TPEE	Polyether-imide	Poly-imide	Silicone resins
Asahi Chemical		Leona		Tenac		Xyron												
Asahi Glass										AFLON	ASAHI-PPS							
BASF Japan	Ultramid B	Ultramid A	Ultramid C&T	Ultraform			Ultradur					Ultrason						
Bayer					Makrolon													
Daicel Huels			DAIAMID TROGAMID DAIAMID-PAE															
Daikin Industries										POLYFLON NEOFLON								
Dainippon Ink & Chemicals							PLANAC				DIC・PPS			OCTA				
DSM JSR engineering plastics			Stanyl (Nylon 46)															
Du Pont KK		Zytel	Zytel (HTN)	Delrin			CRASTIN	Rynite						Zenite			Vespel	
Du Pon-Mitsui Fluorochemicals										Teflon								
Du Pont Toray															Hytrel			
Elf Atochem			Rilsan fine powder															
EMS Japan	GRILON		GRILAMID															
GE Plastics Japan					Lexan	Nortyl										Ultem		
Idemitsu Petrochemical					Idemitsu PC						Idemitsu PPS							
Kanebo GOSEN	Kanebo Nylon						Kanebo PBT											
Kaneka Corporation								Hyperite									Apical	
Kuraray							Hauzer	KURAPET ESMO										
Kureha Chemical											Fortron KPS							

Companies	Nylon6	Nylon66	Other Nylon	Poly-acetal	Polycar-bonate	Modified PPE	PBT	PET	Poly-arylate	Fluoro-polymers	PPS	PSU & PES	PEEK. PEK & PAEK	LCP	TPEE	Polyether-imide	Poly-imide	Silicone resins
Mitsubishi Engineering plastics	Novamid	Novamid	Reny (Nylon MXD6) Grilamid (Nylon12)	Iupital	Iupilon Novarex	Iupiace	Novadur	Novapet			Novapps			Novac-curate				
Mitsubishi Rayon							Tufpet	Dianite										
Mitsui Chemicals												Mitsui PES	Victrex PEEK				Auron	
Nippon Petrochemicals														Xydar				
Phillips Petroleum International											Ryton							
Polyplastics		Polypla Nylon		Duracon			Duranex				Fortron			Vectra				
Showa Denko	SYSTEMER	SYSTEMER		SYSTEMER														
Sumitomo Bakelite											Sumikon FM							
Sumitomo Chemical						Artley Artlex						Sumikaex-cel	Victrex	Sumikasuper				
Sumitomo Dow					Calibre													
Teijin							Teijin PBT	FR-PET							Nouvelan			
Teijin Amoco Engineering plastics												Udel, Radel						
Teijin Chemicals					Panlite Multilon													
Tohpren											Tonen PPS							
Toray Industries	Toray Nylon	Toray Nylon	Rilsan	Amilus			Toraycon				Torelina Ryton			siveras				
Tosoh Corporation											Susteel							
Toyobo	Toyobo Nylon	Toyobo Nylon	Toyobo Nylon					Vylopet			Toyobo PPS resin				Pelprene			
Ube Industries	UBE Nylon	UBE Nylon	UBE Nylon UBESTA (Nylon 12)					UBE PBT									Upilex	
Unitika	Unitika Nylon6	Mayanyl Nylon66	Unitia Nylon					Unitika G-PET	U POLYMER					Rodrun				

Appendix-4 Directory of the companies of Japan Engineering Plastics Technical Committee

