High volumes of heat-shrinkable products are used worldwide every day for many applications. When heated, heat-shrinkable tubing and molded parts conform to the shape and size of cables, wires, connections, coils and many other electrically conductive elements, electronics and alternative underlying materials like automotive brake lines. Heat-shrinkable products can be found in all major markets such as the automotive, electronics, power stations, cable and wire, appliances, power distribution, shipbuilding, communications, off-shore, spacecraft, military, aviation, do-it-yourself stores, medical, rail and rapid transit and building and construction. Typical applications for heat-shrink tubing include insulating, terminating, splicing, cable bundling, color coding, strain relief, wire marking, mechanical protection, environmental protection, corrosion protection and moisture sealing. Heat-shrinkable products can be used as an alternative for insulation techniques like taping or molding-in-place, and they come in a wide range of sizes, colors and materials.

The industry takes some important performance specifications into consideration when manufacturing heat-shrinkable products including the maximum diameter, wall thickness, chemical resistance and the temperature range. Common approvals held by heat-shrinkable products include recognition to UL and CSA. Other international specifications are for aerospace, military, automotive, rolling stock like railways and so on.

Although most heat-shrinkable products are used to provide insulation, heat-shrink tubing and shapes are also available with conductive and anti-tracking properties and coatings.

The Invention

E-beam cross-linked heat shrinkable tubing was introduced by Raychem Corporation in the 1950’s. Private research on irradiation was begun in 1946 by M.I.T., Electronized Chemicals Corporation, a pioneer in the field of irradiation chemistry and General Electric. Today heat-shrinkable products are manufactured by numerous manufacturers all over the world, and industrial e-beam equipment is available in each continent.

The Manufacturing Process

Heat-shrinking manufacturing technology and equipment are available from INHOL bv/PTL. The technology includes the knowledge of compounds, extrusion and molding, cross-linking, expansion and finishing like adhesive coating or inserts like solder rings, press connectors and adhesives.

The general process flow for the heat-shrinkable tubing manufacturing process is shown below on the right. Heat-shrinkable tubing is manufactured from thermoplastic materials such as polyolefin, fluoropolymer, PVC, neoprene, silicon elastomer or Viton. Heat-shrinkable products are expansion-based. In general, the following cross-linking technologies are applied commercially in the heat-shrink industry:

- a) Cross-linking by means of moisture.
- b) Cross-linking by means of radiation (e-beam).
- c) Cross-linking by means of peroxide.

While the improved maximum operating temperature was one of the initial attractions of cross-linking, there are other important product advantages as a result of cross-linking the polymers, such as:

- Reduced deformation under load (creep).
- Improved chemical resistance.
- Increased abrasion resistance.
- Improved impact properties.
- Consistent memory characteristics.

The cross-linking also helps make the tubing and molded parts maintain their shapes, both before and after shrinking. The manufacturing process involves producing the products like tubing as normal, cross-link the tubing,
heating it to just above the polymer’s crystalline melting point and aid stretching (expansion) of the tubing. Finally, it is rapidly cooled. Later when heated, the tubing will “relax” back to the un-expanded size. That means that the product will shrink in ratios of 2:1 to 4:1 or even more to form a tight fit.

In the thermal expansion process, the diameter of the tubing is increased by forces (inside pressure or outside vacuum) at a temperature slightly above the crystalline melting point of the polymer used. Due to the three dimensional cross-links which are incorporated by means of the crosslink process, the tubing does not melt and obtains its perfect shape memory.

Immediately after the tubing reaches its required expanded size, the tubing is cooled down far below its crystalline melting point and thus reaches a state in which a high amount of radial stretch is incorporated in the tubing. This stage is called the “expanded” state.

Expansion process
(heat and pressure/vacuum)
Unexpanded state>>>>>>>>>>>>Expanded state

Shrinking/recovering process
(heating above crystalline melting point)
Unexpanded state<<<<<<<<<<<<<<Expanded state

Compound, Equipment and Technology

Cross-linked heat-shrink tubing and molded parts are a US$1.3 billion per year global market, and it is growing in some areas such as India and China at rates of 30% to 50% per year. The biggest demand comes from power, telecom, military, aerospace, automotive, white goods and electronics applications.

Cross-linked heat-shrink tubing and molded parts are not new, but what is now offered is a one-stop shop of complete plant design, equipment and compounds for any processor that is interested in having a factory up and running 24 hours after installation.

Inhol/PTL has devised a system for wire and cable processors to enter the lucrative cross-linked, heat-shrinkable markets for thin wall products. After the acquisition of S+T in Germany, the company joined forces with other industry experts. The technology and services now offered is backed by more than 20 years of industry experience. The technology was never freely available before as a complete package from a one-stop shop. This has resulted in relatively few companies controlling all market segments of what has become a significant world market.

Compounds are delivered under the PTL brand name from major toll-compounders to Inhol/PTL formulations. Depending on the application, these can include flame-retardant, halogen-free or low-smoke generation products and include up to 12 different additives such as UV stabilizers, processing-aids, fillers, modifiers or anti-oxidants. The compounds of PTL will easily meet the requirements on properties such as tensile strength, elongation at break, flame retardancy, continuous operating temperature, shrink temperature, heat shock, heat aging, flexibility, corrosion resistance, low temperature flexibility, chemical and solvent resistance, shelf life, dielectric strength, volume resistivity, tracking resistance, water absorption and shrink temperature.

Equipment development continues. Recently, Inhol/PTL introduced a new generation of NEXA expansion machines for medium and thick wall tubing. The PTL flattening lines have allowed tubing converters and manufacturers to make sleeves flat for printing and handling in thermal printing systems. Inhol/PTL has already setup or is completing heat-shrink processing lines in Europe, the Far East, the Middle East and the USA. The following equipment and services have been supplied:

- Extrusion lines.
- Cross-link equipment.
- Expansion equipment.
- Printing and packing lines.
- Flattening lines for identification sleeves.
- Hot set elongation measurement systems.
- Laboratory Equipment and QC training.
- Consultancy.

Below: NEXA is the latest generation of a continuous expansion machine for thick wall heat-shrinkable tubing for diameters up to 200 mm (8”). Total line length is 36 m (120’).
Manufacturing Heat-Shrinkable Products...Continued

A turnkey operation for heat shrink tubing is particularly attractive for fast developing countries and markets which impose high duties on imported finished tubing. Where the telecommunications and cable connector market is booming, producers can source raw materials from Inhol/PTL-licensed domestic compounders to avoid these taxes and do their own processing.

Manufacturing Systems for Heat-Shrinkable Products

Here’s a look at more different types of Inhol/PTL manufacturing systems and machines used in the heat-shrinking process. Machines can expand products ranging from large tubing, end caps, thin wall tubing and tubing for identification sleeves.

1. HW-expansion line. This is a continuous expansion machine for thin wall heat-shrinkable tubing for diameters up to 20 mm (3/4").

2. This is an expansion machine for heat-shrinkable end caps.

3. Flattening Line. This is a line for continuous flattening of heat-shrinkable tubing for identification sleeves.

4. Coating machine for large tubing. This line applies hot-melt adhesive into the tubing for watertight applications.

Company Profile...Inhol/PTL is a worldwide operating source for special compounds for wire and cable and heat-shrink products. The heat-shrink activities include technology and equipment. The PTL-branded compounds are based on polyolefins, elastomers and fluoropolymers. www.inhol.com