

THE MANUFACTURE OF POLYETHYLENE

Three classes of polyethylene are imported into New Zealand for extruding into a wide variety of products. These are low density polyethylene (LDPE), high density polyethylene (HDPE) and linear low density polyethylene (LLDPE). Pellets of these plastics are either imported or bought from local recycling companies, and are then extruded and blown to produce film. This film is used for packaging and making plastic bags.

INTRODUCTION

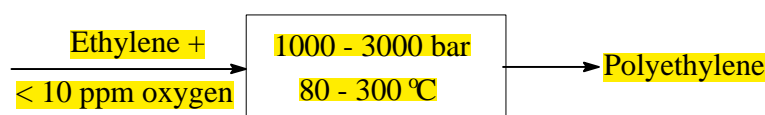
Polyethylene is derived from either modifying natural gas (a methane, ethane, propane mix) or from the catalytic cracking of crude oil into gasoline. In a highly purified form, it is piped directly from the refinery to a separate polymerisation plant. Here, under the right conditions of temperature, pressure and catalysis, the double bond of the ethylene monomer opens up and many monomers link up to form long chains. In commercial polyethylene, the number of monomer repeat units ranges from 1000 to 10 000 (molecular weight ranges from 28 000 to 280 000).

THE POLYETHYLENE MANUFACTURING PROCESS

Today, polyethylene manufacturing processes are usually categorized into "high pressure" and "low pressure" operations. The former is generally recognized as producing conventional low density polyethylene (LDPE) while the latter makes high density (HDPE) and linear low density (LLDPE) polyethylenes. The difference between these polyethylene processes and types is outlined below.

High pressure

Polyethylene was first produced by the high pressure process by ICI, Britain, in the 1930's. They discovered that ethylene gas could be converted into a white solid by heating it at very high pressures in the presence of minute quantities of oxygen:



The polymerisation reaction which occurs is a random one, producing a wide distribution of molecule sizes. By controlling the reaction conditions, it is possible to select the average molecule size (or molecule weight) and the distribution of sizes around this average (molecular weight distribution). The chains are highly branched (at intervals of 20 - 50 carbons). **Figure 1** shows the molecular weight distribution and long chain branching for LDPE.

ICI named their new plastic "polythene" and found that they were able to produce it in a density range of about 0.915 to 0.930g cm⁻³. It is known today as LDPE and has its single biggest usage in blown film.