Name of Companies	Name of Divisions	Phone Number	Addresses
[PA]			
Asahi Chemical Industry	Leona Plastics & Fibers Development Dept.	+81-44-271-2446	1-3-1 Yakou Kawasaki-ku Kawasaki-city 210-0863 Japan
BASF Japan	Polymers Division	+81-3-3238-2400	3-3 Kioi-cho Chiyoda-ku Tokyo 102-8570 Japan
Daicel-Huels	Daiamid Marketing Department	+81-3-5324-6331	2-3-1 Nishishinjuku Shinjuku-ku Tokyo 105-0004 Japan
DSM JSR Engineering Plastics		+81-3-3431-8161	6-14-5 Shimbashi Minato-ku Tokyo 163-0938 Japan
Du pont KK	Engineering Polymers	+81-3-5434-6935	1-8-1 Shimomeguro Meguro-ku Tokyo 153-0064 Japan
ELF Atochem Japan	Performance Polymer Division	+81-3-3288-7121	3-23 Kioi cho Chiyoda-ku Tokyo 102-0094 Japan
EMS CHEMIE(Japan) Ltd.	Engineering Plastics Division	+81-3-3242-3854	Kikuchi Bldg. 3-2-12 Nihombashi Hongoku-cho Chuo-ku Tokyo 103-0021 Japan
Mitsubishi Engineering-Plastics	Quality Assurance Dept.	+81-3-3278-5818	1-1-1 kyobashi Chuo-ku Tokyo 104-0031 Japan
Mitsui Chemicals	Performance Polymers Division	+81-3-3592-4409	3-2-5 Kasumigaseki Chiyoda-ku Tokyo 100-6070 Japan
Polyplastics	Technical Department	+81-3-3593-2181	3-2-5 Kasumigaseki Chiyoda-ku Tokyo 100-6006 Japan
Teijin Amoco Engineering Plastics		+81-3-5210-5570	23-3 Ichibancho Chiyoda-ku Tokyo 102-0082 Japan
Showa Denko	Central Research Laboratory, Kawasaki	+81-44-277-7141	3-2 Chidori-cho Kawasaki-ku Kawasaki 210-0865 Japan
Toray Industries	Plastics Production Technical Dept.	+81-3-3245-5589	2-2-1 Nihombashi-muromachi Chuo-ku Tokyo 103-8666 Japan
Toyobo	Research Institute Polymer Technical Center	+81-77-521-1438	2-1-1 Katata Ohtsu-city Shiga 520-0292 Japan
Ube Industries, Ltd.	High performance Products Group	+81-3-5460-3243	2-3-11 Higashi-shinagawa Shinagawa-ku Tokyo 140-8633 Japan
Unitika	Chemicals & Resins Division	+81-3-3246-7598	3-4-4 Nihonbashi-muromachi Chuo-ku Tokyo 103-8321 Japan
[PC]			
Bayer	Plastics Division	+81-3-3280-9761	4-10-8 Takanawa Minato-ku Tokyo 108-8571 Japan
GE Plastics Japan	Technology Center Product Technology	+81-285-80-2319	2-2 Kinugaoka Moka-city Tochigi 321-4392 Japan
Idemitsu Petrochemical	Engineering Plastics Department	+81-3-3457-8628	5-6-1 Shiba Minato-ku Tokyo 108-0014 Japan
Mitsubishi Engineering-Plastics	Quality Assurance Dept.	+81-3-3278-5818	1-1-1 Kyobashi Chuo-ku Tokyo 104-0031 Japan
Sumitomo Dow Limited	Research & Development Dept.	+81-726-92-5337	2-10-1 Tsukahara Takatsuki-city Osaka 569-1093 Japan
Teijin Chemicals	Environmental & Quality Management Department	+81-3-3506-4717	1-2-2 Uchisaiwai-cho Chiyoda-ku Tokyo 100-0011 Japan
[POM]			
Asahi Chemical Industry	Tenac Development & Technology Department	+81-44-271-2448	1-3-1 Yakou Kawasaki-ku Kawasaki-city, 210-0863 Japan
BASF Japan	Polymers Division	+81-3-3238-2400	3-3 Kioi-cho Chiyoda-ku Tokyo, 102-8570 Japan
Du pont KK	Engineering polymers	+81-3-5434-6935	1-8-1 Shimomeguro Meguro-ku Tokyo 153-0064 Japan
Mitsubishi Engineering-Plastics	Quality Assurance Dept.	+81-3-3278-5818	1-1-1 Kyobashi Chuo-ku Tokyo 104-0031 Japan
Polyplastics	Technical Department	+81-3-3593-2181	3-2-5 Kasumigaseki Chiyoda-ku Tokyo 103-8666 Japan
[PBT]			
Dainippon Ink & Chemicals	Engineering Plastics & Composite Materials	+81-3-5818-1862	No.3 Dic Building 1-8 Sotokanda 6-Chome Chiyoda-ku Tokyo 101-0021 Japan
GE Plastics Japan	Technology Center Product Technology	+81-285-80-2319	2-2 Kinugaoka Moka-city Tochigi 321-4392 Japan
Kanebo Gohsen	Polymers Division	+81-3-5446-3519	3-20-20 Kaigan Minato-ku Tokyo 108-0022 Japan
Kuraray	New Business Development Division	+81-6-6348-2283	1-12-39 Umeda Kitaku Osaka 530-8611 Japan
Mitsubishi Engineering-Plastics	Quality Assurance Dept.	+81-3-3278-5818	1-1-1 Kyobashi Chuo-ku Tokyo 104-0031 Japan
Mitsubishi Rayon	Plastics Technology Administration Office	+81-3-5495-3068	1-6-41 Konan Minato-ku Tokyo 108-8506 Japan
Polyplastics	Technical Department	+81-3-3593-2181	3-2-5 Kasumigaseki Chiyoda-ku Tokyo 100-6006 Japan
Teijin	Plastics Division	+81-3-3506-4306	2-1-1 Uchisaiwai-cho Chiyoda-ku Tokyo 100-8585 Japan
Toray Industries	Plastics Production Technical Dept.	+81-3-3245-5589	2-2-1 Nihombashi-muromachi Chuo-ku Tokyo 103-8666 Japan
Ube Industries, Ltd	High Performance Products Group	+81-3-5460-3243	2-3-11 Higashi-shinagawa Shinagawa-ku Tokyo 140-8633 Japan

