Marlex® Polyethylene Resins

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Polyethylene Invention

- **Development of several types of catalyst (ethylene polymerization at more mild temperatures and pressures).**
  - 1st : chromium trioxide based catalyst - 1951 - by **Banks and Hogan at Phillips Petroleum Company.**

Robert Banks
Born Nov 24 1921 - Died Jan 3 1989

Polymers and Production Thereof
HDPE and Polypropylene Plastics
Patent Number(s) 2,825,721

Paul Hogan
Born Aug 7 1919

Polymers and Production Thereof
HDPE and Polypropylene Plastics
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Inventors of crystalline polypropylene and high-density polyethylene (HDPE)
Together, the plastics were marketed under the brand name Marlex®

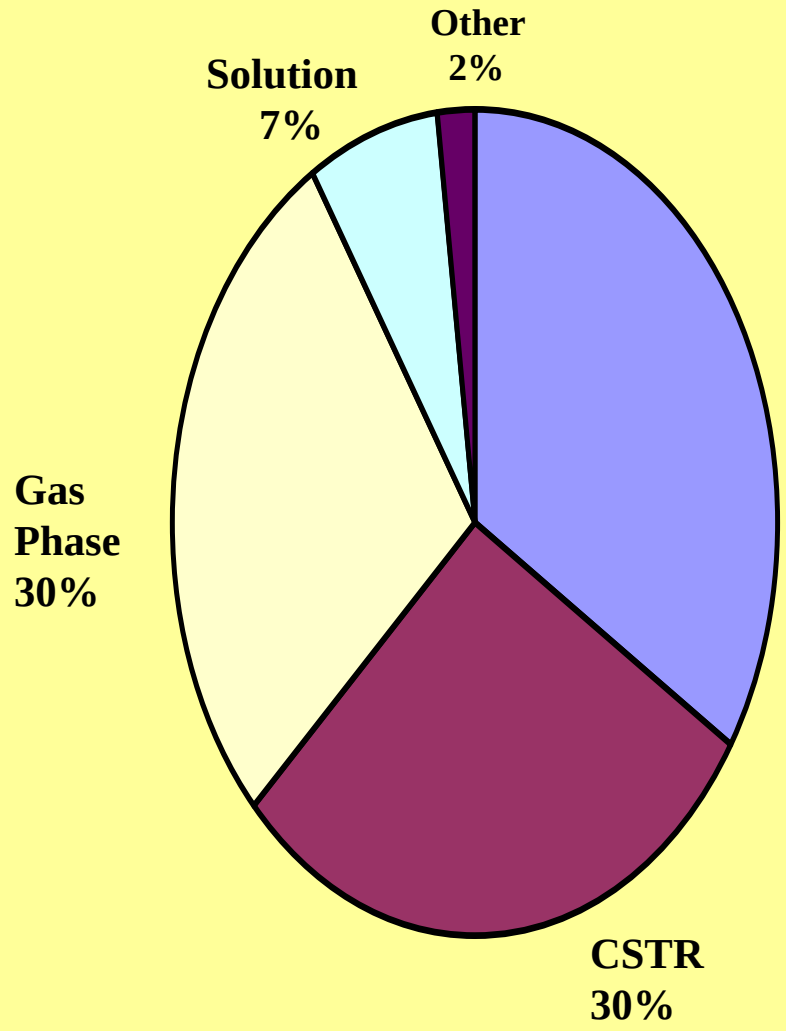
POLYETHYLENE MANUFACTURING PROCESSES

Five main processes

- **Low Pressure**
  - **Slurry**
  - **Solution**
  - **Gas Phase**
- **– High Pressure**