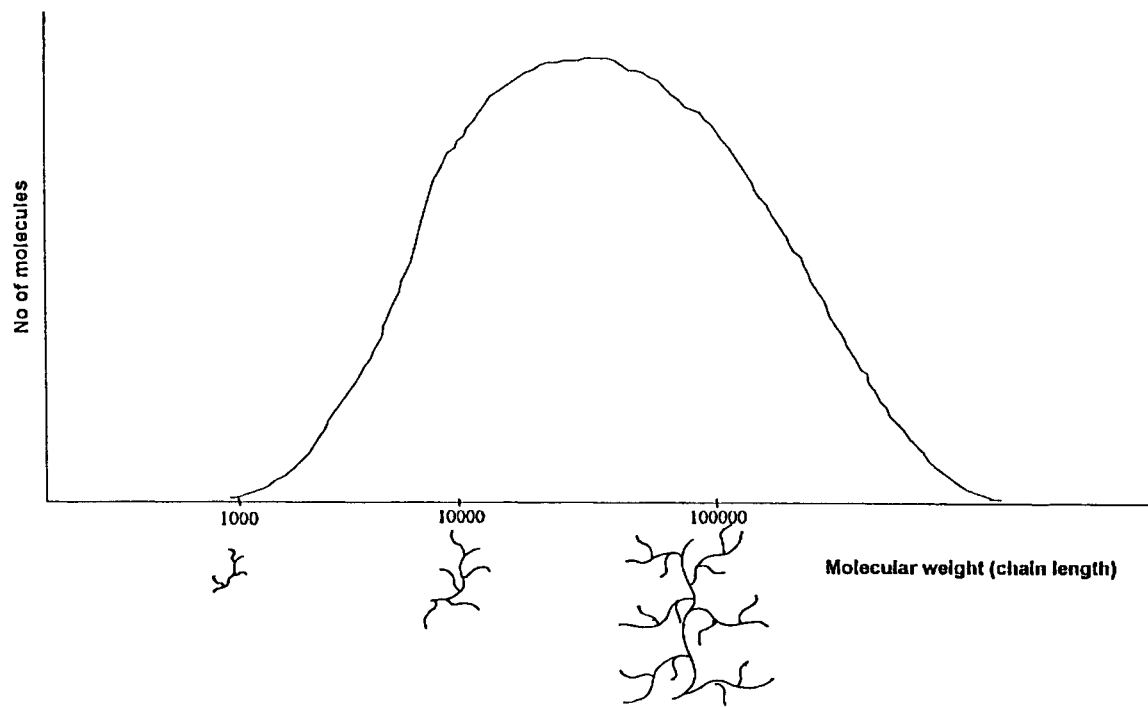


Figure 1 - Molecular weight and long chain branching for 'high pressure' LDPE

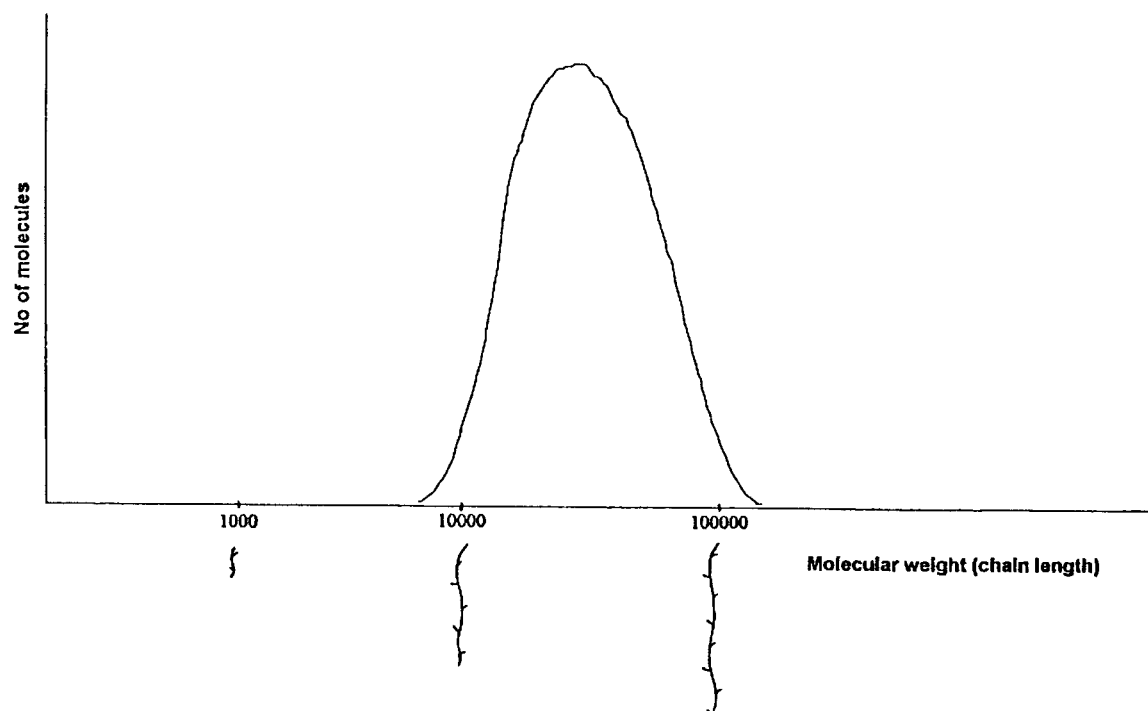
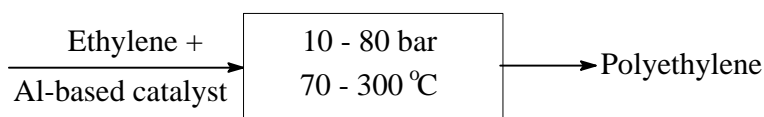


Figure 2 - Molecular weight and short chain branching for 'low pressure' HDPE

Low pressure

The initial discovery of LDPE was an accident. So was the discovery of HDPE in 1952.

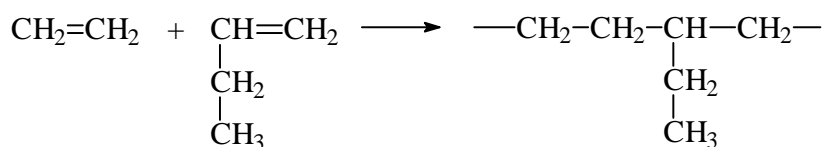
Researchers in Germany and Italy had succeeded in making a **new aluminium based catalyst** which permitted the polymerization of ethylene at much **lower pressures** than the ICI process:



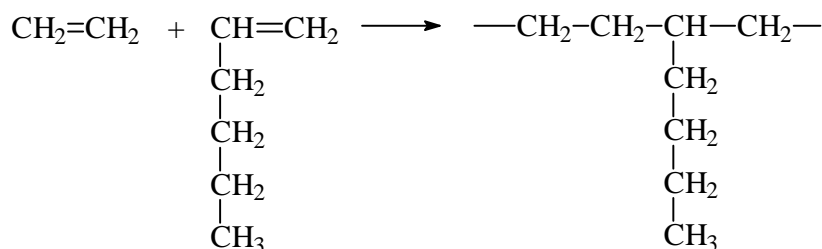
The polyethylene product of this process was found to be much stiffer than any previous with a density range of about $0.940 - 0.970 \text{ g cm}^{-3}$. **The increased stiffness and density were found to be due to a much lower level of chain branching.** The new HDPE was found to be composed of very straight chains of ethylene with a much **narrower distribution of molecular weights (or chain lengths)** and a **potentially very high average chain length.** **Figure 2** shows the molecular weight distribution and short chain branching for HDPE.

In the late 1950's, DuPont Canada first applied the low pressure process to the production of LLDPE. **LLDPE is made by copolymerising with a small amount of another monomer, typically butene, hexene or octene.**

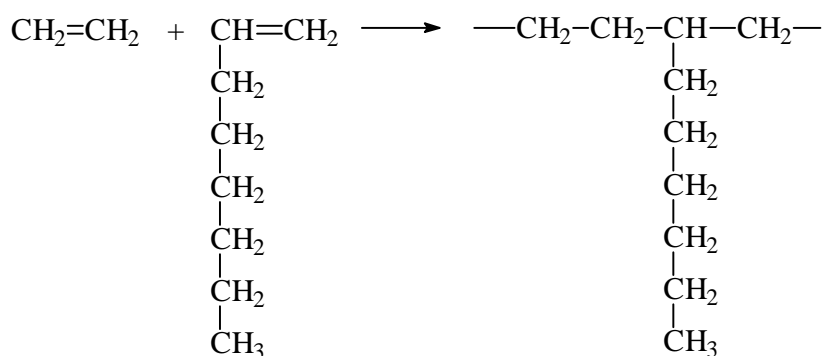
- with butene:



- with hexene:



- with octene:



Whatever the type of polyethylene produced, the end product is usually available in the form of small pellets, varying in shape (spherical, rectangular, cylindrical) depending upon the manufacturer's equipment.

TRANSFORMING POLYETHYLENE FOR USE IN PACKAGING USING BLOWN FILM EXTRUSION

Polyethylene film, produced by blown film extrusion, is commonly used for packaging, whether it be foodstuffs or other products.