Name of Companies	Name of Divisions	Phone Number	Addresses
[FR]			
Asahi Glass	Fluoro Polymers Div.	+81-44-541-4728	3-474-2 Tsukagoshi Saiwai-ku Kawasaki-city 210-0924 Japan
Daikin Industries	Chemical Division	+81-6-6373-4346	2-4-12 Nakazakinishi Kita-ku Osaka 530-8323 Japan
Du Pont-Mitsui Fluorochemicals	Polymer Technical service Group	+81-543-34-2239	3600 Miho Shimizu-city Shizuoka 424-0901 Japan
[PPE]			
Asahi Chemical Industry	Xyron Development & Technology Dept.	+81-44-271-2561	1-3-1 Yakou Kawasaki-ku Kawasaki-city, 210-0863 Japan
GE Plastics Japan	Technology Center Product Technology	+81-285-80-2319	2-2 Kinugaoka Moka-city Tochigi 321-4392 Japan
Mitsubishi Engineering-Plastics	Quality Assurance Dept.	+81-3-3278-5818	1-1-1 Kyobashi Chuo-ku Tokyo 104-0031 Japan
Sumitomo Chemical	Plastics Div. Polypropylene Dept	+81-3-5543-5451	2-27-1 Shinkawa Chuo-ku Tokyo 104-8260 Japan
[PET]			
Du pont KK	Engineering Polymers	+81-3-5434-6935	1-8-1 Shimomeguro Meguro-ku Tokyo 153-0064 Japan
Kaneka Corporation	Techmical & Market Development Group Specialty Plastics Division	+81-6-6226-5322	3-2-4 Nakanoshima Kita-ku Osaka 530-8288 Japan
Kuraray	New Business Development Division	+81-3-3278-5818	1-12-39 Umeda Kita-ku Osaka 530-8611 Japan
Mitsubishi Engineering-Plastics	Quality Assurance Dept.	+81-3-3278-5818	1-1-1 Kyobashi Chuo-ku Tokyo 104-0031 Japan
Mitsubishi Rayon	Plastics Technology Administration Office	+81-3-5495-3068	1-6-41 Konan Minato-ku Tokyo 108-8506 Japan
Teijin	Plastics Division	+81-3-3506-4306	2-1-1 Uchisaiwai-cho Chiyoda-ku Tokyo 100-8585 Japan
Toyobo	Research Institute Polymer Technical Center	+81-77-521-1438	2-1-1 Katata Ohtsu-city Shiga 520-0292 Japan
Unitika	Chemicals & Resins Division	+81-3-3246-7598	3-4-4 Nihonbashi-muromachi Chuo-ku Tokyo 103-8321 Japan
[PPS]			
Asahi Glass	Fluoro Polymers Div.	+81-44-541-4728	3-474-2 Tsukagoshi Saiwai-ku Kawasaki-city 210-0924 Japan
Dainippon Ink & Chemicals	Engineering Plastics & Composite Materials	+81-3-5818-1862	NO.3. DIC Building 1-8 Sotokanda 6-Chome Chiyoda-ku Tokyo 101-0021 Japan
Idemitsu Petrochemical	Engineering Plastics Department	+81-3-3457-8628	5-6-1 Shiba Minato-ku Tokyo 108-0014 Japan
Kureha Chemical Industry	Perfomance Resins Division	+81-3-3249-4693	1-9-11 Nihonbashi-horidome-cho Chuo-ku Tokyo 103-8552 Japan
Mitsubishi Engineering-Plastics	Quality Assurance Dept,	+81-3-3278-5818	1-1-1 Kyobashi Chuo-ku Tokyo 104-0031 Japan
Phillips Petroleum International	Specialty Plastics Division	+81-3-3216-6958	3-3-1 Marunouchi Chiyoda-ku Tokyo 100-0005 Japan