  Free Radical Polymerization
  - **Autoclave**
  - **Tubular**

Worldwide HDPE Production



> 80 Reactors
16 Countries
> 8 million MT/y

HDPE Plant located on Jurong Island, Singapore

MARLEX® POLYETHYLENE

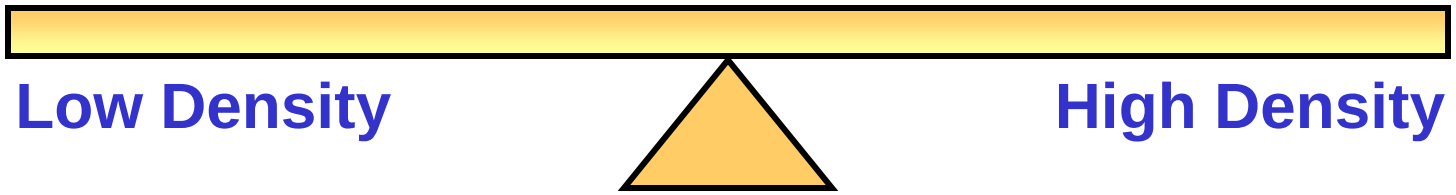
Reactor Fluff

Extruded Pellets

Density

ESCR
Impact
Elongation
Permeability

Stiffness
Top Load
Hardness
Softening Point
Tensile Strength
Chemical Resistance



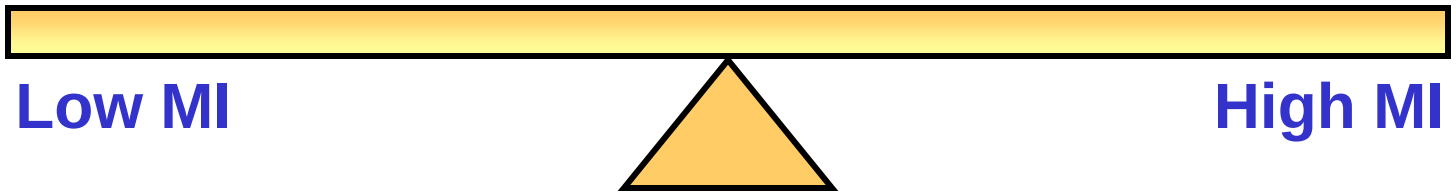
Low Density

High Density

Melt Index

ESCR
Impact
Toughness
Melt Strength

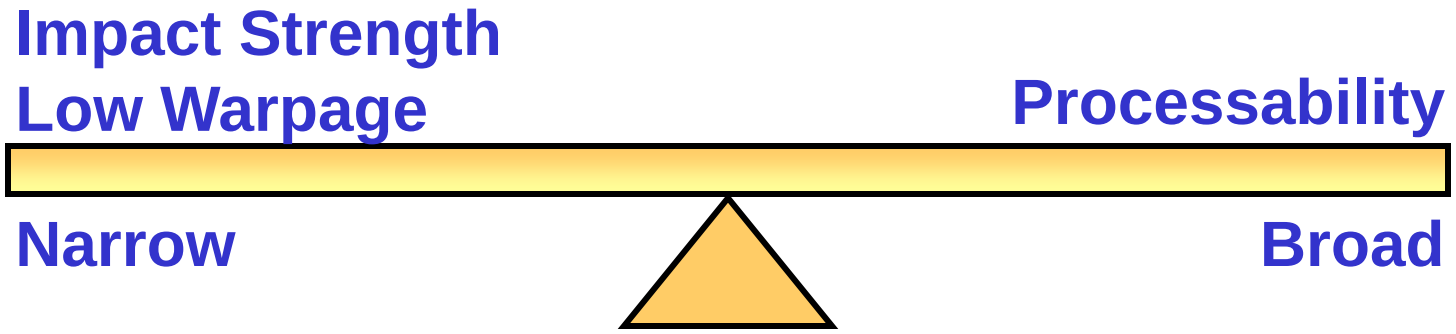
Processability



Low MI

High MI

Molecular Weight Distribution



Typical PE Resin Types

Process	Melt Index	Molecular Weight Distribution
Injection Molding	5 to 60	Narrow
Rotational Molding	3 to 5	Narrow
General Extrusion	Less than 1	Medium - Broad

(Such as: Blow Molding, Pipe, Film and Sheet)

Effect of Properties on Performance

Performance	Increasing Density	Increasing Molecular Weight	Broadening Molecular Weight Dist
Stiffness (Modulus)	+	0	0
Hardness	+	0	0
Tensile Stress at Yield	+	0	0
Tensile Strength at Break	+	+	0
Elongation at Break	-	+	+
Softening Temperature	+	+	+
Impact Strength	-	+	-
Low Temperature Toughness	-	+	+
Permeability	-	0	0
Stress Crack Resistance	-	+	+
Chemical Resistance	+	0	0
Weatherability	0	+	0
Flow/Processability	0	-	+
Long Term Creep	-	+	+

Note: + Increase - Decrease 0 Unaffected

Catalyst Technology

Over 10 Different Catalysts and Treatments Used Commercially

- **MI & Density Capabilities**
- **Molecular Weight Distribution**
- **Special Property Combination**

Additive Formulations

- Processing & application stability
- Antistatic Performance
- Improved Color
- UV Resistance
- Neutralization of Catalyst Residuals

Marlex® Blow Molding Resins

Property	HHM 5202	HHM 5502	HXM 50100	HXM TR-571	EHM 6007	C513
Density, g/cc	0.952	0.955	0.948	0.953	0.961	0.945
MI + [HLMI], g/10 min	0.35 [30]	0.35 [33]	0.06 [9.0]	0.02 [2.5]	0.65 [54]	0.04 [6.2]
ESCR, h Condition B, F_{50}	50	35	>600	300	15	>2000