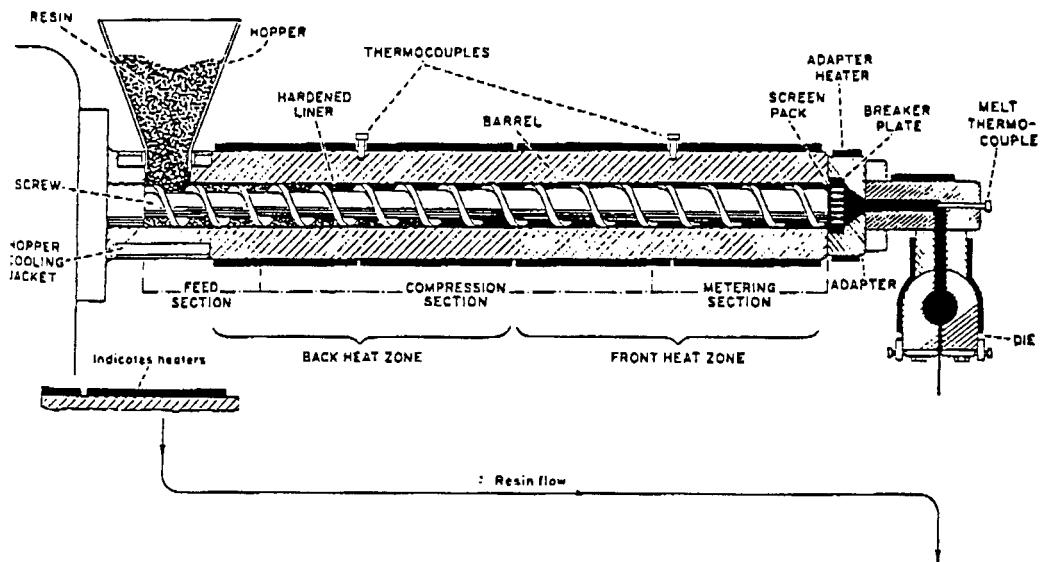


Figure 3 - Cross-section of an extruder

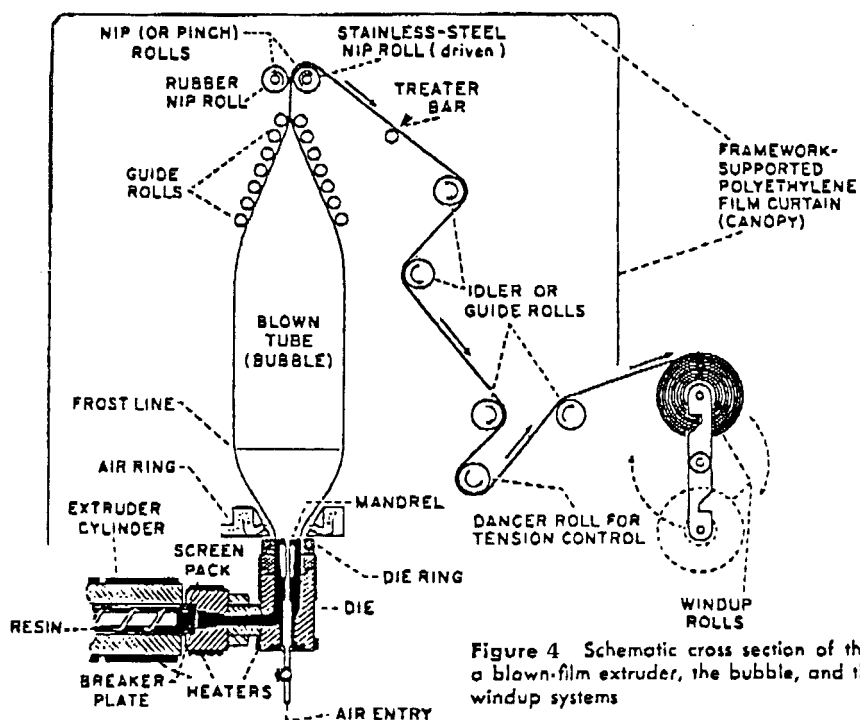


Figure 4 Schematic cross section of the front part of a blown-film extruder, the bubble, and the take-off and windup systems

Figure 4 - Cross-section of a blown film extruder showing front section, bubble, take-off and windup systems

At the centre of any extrusion process is the extruder screw. The conventional extruder screw has three sections: feed section, transition and compression section and metering or pumping section. Figures 3 and 4 depict the extrusion process and the film blowing process.

Generally pelletized polyethylene is gravity fed, from the hopper, into the feed section of the screw which is turning inside a very close fitting and stationary barrel. The resultant frictional force on the material causes it to move forward in the barrel. It heats up as it moves, both from frictional heat generation and conducted heat from the external barrel heaters. The plastic soon begins to melt - this melting continues along the screw until no more solid remains.

After having travelled along the screw channel, the melt passes through a screen pack and supporting breaker plate and the adapter to the die. The screen pack serves mainly as a filter for foreign matter that may have found its way into the hopper.

The melt is then forced through the die adopting the shape of the flow channel (i.e. a circular tube for blown film). The tubular profile from the blown film die is held in tubular form by internal air pressure and is generally externally air cooled with an air ring. The cooled bubble is collapsed at the nip rollers, slit to separate the two halves of the bubble and the resultant two sheets are wound up as rolls. The film sheet can then be converted into bags, pouches, etc. as required. The thickness of the film produced tends to be from 20 - 200 µm.

ENVIRONMENTAL AND ECONOMIC CONSIDERATIONS

A certain percentage of waste is generated, as trim, during blown extrusion when the bubble is split into two webs. Startup, breakdowns, machinery problems can also contribute to the production of waste. Polyethylene film manufacturers would tend to recycle this waste, either in house or using a contract recycler to turn the waste film back into pellets for re-use.

In New Zealand, approximately 7% by weight of the waste stream is due to plastics. Polyethylene, of course, is only one of the many plastics contributing to this figure.

Although recycling of post-consumer (as opposed to post-manufacturer) polyethylene can offer an opportunity to reduce the amount of that material in the solid waste stream, economic considerations must be taken into account. For example, recycling of an HDPE milk bottle would involve collection from the consumer, transport to the recycling plant, sorting, washing, drying and repelletizing. These processes are both time consuming and costly.

The regrind or reclaimed resin must then be sold back to polyethylene users. Purity of the reclaim is also of importance as contaminants can cause problems in manufacture and weaken the finished products.

If the end product (plastic film) is to be in direct contact with food, there must also be compliance with USA Food and Drug Administration Regulations. Most reclaim will not satisfy these regulations and hence cannot be used in direct contact with food. This also limits the use of reclaim.

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