Polyplastics	Technical Department	+81-3-3593-2181	3-2-5 Kasumigaseki Chiyoda-ku Tokyo 100-6006 Japan
Sumitomo Bakelite	Engineering Compounds Sales Dept Engineering Compounds Div.	+81-3-5462-3463	2-5-8 Higashishinagawa Shinagawa-ku Tokyo 140-0002 Japan
Tohpren	Sales Group	+81-3-5778-5270	1-1-39 Hiroo Shibuya-ku Tokyo 150-8410 Japan
Toray Industries	Plastics Prochuction Technical Dept.	+81-3-3245-5589	2-2-1 Nihombashi-muromachi Chuo-ku Tokyo 103-8666 Japan
Tosoh	High Performance Polymers Specialty Materials Division	+81-3-3585-4065	1-7-7 Akasaka Minato-ku Tokyo 107-8451 Japan
[TPEE]			
Du Pont-Toray	"Hytrel" Technical Department "Hytrel" Division	+81-52-613-2820	3804-19 Aza Kita Motohoshizaki-cho Minato-ku Nagoya-city 455-0025 Japan
Toyobo	Research Institute Polymer Technical Center	+81-77-521-1438	2-1-1 Katata Ohtsu-city Shiga 520-0292 Japan
[PAR]			
Unitika	Chemicals & Resins Division	+81-3-3246-7598	3-4-4 Nihonbashi-muromachi Chuo-ku Tokyo 103-8321 Japan
[LCP]			
Mitsubishi Engineering-Plastics	Quality Assurance Dept.	+81-3-3278-5818	1-1-1 Kyobashi Chuo-ku Tokyo 104-0031 Japan
Nippon Petrochemicals	Xydar Business Group	+81-44-276-4544	2-3-1 Yako Kawasaki-ku Kawasaki 210-8545 Japan
Polyplastics	Technical Department	+81-3-3593-2181	3-2-5 Kasumigaseki Chiyoda-ku Tokyo 100-6006 Japan
Sumitomo Chemical	Functional Chemicals Div.	+81-3-5543-5451	2-27-1 Shinkawa Chuo-ku Tokyo 104-8260 Japan
Toray Industries	Plastics Production Technical Dept.	+81-3-3245-5589	2-2-1 Nihonbashi-muromachi Chuo-ku Tokyo 103-8666 Japan
Unitika	Chemicals & Resins Division	+81-3-3246-7598	3-4-4 Nihonbashi-muromachi Chuo-ku Tokyo 103-8321 Japan
[SEP]			
Mitsui Chemicals	Performance Polymers Division	+81-3-3592-4409	3-2-5 Kasumigaseki Chiyoda-ku Tokyo 100-6070 Japan
Sumitomo Chemical	Functional Chemicals Div.	+81-3-5543-5451	2-27-1 Shinkawa Chuo-ku Tokyo 104-8260 Japan
Teijin Amoco Engineering Plastics	Plastics Division	+81-3-5210-5570	23-3 Icibancho Chiyoda-ku Tokyo 102-0082 Japan

エンプラの本（第3版）
1989年1月　初　版　　　　発行
1993年4月　改訂版　　　　発行
1998年4月　第3版　第1刷発行
会員配布資料

発行人　エンプラ技術連合会
（略称：エンプラ技連）
編　集　©広報委員会
東京都港区新橋1-16-6（〒105-0004）
TEL.（03）3592-1668
FAX.（03）3592-1677
印　刷　（株）キャナル・コンピュータ・プリント

A Booklet on Engineering Plastics（1999）
For distribution to the members

Publisher　Japan Engineering Plastics Technical Committee
（JEPTEC）
Editing　Editorial Committee
1-16-6,Shimbashi Minato-ku,Tokyo 105-0004,Japan
TEL.（03）3592-1668
FAX.（03）3592-1677
Printing　Canal Computer Print Co.,Ltd.