Marlex® Blow Molding Resins

Resin Types

5502 and 5202 – General Purpose, typically 5 L and below

50100 – Jerrycans and open top drums

TR-571 – L-ring drums, open top drums and jerrycans

6007 – Bottles for liquid dairy products

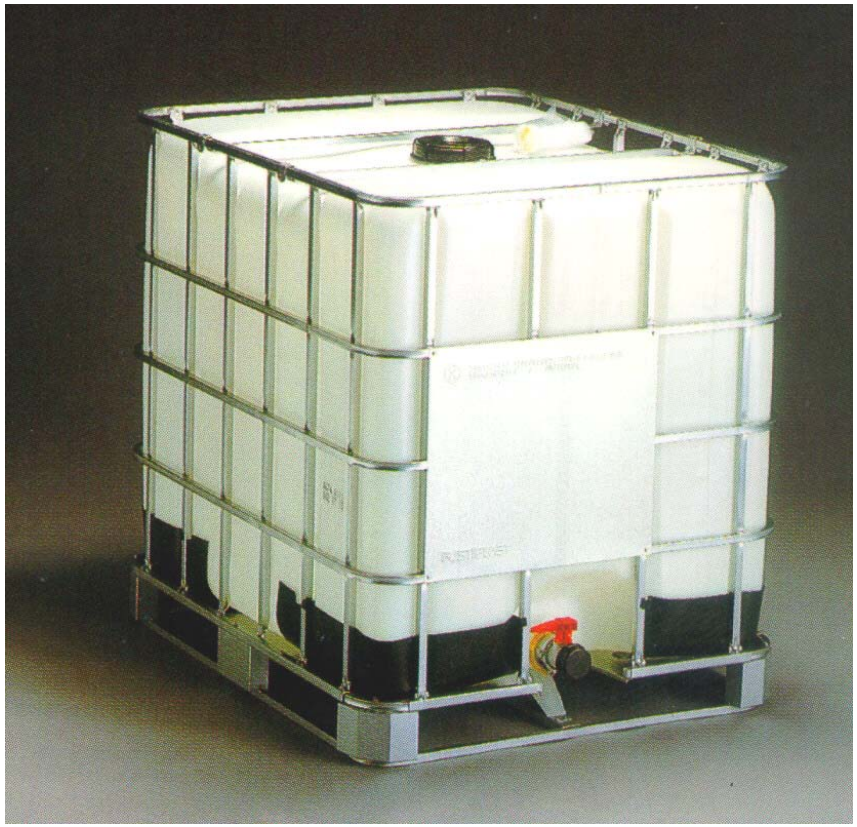
C513 – Intermediate bulk containers

L-Ring and Open Top Drums

L-ring drums may be made by the blow molding process or extrusion followed by welding of injection molded ends

Intermediate Bulk Container

- **Volume Capacity**
  - 1100 L
  - 1320 L



Marlex® HHM 5502BN

Some Regulatory Highlights

2002/72/EC and subsequent amendments

Drug Master File listing – No: 1016(USA); 9398 (Canada)

European Pharmacopeia – 3.1.3 and 3.1.5

FDA – 21 CFR 155.1520(c) 3.2a; Table 1, 21 CFR 176.170(c) and use conditions B to H per Table 2, 21 CFR 176.170(c).

US Pharmacopeia

– USP 26 National Formulary 21 (NF21), 2003, <88> for Class VI Biological Test for Plastics

– USP 26 <661> Containers Physicochemical Tests and Polyethylene Containers

Performance Requirement for Food Packaging

> **Neutral taste and odor**
  - **May be affected by molding process, resin, label, masterbatch,…etc**

> **Resistance against oxidation**
  - **Include an oxygen barrier layer by co-extrusion**
  - **Use an oxygen scavenging polymer**

> **Light barrier**
  - **Include a light barrier layer by co-extrusion**
  - **Pigmentation**
  - **Additives for light blocking**

Some Performance Requirement for Household & Industrial Chemicals

> **ESCR**
  - Resin compatible with characteristics of chemical

> **Top Load**
  - Adequate thickness and thickness uniformity
  - Match expected end-use handling and storage conditions

> **Surface Finish**
  - Influenced by process parameters, cleanliness of screw and die, venting and surface finish of mold

> **Bottle Design**
  - Light-weighting (cost) vs performance
  - Aesthetics vs practicality

Sustainability

- Light-weighting opportunity for lower carbon footprint
- Shorter cycle time for better energy efficiency
- Better balance of top load versus part weight

Summary

- Marlex® HDPE blow molding resins offer good balance of physical properties and processability
- Long proven track records in many countries